Agricultural Mechanization for Productivity and Sustainable Use of the Natural Resource

Edited by: Friew Kelemu, Omar Taha and Gessessew Lekieleh

CRDA
Christian Relief & Development Association
AGRICULTURAL MECHANIZATION FOR PRODUCTIVITY
AND SUSTAINABLE USE OF THE NATURAL RESOURCE

PROCEEDINGS OF THE FIRST AGRICULTURAL MECHANIZATION
POST HARVEST AND FOOD SCIENCE RESEARCH COMPLETED
RESEARCH FORUM

ADDIS ABABA JUNE 5-7

EDITED BY: FRIEW KELEMU, OMAR TAH A AND GESSESEW LEKIELEH
AGRICULTURAL MECHANIZATION
FOR INCREASED PRODUCTIVITY AND SUSTAINABLE
USE OF
THE NATURAL RESOURCE

© EIAR, 2008
Website http://www.eiar.gov.et
Tel: (251-1) 46 26 33
Fax: (251-1) 46-12-94
P.O.Box 2003
Addis Ababa, Ethiopia

ACKNOWLEDGEMENTS

We would like to thank the Ethiopian Agricultural Research Institute, the Oromya and Amhara Agricultural Research Institutes, which made the workshop possible starting from the inception through the implementation period. We are grateful to CRDA, which has been the major financer for the production of this proceeding. In addition, our thanks go to SG 2000 and the Ethiopian Science and Technology Agency, for partially sponsoring the workshop and publication of the proceedings. We also extend our sincere appreciation to all the mechanization staff members of the different institutes and people from other organizations, who found some slot in their busy schedule to attend the forum.
# Table of Contents

ACKNOWLEDGEMENTS .............................................................................................................V
WELCOME ADDRESS .............................................................................................................1
  Friew Kelemu .......................................................................................................................1
OPENING ADDRESS .............................................................................................................2
  Dr. Solomon Assefa ..............................................................................................................2
DETERMINATION OF OPTIMUM DRAUGHT CAPACITY OF CAMELS IN
THE MID RIFT VALLEY OF ETHIOPIA ..................................................................................4
  Workineh Abebe\(^1\), Amdom G/Medhin\(^1\) and Mengistu Alemayehu\(^2\) .....................4
EVALUATIONS OF ARDU MOULD BOARD PLOUGH FOR DONKEYS
AND HORSES ......................................................................................................................10
  Wondiy Gezahegn ..............................................................................................................10
DEVELOPMENT AND TESTING OF PNEUMATIC TIRE WHEEL RIM AND
AXEL FOR ANIMAL DRAWN CART ..................................................................................13
  Wondiy Gezahegn\(^1\), Alamnati Hiruvi\(^1\) ........................................................................13
DEVELOPMENT AND EVALUATION OF CAMEL DRAWN CART ................. 19
  Geta Kidan Mariam and Thilahun Tadesse ...................................................................19
PARTICIPATORY EVALUATION OF TIED RIDGING TECHNOLOGY FOR
MAIZE PRODUCTION IN THE CENTRAL RIFT VALLEY OF ETHIOPIA. 27
  Tewodros Mesfin Olani Nikus, Hussen Harrun and Abuhay Takele ......................... 27
EVALUATION OF VOTEX THRESHER FOR BLACK CUMIN .......................... 35
  Lelliso Eddoshe and Birhanu Atomsa .........................................................................35
MODIFICATION AND EVALUATION OF IAR MODEL HAND OPERATED
MAIZE SHELLER ....................................................................................................................44
  Zelalem Biru, Asafa G/wold, Tolosa Dabare, and Yossief Assefa .................................44
IMPROVEMENT OF MANUALLY OPERATED
ROTARY GROUNDNUT SHELLER ......................................................................................51
  Laike Kebede .....................................................................................................................51
INTERNAL AGITATOR PERFORMANCE AND CHURN DESIGN
CONSIDERATION UNDER SMALL SCALE DAIRY PROCESSING ......................... 56
  Abstract ..............................................................................................................................56
DEVELOPMENT OF MULTI-CROP THRESHER .................................................. 65
  Seyoum W/Senbet, Laike Kebede and Girma Mogos ................................................. 65
ON-FARM VERIFICATION OF MANUAL OPERATED
MILK CHURNS .....................................................................................................................71
  Abu Tefera .........................................................................................................................71
DEVELOPMENT OF HORIZONTAL MODERN BEEHIVE ............................ 78
  *Hussen Abbagissa ..........................................................................................................78
TECHNICAL EVALUATION OF TREADLE PUMPS FOR ABILITY .................. 84
TO LIFT WATER IN MICRO-IRRIGATION SCHEME .............................................. 84
  Oumer Taha .....................................................................................................................84
DEVELOPMENT OF HUMAN OPERATED MICRO-IRRIGATION PUMP ........ 95
  Zewdu Ayalew, Associate Researcher ...........................................................................95
ENSET PROCESSING DEVICES .............................................................................. 102
  Friew Kelemu, Endeshaw Habte and Girma Moges ....................................................102
DEVELOPMENT OF TOMATO SEED EXTRACTOR ........................................ 110
  Friew Kelemu and Amdom Gebrmedhin ..................................................................110
TRADITIONAL CHOPPING PRACTICES IN ETHIOPIA: TECHNICAL
CONSTRAINTS AND METHODS FOR IMPROVEMENT ........................................ 116
OPENING ADDRESS

Dr. Solomon Assefa

Mr. Chairman
Invited guests,
Colleagues,

It is an honor and privilege to address this important gathering on Agricultural Mechanization, Food Science and Post harvest research program especially at this time when the research community is expected to generate technology, which lessens drudgery, minimizes losses and guarantee the wise utilization of the resource base without jeopardizing its future use for a society. The research community should move at a much faster pace more than ever to fulfill the food security, export promotion, import substitution and environmental protection agenda of the country. The Agricultural engineering program in general and the two projects in particular are now highly relevant to help us address the current issues and achieve the development objective of the state.

Ladies and Gentlemen;

According to economic theory, the wise mix of production factors helps increase production and productivity. In agricultural production, production actors cannot be simplified as land, labor and capital and rely on them to effect increased agricultural production and productivity. From the development context, one has to go further and see which production factors are pivotal both for increasing agricultural production, minimizing losses, value addition, increasing productivity and contribution to the overall economic development of a country. Agricultural production can be increased by using direct inputs (seed fertilizers) or by bringing in more land into production. However, in reality, this alone cannot make a difference. The bio-chemical inputs (seed and fertilizer) should be helped to express their optimum potential by creating the conducive environment (good seedbed, timeliness, irrigation) through the provision of the proper implements. The issue of value addition and increased shelf life should also be considered if the farmer is to benefit from a planned marketing system, which requires the technology as well as the input delivery and proper output recovery system. The Ethiopian population is increasing at a rate, which by far exceeds the increase in agricultural production. This needs that the above components are strengthened and a wise mix be made to meet the challenges.

Ladies and Gentlemen,

It has been nearly two decades since we started the implements and food science research works at EIAR and have transformed through different phases, before they attained their present project status. As mentioned above, biochemical inputs should be supplemented with physical science based inputs to meet the agricultural production challenges. It was with this understanding that the former IAR established the department of Agricultural Engineering comprising of Farm Power and Machinery, Soil and Water Engineering, Home Science and Food Technology sections in 1977. Later on, Soil and Water Engineering was amalgamated to the Soil and Water Mgt, the Food Science was dissociated, and the Energy sector was deemphasized. The Implements section remained the only Engineering section. This section was strengthened because of the UNDP project signed in 1984.
Dr. Solomon Assefa
Invited guests
Colleagues,
On behalf of the organizing committee and on my behalf, I welcome you to this important forum, which is an important gathering for the agricultural implements food science and post harvest professionals. It is also an important forum for other colleagues, who are willing to go with us long enough to see that we make a difference in the agricultural production, post harvest handling and value addition and wise utilization of the natural resource base without jeopardizing its future service for generations to come. I would like to thank you all for honoring our invitation. This workshop is a forum to deliver the outputs of the program, which have been going on for the last so many years. Today there will be 30 papers from the federal and regional research centers; posters and exhibits from these groups, NGOs, machinery dealers and colleagues and other invited institutions.
This gathering would have not been possible had it not been for the support of the EIAR management, the CRDA, SG-2000, the Ethiopian science and technology Agency, the Oromia and Amhara Agricultural Research Institutes. We thank all of you who have found some slot in your busy schedule and have come all the way even from very far places to attend this gathering.
With this brief remark I respectfully invite, if I may, Dr. Solomon Assefa, the Deputy Director of the Ethiopian Institute of Agricultural Research, to open the forum.
DETERMINATION OF OPTIMUM DRAUGHT CAPACITY OF CAMELS IN THE MID RIFT VALLEY OF ETHIOPIA

Workineh Abebe1, Amdom G/Medhin1 and Mengistu Alemayehu2

1 Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center P.O.Box 436 Addama. E-mail: narc@ethionet.et
2 Ethiopian Institute of Agricultural Research, Holeta Agricultural Research Center P.O.Box 2003, Addis Ababa. E-mail: mengalemayehu@yahoo.com

Abstract
Ethiopia has 2.78 million one humped camels (Camelus dromedarius), which are important sources of power and food in the lowlands of the country. Currently, camels are beginning to serve as sources of draught power for crop cultivations as crop production has continued to expand in the lowland areas of the country. Past efforts in assessing their work performance did not look into the effect of the workload level and type on the physiological stress it imparts on the camel... With the objective of addressing these limitations this study was conducted at Bofa where the animals are widely used for ploughing. Three camels were selected and the pull, speed, work output and physiological reactions were assessed by applying five different levels of pull (50, 80, 95, 110, and 140 kg). The result indicates that a single camel can generate a draft force of 120 kgf for ninety minutes without abnormal signs of fatigue. For loads up to 110 kg, the speed recorded was 1.13 m s⁻¹ for 3 hours while it was 1.09 m s⁻¹ for 2 hours for loads up to 140 kg. The power and work output for loads up to 110 kg were 0.73 kW and 1.46 MJ for 3 hours, while 0.69 kW and 1.33 MJ were recorded for 2 hours on loads up to 140 kg. As this study is limited to, camels found in the central rift valley, similar works should be done in other areas of the country.

Introduction
Ethiopia with an estimated number of 1 million camels (Camelus dromedarius or one humped camel) ranks 3rd in Africa (next only to Somalia and Sudan) and accounts for 7.8 % of the African camel population (ILCA, 1993). The main regions where higher camel population found are Somali, Afar, Oromiya, Tigray, Amhara and Dire Dawa. The eastern part of the country mainly the Somali region is believed to be the heartland of camel population of Ethiopia. In the Hararghe province which is situated in the eastern part of the country there are about 0.7 million heads of camels (Tezera G. et al., 1998). Pastoralists and agro-pastoralists who account for about 55% of the land area and 15% of the population in arid and semi arid zones of the country rare their camels in this area, where feed resources are frequently scarce.

Camels possess a remarkable ability in exploiting limited resources and are usually reared in areas where feed resources are scarce. The camel can stand high temperatures and extremely low humidity, which makes it to have a definite advantage over cattle and horse for draught work on arid sands (Pathak, 1984). It was first domesticated for use as pack and riding animal and later for ploughing. The draught camel is needed for a variety of functions including pulling carts, drawing wheels, ploughing and conveying water. It is also used in processing plants, sugar cane crushers and oil mills (Mathew, 1987).

From the national point of view, this animal provides an attractive solution to farm power needs in the rural economy, and it is a national asset, which consumes renewable resources not requiring foreign exchange. The ability to endure harsh environment has made camels to be the most important animals that assure better survival and continue to support the pastoral society of Ethiopia. In addition to this, these days’ camels, inhabiting agro pastoral regions, are coming close to the high land regions, which was not the case before. As the result, they can serve as potential source of draught power, for crop cultivations in these areas as well. A
Currently, the Agricultural Mechanization and Food Science research projects are operating under one program. The regional rural technology research centers, which all are here today, reflect the due emphasis given to the sector by the policy makers. The effort to date has been on the improvement of farm tools and implements, delivery of processing technologies and recipes. Yes, so many are developed, yet the step forward is not only invention, but we must be innovative enough so that new ways of doing things must also be the agenda and technology should reach the end users and change their livelihood. At this forum, during these three days, scientific discussion will be held, mature technologies will be exhibited and there will be a poster session as well, which all will be the interface between the research and the end user. It is timely and appropriate to set this forum and I hope we will have it at least once in two years to deliver technologies to the end user. We have traders, manufacturers along with the users, who can very much be instrumental in the diffusion of the technology.

The machinery sector as well as the processing side has been moving following the classical way, but the new order of the world may not permit us to move at a snail's pace. Preserving the environment should be the agenda; as it has not been that much spoiled, so we should grab always the best and take a leap to survive in this competitive world not only for today but for tomorrow as well.

These days the developed world is on precision agriculture, where site-specific agricultural conditions are monitored and inputs like fertilizer, herbicide and other amendments are metered and delivered on the spot. In our case, we are still working on blanket recommendation across regions, which we cannot afford to continue both from detrimental effects to the environment and cost factors. The Agricultural Engineering technology should focus on versatile technology to suit site-specific conditions with minimal effects on the environment on sustainable basis. Currently there are quite a few technologies and whatever is available is underutilized, because few know of their existence and such a forum is one of the ways to communicate the technologies to the different stakeholders. The access to this information and the governing policies are crucial to direct the development. As mentioned above the Agricultural mechanization Food Science and Post harvest research program generates technologies, which create the environment for the biological inputs to perform to their optimum potential and work on value addition to help farmer's reap the benefits. Tremendous efforts have been made in this context, which we will hear in the deliberations and see in the exhibition and poster session. Today quite a few papers will be presented by the six centers and invited organizations, manufacturers, dealers, which will help us to recognize what have been done so far, and what is to be done in the years to come. I would like to thank the organizers, the funding organizations, and all the participants for making the forum possible. Hoping that you enjoy the deliberations, I officially declare the event open.

Thank you
The camels worked continuously on each of the draught load for three hours daily. The physiological responses (respiration rate, pulse rate and body temperature) of the camels were recorded before the work and after each half an hour of work, by stopping them for 5 min. Respiration rate was recorded by putting the hand in front of the nostril and counting the expired air. Pulse rate and rectal temperature were recorded by clinical veterinary stet scopes and clinical veterinary thermometer respectively. The ambient temperature and relative humidity were recorded during the experiment period.

Factorial experiment in complete block design (Gomez and Gomez, 1984) with three replications was used for the study. ANOVA was performed using SAS (SAS Institute, 1999). Means were then compared at $p<0.05$ using Duncan's Multiple Range test.

Figure 1 Sledge in use in the loading experiment.

Figure 2 Determination of the pull using a load cell.
survey by Yohannis et al., (2007) revealed that ploughing using camels is more common in Kebriboyah than in Babilie and there is a saying in Kebriboyah, “a camel is a tractor”, indicating its greater power for ploughing a land. In Bofa area, which is located in the central rift valley of Ethiopia, ploughing with camels is also a common practice.

To obtain the optimal use of camels, their sustainable level of work performance needs to be assessed. Achieving this requires knowledge on the level of acceptable draught force, which depends on the physiological factors and the working conditions (Starkey 1989; Singh 1999). One of the dominant factors in assessing the work performance of the draught animal is the draught force. If the draught force required to move implements is greater than the force the animals can produce the task cannot be carried out, and if the force required is unacceptably high, the work cannot be sustained (which was not taken in to consideration in the previous works). The other dominant factors used to assess performance are working speed and change in physiological parameters during and after work. Draught animal physiology study usually involves the measurement of the effect of various level and intensities of work on the physiology of working animals like body temperature, heart rate, breathing rate and oxygen uptake. Physiological parameters help to assess the animal’s ability to perform the work.

Some interesting works were done regarding the suitability of camel for draught power in Ethiopia. However, limited or no study was conducted on camel draught capacity in relation to its work physiology under natural environment. The previous researches lack these very important parameters in their methodology. It was, thus, found essential to test draught performance of camels in light of their physiological reactions under actual field conditions, to give a comprehensively picture about the draught potential of Ethiopian camels.

Materials and methods

The experiment was conducted on-farm at Bofa, located in the central rift valley of Ethiopia, where ploughing by camels is common. Based on their earlier experience on ploughing, three good medium size camels, non-descript of breed, were selected for the study. Their ages and body weights were between 5-6 years and 525-555 kg, respectively. The camels were trained for two weeks by letting them pull sledges. Throughout the experiment period, the camels were left to be managed by their respective owners through the conventional system.

The camels were subjected to the different draught loads by changing the weight levels on the sledges as shown in Figure 1. The draught capacity and physiological response of each camel at 50kg, 80kg, 95kg and 110 kg weight levels were measured. These ranges were selected as the animal generally works at draught loads of 18 to 20 percent of the body (Anonymous 1999). The pull at different weight level settings of the sledges was measured using a load cell and a load cell indicator (Novatch equipment) as shown in Figure 2. Speed was measured for the set distance (40m) using a stopwatch and a measuring tape. The angle of pull (θ) was calculated from the horizontal and vertical distance from the point of hitching of the sledge to the fixing point on the harness. Then the horizontal draught force was calculated using the relation (Starkey, 1989):

$$D = P \cos \theta$$

Where: $D$= horizontal draught force; $P$= pull and $\theta$= angle of pull.

Using the speed, distance covered and draught force the work and power output was calculated.
Results and discussion

The ambient temperature varied between 33°C and 38°C while the relative humidity ranged between 36% and 47%. This indicates the relatively drier weather in which the camels are operating.

**Speed, horizontal draught force and work and power outputs**

**Speed**

Significant ($p<0.05$) difference was observed in some of the working speeds at the different weight levels under which the camels operated (Table 1). The working speed at the 50 kg (1.43m/s) weight level was the highest while that of the 110kg (0.62m/s) was the lowest. Between the 80kg and the 95kg weight levels, the variation in speed is not significant. The working speeds of the camels during the three hours of work decreased with the increase of the loads. The working speed of the camels decreased with the increase of the work duration and this agrees with the findings of Bhatt et al., (2002). The working speed of the camels varied between 1.197m/s (in the first one-hour period) and 1.07m/s (in the third one hour period). However, between the second and the third one hour periods it did not show significant variation. No significant ($p>0.05$) difference due to the interaction of draught load and work duration was observed.

**Horizontal draught force**

The horizontal draught forces increased with the increase of the weight level. Each horizontal force exerted on respective load levels significantly ($p<0.05$) varied. The minimum was recorded at the 50kg weight level (444.27N = 8.3% of the average body weight of the camels) and the maximum at the 110kg (822.41N = 15.4% of the average body weight of the camels). The horizontal draught forces exerted in every consecutive work hour durations were significantly ($p<0.05$) different. The lowest horizontal draught force exhibited was in the first one hour period (615.3N=11.5% of the average body weight) while the highest was on the third one hour period (643.1N=12% of the average body weight). The interaction of draught load and duration of work was not significant ($p>0.05$).

**Work output**

The work output at 110kg (1.53MJ) and 95kg (1.49MJ) load levels were considerably higher than the remaining weight levels. The work output at 80kg (1.32MJ) weight level was significantly higher than the 50kg (0.98MJ). As work output is the product of force exerted and distance covered, the work output on the four load levels almost followed the trend of the horizontal draught forces. The work output decreased with the increase of the work durations. The work output in the first hour period (1.44MJ) was significantly ($p<0.05$) higher than the remaining two consecutive one hour periods. However, there was no significant difference between the second hour period (1.28MJ) and the third hour period (1.27MJ). The interaction of load levels and duration of work was significant ($p<0.01$).

**Power output**

The power output at the four weight levels showed significant difference ($p<0.05$). They ranged between 0.634KW (50kg weight level) and 0.774 KW (95kg weight level). The power output at 95kg weight level was significantly higher than the rest of the weight levels, which
Proceedings of the first mechanization and food science research forum

had no significant deference among themselves. The trend of an increase in the power out put with the increase of draught load until certain limit and declining with further increase of draught load agrees with the conclusion made by Starkey (1989). However, no significant (p>0.05) variation in the power outputs was observed in the each one hour period of the three hour continuous experimental duration. The maximum power out put was recorded in the first hour period (0.706KW) while the lowest was for the third hour period (0.659KW). No significant (p>0.05) difference due to the interaction of load levels and work duration was observed.

Table 1 Work speeds, horizontal draught forces, work and power outputs of the camels.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Speed (m/s)</th>
<th>Horizontal draught force (N)</th>
<th>Work output (MJ)</th>
<th>Power output (KW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight level (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>1.427a</td>
<td>444.27a</td>
<td>0.98c</td>
<td>0.634b</td>
</tr>
<tr>
<td>80</td>
<td>1.143b</td>
<td>568.23c</td>
<td>1.32b</td>
<td>0.647b</td>
</tr>
<tr>
<td>95</td>
<td>1.137b</td>
<td>681.40b</td>
<td>1.49a</td>
<td>0.774a</td>
</tr>
<tr>
<td>110</td>
<td>0.617c</td>
<td>824.09*</td>
<td>1.53a</td>
<td>0.671b</td>
</tr>
<tr>
<td>Measurement time (min.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>1.197a</td>
<td>615.30e</td>
<td>1.44a</td>
<td>0.706a</td>
</tr>
<tr>
<td>120</td>
<td>1.126eb</td>
<td>630.09b</td>
<td>1.28b</td>
<td>0.679b</td>
</tr>
<tr>
<td>180</td>
<td>1.07b</td>
<td>643.10a</td>
<td>1.27b</td>
<td>0.659a</td>
</tr>
<tr>
<td>CV (%)</td>
<td>9.36</td>
<td>2.26</td>
<td>6.08</td>
<td>10.13</td>
</tr>
</tbody>
</table>

Values within the same column with different letters are significantly different (p<0.05).

Physiological responses

Pulse rate

The mean pulse rates of the camels during the three-hours of continuous work, being subjected to varying loads increased as the weight level and duration of work increased (Table 2). This agrees with reports elsewhere (Bhatt, et al., 2002). Significant (P<0.01) difference in pulse rate was observed across load levels and it ranged between 20.4 beats/min (for the 50 kg load) and 25.8 beats/min (for the 110 kg load) (Table 2). Similarly, pulse rate appeared to increase with duration of work. However, no significant difference was observed after working for the first one hour period. This could perhaps tell that the pulse rate of the camel seemed to stabilize after the second 30 min period. The interaction between load level and duration of work was found to be significant (P<0.01).

Rectal temperature

The mean rectal temperature of camels over four load levels ranged between 37.5 °C and 38.01 °C (Table 2). Rectal temperature appeared to significantly (P>0.05) rise with increase in load level. However, the rectal temperature at 50 kg weight level was higher than at 80 kg and this would probably associate with the influence of the weather conditions. Agreeing with the works of Bhatt et al., (2002) mean rectal temperatures increased with duration of work. Except the fourth 30 min period (38.01 °C), the mean rectal temperatures at the fifth (38.07 °C) and the sixth (38.15 °C) 30 min period were significantly higher than the rest of the work durations as this time coincides to mid day when the sun comes right over the head. However, no marked variation (p>0.05) was observed among the mean rectal temperatures in the first (37.75 °C),
second (37.75°C) and third (37.88°C) 30 min. periods. The interaction between load levels and duration of work was significant.

Respiration rate

The mean respiration rate of camels at four load levels during the three hours of work period is presented in Table 2. It ranged between 14.9 breaths/min and 18.0 breaths/min. Respiration rate exhibited more or less a similar trend over all the load levels like the pulse rate. The respiration rate counted at 95kg (18.00 breaths/min) and 110kg (17.71 breaths/min), load levels did not show considerable difference. Respiration rate of the camels increased with the increase in duration of work, confirming the findings of previous workers (Anonymous 1999; Bhatt et al., 2002). Respiration rate of camels increased while working up to the first one hour and then continued without significant change. Here also the interaction between load levels and duration of work was significant (p<0.05).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean Rectal Temp. (°C)</th>
<th>Mean Pulse rate (beats/min)</th>
<th>Mean Respiration rate (breaths/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight level 50</td>
<td>37.79°C</td>
<td>61.2855e</td>
<td>14.93e</td>
</tr>
<tr>
<td>(kg) 80</td>
<td>37.50c</td>
<td>67.7142c</td>
<td>15.7887b</td>
</tr>
<tr>
<td>95</td>
<td>37.98a</td>
<td>71.5713b</td>
<td>18.0000a</td>
</tr>
<tr>
<td>110</td>
<td>38.01b</td>
<td>77.4285a</td>
<td>17.7144b</td>
</tr>
<tr>
<td>Duration of work 0</td>
<td>37.03d</td>
<td>42.2499d</td>
<td>11.7501°</td>
</tr>
<tr>
<td>(min.) 30</td>
<td>37.75c</td>
<td>69.7500°</td>
<td>18.8409b</td>
</tr>
<tr>
<td>60</td>
<td>37.84a</td>
<td>71.4999b</td>
<td>19.2501b</td>
</tr>
<tr>
<td>90</td>
<td>37.88a</td>
<td>74.0001a</td>
<td>19.7499b</td>
</tr>
<tr>
<td>120</td>
<td>38.01b</td>
<td>75.0000b</td>
<td>20.0001b</td>
</tr>
<tr>
<td>150</td>
<td>38.07a</td>
<td>77.0001b</td>
<td>21.5001b</td>
</tr>
<tr>
<td>180</td>
<td>38.15a</td>
<td>77.0001b</td>
<td>21.5001b</td>
</tr>
<tr>
<td>CV (%)</td>
<td>6.08</td>
<td>0.53</td>
<td>11.31</td>
</tr>
</tbody>
</table>

Values within the same column with different letters are significantly different (p<0.05).

Conclusions and recommendations

Camels are potential and good sources of draught power in hotter areas. A single camel has been seen to work in hotter place up to a horizontal draught force level of 568.23N comfortably without encountering any physiological stress. This level of pulling force is believed to suffice for ploughing light soils that are predominant in arid and semi-arid areas. At this draught level, the camel can work at an average speed of 1.14m/s and can generate 0.65KW power.

As this study is limited to, camels found in the mid rift valley, similar works should be done on camels found in other areas of the country.

References

EVALUATIONS OF ARDU MOULD BOARD PLOUGH FOR DONKEYS AND HORSES

Wondiye Gezahegn
Asella Rural Technology Research Center P.O.Box 06. Asella
e-mail: wondiye2@yahoo.com

Abstract
Agriculture in Ethiopia is mainly performed using oxen power and hand hoe technology. Agronomic practices such as frequency and time of land preparation are determining factors in productivity of a given land. Due to shortage of oxen, and labour, farmers at times fail to prepare their farm on time; this reduces the opportunity for early planting and this adversely affects crop yield. Thus taking the advantage of ample numbers of pack animals (donkeys & horses) and experience of using them for tillage activities, this experiment was planned to evaluate the draft power of these equines for primary tillage. The experiment was conducted at Dodota Sire, Arsi Zone, where the predominant soil type is sandy. Four treatments were used under Randomized Complete Block design for three consecutive days on a farmer’s plot size of 50mx50m after training the working animals. Data on working depth, width, time, management practices were collected and subjected to ANOVA. No significance difference was observed in terms of working capacity among the treatments. The result showed that donkeys and horses can produce sufficient power to do form activities in areas similar to the test site. Thus, extensive demonstration should be conducted and farmers should be trained on the use of horses and donkeys for draught purposes.
Introduction
In many developing countries such as Ethiopia, the whole agricultural production system depends mainly on hand hoe technology and oxen powered traditional plough. Lack of adequate power (oxen) during the time of land preparation, cultivation, and other activities is one of the main constraints of the farming system in many areas. On top of this, farmers’ dependence on oxen and the poor condition of the oxen at the onset of rain because of prolonged dry season results in delay of farm activities, which will reduces the opportunity for early cultivation thereby adversely affecting crop yield. On the other hand, the ample source of equines such as horses and donkeys and experience of using them for farming activity is a good solution for the problem. In many rural parts of Ethiopia, donkeys and horses are primarily used for transporting purpose, despite their high potential for drawing other agricultural implements other than transport devices. However, in many parts of the country like Tigray and South Wollo, a donkey harnessed with a horse, or with an ox is observed to perform tillage activities, which indicates a good indigenous farm level resource utilization enhancing agricultural productivity. This alleviates labour shortage, especially during peak periods. Taking the ample number of equines in every rural household and shortage of draught power at peak periods into account, this project was initiated to evaluate donkeys and horses draught power for tillage activities.

Materials and methods

Experimental Area Description
Dodota Sire is located some 125 km south east of Addis Ababa in the in the mid Rift Valley. The area is characterized by low altitude, between 1000m and 2500m a.s.l. and has annual rain fall between 400mm and 700 mm and temperature ranging between 15 °C and 25 °C. The farming system of the area is mixed type (crop- livestock). Even though rain fall is bimodal in the area, the Belg rain is usually late and poor, decimating the Belg crops, hence reducing the area cultivated during Belg, and Meher cultivation is common for major crops like tef, wheat and low land pulses. The main season rainfall is very variable with prolonged dry spells on many areas and mostly heavy in July and August. Since Awash River crosses the woreda, irrigation around the riverbank is commonly practiced where vegetables like onion, tomato potato; and fruits crops such as mango, papaya, banana avocado etc are highly produced during off season.

Materials
Materials used for the experiments were
- ARDU plough with all its accessories
- Local yoke with local harnessing materials
- Data collecting equipment such as measuring tape, ruler, stopwatch, ropes
- Working animals (two oxen, one horse, one donkey)

Methods
A plot size of 50mx50m was allotted for the experiment on the selected farmer’s farm at Awash Fashola peasant association some 5km west of Dhera, main city of the project woreda. The working/experimental/animals for the experiment were selected randomly, from the local breed. Hence two oxen, a horse and a donkey were selected for the experiment. The animals were trained for three days prior to the setting of the experiment and were aquatinted with each other and worked freely. Hence, Variation caused due to training would be minimal. Four treatments; ox-ox, ox donkey, ox- horse and ox-ox (control) combination were formed and each pair (treatments) was replicated three times every other day.
Experiment time
The experiment was conducted at Dodota Sire Woreda, Awash Fashola peasant association. The area is characterized by light sandy soil and bimodal of rainfall. The test started right on the onset of the meher season early March, when land preparation is usually started. The farm was non fallowed and of medium moisture condition, when the experiment commenced.

Data Collection
The experiment was conducted in RCBD. Four treatment combinations were considered for the evaluation purpose, where each treatment was tested on the same day and replicated on the next two days. Due to incompatibility between donkey and horse and unsuitability of yoke for these animals, data on the fourth treatment was not taken. Data on width and depth of ploughing, problems observed while harnessing and ploughing, time were recorded for every furrow making operation having 50m length. Average working speed, working capacity were calculated by using appropriate mathematical formula. The data was subjected to ANOVA.

Results and discussion
The animals were made to work for one continuous hour and time taken to cover each furrow was recorded excluding time elapsed for turning operation. The working capacity for each treatment is calculated by dividing total area (average for on width x depth) by average time taken. The ox was guided by children in all cases to avoid additional source variation due to incompatibility of working animals. The horse’s eyes were covered from the sides, for better walking as horses are well trained in transporting carts in this manner. The yoke was made to suit the body of horse and donkey by laying straw filled bags under the yoke to avoid injury over their shoulder. Horses were found not to move straight with in furrow and it was the ox that was responsible to keep the horse in furrow this created stress and discomfort to the ox from the side during the experiment. The working capacity for ox- donkey combination (531.8m²/hr) was found superior than ox–horse pair formation (491m²/hr) and the control combination (487m²/hr). However, there was no significance difference between them at 5% probability level. Similarly, there was no significance difference between treatments for other dependent variable (walking speed) which is a bout 0.53m/s for ox-horse, 0.5 m/s of ox-donkey and 0.49 m/s of the control treatment but the horse was able to produce fast working speed than the others. Thus, it is concluded that horse and donkey can equally produce sufficient drought power as oxen do, in pulling the plough. Even though 3 days training was given, the horse failed to go straight with in the furrow and the ox was observed taking responsibility of keeping the team in the furrow. This created stress and discomfort on the ox from the side. A better result was obtained, when guided by children and the horse’s eyes were covered from the sides. The horses moved faster than ox and donkey even though there was no significant difference between working areas and depth of ploughing. Ploughing with horse/donkey, was unusual for the locality and out of culture, but at the end, they were convinced and were happy with the result.

Table 1 Average value of dependent variables calculated for each treatment.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$T_1$ (Ox-Ox)</th>
<th>$T_2$ (Ox-Horse)</th>
<th>$T_3$ (Ox-Donkey)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave Width of cut (cm)</td>
<td>32</td>
<td>32.5</td>
<td>34.3</td>
</tr>
<tr>
<td>Ave Depth of cut (cm)</td>
<td>14.1</td>
<td>12.1</td>
<td>14.3</td>
</tr>
<tr>
<td>Ave Working Capacity (m²/hr)</td>
<td>487</td>
<td>491</td>
<td>531.8</td>
</tr>
<tr>
<td>Walking speed (m/sec)</td>
<td>0.49</td>
<td>0.53</td>
<td>0.50</td>
</tr>
<tr>
<td>Total distance covered (m)</td>
<td>1521.7</td>
<td>1510.8</td>
<td>1555.5</td>
</tr>
</tbody>
</table>
Table 2 Average working speed in m/s calculated for each replication by taking three sample interval times

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rep 1</th>
<th>Rep 2</th>
<th>Rep 3</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ox-Ox</td>
<td>0.61</td>
<td>0.45</td>
<td>0.43</td>
<td>0.49</td>
</tr>
<tr>
<td>Ox-Donkey</td>
<td>0.57</td>
<td>0.49</td>
<td>0.44</td>
<td>0.50</td>
</tr>
<tr>
<td>Ox-Horse</td>
<td>0.58</td>
<td>0.57</td>
<td>0.43</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Table 3 ANOVA for each treatment values against parameters used for evaluation.

<table>
<thead>
<tr>
<th>Width of cut</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>Fcal</th>
<th>Ftab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between treatment</td>
<td>8.59</td>
<td>2</td>
<td>4.295</td>
<td>0.28</td>
<td>5.14(5%)</td>
</tr>
<tr>
<td>With in treatment</td>
<td>91.89</td>
<td>6</td>
<td>15.315</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>100.49</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth of Plough</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>Fcal*</th>
<th>Ftab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between treatment</td>
<td>4.56</td>
<td>2</td>
<td>2.28</td>
<td>1.259</td>
<td>5.14(5%)</td>
</tr>
<tr>
<td></td>
<td>3.78(5%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With in treatment</td>
<td>10.88</td>
<td>6</td>
<td>1.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>15.44</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- No Significance difference between the three treatments

DEVELOPMENT AND TESTING OF PNEUMATIC TIRE WHEEL RIM AND AXEL FOR ANIMAL DRAWN CART

Wondiye Gezahegn¹, Alamnahi Hiruyi¹
¹Asella Rural Technology Research Center
P.O.Box 6, Asella

Abstract

The common types of wheeled carts produced in Ethiopia are made from imported pre fabricated cast wheel rim and is not available in the market. Asella Rural Technology Research Center has faced problem of manufacturing animal drawn carts despite the high demand. To address the issue, different size sheet metals, angle irons, steel shafts, bolts and nuts were selected for production of three kinds of carts with different rim-axles. They were taken to Addis Tire and Metal Products Development Center to check for the strength of the rim and compatibility of the rim for the tire produced in the country. Secondary test was carried out at Dodota Sire wereda where the cart was used for transporting load. Data were collected on distance traveled per day (km), amount of material transported/day, type of load and problem encountered over a period of 3-4 month. The results indicated that the rim made from 6mm plate had a superior performance and found to substitute the imported ones for a maximum load of 10 quintals, which is the maximum safe load
recommended to be transported on level terrain (<5% slope). The use of wire reinforced tire could inflate the production cost of the cart, but this can be significantly reduced by using the cheapest tire available on the local market or used vehicle tire or non reinforced tire. Detaching the wheel rim from the shaft and the tire from wheel rim can be easily done just with two types of spanners. Thus, further demonstration need to be done on farmers' field.

Introduction
Transportation often constitutes a major problem in rural areas of Ethiopia. Adequate means of transport facilities are unavailable and even large loads are mostly still moved on the back of donkeys, horses, mules and human beings. Besides, most farmers use sledges, which slide on runners. This imposes a considerable burden on rural communities and imposes a considerable constraint on improving their standard of living. Simple wheeled carts such as hand carts and animal drawn carts can have a major impact on reducing the transport burden, but at present, they are used for only about 10% to 15% of goods transported. Although affordability is the main limitations on their wider use, production and supply of these carts are also often serious constraints.

The quality of the wheel-axle assembly is the most important factor affecting the performance of simple carts and is the main cost item, usually comprising at least 50% of the total cost. Lack of suitable wheels and axles are the limiting factors for producing low-cost carts, particularly in rural areas. The importance of animal drawn cart in general for agricultural and non agricultural activities is tremendous. It is playing a key role in transporting harvested crop from field to threshing place, from threshing place to home or market place. It is also used for non agricultural activities like transporting, water, people and even in some areas serves as rural ambulance when required.

Pneumatic wheels and axles were imported by donors long years ago and now the Assela Rural Technology Research Center is running out of stock and unless some solution is found in time, the center may be forced to stop producing carts.

The solution is either to continue importing from outside or to produce in the country from locally available raw material. By considering these factors, this project was proposed to find a solution by producing the rims in the country from locally available material.

Material and methods
Material selection
The material selected for this experiments was, steel shaft believed to be strong enough to carry 10 quintals safely. Aluminum sheet, low grade sheet metal or even carbon steel, C35-C40, carbon content were recommended for the drum. Light bolts and nuts (M6-M8 type) were selected for the production of the samples. The determining factor is balancing of the rim while manufacturing than the strength of individual material.
Table 1 Material used for sample production.

<table>
<thead>
<tr>
<th>Parts of the Prototype</th>
<th>Materials used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample No 1</td>
<td></td>
</tr>
<tr>
<td>- Outer rim</td>
<td>6 mm sheet metal</td>
</tr>
<tr>
<td>- Inside rim plate</td>
<td>4 mm sheet metal</td>
</tr>
<tr>
<td>- Outer rim flange</td>
<td>Angle iron 30x30</td>
</tr>
<tr>
<td>Bolt and nut</td>
<td>M6-M8 type</td>
</tr>
<tr>
<td>Sample No 2</td>
<td></td>
</tr>
<tr>
<td>- Outer rim</td>
<td>4 mm sheet metal</td>
</tr>
<tr>
<td>- Inside rim plate</td>
<td>6 mm sheet metal</td>
</tr>
<tr>
<td>- Outer rim flange</td>
<td>Angle iron 30x30</td>
</tr>
<tr>
<td>Bolt and nut</td>
<td>M6-M8 type</td>
</tr>
<tr>
<td>Sample No 3</td>
<td></td>
</tr>
<tr>
<td>- Outer rim</td>
<td>3 mm sheet metal</td>
</tr>
<tr>
<td>- Inside rim plate</td>
<td>4 mm sheet metal</td>
</tr>
<tr>
<td>- Outer rim flange</td>
<td>Angle iron 30x30</td>
</tr>
<tr>
<td>- Bolt and nut</td>
<td>M6-M8 type</td>
</tr>
<tr>
<td>Axe for wheel rim</td>
<td>-Sheet metal 6mm</td>
</tr>
<tr>
<td></td>
<td>-Hollow steel pipe Ø 70</td>
</tr>
<tr>
<td></td>
<td>-Steel shaft Ø 80, 70, 60</td>
</tr>
<tr>
<td></td>
<td>-Bearing 1308, 6208</td>
</tr>
</tbody>
</table>

Manufacturing operation

The following workshop activities were employed for manufacturing the samples:

- Designing
- Measuring & Tracing
- Cutting
- Drilling
- Forming including bending, rolling and lathing
- Welding & finishing
- Assembling
- Painting

The Wheel rim

The rim had a detachable flange so that the tire could easily slide on to the main part of the rim and then held in position by bolting on the other part of the rim. The tire was readily fitted with little effort using spanners. The rim was formed from a piece of sheet metal, 190mm wide and 4mm thick and the material was selected to take a 16” animal drawn cart pneumatic tire wheel. For considerations of strength, the rim section should not be less than 4mm thick, but a section greater than 6mm thick will be more difficult to roll or bend and will add unnecessary weight to the wheel. The inside and outside diameters of the rim were 400mm and 408mm respectively and its length was 1242mm with 2mm gap for welding. The rim flange was rolled from 30 30mm angle iron. The inside rim flange diameter and its length were 412mm and 1294mm respectively. The flanges were set right at
the edge of the rim to give the greatest width between the flanges to fit the pneumatic tire wheel. Only one flange was welded to the rim. The other was drilled at six equally spaced points and six clamps were welded for bolting and clamping on to the main part of the rim. The plate, which joined the rim to the axle, was prepared from 6mm thick sheet metal and welded perpendicular to the center and rim.

The Axle for the wheel rim
The axle supports the wheel and transfers forces between the wheel and the cart body. The radial and side loads on the wheel cause bending of the axle with maximum bending stresses on the top and bottom surface of the axle. The axle was designed to be strong enough to withstand these bending stresses. The shocks and impacts of running over stones, bumps, potholes together with the wheel loads result in continuously varying bending stresses in the axle and thus the axles had to be designed against fatigue failure. Fatigue failure is an accumulative form of damage, in which the stress cycles (variation) build up until a crack starts in the material and the crack then grows until the material section breaks (fractures). Fatigue failures may therefore not occur until the cart has been operating for several years and axles need to be designed to last for an acceptable lifetime. Based on the above facts, an axle sample, which can substitute the imported one was designed and produced.

Testing

All the three samples of the rims were taken to the local tire factories and concerned institute to check for the strength and compatibility with the tires available on the market. Thus, Addis Tire, the major tire producers in the country and Metal Products Development Center metal strength testing institute were selected for the purpose.

Addis Tire
Addis Tire, the only car tire producer in the country producing two types tire size for 15” and 16” rim size was selected for the project purpose. The rim size (16”) was compatible with the tire size available in the market. They can produce wireless tire, which is appropriate for our purpose, based on request. Hence, this can reduce the price significantly. In addition to this, the availability of 15” tire rim was also taken in to account if tire rim 15” size is produced in minimizing cost of production.

Metal Products Development Center
Though they did not have machine test, they evaluated and commented on the samples based on the engineering principles selected for the work i.e. dynamic load balance and the strength of sheet metals, bolts and nuts selected were strong enough to carry a pay load to 10 quintals safely on a smooth and small gradient road condition. Uniformity of the rim (symmetrical) in shape, weight, holes, distance between flanges, electrode distribution etc had to be kept minimal. Thus, the geometrical and positional errors should be balanced to avoid dynamic load effects.
Results and discussion
After making the necessary corrections on the defects based on the comments given, the rims were fitted to the cart body and primary tests were carried out in the center. In addition, secondary test was carried out in the selected sites in Dodota Sire woreda, where the whole activity of the project was conducted. Data on distance traveled per day (km), amount of material transported/day, type of load and problem encountered over 3-4 months period were collected. The rim made from 6mm rim plate had superior performance and found to substitute the imported ones for a maximum load, of to 10 quintal, which is the maximum safe load recommended to be transported on level terrain (≤5% slope), as compared to the rest of the samples, which cracked. The use of wired reinforced tire could escalate the production cost of the cart but this can significantly be reduced by using the cheapest tire available on the local market or used vehicle tire or non-reinforced tire. Detaching the wheel rim from the shaft and the tire from the wheel rim is effected using only two spanners.

Recommendation
From the result rim no 2 with the modified shaft showed superior performance and is recommended to substitute the imported ones for up to a maximum load of 10 quintal, which is the maximum safe load recommended to be transported on level terrain (≤5% slope).

The use of wire reinforced tire, inflated the production cost of the cart but this can significantly be reduced by using the cheapest tire available on the local market or used vehicle tire or non-reinforced tire.

From the performance of the carts it is concluded that, the more symmetrical the wheel rim, the less the plate cracks or wear and the more durable the cart will be. Hence, it has to be produced by using jigs and fixture in order to keep symmetry of the rim.

The possibility of detaching the wheel rim from the shaft and the tire from wheel rim, with only two types of spanners, eases maintenance service, which is an additional merit of the carts. Hence, the carts have to be widely demonstrated among the users.
Table 2 Analysis of Field Tests of Modified of Axle and Rim of Animal drawn Cart

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Testing(observation) Period</th>
<th>Total Distance Traveled (KM)</th>
<th>Average Distance Traveled per day(km)</th>
<th>Total Amount of material transport</th>
<th>Average Amount of material transported each day</th>
<th>Total Number of Days the cart is in operation</th>
<th>Treatment effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-</td>
<td>Outer rim 6 mm sheet metal</td>
<td>4.5 month</td>
<td>1608</td>
<td>20</td>
<td>785</td>
<td>9.8</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Inside rim plate 4 mm sheet metal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The inside part of the rim(plate) at the joining (welding)point cracked &amp; bolting hole of the rim became wider</td>
</tr>
<tr>
<td>2</td>
<td>Outer rim 4 mm sheet metal</td>
<td>3 month</td>
<td>1315</td>
<td>20.2</td>
<td>638</td>
<td>9.8</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Inside rim plate 6 mm sheet metal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Not Significant problems so that it is still working</td>
</tr>
<tr>
<td>3</td>
<td>Outer rim 3 mm sheet metal</td>
<td>2 month</td>
<td>506</td>
<td>20.4</td>
<td>240</td>
<td>9.6</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Inside rim plate 4 mm sheet metal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The inside part of the rim(plate) at the joining (welding) point cracked &amp; bolting hole of the rim became wider</td>
</tr>
<tr>
<td></td>
<td>Outer rim flange</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>control</td>
<td></td>
<td>4 month</td>
<td>1608</td>
<td>20.1</td>
<td>785</td>
<td>9.8</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Performed with bowt any problem</td>
</tr>
</tbody>
</table>
DEVELOPMENT AND EVALUATION OF CAMEL DRAWN CART

to move the maximum set payload using an average size camel.
To see maximum slope and maximum load, which the camel can overcome, the
following calculation was calculated:

\[ F = \frac{2500 \times 0.04 \times \cos \theta}{0.966} \]

We assume slope \( \theta = 1\)° - 3°.

Transport of goods and persons in most rural areas of Ethiopia including the Amhara Region is carried out
mainly by humans on foot imposing burden on rural household in terms of both time and effort. In the region
still people travel on foot and animal back. Among the draft and pack animals, camel has become more popular,
especially in low-lands of East Amhara region. The long legs of camels allow them to walk quickly with
approximate speed of \(2\) m/s, but the height poses some problems for effective harnessing and applying effective
traction force. The average camel weighs 500kg and produces a draft force of 10-15\% of its body weight i.e.
more than 750 N force. Transporting by camel means generally transporting by far many goods in different
places and to attain this appropriate size camel drawn cart was developed. The tests revealed that the cart could
carry 13 quintals in a slope of 0° - 2°. For a maximum slope of 15° the optimum load was around 200 kg, and
beyond it would be better to use the camel as a pack animal. When the transverse angle increased above 29°, the
cart turned over. When the center of gravity height was more than 1.5m the angle was less than 29°, which
indicated the effect on the type of load, which can vary the height of the center of gravity of the cart as a whole. A
haulage test, impact test and field trials were conducted according to FAO testing procedure. Further evaluation
of the cart on farmers' field and durability study, and at the same time pre extension demonstration are
recommended in any part of Ethiopia where camels are available and the road condition fulfill the above
requirement.

Introduction

In Ethiopia, there are plenty of camels, which are not properly utilized. In North Wello where
is access to utilize these animals, their only used on contract base for packing and ploughing
purposes at a daily rate of 50 birr. Hence, the use of using camels for pulling carts is worth
considering. There is no information be it in the region or in the country on camel drawn
carts. Therefore it is important to give attention to all designing process and have appropriate
sized cart.

The basic issues to be addressed were the use of camels' drought power for various farming
techniques and off farm activities. Today, owning camels is a sign of having a lot of income
and ones wealth status, especially in North Wello, Kobo and Habru wereda. This was initiated
was based on the observation of experts from Kobo Girana Valley Development Project and
Kombolcha Rural Technology Promotion Center (KRTPC) around Kobo Valley. In addition,
for areas like Kobo plateau animal drawn carts give a lot of advantage for transporting
different types of load. The number of donkey carts around Kobo is estimated to be more than
200 (only around Kobo areas from wereda BOA). The farmers commented that the donkey
cart is utilized to transport a load of not more than 7 quintals and only for a short distance. To
transport more load over a long distance, the camel cart may be the choice. Based on the above
argument, a proposal was developed approved and as a result, two types of camel drawn carts
were developed.
Materials and methods

Base Line Survey
Assessment was made in Kobo and Habru weredas, using questionnaires. Farmers and development agents were interviewed; data on the area and camel population and conditions, body confirmation were recorded. Some of the parameters considered were:

- Average walking speed with out any load at normal ground surface -2m/s
- Average life of the camel -estimated 40 years
- Average starting in service -from 4 years
- Average price of the camel in Kobo-big camel 1500 birr, small camel 450 birr
- Types of service(utility of camel) -as pack animal up to 2 quintal

Camel Drawn Cart Design

Camel
The long legs of camels allow them to walk quickly with approximate speed of 2m/s, but the height poses some problems for effective harnessing and applying effective traction force. Unless, the traces of a camel harness are long (making turning difficult) the angle of pull is quite large, giving significantly higher ratio of "lift "to "pull" than with short animals. The amount of force, which an average sized camel can produce, was calculated according to the following formula:

Estimated weight (kg) = SH X HG X TG X 50

Where: SH – Shoulder height in meters
TG - Thoracic girth in meters
HG – Hump girth in meters

Accordingly, for the average sized camel, in the trial sites:
TG= 1.95 meter, HG=2.2 meter and SH= 2.0 meter
So estimated weight Gc= 2.0 x 1.95 x 2.2 x 50 = 429 kg almost 500 kg
Draft force (Df) is 10% -15% of their body weight
Df = 500 x 15% = 750 N

Cart Design Features

Cart Capacity
The average camel weighed 500 kg, and produce a draft force of 10 -15 % of its body weight i.e. about 750 N force. This amount of traction force at an average walking speed of camel, 2 m/s was the basis to design a cart with its appropriate size and shape. The average draft capacity of a camel was assumed 700 N. The limit on a cart with over all resistance factor of 0.1 of wheel resistance, bearing friction and gradient was estimated to be 700 kg load and the cart should over come twice this load, 1400 kg. Taking a design load of the cart, 14 quintals, the height of an average camel to the center of the back and the breast, where the beam is attached to the harness is around 180 cm and 127 cm respectively. The length of the average camel from the tail to the breast is set at 140 cm.
Options
From the above information and to fulfill the requirements, the following options were considered:

1. Single Axle: One axle with two wheels
2. Three wheels: One axle as the previous one and the other for steering and supporting the load (small axle for one wheel)
3. Two axles: Two wheels with one axle at the front (with flexible joint or rolling joint for steering) and two wheels with one axle on the back to support the load exerted on the cart.

Considering the base line data’s we tried to design the first and third options and select the best option for promotion. The options were Single axle and Double axle.

II.2. Details
The camel cart was designed to fulfill the following assumptions:
- Easy for loading and unloading
- Affordable for average farmer
- Easy to manufacture
- Durable
- Easy to maintain and repair with available materials and limited tools and spares
- Comfortable to the camel, with appropriate harnessing system to be pulled with a minimum draft force.

The cart had three main functional parts
A. The cart body (platform)
B. Suspension(support)
C. Axle and Wheel

A. Platform
The platform can be made from metal or wood. It depends on the interest of the farmer, but initially the platform was fabricated from sheet metal, because of its lightweight, availability, durability and ease of manufacture.

The following were considered in setting the size of the platform:
- Enough in volume and strength to carry a mass of 1500kg loads considering the type of loads and system of packing
- The width was set to be appropriate to the road size, 1.2-1.6 meters
- The length was set in the range of 1.8 meters -2.2 meters by the capacity of the cart
- For this particular case the area of the platform was set to be 2.8² meter, hence, the width is 1.4 meter and the length 2m or in other option, the width is 1.3 m and the length 2.2 m.

Each parameter of the cart parts were determined according to the strength of the material by considering the weight it exerts per unit area, assuming that the weight to be uniformly distributed.
B. Suspension (Support)

The suspension (support) as its name indicates supports the whole platform (body) and transfers the load from the floor area into the axle and wheel. It was made from angle iron 50mm x50 mm, with a “V” shape, supporting the platform on its sides at the front, the other side at the rear of the body. It was connected to the sheet plate welded on the bottom side and tightens with bolt and nut on the axle.

C. Wheel and Axle

The axle was made from a solid square shaft 70mm x70 mm, to effectively support and to resist the concentrated load in the short length and for supporting axial load. To join the two sides of the solid square shaft, a hollow shaft of 70 Ø mm was used.

Harnessing (Harness and Beam)

A ploughing harness with some modification was used in the study. Nevertheless, the length of the beam was calculated according to the size of the cart. Beam length was calculated by considering the height and length of the camel i.e. L=300cm

Before using the camel cart at different type of terrain and slope it is essential to know its draft force requirement. To calculate the force, the following method was employed:

Climbing upward (Figures 1 and 2)

\[ F_h = F_s + F_v \]

\[ F_s = G \times \sin \alpha \]

\[ F_v = G \times f \times \cos \alpha \]

Where,

- \( F_h \): draft force which is required to overcome other forces
- \( G \): weight of the cart (useful and dead weight)
- \( H \): the height of the center of gravity, Assume \( H=1.5 \) m
- \( F_s \): force against motion for the case of terrains slope it can be positive or negative (according to the motion of the cart upward or downward)
- \( F_v \): force of friction in different type of roads and wheels
- \( f \): coefficient of friction for different roads and rubber wheels
  - For asphalt \( f=0.012-0.018 \)
  - For rough road \( f=0.02-0.04 \)
  - For field (dry) \( f=0.03-0.05 \)
  - For field (wet) \( f=0.05-0.15 \)
  - For cultivated field \( f=0.16-0.18 \)
  - For sandy (dry) \( f=0.10-0.30 \)
  - For sandy (wet) \( f=0.10-0.15 \)

Draft force (\( F_h \)) is the sum of force against the motion (resistance force) i.e. \( F_s \) (force on the terrain), \( F_v \) (force of friction on different road conditions) and other forces (in our case force against wind, inertia force ... are negligible).

The draft force (\( F_h \)) required to pull the load \( G=5500N \) on the slope 5° terrain is

\[ F_h = F_s + F_v \]

\[ F_s = G \times \sin \alpha =5500 \times \sin 5^\circ = 479 \text{ N} \]

\[ F_v = G \times \cos \alpha =5500 \times 0.04 \times \cos 5^\circ = 219 \text{ N} \]

\[ F_h = 479 + 219 = 698 \text{ N} \]

The draft force required to climb on 5° slope terrain with the useful load of 450 kg (4500N) is 698N

Since the camel produce more than 700N it is easy to pull the above the specified load at this slope range. As 698N < 700N and it is within the draft capability of an average size camel.
At a maximum set slope angle, effort was made to check whether it could be possible to move the maximum set payload using an average size camel.

To see maximum slope and maximum load, which the camel can overcome, the following calculation was employed.

We assume slope $\alpha = 15^\circ$, $G= 2500 \text{ N}$ and $F_h = F_s + F_v$

$F_s = 2500 \times \sin \alpha = 647.04 \text{ N}$, $F_v = 2500 \times 0.04 \times \cos \alpha = 96.6 \text{ N}$

$F_h = 647.04 + 96.6 = 743.6 \text{ N}$

$743.6 < 750 \text{ N}$ and it is possible to pull on slope $15^\circ$ slope with the useful load of 200 kg (2000N)

To have slope and load relation on the table we apply the formula

$F_h = G \left( \sin \alpha + f \times \cos \alpha \right)$

Then $G = \frac{F_h}{\left( \sin \alpha + f \times \cos \alpha \right)}$

$F_h$ - draft force produced from the average camel (we took this as our reference)

When $\alpha = 0$, for rough road $f=0.04$ and

$G = F_h = 700 = 17500 \text{ N}$, then

$F_h = G \left( \sin \alpha + 0.04 \times \cos \alpha \right)$

Slope and load relation is calculated by substituting different slope (angle)

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$f$</th>
<th>$G$</th>
<th>$F_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.04</td>
<td>17500 N</td>
<td>700N</td>
</tr>
<tr>
<td>2</td>
<td>0.04</td>
<td>9348.9 N</td>
<td>700N</td>
</tr>
<tr>
<td>5</td>
<td>0.04</td>
<td>5511.6 N</td>
<td>700N</td>
</tr>
<tr>
<td>10</td>
<td>0.04</td>
<td>3285.7 N</td>
<td>700N</td>
</tr>
<tr>
<td>15</td>
<td>0.04</td>
<td>2353.3 N</td>
<td>700N</td>
</tr>
</tbody>
</table>

For maximum slope of $15^\circ$ the useful load is around 200 kg, beyond rather it is better to use the camel cart as a pack animal.

Downward (pressure on the camel)

$F_s$ - Is force acting downward, it can be additional force to the draft force.

$F_h = F_v - F_s = G \left( f \times \cos \alpha - \sin \alpha \right)$

When $\alpha = 5^\circ$ then

$F_h = 5500 \left( f \times \cos 5^\circ - \sin 5^\circ \right) = -260.19 \text{ N}$

$-260 < 750 \text{ N}$

When $\alpha = 15^\circ$ then

$F_h = 2300 \left( f \times \cos 15^\circ - \sin 15^\circ \right) = 506.4 \text{ N}$

$506.4 \text{ N} < 750 \text{ N}$

So the camel can resist downward pressure (pressure) of the cart as inertia force by its body weight. The longitudinal static stability is balancing at dead weight but during driving (pulling) on different terrain it is very essential giving attention during loading of useful loads, well and uniformly distributed loads on the platform keep the stability, otherwise the accident (lifting of the camel or turnover of the cart) can occur.
Transverse stability

H- We assume the useful load (can be hay, straw or any load) with dead weight can have the height of the center of gravity, \( H = 1.5 \) meter

L- Width of the cart from one center of the wheel to the other center, \( L = 1680 \) mm=1.68 meter

To calculate the relation we use the moment equation, Moment at point \( a = 0 \) is in balance,

Hence \( Ma = 0, G \cdot \cos \alpha \cdot L/2 - G \cdot \sin \alpha \cdot H \)

And \( G \cdot \cos \alpha \cdot L/2 = G \cdot \sin \alpha \cdot H \)

\( L = 2H \cdot \sin \alpha / \cos \alpha \)

\( \tan \alpha = L/2H = 1.68/3 \), Then

\( \alpha = 29^\circ \), When \( \alpha = 29^\circ \) it is in balance but it is critical (maximum)

So when the transverse angle is more than \( 29^\circ \) the cart will turnover.
If the center of gravity height is more than 1.5 m the angle will be less than 29°. So it depends on the type of load which can vary the height of the center of gravity of the cart as a whole.

Draft Force parameters for double axle cart

- **G**: Weight of the cart (useful + dead weight)
- **Dead weight of the cart**: 200 kg
- **H**: the height of the center of gravity, assume to be, H = 1.5 m
- **Fs**: Force against pull for the case of slope
- **Fv**: force of friction in different type of roads and wheels
- **Fh**: draft force

\[ F_h = F_s + F_v \]
\[ F_v = F_v1 + F_v2 \]
\[ F_s = G \sin \alpha \]
\[ F_v1 = G_1 f \cos \alpha \]
\[ F_v2 = G_2 f \cos \alpha \]
\[ G = G_1 + G_2 \]

Hence, \[ F_v = G_1 f \cos \alpha + G_2 f \cos \alpha = (G_1 + G_2) f \cos \alpha = G f \cos \alpha \]

For our case, \( G = 5500 \) N

- The dead weight of the cart is around 2000 N
- In addition, the useful load is 3500 N
- \( f = 0.04 \) — coefficient of friction on rough road

Draft force required to pull the cart with the above load on the slope of 5° terrain is

\[ F_h = G \sin \alpha + G f \cos \alpha = G (\sin \alpha + f \cos \alpha) \]
\[ F_h = 5500 (\sin 5° + 0.04 \times \cos 5°) = 698 \text{ N} \]

The camel can produce around 750 N

Therefore, 698 N ≤ 700 N and it is possible to pull by a single camel.

We can calculate slope and draft relation as the above. The stability of the cart and comfort for the camel, easiness of loading is the advantage of this double axle cart. The draft force requirement especially for sloppy terrain is more than the single axle one.

For flat area, the double axle is much easier than single axle, regard of pulling and can carry much load at any position of the cart with good stability.

**Summary of the results:**

- Two types of camel drawn cart (single axle and double axle were designed and produced, it fulfills that, easy for manufacturing from available material, easy
for maintenance and comfort for draft animal. It was tested on haulage test, impact test and trials on farms according to FAO testing procedure.

- The size of the cart was W x L x H
  - 1400 x 2200 x 1340 for double axle cart
  - 1400 x 2200 x 1400 for single axle cart
- The maximum loading capacity of the cart was 15 quintals on flat terrain
- The cart can pulled by a single camel

**Discussion:**
In the country, there is no any camel drawn cart and this cart can carry a maximum of 15 quintals and comfortably transport on a surface up to 5° slopes. The load slope terrain relation shows that up this cart can be used up to 15° slope terrain on the rough road.

The farmers felt that it was good to use camel as a multi-purpose animal (for ploughing, as a pack, for cart ...) and better be demonstrated as much as possible. Two options of camel carts (single axle and double axle) were fabricated. During testing with farmers in Kobo wereda, most farmers liked the double axle, for its stability, comfort to the animal and ease to synchronize the motion of camel to the cart.

The single axle cart is simple in construction and cheap in price, but it could not synchronize the walking motion of the camel to the cart. The beam and drawbar plates were broken during the test. The camel walking motion was not normal and similar as to other animals. At the back, where the harness is hitched the motion reciprocated (forward and back ward) and it causes so many actions at the draw bar plates hitch point shock and vibration and then breakage. The cart can normally carry up to 15 quintals load and was stable on a terrain of 5° slope with a load of 7.1 quintals. The test was conducted on a total distance of around 23 km.

**Conclusion and recommendation:**
We have seen that both types of camel drawn carts were very important and simple to transport goods up to an amount up to 15 quintals, on ground slope 0°-5°. Further demonstration at different areas, especially where the camel can adopt very well is recommended.
PARTICIPATORY EVALUATION OF TIED RIDGING TECHNOLOGY FOR MAIZE PRODUCTION IN THE CENTRAL RIFT VALLEY OF ETHIOPIA

Tewodros Mesfin, Olani Nikus, Hussen Harrun and Abuhay Takele

Ethiopian Institute of Agricultural Research (IIAR), Melkassa Research Centre (MARC), P.O.Box 436, Nazareth, Ethiopia

Abstract

Tied-ridging can reduce runoff losses and results in more yields in semi-arid areas of Ethiopia. A simple ox-drawn tied-ridging implement has been developed as a modification of the traditional plough 'maresta'. The implement was tested with farmers at three locations in the semi-arid areas of the Central Rift Valley of Ethiopia with the objective of obtaining farmers' assessment of the tied-ridging technology, the suitability and economic feasibility of the implement under their farming conditions.

On-farm participatory evaluation of tie-ridging practices using improved maize varieties recommended for the area was conducted at two locations in the Central Rift Valley of during 2001 and 2003 cropping seasons. The experiment had two factors: two land preparation and two maize varieties. Thirty farmers who participated in on-farm research on tied-ridging were interviewed to evaluate the tied-ridge technology and the implement during on-farm evaluation of the technology and the implement. The main effect, variety affected significantly the grain yield at Melkassa and Mieso in 2001 (Table 1). Where as, grain yield was only affected significantly by land preparation method and the interaction effect of land preparation by variety at Melkassa in 2003. The farmers appreciated the advantage of tied-ridging. Nearly all farmers felt that tied-ridging was superior to their practice of flat cultivation in preventing runoff and for better crop performance. The implement was seen as culturally appropriate modification of their local plough and was well rated for its different attributes. The result of economic assessment of the farming for the near normal and wet year (2003) at different locations proved profitable. Using tie-ridging implement was economically superior to their traditional flat tillage, providing positive net income and higher marginal rate of return.

Introduction

Maize is one of the high priority crops to feed the increasing population especially in the drought-affected Central Rift Valley of Ethiopia. In these areas, yields of maize have remained low because of prevalent inadequate and erratic rain (Mandefro et al., 2000). Most of the rain comes in heavy storms that last for short durations, between July and September, resulting in high runoff losses from the fields (Kidane and Rezene, 1989).

Techniques are helpful to ensure enough of the received rainwater to be available around the crop root zone. Tied-ridging is one way to reduce runoff by using ridges constructed across the slope to retain more water for efficient water use. Several research results indicated that tie ridging is a simple and effective method, which considerably increases grain yield of many crops. The potential of tied ridging in improving grain yields primarily depends on rainfall (amount, intensity and distribution), soil characteristics, slope, landscape position and crop species. Past and recent research results in different countries have also revealed that tied ridging is effective in reducing surface runoff, increasing soil water storage and grain yield (Hulugalle, 1987; Krishna, 1989; Carter and Miller, 1991; Piha, 1993).

Research carried out on tie ridging in semi-arid areas of Ethiopia demonstrated that the use of tie-ridging is efficient in storing the rainwater with substantial yield increase in maize and sorghum. Kidane and Rezene (1989) suggested to grow crops in tied furrows, to concentrate rainwater into the root zone of crops rather than the traditional farmers' practice of planting on flat land. The results revealed that tied-ridges produced higher maize yield of 1500 kg ha⁻¹ than the traditional flat planting with a yield of 598 kg ha⁻¹ at Kobo and Melkassa, respectively. Despite the proven effectiveness of tie-ridging and positive
response of farmers to the technology under diverse situations, majority of the farmers in Ethiopia and in many Sub-Saharan African countries have not adopted tie ridging. Virtually, the drudgery and time-consuming nature of tie ridging is the possible cause. It is estimated, 26-30 man days per hectare should be engaged to construct tied ridges manually with a small hand hoe (Kidane and Abuhay, 1997). Moreover, the gain yield across growing seasons is not always matching the required extra labour (Kidane and Abuhay, 1997; Wiyo and Feyen, 1999).

The agricultural Implement Research and Improvement Center at Melkassa has developed a simple oxen-drawn tie-ridging implement as the modification of traditional plough *maresha* to facilitate this practice. The implement was verified on farmers’ fields and found to be convenient to use and four times more efficient than manual tied-ridging (Melese, et al., 2002). The purpose of this work was to demonstrate, assess farmers’ attitude and economic profitability of the technology and effectiveness of the tie-ridger under farmer’s condition to facilitate technology transfer.

**Materials and methods**

On-farm evaluation of two tillage practices was conducted at three locations in the Central Rift Valley of Ethiopia (Melkasa, Boffa and Meiso) during 2001 and 2003 cropping seasons. The areas is semi-arid region characterized by low, erratic, and poorly distributed rainfall. It receives 540mm to 765 mm mean annual rainfall. The On-farm sites were selected based on the number of years under maize cultivation and accessibility. The soil types in semi-arid areas of Ethiopia are also diverse, dominantly poor in soil structure and fertility content (Reddy and Kidane, 1993). Melkasa is dominated by silty to silty clay loam soil with aridic properties and Mieso’s soil is black mostly silty loam classified as eutric-vertisol (Eylachew and Yusuf, 2002).

The experiment had two factors; two land preparation and two maize varieties released for moisture deficit areas. At each site, the land was ploughed two to three times with a pair of oxen drawing a wooden *ard* plough, locally known as *maresha*. After ploughing, the tie-ridged plots were marked and the ridge were constructed using oxen-drawn tied-ridging implement and a soil bund as cross-tie, were erected by intermittently lifting the handle of the plough at three to five meter interval across the ridges. In all cases, the cross ties; 10cm-20 cm deep as micro-catchments basins and the ridges with 30cm-40 cm deep were constructed so that all the water flows side ways into the next basin not down the slope. The plot size for flat planting and tied-ridge was 250 m². All other cultural practices were performed as recommended for each specific area. At maturity, crops within 100 m² were manually harvested and grain yield was corrected at 12.5% moisture content. Stover dry weight was measured from randomly selected ten plants and after each plant was dried separately at 60°C for three to four days adjusted to oven dry weight. Statistical data were analyzed using analysis of variance and treatment means were separated using least significant difference at 0.05 and 0.01 probability level.

A structured questionnaire composed of both open and close-ended questions to help collect relevant primary data was drawn up. A draft questionnaire was pre-tested on six farm households in the vicinity of the study. The result of the pre-testing helped in final restructuring of the questionnaire by incorporating missing information, omitting irrelevant question and paraphrasing questions that appeared ambiguous to the respondents. The final questionnaire had two sections. The first section consisted of general questions including socio-economic characteristics of the respondents and their household as well as farming systems under which they operate. The second section focused on farmers’ attitude towards tied-ridging technology and the third section focused on farmers’ attitude about the merits and demerits of the implement.
Thirty farmers who participated in on-farm research on tied-ridging practice for the several past years were interviewed to evaluate tied-ridging technology and the tied-ridging implement that was developed as the modification of the maresha plow. Information on land preparation for flat tillage using oxen-plough, tied-ridging technology and oxen-drawn tied-ridging implement was gathered through talking to several farmers. The value of labour used on land preparation operation in the production of maize was estimated based on survey and from discussions held with the farmers. Economic analysis was computed to determine the profitability of using improved a simple, oxen-drawn tied-ridging implement.

Results and discussion

No yield data was recorded during 2002 cropping due to crop failure due to severe drought. The rainfall during 2001 and 2003 growing season was near and above average respectively (Figures 1 and 2) for both study sites. In 2001, there was good distribution with adequate amount of rainfall at both Melkassa and Mieso, even though the crop did experience moderate to severe water stress from late September to October, which caused incipient wilting on several occasions. In 2003, the rainfall amount was inadequate and erratic in distribution during early seedling stage. The rainfall amount was below long-term average in May and June at Melkassa but with relatively good amount for the rest of the growing season. Similarly poor and erratic rainfall distribution, with large deviation from the long-term rainfall average in late May, early June and mid July of the season was recorded at Mieso. Considerably poor amount and distribution of rainfall in May and July and quite the reverse, high amount of rainfall was recorded in June and September (Figures 1 and 2).

Grain yield

The main effect, maize variety affected significantly the grain yield at Melkassa and Mieso in 2001 (Tables 1 and 2), where as only land preparation and the interaction effect of land preparation by variety affected grain yield at Melkasa in 2003 (Table 2).

In 2001 the maize variety, ACV-6 gave higher grain yield than Melkasa-1 at Mieso while Melkasa-1 produced higher yield at Melkasa. In general, ACV-6 yielded better on tied-ridge plot especially at Mieso with soils of good water holding capacity that could possibly sustain growth during the recurring terminal dry days. Generally, ACV-6 gave a yield increment of 29% on tied-ridge compared to those on flat tillage treatments across the two locations. However, the average performance of Melkassa-1 was similar under both land preparation techniques, which might be attributed to its earliness to avoid dry spell occurred at the terminal growth stage of the crop.

Remarkable performance from tie ridging was recorded in 2003 at Melkassa with a yield gain of 77% and 69% for ACV-6 and Melkassa-1 respectively (Table 2). Such result was apparent in many areas during normal and wetter seasons, with heavy rainfall in the growing season accompanied by intermittent dry spell at critical growth stage of the crop. Hence, the yield advantage obtained could be because of minimum runoff and maximum infiltration storage (Marimi, 1978; El-swaify, 1983; Adjei-Twum, 1987; Hulugalle, 1987; Krishna, 1989; Carter and Miller, 1991; Piha, 1993).

Farmer's views on the tied-ridging technology and implement

Ten farmers who participated in the tied-ridging research in each of the three locations had evaluated tied-ridge tillage and the implement. The advantage of tied-ridging is well appreciated by the farmers. Nearly all the farmers felt that tied-ridging was superior to their practice of flat cultivation in preventing run-off and for crop performance and other desirable characters (Table 3), while two farmers differed with the majority saying that tied-ridging brought more soil crusting.
Farmers identified situations when tied-ridging is effective, and has suggested different time of tied-ridging for various reasons. Many farmers suggested that tied-ridging should be done at planting and repeated when the crop was at 'knee-high' to renew the ridges and to control weeds, although there was concern by some farmers that row spacing would be uneven presenting risk of crop damage if tied-ridging is done at latter stage. A few farmers differed from the majority saying that tied-ridging should be done only once the crop had well established as the ridges made at planting time may break during heavy downpours with the risk of rill erosion.

The tie-ridger is well rated for different attributes and seen as an appropriate modification of their traditional and plow *maresha* due to its simplicity, lightness and low cost nature which worth 90 to 120 Birr (12 to 15 US dollar). They found it easy to operate (Table 4). Negative comment about tied-ridging included, poor performance in wet soil; poor seed coverage when planting in combination with ridging. Farmers were asked to state their willingness to adopt the technology and in the use of the implement. Even if most of the farmers were impressed about the technology and the implement, few farmers were unable to conceptualize how the technology is applied and perceive the performance of the technology because of the short duration experience they had with the technology. It was generally observed that farmers would require more time to realize full benefit, and for testing and dissemination of the technology to create awareness and enable the farmers make informed decisions, to either adopt or reject the technology. This study result suggests that demonstration of the implement over large-scale, training farmers on how to use the technology and the implement, and targeting situations with high probability of beneficial effect with follow-up, monitoring is very important for possible adoption of the technology and the implement.

**Economic evaluation of different land preparations**

The economic analysis was computed considering the opportunity cost of labour. Although, a less resourceful small-scale subsistence farmers provides own family labour at zero cost for preparatory tillage and tied-ridging, and a more resourceful rely entirely on hired labour (8 birr per day) for all tillage operation, in both cases, cost of equipment for tied-ridging and costs of tillage operation are otherwise fully included (hired labour). The many unit operation and the average market prices prevailing at the three sites during the experimental period and other information were collected from farmers, markets and informed persons. The additional cost of making tie-ridger (implement) was being subtracted from the economic advantage and was calculated by estimating five productive service lives. The additional cost of fabrication per year was 16 Birr. Labour cost less to total cost (40 %) when tied-ridging were used compared to flat tillage.

The results of economic analysis made for the traditional flat tillage and tied-ridging across sites showed that tied-ridging gave marginal rate of return that is higher than the minimum acceptable level (Table 5). The analysis suggests that it would be beneficial for maize farmers to practice tied-ridging in the moisture deficit areas of Ethiopia. The result of economic assessment for the near-normal year in 2003 showed that tied ridging is generally profitable with net benefit of 2488 Birr and marginal net benefit of 578 Birr over the traditional flat tillage. Generally, tied-ridging implement is economically superior providing positive net income and higher marginal rate of return. The economic benefit of the tie-ridger could be increased with the assumption that the farmers could provide family labour at zero cost for the tillage operation.
References


Proceedings of the first Agricultural Mechanization Completed Research Forum

Figure 1 Long-term and cropping season mean monthly rainfall at Melkassa and Mieso

Table 1 Maize grain yield as affected by main effect of different NP level, land preparation techniques and varieties at Melkassa and Mieso in 2001

<table>
<thead>
<tr>
<th>Main effects</th>
<th>Grain yield (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Melkassa</td>
</tr>
<tr>
<td>LP Flat tillage</td>
<td>1915</td>
</tr>
<tr>
<td>Flat tillage</td>
<td>1915</td>
</tr>
<tr>
<td>Tied-ridging</td>
<td>2169</td>
</tr>
<tr>
<td>Variety</td>
<td></td>
</tr>
<tr>
<td>ACV-6</td>
<td>1495</td>
</tr>
<tr>
<td>Melkassa-1</td>
<td>2589</td>
</tr>
<tr>
<td>Fertilizer level (kg ha(^{-1}))</td>
<td></td>
</tr>
<tr>
<td>0/0</td>
<td>1228</td>
</tr>
<tr>
<td>18/46</td>
<td>2118</td>
</tr>
<tr>
<td>41/46</td>
<td>2132</td>
</tr>
<tr>
<td>64/46</td>
<td>2108</td>
</tr>
<tr>
<td>Significance</td>
<td></td>
</tr>
<tr>
<td>LP (A)</td>
<td>ns</td>
</tr>
<tr>
<td>Variety (B)</td>
<td>127.71**</td>
</tr>
<tr>
<td>CV (%)</td>
<td>24.84</td>
</tr>
</tbody>
</table>

*, ** Significant at the 5 % and 1 % levels respectively
ns, Not significant at the 5 % level
Table 2 Maize grain yield (kg ha⁻¹) as affected by variety and land preparation at Melkassa in 2003.

<table>
<thead>
<tr>
<th>Varieties</th>
<th>ACV-6</th>
<th>Melkassa-1</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>LP</td>
<td>1548</td>
<td>1254</td>
<td>1401</td>
</tr>
<tr>
<td>FP*</td>
<td>2743</td>
<td>2122</td>
<td>2432</td>
</tr>
<tr>
<td>Mean</td>
<td>2145</td>
<td>1688</td>
<td></td>
</tr>
<tr>
<td>LP</td>
<td>320.65**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variety</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPx variety</td>
<td>453*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>19.64</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant at the 5 % level. LP = Land preparation (flat planting* and tie-ridging®) ns, Not significant at the 5 % level.

Table 3 Farmers' opinions about the benefits of tied-ridging (n=30).

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Percentage</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce runoff and soil loss</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Large yield response</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Excellent plant stand</td>
<td>28</td>
<td>93</td>
</tr>
<tr>
<td>Hasten crop maturity</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>Reduce wind-lodging</td>
<td>10</td>
<td>33</td>
</tr>
</tbody>
</table>

| Disadvantage                                  |            |           |
| Induce more soil crusting                     | 2          | 7         |

Table 4 Farmers' response about the tie-ridger (n=30).

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good speed of work</td>
<td>27</td>
<td>90</td>
</tr>
<tr>
<td>Decrease weeding</td>
<td>23</td>
<td>77</td>
</tr>
<tr>
<td>Easily pulled</td>
<td>20</td>
<td>67</td>
</tr>
</tbody>
</table>

| Disadvantage                                    |            |           |
| Poor performance under wet condition           | 9          | 30         |
| Difficult to pull                              | 6          | 20         |
Table 5 Economic analysis of two-land preparations on maize yields average across three sites under near-normal rainfall in 2003.

<table>
<thead>
<tr>
<th>Items</th>
<th>Land preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tied-ridges</td>
</tr>
<tr>
<td>Average maize yield (kg ha(^{-1}))</td>
<td>2444</td>
</tr>
<tr>
<td>Adjusted maize yield (-10%)</td>
<td>2200</td>
</tr>
<tr>
<td>Gross benefit (Br. ha(^{-1}))</td>
<td>2640</td>
</tr>
<tr>
<td>Labour cost for land preparation (Br. ha(^{-1}))</td>
<td>112</td>
</tr>
<tr>
<td>Cost of tie-ridger fabrication</td>
<td></td>
</tr>
<tr>
<td>Per year</td>
<td>16</td>
</tr>
<tr>
<td>Labour cost for weeding and cultivation (Br. ha(^{-1}))</td>
<td>24</td>
</tr>
<tr>
<td>Total cost that vary (Br. ha(^{-1}))</td>
<td>152</td>
</tr>
<tr>
<td>Net benefits (Br ha(^{-1}))</td>
<td>2488</td>
</tr>
<tr>
<td>Marginal net benefit (Br)</td>
<td>578</td>
</tr>
<tr>
<td>Marginal variable cost (Br)</td>
<td>48</td>
</tr>
<tr>
<td>Marginal rate of return (%)</td>
<td></td>
</tr>
</tbody>
</table>

Maize selling price = 1.20 Br/kg, Br = Ethiopian Birr, ha = hectare
Labour cost= 8 Birr/ man days, Labour for preparatory tillage and constructing tied ridges= 14 man days/ha,
Flat planting= 10 man days/ha, Labour cost for weeding in flat planted plots= 3 man days/ha
for weeding in tied-ridges plot= 3 man days/ha.
Acceptable marginal rate of return= 100% Conversion rate 8.6 Birr per US dollar
EVALUATION OF VOTEX THRESHER FOR BLACK CUMIN

Leiliso Eddoshe and Birhanu Atomsa
Oromiya Agricultural Research Institute, Harar Rural Technology Research Center
Contact address, e-mail: biratomsta@yahoo.co.uk

Abstract

A Votex thresher was evaluated on black cumin (Nigella sativa var. Arsi Zone of Oromiya region at Tereta, Chole and Zenbaba kebles within Shirka district in 2006. The treatments were concave clearances, cylinder speeds and feed rates at two, three and three levels, respectively. The treatments were arranged in factorial combination and laid in split plot block design in three replications. The statistical test result indicated significantly different means between the treatment levels of each factor and between combinations of the different factors levels. Maximum threshing efficiency of 97.17% was obtained at minimum concave clearance and maximum threshing speed with the values varying between 80.92% and 97.17% at the entire factors combination levels with grand mean of 89.79%. No grain loss was registered due to mechanical damage, but losses due to unthreshed grains and grains blown with the straws and chaffs were very high. Means of the grain losses were significantly (p<0.01) high as affected by the interactions between different levels of clearance, speed and feed rate combinations. Means of unthreshed grain losses recorded for the interaction effects significantly varied between 2.83 and 19.02% with a grand mean of 10.21%. The maximum mean unthreshed grain was registered at 17mm concave drum clearance and speed of 640 rpm when the feed rate was 11.50kg/min while the minimum was obtained at clearance of 14mm when drum speed and feed rate were 880 rpm and 6.20kg/min, respectively. Separation losses due to grains blown away with the straws and chaffs were highly significant with high mean differences as affected by the cylinder speed. Means of separation grain losses varied between 12.9% and 21.51% with the entire mean of 15.63%. The blowing action of the drum generated strong air stream at velocities exceeding the terminal velocity of the black cumin grain particles and resulted in a very high percentage of grain losses blown with the straw and chaff.

The average capacity of the machine was 3.33 q/hour and ranged between 2.35 and 4.54 quintals per hour for the average grain-straw ratio of 1.7 used in this experiment. Highly significant mean differences in capacity were recorded with the feed rate, while differences due to cylinder speed were slightly significant at 0.05 of probability, but no significant capacity differences was recorded due to differences in concave clearance.

Introduction

Black cumin (Nigella sativa L.) belongs to the family Ranunculacea and it is grown for its seeds. It is cultivated at small-scale level in Ethiopia in various agro-ecological zones, possibly belongs to indigenous flora (Johnson 1981). Black cumin is one of most popular spice crops cultivated in Arsi, Bale, Hararge, Jimma, llubabor and Wallagga highlands of Oromiya region and it is also produced in lower and mid highlands of the region. The seed is obtained by threshing the head capsule of the plant. It is used in perfumery, soaps industry, for condiments, as a spice in cakes, breads, pastries, confectionery, sauces, cheese, etc. It is also widely used in pharmaceuticals for medicinal ingredients. Cumin oil is also used as a stabilizing agent for edible fats. Locally, its oil has an aesthetic value, widely used in traditional medicine, and culinary preparations. It is used as ornamentals and considered important for its abundant nectar secretion in many countries.

A significant amount of the Ethiopian cumin seed is exported illegally to the Middle East, through the Red Sea and Somalia (for example, a black soap and oil product of cumin seed imported from Saudi Arabia advertisement mark says “product pure Ethiopian black cumin). It is also becoming more and more popular in the west with the current steadily increasing consumers’ demand. If wisely managed, black cumin generates hard currency, which has a huge potential in improving the economy of the country and the livelihood of the people as well.
However, threshing and cleaning of black cumin has high drudgery and is tedious to the farmer. Traditionally, threshing of black cumin is done either by spreading the crop on the floor and beating with a stick or by driving animals over the crop harvests spread on floor. However, such a traditional method is an arduous operation and results in major product quality reduction, leading to a major loss of value especially in export market. Thus, it is very important to consider appropriate type of improved threshing and cleaning methods to reduce farmers’ drudgery while also avoiding both qualitative and quantitative loss of the product.

Nonetheless, as the research on this crop in Ethiopia, is initiated lately and as the crop is not widely produced in developed western countries, there is no sufficient information available concerning biomechanical and aerodynamic properties of this crop that would help to select or develop the appropriate type implement to be used. Therefore, this experiment was initiated to evaluate Votex Rice Fan, for threshing black cumin, with the expectation that the result would help set future directions. Thus, the objective of this experiment was to evaluate suitability and performance of Votex thresher for black cumin to generate practical information and suggest ways and means for further development of appropriate thresher to alleviate farmer’s problem in production of this specific crop.

**Review of literature**

Black cumin (*Nigella sativa*) is an important spice seed. Commercially cumin seed is a widely used spice and is an important ingredient in pharmaceutical Industry (Datta 2004). The seed contains essential oil, used in preparation of insecticide, and contains about 30% edible fatty (Pruthi 2001). The low numbers observed for *Staphylococcus aurous* and *Bacillus cereus* make black cumin seeds acceptable, without any associated health hazard (AlJassir 1992). *Nigella* revealed positive agronomic traits, such as short growing cycle, good seed retention at harvest time and apparent low susceptibility to diseases (Filippo et al., 2002). Black cumin is a delicate herb, which attains a height of 30-50 cm, and fruits are pods segmented containing black seeds when mature and dried (Datta 2004). Number of fruits per plant varies from 10 to 20, and each pod contains 50-90 seeds. The crop is harvested when matured plants start yellowing as the shattering loss is high if dried before harvest. Traditionally, harvesting is done by uprooting or cutting the crop just above the ground and stacking under the sun from one to three days to dry for threshing. The crop is beaten lightly with stick to break the pods and release grains. It is then cleaned and filled in bags to store, as the production has been mostly on small scale levels. The seed (*Semen Nigella*) of the plant is used as a spice, and it is commonly cultivated in Afyon, Burdur, Isparta and Denizli regions of Turkey (Donmez and Mutlu 2004).

Cumin seeds are black in color, rigorous and tubercular in shape. At 7% moisture content a Black cumin seed has an average length, breadth and thickness of 5.61 mm, 1.77 mm and 1.55 mm respectively; bulk and true density of 477 kg m⁻³, 1.047 kg m⁻³, 4.16 gms thousand seed mass and 2.6 m s⁻¹ terminal velocity (Singh and Goswamy 1998). The force required to initiate rupture at 7% moisture content were 50N and 31 N for horizontal and vertical direction at 7% (db) moisture content (Singh and Goswami 1995). Any mechanical thresher cannot thresh different crops at equal efficiency due to variation of crop properties that needs principles of different mechanical actions with varying design of functional elements. The size and shape are important in development of threshing, cleaning (separation from undesirable materials), sorting, grading and processing agricultural machinery (Mohsenn 1970).

Newberg evaluated the damage imparted on soybean by rotary and conventional rasp bar mechanisms. They used three different threshers (single-rotor, double-rotor and conventional rasp bar cylinder mechanic) at four velocities and reported that the percentage of split were
significantly higher for the rasp bar than for the single and the double rotor threshing mechanisms at similar speeds (Newberg et al. 1980).

Vejasit and Salokhe studied machine-crop parameters of an axial flow thresher for soybean, and reported that the power requirement of the threshing unit increased as the drum speed, feed rate, and moisture content were increased. They concluded that the increases were due to greater compression of the material, increased friction between crop material and threshing system. They also reported that moisture content, feed rate and drum speed affected the output capacity, threshing efficiency, grain damages and total grain losses during threshing. A good performance of cleaner unit was reported to be likely obtainable with fan speed of 900-1500 rpm and fan angle of 105° -120° (Adewumi et al 2006):

Materials and methods

This experiment was conducted on farmers' farm in Gobess, Chole, Tereta and Zenbaba Peasant Association kebeles in Shirka district of Arsi zone, Oromiya region. The site is a major black cumin producing area and there was no problem of getting enough test crops from the farmers.

Vortex thresher of a rasp-bar drum type with radial threshing mechanism was used for the test. It was initially donated from EEC to the people of Ethiopia through the Ministry of Agriculture in the 1980’s. The threshing cylinder consisted of rasp bars for threshing action and flat plates fitted between the rasp bars functioning as fan impellers for separation of crop materials while threshing. The drum rotates on a fixed shaft. Its cylinder-concave clearance is adjustable between 14mm and 24mm depending on the crop type and the instant threshing condition need be handled. The thresher is driven by diesel engine of 7 hp indicated capacity of ACME model. Mixture of the threshing outputs (grains, chaff and broken straw of smaller size) are collected in plastic pan placed under the machine, which can be replaced when filled.

Black cumin freshly harvested and dried in the sun secured from the farms, was used for the test. The moisture content of the grains was 8% for the grains and that of the straw was 9.5%. The treatments were cylinder-concave clearance, drum speed and feed rate with two, three and three levels, respectively, as indicated in Table 1 below.

<table>
<thead>
<tr>
<th>Table 2 Treatment factors and values of their levels.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment Factors</strong></td>
</tr>
<tr>
<td><strong>Cylinder-concave clearance (C)</strong></td>
</tr>
<tr>
<td><strong>Threshing Cylinder speed (S)</strong></td>
</tr>
<tr>
<td><strong>Feed rate (F)</strong></td>
</tr>
</tbody>
</table>

The treatment factors and their levels were arranged in factorial experiment and laid in split-split-plot design in three replications.

Values of the following dependent variables were collected during experimentation.

Weight of the materials in the unit feed (W_F): Total material of the unit feed (both grains and non-grain materials were weighed together before threshing and the value was recorded for W_F.

Grains in the feed (W_GF): Grains obtained in the unit feed, collected from the output pan, distributed around the thresher by threshing actions, and from the straws that remained unthreshed was registered as total weight. All values were added and recorded as W_GF.
Weight of straws and other non-grain materials ($W_s$): The difference between weight of the feed and weight of the grains in the feed was recorded as $W_s$, the weight of non grain materials in the feed (straws, chaffs and others foreign materials in the feed, all together).

Grain in the pan ($W_p$): the mass of grains collected in the pan at the grain outlet was cleaned and recorded as $W_p$.

Grains collected out of the pan, as blown away ($W_b$): The grain threshed but blown away with straws and chaffs or tossed and went out of grain outlet were manually collected, cleaned, and weighed and for the variable of $W_b$.

Damaged grains ($W_D$): three random samples of 0.25kg were taken from every threshing unit output pan in the $W_F$ and the seeds obtained with visible crack, breakage or having any visible mechanical damage due to the action of the threshing force were separated, and the mean of the samples was recorded as $W_D$.

Unthreshed grain ($W_U$): grains obtained unthreshed in the straws and detached capsules of the heads after one pass through the threshing machine were manually collected, cleaned, weighed and recorded for the variable $W_U$ in each threshing unit run.

The raw data collected were subjected to the following mathematical operations for ease of statistical analysis.

1. Total Weight of the unit feed materials (kg), $W_F = W_{GF} + W_s$
2. Total weight of the threshed grains (kg), $W_{TG} = (W_{GF} - W_U) = (W_p + W_b + W_D)$
3. Threshing efficiency (%), $E_T = \frac{W_{TG}}{W_{GF}} \times 100$
4. Unthreshed Grain loss (%), $G_U = \frac{W_U}{W_{GF}} \times 100$
5. Grains blown with chaffs and Straws (%), $G_B = \frac{W_b}{W_{GF}} \times 100$
6. Threshing capacity (kg/min), $T_C = \frac{W_{TG}}{t}$ where, $t$ = time of a unit threshing run

Finally, the data were subjected to ANOVA. Significance of the mean differences between the treatment factor levels and combinations of different levels were tested by least significance difference (LSD) method. Relations between the treatments and performance parameters were plotted graphically with curves passing through the mean points of the variables and the trend lines’ equations were generated using Excel as indicated under the graphs with their respective R^2 values.

Results and discussion

The analysis of variance indicated existence of significant differences between the means of performance parameters as affected by both the main factors and the interaction between the levels of concave clearance (C), drum speed (S) and feed rate (F), for all the parameters considered.
**Threshing Efficiency (E_t)**

Significantly different means were recorded for different factor levels and different levels combinations at 1% level. Test results showed that the mean threshing efficiency recorded for the effects of concave clearance levels, interaction of clearance with drum speed, and clearance with feed rate were significantly different (Table 2).

Table 3: Threshing efficiency as influenced by concave clearance(C), speed (S) and feed rate (F) as well as by interaction between clearance and speed, and clearance and feed rates.

<table>
<thead>
<tr>
<th>Clearances</th>
<th>Cylinder Speed Levels</th>
<th>Feed rate Levels</th>
<th>Means at Grand C Levels</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
<td>F1</td>
</tr>
<tr>
<td>C1</td>
<td>89.20</td>
<td>94.27</td>
<td>96.70</td>
<td>96.23</td>
</tr>
<tr>
<td>C2</td>
<td>84.46</td>
<td>87.76</td>
<td>90.96</td>
<td>90.94</td>
</tr>
<tr>
<td>Means</td>
<td>86.83</td>
<td>91.02</td>
<td>93.83</td>
<td>93.42</td>
</tr>
</tbody>
</table>

Means of the threshing efficiency, as affected by clearance levels, were 93.39% and 87.73% at 14 and 17mm clearances levels, respectively. The graph of the threshing efficiency as related to the cylinder speed levels and the feed rates are indicated in Figure 1 (A and B) including the equations of their relation and their respective coefficient of determination, $R^2$. Higher threshing efficiency was recorded at the lower concave clearance; the means were increasing with the increase of the cylinder speed and decreasing with increase of the feed rates for both clearance levels.

The threshing efficiency significantly varied between 84.46% and 96.70% for the interaction between concave clearance and cylinder speed levels while it ranged between 85.19% and 96.23% for the interaction between clearance and feed rates, with a mean of 90.56% (Table 2). The threshing efficiency increased significantly for the increase in cylinder speed for all the feed rate levels, but decreased with increasing feed rates for all the cylinder speed levels (Figure 2).
Figure 3  Threshing efficiency ($E_T$) as affected by cylinder speed for different feed rates.

Grain losses

Grains that remained unthreshed in the head capsule and blown away with chaffs and straws due to the blowing effect of the threshing drum were recorded as grain loss. Losses recorded for each of the two parameters were very high at all level of each treatment factors as well as at combination levels of the factors interactions. However, Loss due to mechanical damages to the grain was nil.

Unthreshed grain loss ($G_u$)

High unthreshed grain losses were recorded with significantly different means as affected by variation of the levels of each factor, and by the differences in combination of the treatment factors levels.
The changes in the level of cylinder-concave clearance indicated significantly very high variations in the means of unthreshed grain losses. A clearance main effect mean of 7.94% unthreshed grain loss was recorded at 14mm. The loss increased to 12.47% when the concave clearance increased to 17mm. Means of unthreshed grain losses, for the entire levels of the factors (clearance, speed, and feed) interactions varied between 2.83% and 19.08% with a grand mean of 10.21%. A mean of 19.08% unthreshed grain loss was registered at a clearance of 17mm and at a speed of 640 rpm, for the feed rate of 11.50kg/min and the minimum mean was recorded at 14mm concave clearance when the speed level and the feed rate were 880 rpm and 6.20kg/min, respectively.

**Separation loss**

Grains blown away through straw outlet with straws and chaff by fan effect of the drum is termed here as separation loss. Highly significant mean differences (p<0.05) were recorded for the values of grain blown away with the straws as influenced mainly by separate effects of cylinder speed and feed rates, but slightly affected by concave clearance and by the interaction between these two factors. The grain/seeds of black cumin are very small as compared to wheat and rice and are easily blown away by the air steam driven by blades on the threshing drum.

**Equations for Lines on fig 4 (A)**

<table>
<thead>
<tr>
<th>Speed Level</th>
<th>Equation</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₂</td>
<td>Y = 2.171x + 14.034</td>
<td>0.9979</td>
</tr>
<tr>
<td>C₁</td>
<td>Y = 1.4245x + 12.71</td>
<td>0.9662</td>
</tr>
</tbody>
</table>

**Equations for Lines on fig 4 (B)**

<table>
<thead>
<tr>
<th>Feed Rate</th>
<th>Equation</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₂</td>
<td>Y = -1.865x + 19.243</td>
<td>0.9591</td>
</tr>
<tr>
<td>C₁</td>
<td>Y = -2.955x + 17.991</td>
<td>0.9949</td>
</tr>
</tbody>
</table>

Figure 5: Grains blown with the chaff and straws as affected by speed (A), and as affected by feed rates (B).

Losses due to grains blown away with the straws and chaffs were registered with significantly high mean differences as affected by the cylinder speed. The blade elements integrated with the cylinder rasp bars blow the air stream. The blowing action of the drum drives air stream of...
varying speed levels corresponding to the drum speeds, mostly at velocity exceeding the terminal velocity of the grain cumin particles that resulted in a very high percentage of grain blown with the light straws and chaffs. Losses for the blown grains ranged from 12.90% to 21.51% with a grand mean of 15.63%. A 17.37% mean blown grain loss was recorded simultaneously with a maximum threshing efficiency of 97.17% at a cylinder speed of 880rpm and feed rate of 6.2kg/min. The loss increased to 21.51% when the feeding rate increased to 11.5kg for the same speed.

The average capacity of the machine was 3.33 qt/hour, and ranged between 2.35 quintals and 4.54 quintals per hour for the 1:688 average grain-straw ratio of the crop used in this experiment. A very high significant mean difference in capacity was observed with the feed rate, while differences due to cylinder speed were significant at 0.05 of probability. No significant mean differences were registered between concave clearances.

Conclusion and recommendation

Conclusions

1) During this investigation, a maximum threshing efficiency of 96.70% at a minimum (14 mm) concave clearance, maximum cylinder speed of 880rpm and at the least feed rate of 6.2 kg/min was recorded.

2) Loss due to mechanical damages to the grain remained nil for all treatments levels and their combinations throughout this experiment. This was due to the small size of cumin seed grains compared to the concave clearance even at its minimum position.

3) The minimum unthreshed grain loss recorded, ranged between 5.4% and 18.5% with a mean of 10.44%. This was due to the minimum attainable concave clearance of Vortex, which is far greater than cumin seed size, and even exceeded the size of some cumin head capsules that allowed them to pass easily untouched by the threshing action of the machine.

4) Cleaning action of the threshing cylinder blows high air steam and with the air speed exceeding the terminal velocity the black cumin, resulted in 15.63% loss of grains blown with the straws and chaffs through straws outlet at all levels of the drum speeds.

5) Significant percent of speed loss was observed in the power transmission system due to high slippage of the belt. The was due to the use of V-belt and grooved driver pulley on the engine with flat driven pulley on the drum. This resulted in lower contact area between the belt and the drum pulley causing reduced friction that led to excessive belt slippage.

6) Capacity of the thresher is not compatible with its engine power while price of the machine is also not affordable by individual farmer as it is beyond the capacity of their financial reach, except those very few at the highest economic status. Thus, its acceptance by the peasant family would be challenging, despite its good performance.

7) Though the recorded threshing efficiency level was not sufficient, the output was of high grain quality with dark color of clean seeds having attractive appearance and strong aroma which resulted in high price difference of more than 260 Birr/qt over the grains obtained with the traditional threshing method.

Recommendations

1. Matching between the belt and the pulley needs correction with appropriate and standard synchronization of belt and pulley relation to minimize slippage and power loss observed.

2. As this thresher was developed for rice, the size of its concave clearance was also designed for crops of rice size, which are non-comparable with the size of black cumin seeds, and in some case, the clearance exceeded even the size of the head capsules of the black cumin. So reducing its concave clearance will increase threshing efficiency.
3. Cleaning action of the threshing cylinder need to be separated from the drum. A fan speed control system independent of the cylinder speed, will helps to reduce percentage grains blown away and can be conveniently used for different crops.

References


Johnson 1981. Spices, condiments and medical plants in Ethiopia: their taxonomy and agricultural significance. Center for Agricultural publishing and documentation, PCM; Addis Ababa, pp 76-85.


Modification and Evaluation of IAR Model Hand Operated Maize Sheller

Zelalem Biru, Asafa G/wold, Tolosa Dabare, and Yossief Assefa
Bako Rural Technology Research Center P.O.Box 07 West Shoa, tel. (057)6650045/55/171, E-mail: brtrc@telecom.net.et Fax(057)665-00-42

Abstract
Maize production has increased in the last few years in the country. Despite the increase, there are still many problems that are not solved in the production system, among which shelling operation seems the first. The traditional methods of shelling like rubbing the (cob) corn together, fraying by hand finger, beating the cobs using stick, or by pestle in special mortars made of wood and animal trampling are labor intensive, time consuming and cause high grain loss. In order to overcome the problems encountered with the above methods, the Bako Center had formerly designed and developed a very compact and efficient P.T.O and engine operated maize sheller. Though the machine has a high shelling capacity with a very good shelling efficiency and insignificant grain loss; it was beyond the economic reach of the individual farmers. To address this problem, the center improved the EARO model manual operated maize sheller, increasing its capacity from 1.7-3 quintal/hr to 8.5-10qnt/hr with a shelling efficiency of 99.1% and insignificant grain loss. Besides, this, machine can be fabricated and maintained locally, it is simple and can be operated by children and women. The net unit shelling cost of maize using this machine is decreased by half compared to those automated by fuel. We believe that the sheller is more suitable for small-scale farmers and will help them to increase their income.

Introduction
Maize is one of the important cereal crops widely used for human consumption, animal feed, industrial raw material, as the source of starch and starch derivatives. According to recent information, maize is currently grown almost in all parts of the country, as different maize varieties adaptable to different agro ecologies of the country are released by agricultural research centers. According to the Central Statistics Agency, agricultural sample survey, in 1994/95 the production of maize in Ethiopia was 70,117,990 quintals, where a major contribution of 35,436,510 quintals was from Oromia region. In 1995/96, the production reached 92,791,100 quintals and 47,493,530 quintals in the country and in Oromia respectively. Although the production of maize is increasing from year to year, there are still many unsolved problems in the production system among which shelling is an important operation. The success in shelling can influence other successive operations such as storage life, quality, insect attack and nutritive value of the crop. Traditionally farmers have experienced some methods of shelling maize, which includes rubbing the cob of corn together, fraying by hand finger, beating the cobs by using stick, by pestle in special mortars made of wood, animal trampling, ridding cattle over the corn cobs spread on flat smoothed and cleaned ground. All of the above methods are labour intensive, time consuming and moreover decrease the quality of production and increase grain losses.

In order to overcome the above-mentioned problems the former Bako Rural Technology Promotion Center and the current Bako Rural Technology Research Center designed and developed a very compact, efficient and easily transportable P.T.O. and Engine (11.5Hp-12Hp) operated maize sheller in association with foreign experts during 1978-82 E.C. In fact, the machine has a high shelling capacity of 50-60 qt/hr with a very good cleaning and shelling efficiency, with no breakage and grain loss.
Despite the above mentioned advantages, the sheller was expensive for the individual farmer, due to the high initial cost of the machine and the unavailability of the power source on the market.

Therefore, in order to solve the above-mentioned problems, the Bako Rural Technology Research Center geared towards seeking another improved machine that can be within the economic reach of the individual farmers. Accordingly, the center improved the IAR model manual operated maize sheller, which originally had a capacity of 1.7-3 quintal/hr to 8-10 quintal/hr, which is three to four folds compared to the original machine.

Materials and methods

The main components of the machine are the frame, drum, concave assembly, and feeding table. The frame is made from 4mm thickness, 40mm square pipe and a 50mmX50mmX4mm angle iron bars. Whereas a drum of 453mm diameter made of 15mm sheet metal filled with sand on its peripheral with a thickness of 40mm, having helical (4degree) formed rasp bar of 10mm diameter is mounted on a mild steel shaft of 30mm diameter.

![Figure 1 Modified IAR manual operated maize sheller.](image)

Before making any modification on the machine the drawback of the original machine were thoroughly studied and identified. To rectify all its defects, the improvement work was done in to two phases. In both cases a technique of keeping one parameter constant and varying the remaining parameter was adopted to select the best performing sheller.

**Phase I**

In phase I, more attention was given on the modification of the flywheel, which was considered as a supplement of power source. Its improvement was done based on the general principle of moment of inertia as related to hollow cylinder.
\[ I = \frac{1}{2} m (R_1^2 + R_2^2) \]  

For solid cylinder:  
\[ I = \frac{1}{2} m R^2 \]  

Where,  
- \( I \) = Moment of inertia in gm-cm\(^2\)  
- \( m \) = Mass of the wheel in gm  
- \( R \) = Radius of solid fly wheel  
- \( R_1 \) and \( R_2 \) in cm are internal and external radius of the fly wheel.

Based on equations (1) and (2) four types of fly wheel, having the same mass and different shape filled with mortar, named as solid uniform flywheel, flanged solid fly wheel, hollow uniform fly wheel and flanged hollow fly wheel were produced in the workshop. In determining the shape of the flywheel, the basic principle, which underlines that the inertia of a flywheel will be maximum when the mass is concentrated on the outer surface of the flywheel, was considered.

Figure 2 Different shapes of flywheel used during phase I.

The machine was tested with this different fly wheels, using Bh 660 maize variety having a grain to cob ratio of 4.9:1. The total treatment combinations were 25 and for each treatment, the mean of five replications was taken. The moisture content of the grain was determined on dry weight basis using the oven method at 103 °C for 24 hr. taking a sample of 100gms. Also at the time of the test, the moisture content of the grain was determined using a universal moisture meter.

Seed germination test was undertaken using 100 kernels of seed from each treatment for each replication. The kernels were kept in Petri dishes, lined with a moist filter paper in five replications and incubated at room temperature for 7 days. The seeds that germinated out of the total were counted and percentage of germination was determined.

For each test run, a 50 kg of unshelled maize was fed at a time. Then, the shelling time and, rotational speed (rpm) were recorded using a stopwatch and speedometer respectively. The above procedure was repeated five times for all treatments.

**Phase II**

In the second phase, the selected fly wheel (flanged hollow) was kept constant and concave arc length was varied to increase the performance of the machine more than what had been
achieved during phase I. considered to be the main part of the machine. The modification on the concave-drum part was made based on the size of dry maize cobs.

In order to determine the appropriate inlet and outlet opening, concave-drum clearance, concave arc length, the diameter of 100 dry unshelled and shelled maize cobs were measured using caliper. Inlet concave-drum clearance was determined based on the mean diameter of unshelled dry maize cobs where as outlet concave-drum clearance was based on the diameter of shelled maize cobs. The arc length of the concave was determined based on the mean circumference of unshelled dry maize cobs, considering a 3.25, 3.50, and 3.75 times rotation of a single maize cob during the operation. Accordingly arc-concave lengths of 54.00 cm, 57.30 cm and 58.50 cm with different drum diameter, tapered concave-drum clearance, wider at inlet and narrower at outlet were made to handle different size of cobs. Moreover, the concave, which was originally almost horizontal, was made vertical to facilitate the movement of maize cobs.

Concave grills were arranged from in let side with maximum radius and ended up with minimum radius on the outlet. All grills between the two ends were arranged by decreasing the radius of concave equally until the end of the grill. With this arrangement, the grills created smooth curve (spiral shape). With this arrangement, the grills had 13mm clearance (slot) for separation of shelled maize.

The machine with this different arc length was tested using maize bh 660 variety, grain to cob ratio of 4.9:1 keeping the other parameters constant. The total treatment combinations were 20 and for each treatment, the mean of five replications was taken. All the parameters taken during first phase were repeated for the second phase. Finally, the variability in capacity, efficiency of the sheller and breakage of grain were analyzed using SPSS. During the first phase different shape of flywheel (uniform solid, hollow uniform, flanged solid and hollow flanged) were considered as treatments and during the second phase different arc-concave length (54.00cm, 57.30 cm, and 58.50cm) were considered as treatments.

Results and Discussion

During the first phase it was observed that the effect of different flywheel on shelling capacity and efficiency was highly significant (P<0.01) (table 1) though grain breakage was found to be non significant. A maximum shelling capacity of 690.87±75.92 kg/hr, shelling efficiency of 99.26±.19% (table 2) were obtained at a speed of 120 revolutions per minute at a moisture content of 7.6% and inlet and outlet concave-drum clearance of 4.8 cm and 2.8 cm respectively with a flanged hollow fly wheel used as a supplementary power source. The minimum shelling capacity of 320.21±37.04 kg/hr and shelling efficiency of 80.72±3.8% was observed at a speed of 113rpm at the same moisture content and concave-drum clearance when using the original machine (Control).
Table 1 Measured level of significance from the average of variance for capacity, efficiency, and breakage.

<table>
<thead>
<tr>
<th>Variables</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>4</td>
<td>121334.13</td>
<td>22.59</td>
<td>0.000 **</td>
</tr>
<tr>
<td>Efficiency</td>
<td>4</td>
<td>239.31</td>
<td>72.13</td>
<td>0.000 **</td>
</tr>
<tr>
<td>Breakage</td>
<td>4</td>
<td>0.64</td>
<td>7.47</td>
<td>0.071 NS</td>
</tr>
</tbody>
</table>

**- Significant. NS- Non Significant

Table 2 The effect of different flywheel on the mean value of different parameters (capacity, efficiency and breakage).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Capacity (kg)</th>
<th>Efficiency (%)</th>
<th>Breakage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform solid</td>
<td>363.11 ± 37.04</td>
<td>93.85 ± 86.0</td>
<td>1.25 ± 0.27</td>
</tr>
<tr>
<td>Hollow uniform</td>
<td>381.20 ± 8.21</td>
<td>94.47 ± 64.0</td>
<td>2.02 ± 41.0</td>
</tr>
<tr>
<td>Flanged solid</td>
<td>552.97 ± 139.59</td>
<td>93.67 ± 92.0</td>
<td>1.29 ± 14.0</td>
</tr>
<tr>
<td>Hollow flanged</td>
<td>690.87 ± 75.92</td>
<td>99.26 ± 19.0</td>
<td>1.23 ± 30.0</td>
</tr>
<tr>
<td>Control</td>
<td>320.21 ± 37.04</td>
<td>80.72 ± 3.8</td>
<td>1.74 ± 30.0</td>
</tr>
<tr>
<td>LSD</td>
<td>6.29</td>
<td>11.22</td>
<td>3.62</td>
</tr>
<tr>
<td>CV (%)</td>
<td>1.01</td>
<td>9.19</td>
<td>1.83</td>
</tr>
</tbody>
</table>

During the second phase the combined effect of hollow flanged flywheel and concave arc length on the capacity of the sheller was highly significant (P<0.01) though not significant difference was observed on breakage. The capacity and efficiency of the sheller was maximum when flanged flywheel combined with longer arc length 58.50cm, was used at a peripheral speed of 113 rpm with the inlet concave drum clearance of 5.3cm and outlet 2.6cm at 7.6% moisture content of grain. Field observations revealed that the hollow flanged flywheel with longer arc length was easier for the operator and reduced drudgery in addition to its high shelling capacity and efficiency. The lowest capacity and efficiency of the sheller were observed when the original sheller (Control) was used to shell the same grain at 88 rpm. Shelling capacity and efficiency of the sheller ranged between 320.21±12.96 kg/hr and 887.71±33.97 kg/hr (table 4) and 80.72±3.81% to 99.10±4.7% respectively when the peripheral speed varied from 88 rpm to 113 rpm. The seed germination test revealed that under all treatments the result obtained was more than 90%.
Figure 3 Mean capacity of the sheller when different flywheel used.

Table 3 Measured level of significance from the average of variance for capacity, efficiency, and breakage.

<table>
<thead>
<tr>
<th>Variables</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>3</td>
<td>335890.42</td>
<td>135.56</td>
<td>0.000 **</td>
</tr>
<tr>
<td>Efficiency</td>
<td>3</td>
<td>399.64</td>
<td>106.77</td>
<td>0.000 **</td>
</tr>
<tr>
<td>Breakage</td>
<td>3</td>
<td>0.395</td>
<td>2.72</td>
<td>0.079 NS</td>
</tr>
</tbody>
</table>

** -Significant  
NS - non significant

Table 4 Combined effect of selected flywheel and concave arc length on the mean value of different parameters (capacity, efficiency and breakage).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Parameter</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capacity (kg)</td>
<td>Efficiency. %</td>
<td>Breakage %</td>
<td></td>
</tr>
<tr>
<td>Short arc length /54.00 cm</td>
<td>839.06 ± 49.59</td>
<td>97.86 ± .43</td>
<td>1.32 ± .09</td>
<td></td>
</tr>
<tr>
<td>Medium arc length /57.30 cm</td>
<td>752.20 ± 78.29</td>
<td>98.63 ± .16</td>
<td>1.99 ± .69</td>
<td></td>
</tr>
<tr>
<td>Longer arc length /58.50 cm</td>
<td>887.71 ± 33.97</td>
<td>99.09 ± .47</td>
<td>1.63 ± .02</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>320.21 ± 12.96</td>
<td>80.72 ± 3.81</td>
<td>1.74 ± .29</td>
<td></td>
</tr>
<tr>
<td>LSD</td>
<td>13.42</td>
<td>10.21</td>
<td>2.46</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>9.06</td>
<td>11.73</td>
<td>1.42</td>
<td></td>
</tr>
</tbody>
</table>
Under all circumstance except in the original model, shattering losses were minimal, attributed to the provision of flexible protector (sheet metal attached to drum cover by hinge).

The economic analysis revealed that the cost of the sheller, including the cost of fabrication, was Etl Birr 1078.50 and the operation cost of the sheller was Birr 0.17/quintal using man as the power source, whereas the cost of shelling by conventional methods was calculated at Birr 2.00/quintal of shelled maize.

![Figure 4 Mean capacity of the sheller when flanged hollow flywheel with different arc length.](image)

**Conclusion**

The hollow flanged flywheel with longer arc length sheller, separated the kernels from the cobs with improved capacity and efficiency with insignificant damage to the kernels. The grain shelled by this modified sheller can be used for seed, storage and marketing.

Grading of the maize cobs into smaller, medium and bigger lots for shelling as in the case of original model is totally avoided using this machine by an arrangement made to handle different size of cobs. However, to get the reported capacity and efficiency of the modified sheller more attention should be given to the accuracy of manufacturing. To get satisfactory result, it has to be fabricated as per to its design. Moreover, to use the sheller effectively, the operator has to initially rotate the flywheel with out feeding any maize cobs into the sheller to develop moment of inertia. Thus the drum of the sheller can be rotated during the actual shelling with out exerting, much force by virtue of developed flywheel moment of inertia. As the result, even children and women can operate the sheller.

The modified IAR type maize sheller is very efficient, simple to operate, fabricate and maintain locally. Moreover, the machine is found to be with in the economic reach of the individual farmers. Therefore, with all these advantages, this machine is especially suitable for
small-scale farmers to perform shelling faster and timely thereby helping to increase their income.

Two persons can operate the machine; the net unit cost of shelling maize using this machine was Birr 0.17/quintal, as opposed to the conventional method, which costs 2.00 birr per quintal. In fact, the machine has to be tested for all varieties of maize so long as a number of maize varieties are existing in the country.

References


IMPROVEMENT OF MANUALLY OPERATED
ROTARY GROUNDNUT SHELLER

Laike Kebede
Melkassa Agricultural Research Center

Abstract
The smallholders undertake groundnut production in Ethiopia and shelling is predominantly done by hand. To minimize the drudgery and improve the shelling efficiency, the Agricultural Mechanization Research Program at Melkassa developed three models of manually cranked groundnut shellers. Further improvement on the most promising sheller was made by increasing the shelling capacity and reducing the kernel breakage. The improved design has a shelling unit consisting of an open type cylinder with detachable shelling bars made of flat mild steel with a canvas strip fixed on its periphery. The semi cylindrical cylinder is made with 6 mm diameter bar and it has a rectangular sieve opening based on size variation of the pod and kernel of the tested groundnut varieties. The sheller was tested for its shelling efficiency and capacity and visible kernel breakage using six groundnut cultivars namely Sedi-Y 2000, NC. 4X, NC-343, Roba, Shulamiz and Oldehel (local variety). The results showed that shelling efficiency varied from 82.7% to 94.2%, capacity from 408.4 kg hr\(^{-1}\) to 596.3 kg hr\(^{-1}\) and kernel breakage from 9.7% to 28.1% depending on the type of variety. The maximum shelling capacity with maximum shelling efficiency was obtained when using the local variety while broken kernel was minimal for Sedi-Y2000 variety. Compared to the old version, the shelling capacity of the new design was doubled for all varieties. Kernel breakage was also reduced by 10.9%, 1.2% and 6.8% for the local oldehel, Sedi-Y 2000 and Roba varieties respectively.
Introduction
Groundnut/Arachis hypogea L. is one of the most important oil crops grown in tropical and sub tropical regions of the world principally for its oil as a source of food and cash income. In Ethiopia, groundnut grows extensively in Eastern and North Western parts of the country. The Southern and Western administrative zones are also potentially suitable for groundnut cultivation. Despite the wide potential, the total area planted under groundnut over the past 10 years has been limited to less than 20,000 hectares (CSA 1991 and CSA 2000). Mainly small holders in plot sizes ranging from 0.1 ha to 0.5 ha (CSA 2000) undertake the production of groundnut in Ethiopia. Due to the small size of the plots, most field operations are done manually. Lack of appropriate equipment, apart from drought stress, insufficient supplies of improved seeds, poor cultural practice is one of the major problems in groundnut production. Manual groundnut harvesting, pod stripping and shelling are tedious operations, consuming a lot of energy and time that have discouraged farmer's and affected their attitude towards this crop compared to the staple crops, which receive higher priority.

Shelling operation involves the process of freeing groundnut kernels from the shell or pod by cracking the shells. Traditionally farmers, normally women and children shell groundnut by using their hands. Though hand shelling keeps kernel breakage low, crushing the groundnut pod by applying finger pressure is very tiresome, wound fingers, when large quantities of groundnuts are handled and has low output 5 to 8 kg/person-day (Personal communications with the staff of low land oil crops research program). To replace hand shelling, the Agricultural Mechanization Research program, targeted for a simple, efficient, low-cost machine, and developed three manually cranked models.

Materials and Methods

The crop
Unshelled groundnuts were obtained from Melka Werer Agricultural Research Center. Six cultivars namely Sedi Y-2000, NC-343, NC 4X, Roba Y-2000, Shulamith and the local Oldelie grown at the research center in 2002/2003 cropping year were used for the test. Groundnuts were dry enough for storage and the initial moisture content of the pods, ranged from 9.45% to 11.97 % (dwb). Pod and kernel size were determined by measuring the thickness (major diameter) of 100 randomly selected cleaned pods, using a vernier caliper reading to 0.05mm precision. Pod shape distribution was identified by visual observation.

Description and operation of the sheller
The improved prototype (Figure 1) has a shelling unit consisting of an open type rotary cylinder, concave, frame, feeding table, cranking handle and an outlet. The rotating cylinder has 10 detachable shelling canvas strips fixed on the periphery of two circular plates at the two ends of its length. It can be adjusted to create a clearance that is less than the pod size but greater than the seed size with the stationary concave. The semi cylindrical concave around the cylinder has a rectangular grate opening made of 6mm diameter bar welded at the periphery of two semi- circular plates. Two people, one cranking the handle to drive the sheller while the other one feeding unshelled pods at the feed end, operate the sheller. Groundnuts are placed on the feeding table, then slightly pushed to fall through an opening called the throat, and settle into the clearance between concave and cylinder. As the handle is cranked, the shells and
kernels fall through the grid opening into a container placed under the base. Winnowing is done by hand.
The old and new version shellers were later tested with the above groundnut varieties. Good results were obtained with 12mm cylinder concave clearance in the preliminary tests and this clearance was maintained throughout the performance tests.

![Figure 1 Final design of the improved manually operated groundnut sheller.](image)

**Performance tests and evaluation**

Tests were conducted to evaluate the performance of the groundnut sheller. During testing, the feeder table base was completely closed using the flow rate control slide gate. Then it was filled with groundnut pods of predetermined total weight ($W_T$) of about 4 kg. The pods were fed into the machine and shelled until the hopper was emptied. The weights of pods that were completely shelled and unbroken ($W_1$), completely shelled but broken ($W_2$), and unshelled pods ($W_3$) were determined at the end of each run. The test was replicated three times and the performance of the sheller was evaluated on the basis of the following indices:

(a) Shelling efficiency (%) = \(1 - \frac{W_1}{W_T} \times 100\)

(b) Percentage damage (%) = \(\frac{W_2}{W_T} \times 100\)

(c) Shelling capacity (kg/hr) = \(\frac{W_T}{t}\)

**Results and Discussion**

**Physical properties**

*a) pod shape distribution*

Pod shape distribution of six groundnut varieties determined was presented in Table 1. The percentage of normal shaped pods was greatest (80%) for Sedi –Y 2000 and lowest (6%) for Roba 2000. Pod shape affects performance of the machine (Pattee and Young, 1982). Normal
pod shape has best shelling characteristics than pods of other shapes. One seeded pods are stronger and have lower shelling rates. Tapered, one seeded and constricted pods have lower separation efficiencies. Tapered, odd and constricted pods clog screen more frequently than normal and one seeded pods. Many of the tapered seeds are immature and are very difficult to shell.

Table 1 Pod shape distribution of six groundnut varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Normal</th>
<th>Constricted</th>
<th>One seeded</th>
<th>Tapered</th>
<th>Odd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedy Y-2000</td>
<td>80</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Shulamith</td>
<td>11</td>
<td>44</td>
<td>17</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>Roba 2000</td>
<td>6</td>
<td>53</td>
<td>13</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>NC4X-Y2000</td>
<td>14</td>
<td>23</td>
<td>35</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>NC-343</td>
<td>13</td>
<td>47</td>
<td>20</td>
<td>17</td>
<td>5</td>
</tr>
<tr>
<td>Oldh'e</td>
<td>41</td>
<td>19</td>
<td>14</td>
<td>15</td>
<td>11</td>
</tr>
</tbody>
</table>

Pod and kernel thickness

The maximum, minimum and average values with the standard deviation of pod and kernel thickness (major diameter) are reported (Table 2). This property plays an important role in the determination of the sheller features and performance characteristics. The pod size governs the clearance between cylinder and concave, which is an important determinant for effective shelling operation. Kernel thickness determines the grate size of the concave.

Table 2 Pod and Kernel thicknesses of different groundnut varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Thickness (major diameter) -mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
</tr>
<tr>
<td>Pod</td>
<td></td>
</tr>
<tr>
<td>Oldh'e</td>
<td>15.60</td>
</tr>
<tr>
<td>Roba 2000</td>
<td>17.60</td>
</tr>
<tr>
<td>Sedy Y-2000</td>
<td>14.71</td>
</tr>
<tr>
<td>NC4x</td>
<td>18.42</td>
</tr>
<tr>
<td>Shulamith</td>
<td>15.99</td>
</tr>
<tr>
<td>NC-343</td>
<td></td>
</tr>
<tr>
<td>Kernel</td>
<td></td>
</tr>
<tr>
<td>Oldh'e</td>
<td></td>
</tr>
<tr>
<td>Roba 2000</td>
<td>12.58</td>
</tr>
<tr>
<td>Sedy Y-2000</td>
<td>9.81</td>
</tr>
<tr>
<td>NC4x</td>
<td>11.67</td>
</tr>
<tr>
<td>Shulamith</td>
<td>11.77</td>
</tr>
<tr>
<td>NC-343</td>
<td></td>
</tr>
</tbody>
</table>

* mean ± standard deviation
Performance of the improved sheller

The performance of the sheller in respect of visible kernel breakage, shelling capacity and shelling efficiency was evaluated with six groundnut cultivars. The result showed that percent kernel damage with the improved sheller ranged from 9.7% to 21.3% depending on varietals difference with a minimum for Sedi Y-2000 followed by the local variety (12.7%) and a maximum for Shulamith (Table 3). The reason for the variation of the kernel breakage could be due to the difference in size and shape of groundnut varieties. Since kernel breakage also increases with decreasing moisture content, the relatively lower pod moisture content could also contribute for a higher kernel breakage for all varieties. Shelling capacity ranged between 133.7 and 171.3 kg per hour. The variation in shelling capacity could arise from operating condition variations such as feed rate and cylinder rotational speed, which could likely occur in manual operating systems. Comparatively the improved sheller has better shelling performance with respect to shelling capacity and reduced kernel breakage than the old sheller. However, its performance with respect to shelling efficiency relatively decreased for all varieties (data not presented). Compared to the old version, the shelling capacity of the new design was almost doubled for all varieties. Kernel breakage also considerably reduced by 10.94, 1.22 and 6.77 percent for the local oldhel, Sedi-Y 2000 and Roba varieties respectively.

Table 3 Performance result of improved manually operated groundnut sheller.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Capacity(kg/hr)</th>
<th>Damage (%)</th>
<th>Efficiency%</th>
<th>Rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC-4X</td>
<td>171.32 ±12.9</td>
<td>17.8 ± 1</td>
<td>70.6</td>
<td>85.1 ± 6.6</td>
</tr>
<tr>
<td>Oldhle</td>
<td>145.87 ± 7.8</td>
<td>12.7 ± 2</td>
<td>82.0</td>
<td>91.6 ± 4.4</td>
</tr>
<tr>
<td>Sedi Y-2000</td>
<td>159.01 ± 12.4</td>
<td>9.7 ± 1</td>
<td>91.0</td>
<td>84.9 ± 8.7</td>
</tr>
<tr>
<td>Roba 2000</td>
<td>133.66 ± 15.4</td>
<td>16.6 ± 3</td>
<td>73.0</td>
<td>89.3 ± 6.2</td>
</tr>
<tr>
<td>Shulamiz</td>
<td>141.35 ± 16.1</td>
<td>21.3 ± 3</td>
<td>62.0</td>
<td>87.2 ± 5.4</td>
</tr>
<tr>
<td>NC 343</td>
<td>133.85 ± 15.9</td>
<td>20.9 ± 2</td>
<td>55.0</td>
<td>83.8 ± 9.5</td>
</tr>
</tbody>
</table>

*mean of three replications ± Standard deviation

Summary and conclusion

- For oldehel (local), Sedi Y-2000 and Roba varieties shelling capacity of the new design almost doubled and kernel breakage considerably reduced
- It is recommended for extensive testing and pre-extension popularization.
- Further modification need to be carried out to adopt specific varieties and local circumstances
INTERNAL AGITATOR PERFORMANCE AND CHURN DESIGN CONSIDERATION UNDER SMALL SCALE DAIRY PROCESSING

Minwiyelet Nigatu

Ethiopian Institute of Agricultural Research
Melkassa Agricultural Research Center
P.o.box: 436, Nazareth, Ethiopia
nminwiyelet@yahoo.com

Abstract
Laboratory test was conducted in 2002 at Holleta Agricultural Research Center (HARC) to observe the effect of paddle shape and rotational speed on churning time and butterfat recovery. The agitator types involved during testing were Type A (four paddles alternatively fitted on square shaft inclined at 45° from the horizontal axis), Type B (four paddles bored at the center and alternatively fitted on square shaft with full radial projection) and Type C (paddle wheel consists of four wings having a position of 90° with each other). They were evaluated at 150 rpm, 203 rpm and 250 rpm in three replications using a variable speed electric motor. The test results revealed that a churn with 15 l capacity and Type A agitator spun at 200 rpm accomplished the butter making operation in <>.72 min ensuing 87.6% fat recovery. The independent effect of agitator shape and rotational speed on butterfat recovery were highly significant (p<0.01) whereas agitator speed affected only churning time significantly (p<0.05). Useful design criteria were generated to develop efficient wooden churn for capacities of 15 l to 50 l apt to small dairy processors in the country.

Key words: agitator, butter making, churning efficiency, design, smallholding dairy processing, sour milk

Introduction
Dairy farmers in developing countries face many difficulties to sustain their production. They are subjected to low and fluctuating raw-milk prices, lack of infrastructure required for milk collection and transportation, and poor handling methods (FAO, 1990). One possible way for small dairy operators to improve their situation involves processing their own milk into byproducts, a move offering an efficient way of adding value and marketing fresher products. This should be supported through the development and application of appropriate processing units congruent to the existing condition. It is a milestone to realize 'mini-dairies' near to the point of milk production (Kurwijila 1987).

In Ethiopia butter is the most common dairy product for its richness in butterfat and high marketability although it is largely produced traditionally using inefficient methods. Its production is characterized by smaller amount, poor quality and longer processing period. The traditional butter making practice commonly seen in the country involves rocking of clay pot filled with sour milk, application of stirring action to agitate sour milk with mebekia (branched stick) or employing the combination of both methods (Zelalem Yilma and Inger Ledin 2001). Sometimes one may encounter a method where a churn hung on a tripod is swung to and fro.

The choice of processing sour milk is based on the reasons like high ambient temperature, small daily quantities of milk, consumer preference, increased keeping quality, and apart this it makes the milk easier to churn retarding undesirable micro-organisms (C.B.O’ Connor 1995). Apparently, churning sour milk instead of cream seems more economical as it does not require
another resource consuming operation, i.e. cream separation. This makes the production of butter greatly adaptable to small scale processing.

In the past, different organizations have attempted to develop butter making equipment addressing the problems of traditional dairy processing in the country. For instance, Small Dairy Development Project (SDDP) in collaboration with Selam Technical and Vocational Center (STVC) has developed a butter churn using stainless steel in which a pierced rotary plate agitator is fitted. STVC has also developed revolving churn having built-in vanes inside its wall. Similarly, Basic Metal and Engineering Agency (BMEA) has developed a device that constitutes triple paddle-wheel agitator, plastic jar and gear drive mechanism. To improve the traditional butter making operation, International Livestock Research Institute (ILRI) has developed a paddle-wheel agitator to be fitted inside a clay pot that cuts the churning time in half and increases recovery of butterfat (C.B.O' Connor, 1995). Another experience showed that a wooden churn with four inclined paddles originally designed by the author has been mass produced and distributed by Hawassa University. However, most of these endeavors to date are only limited to the design and fabrication aspects of mechanical parts. They often did not consider the optimum operational condition and compatibility with the existing demands of the small dairy processors. To fill the gap, the Agricultural Mechanization Research program of the Ethiopian Institute of Agricultural Research (EIAR) conducted a study in 2001-2002. The main objective of this work was to evaluate the effects of degree of agitation in terms of agitator rotational speed and shape factor on churning efficiency. It was also envisaged to set out typical design criteria useful for the development of appropriate equipment (churn) that caters to small-scale dairy processing.

**Materials and Methods**

**Prototype development**

The choice of size and type of technology is the culmination of a thorough assessment over-viewing the amount of milk production, existing knowledge and socio-economic advantages akin to the small dairies. A prototype of cylindrical wooden churn of 15 l capacity was fabricated in the workshop, Melkassa Agricultural Research Center.

Three types of internal rotary agitators having fundamental difference in shape and arrangement were selected and made ready. These were Type A (four paddles alternatively fitted on square wooden shaft inclined at 45° from the horizontal axis), Type B (four paddles bored at the center and alternatively fitted on square wooden shaft with full radial projection), and Type C (paddle wheel consisting four wings arranged at an angle of 90° with each other). Figure 1. illustrates their schematic drawings with their maximum projected area in the direction of motion.

The churning unit was developed in a way that accommodate any one of these agitators preceding the experiment. Its cover was fitted with a viewing window and vent that enable to monitor the internal phenomena. A throughput valve was also fitted at one side of the cylinder to access the byproduct and for easy cleaning.
Proceedings of the first Agricultural Mechanization Completed Research Forum

Type A – four paddles alternatively fitted on square wooden shaft inclined at 30° from the horizontal axis
Total paddle area 16.72 cm²

Type B – four paddles bored at the center and alternatively fitted on square wooden shaft with full radial projection
Total paddle area 20.74 cm²

Type C – paddle wheel consists of four wings having a position 90° with each other
Total paddle area 47.97 cm²

Figure 1. Schematic drawing of three internal agitators with their maximum projected area in the direction of motion.

Measurements and analyses

Laboratory test was conducted in Dairy Division of the Holleta Agricultural Research Center suited at 2400 m a.s.l and 45 km away west of Addis Ababa. It receives an average of 1100 mm annual rainfall with maximum daily temperatures of 21.3°C.

Each type of agitator was tested at rotational speeds of 150 rpm, 200 rpm and 250 rpm in three replications. A variable speed electric motor was used to attain the desired level of rotational speed at a constant rate during the whole churning process. The agitator speed was controlled thoroughly with the help of tachometer taking a number of rpm readings while churning.

For each test batch, about 45 l of milk was collected and at least three samples were taken to determine fat content of the whole milk. It was difficult to collect the desired amount of milk from a single cow for each set of trial. The milk was kept in a closed room for natural fermentation mostly at ambient temperature of 20-22°C. About three days of fermentation period was required to achieve standardized 0.85% of acidity. A digital pH meter (Orion FA with El 9102 pH electrode, USA) was used to monitor the level of acidity.

A 15 l of sour milk was pored in to the chum (i.e. 2/3 of its total volume) for each observation. As it is customary to break up the curd before the start of churning operation, cold water was added and the content was stirred constantly for a few seconds. The process continued until butter grains started to form while the churning temperature was kept between 19°C to 20°C and the gas pressure developed during the processes was released through the vent.

When the butter grains reached the size of a pea, the breakpoint of butterfat recovery said to be attained and churning would have to be stopped. At this instance, after poring relatively cold water into the churn, the agitator speed should be slowed down at least by half to merge the

58
separately released fat globules and recover as butter (Sukumar De, 1982). Then the recovered butter was collected and weighed. Samples were also taken from the byproduct (buttermilk) to determine the amount of fat not recovered from the process.

Normally, churning efficiency is measured in terms of the time required to produce butter granules and by the percentage of fat recovered or lost in the buttermilk. The elapsed time from starting the churning process up to the time of butter recovery (churning time) was recorded using a stopwatch. Butterfat recovery of each operation was determined after chemical analysis of the whole milk and buttermilk was carried out for their respective fat contents. The following formula was used to calculate percent of fat recovered (O'Mahony and Ephraim, 1985; Zelalem Yilma and Inger Ledin, 2001).

\[
\text{Fat recovery} = \left(\frac{\text{Fat in whole milk} - \text{Fat in buttermilk}}{\text{Fat in whole milk}}\right) \times 100
\]

Effects of agitator types and their rotational speeds on churning efficiencies were evaluated by executing standard statistical analysis based on completely randomized design of a controlled experiment (Gomez and Gomez, 1984). It was also attempted to optimize the system and generate design criteria considering test result, basic theories and empirical models with regard to churning process.

**Result and Discussion**

*Effects of degree of agitation*

Test results are presented on Table 1 and Figure 1. Regardless of the agitator type, fat recovery percentage increased with decreasing churning time as the agitator speed climbed from 150 rpm to 200 rpm. Then it decreased with increasing churning time when the speed further reached to 250 rpm. The churning time associated with Type A did not show any trend with respect to the intrinsic fat recovery percentage contrary to the others.

For all rotational speeds, higher and lower fat recovery percentages were observed under agitator Type A, and C respectively, while Type B performance was between the two (Table 1). As LSD test shows, the effect of agitator shape on fat recovery percentage was significantly \((p<0.05)\) different only for the speed levels of 150 rpm and 200 rpm. On the other hand, for all agitator paddle shapes, churning time is minimum under 200 rpm and maximum under 150 rpm. The two-factors statistical analysis run using MSTATC also revealed that the independent effects of agitator shape and speed on butterfat recovery were highly significant \((p<0.01)\). However, it is only the speed that affected the churning time significantly \((p<0.05)\).
Table 1 Fat recovery and churning time as affected by agitator shape and rotational speed.

<table>
<thead>
<tr>
<th>Agitator Shape</th>
<th>Fat Recovery, %</th>
<th>Churning Time, min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150 rpm</td>
<td>200 rpm</td>
</tr>
<tr>
<td>Type A</td>
<td>82.32</td>
<td>87.59</td>
</tr>
<tr>
<td>Type B</td>
<td>76.51</td>
<td>83.14</td>
</tr>
<tr>
<td>Type C</td>
<td>66.09</td>
<td>77.50</td>
</tr>
<tr>
<td>EMS (±)</td>
<td>30.31</td>
<td>5.31</td>
</tr>
<tr>
<td>LCD (p&lt;0.05)</td>
<td>12.48</td>
<td>5.23</td>
</tr>
<tr>
<td>CV %</td>
<td>7.34</td>
<td>2.78</td>
</tr>
</tbody>
</table>

Figure 1 Plot of fat recovery (a) and Churning time (b) against agitator rotational speed.

Throughout the whole experiment period, the observed maximum and minimum butterfat recovery were as high as 91% for Type A agitator spun at 200 rpm and as low as 56% for Type C agitator spun at 150 rpm respectively. The corresponding minimum and maximum times were about 5 min and 17 min respectively. In general, the churning unit fitted with Type A agitator spun at 200 rpm rotational speed performed best with average maximum butterfat recovery of 87.6% and average minimum churning time of 6.7 min (Table 1). The average
churning time for all of the operations was 9.75 min with a standard deviation of 2.38 among the means. Grover and Agrawala (1985) found that a six wooden paddles agitator run at a speed of 600 rpm could accomplish butter making operation in 16 min with a maximum of 85.7% butterfat recovery.

Under small-scale butter production, the resulting buttermilk with tolerable fat content should not be considered as a total wastage. Because a fermented byproduct of acceptable quality may be made from this buttermilk having additional economic advantage overtime (Kurwijila, 1987). A survey conducted in some areas of Ethiopian highland ascertained that long churning time is the major problem that hinders smallholding dairies from fulltime engagement in the sector (Zelalem Yilma and Inger Ledin, 2001). They found that churning time may last as much as 222 min on average when working with traditional butter making method and 80 min with ILCA internal agitator fitted in a clay pot. Taking in to account the best performance of Type A agitator with inclined blades as observed constantly in the experiment, it is possible to infer that frictional force plays a greater role in breaking up fat membrane than drag force which is common for fully projected plates (i.e. perpendicular to the direction of motion). This complies with the anecdote that shear stress is the most prevalence with liquid foodstuffs (Szczesniak, 1981). Thus, the effect is more pronounced for agitator paddles having inclined position in the direction of flow rather than being shaped or bored. The relative advantage of the thumping area is minimal for a fully projected paddle as observed by Type C agitator although it has maximum surface area among the agitator types.

**Formulating the design criteria**

Once an effective butter making mechanism has been identified, it will be logical to formulate the design parameters that suit the small-scale dairy processing based on the test results and experiences. This entails the reconsideration of previous scientific findings, and technological innovations in useful manner. As the churning process involves moving body submerged in raw milk, fundamental theories and empirical models in this regard have also paramount importance to fully understand and explicate the system as a whole. Under this case, it was attempted to underscore the design criteria vogue in small-scale butter making operation – in terms of churning efficiency, hygiene, on-work stability and anthropometric considerations.

Churning efficiency, the key design criteria, normally depends upon the rheological/mechanical properties of whole milk and the way and rate of pressure applied (Szczesniak, 1981). Recovery of butterfat from the whole milk is achieved when it is agitated against the resistance to de-emulsification. The factors contributing towards the stability of the fat-in-skim emulsion are force tension, adsorption phenomenon on the surface layer of fat globules, electric charge on the fat globules and viscosity (Sukumar De, 1982). Accordingly, the effect of these factors on the rate of emulsion is highly influenced by temperature, acidity, fat content and specific gravity of the whole milk.

The rheological studies indicated that dairy products generally show a shear thinning (pseudo plastic) behavior as a result of weak physical, electrostatic and hydrophic forces (Telcioglu and Kayacier, 2007). They govern the rate of material deformation and flow that portray the relationship between stress and strain for the applied forces. Pseudo plastic flow obeys an empirical equation known as ‘power law’ (Eqn.1) that explains the decreasing viscosity with increasing shear rate (Szczesniak 1981; Telcioglu and Kayacier 2007).


\[ \tau = k \gamma^{(n-1)} \]

(1)

Where \( \tau \) is shear stress (Pa), \( k \) is consistency coefficient (Pas\(^n\)), \( \gamma \) is shear rate (s\(^{-1}\)) and \( n \) is dimensionless flow behavior index. According to Telcioglu and Kayacier (2007), raw milk with full fat content (3.4 %), \( k \) is 255 mPas\(^n\) and \( n \) is 0.53. They also found that the apparent viscosity of whole milk is about 250 mPas at 1 s\(^{-1}\) shear rate at 25\(^\circ\)C ambient temperature.

There are certain mechanical properties that usually deal with the motion of fluids as a result of applied force in the system. Some of the properties involved here are drag coefficient, rebound coefficient in impact and flow of material in bulk (Sukumar De 1982). The magnitude of a force applied by a thin plate and its effect on the flow phenomenon is determined by area, velocity and shape factor of a plate and mass density of a fluid in action (Rouse 1970). Shape factor refers to the dimension, shape and position of a plate facing in the direction of flow. For rectangular thin plate with 2:1 length to width ratio (L/B), the estimated drag coefficient is about 1.15 and it increases with plate length (Modi and Seth 1991). As indicated by the fundamental shear analysis, maximum shear stress occurs on the line of 45\(^\circ\) away from the horizontal plane, in this case from the flow direction.

Pertaining to churning process, under optimum operational condition, churning rate (the capacity of churn over churning time) is directly proportional to the square of agitator rotational speed (Sukumar De 1982). In order to ensure better churning efficiency, the churn should not be filled to the maximum level. Similarly, the churning operation should be free from higher pressure due to foaming and from the formation of vortex as a result of concentrated eddies near moving parts.

The stability of churning equipment can be attained through compact design after thorough analysis of force distribution while operating the system. It should be free of vibration that may be caused by unbalanced pressure intensity inside the churn at a point away from the line of the center of gravity. In addition, working suitability of the equipment, depends on ease of the operation in terms of power requirement. Generally, the physical power output of a 60 kg person that can be sustained for 10 min, 60 min and 480 min is approximately 142 watt, 100 watt and 75 watt respectively (O’Hea, 1982). An adult person can also spin a rotary handle at a speed range of 60rpm to 80 rpm comfortably. The availability of facilities such as a watertight cover with glazing, vent and byproduct outlet valve can ease the churning operation in general.

The type of material and the quality of surfaces are the criteria for hygienic design of dairy processing equipments. A difference shall be made between product-contact and non product-contact surfaces; most attention should be paid to the product-contact surfaces because they directly determine the hygienic quality of the equipment (Landré, 1987). The internal parts must have smoother surfaces freed from chemical contaminants and other local defects.

To tailor the information listed here in a pragmatic way, they should be changed to optimum design parameters seizing the feature of small-scale butter making system under Ethiopian context. As far as traditional butter making operation is concerned, for small dairy production in Ethiopian highland, whole milk characterized by fat content of 4 % with 1032 kg m\(^{-3}\) specific density and soured at 0.9 % acidity should be churned in ambient temperature below 20\(^\circ\)C using improved technology (O’Mahony and Peters, 1987; Zelalem Yilma and Inger Ledin, 2001). Locally made wooden butter chums up to 50 l capacity can substantially
improve the traditional butter making in developing countries while underpinning rural community development (O’Mahony and Ephraim, 1985).

As a result, the following design indexes were generated for optimal wooden cylindrical churn with inclined paddle agitator to cater for mini dairy processors in the country.

- The total volume of the churn container should be at least 3/2 times of its churning capacity.
- Churning rate \( CR \) as a function of square of agitator rotational speed \( N \) were fitted based on the data from laboratory test and found (Eqn.2).

\[
CR = 3.87 \times 10^{-3} N^2
\]  

(2)

- For the average churning time of 10 min obtaining from this experiment, the optimum of agitator rotational speed can be calculated as a function of the desired churning capacity of the equipment (Eqn.3).

\[
N = 50.84 \sqrt{C}
\]  

(3)

- A 1:2 radius to length ratio \( R/L \) of a cylindrical barrel is required for compact design.
- The ratio of a single blade volume to the barrel volume should at least be 3/500.
- Length to width ratio \( l/b \) of an agitator blade is 2.
- The agitator blades should be even in number and arranged in a radial fashion along the longitudinal axis. Half of the blades will be inclined by 45° facing at one direction and others inclined similarly but facing oppositely so as to avoid unbalanced forces and vibration.
- The clearance between the consecutive blades and from the cylinder wall should be as small as 1 cm to avoid the formation vortex inside the churn. It should be ensured that agitator blades are in a submersible state during most of the time of processing.
- The churn top cover should be watertight and provided with vent and transparent glaze. It should have a sufficient size for easy access of a product and internal cleaning.
- The maximum power requirement for churning is to be estimated based on the understanding that shear stress is the most prevalence to initiate a bulk flow of liquid milk and more importantly to break fat membrane. This requires considering all shearing planes within the system and the moment of inertia of the rotary agitator. As Grover and Agrawala (1985) indicated, power for churning is strongly related to the rotational speed of curd beater. Therefore, the following equation was developed for this case comprising both theoretical and empirical bases.

\[
P_c = 0.0231 e^{0.0234N}
\]  

(4)

Possible design criteria formulated according to small scale butter making equipment (churn) are summarized in Table 2 for a capacity from 15 l to 50 l of soured whole milk.
Table 2 A summery of formulated design criteria for cylindrical wooden churn with inclined paddle agitator for capacities from 15 l to 50 l.

<table>
<thead>
<tr>
<th>Capacity (l)</th>
<th>Barrel Radius (cm)</th>
<th>Barrel Length (cm)</th>
<th>Agitator Speed (rpm)</th>
<th>Blade Length (cm)</th>
<th>Blade Width (cm)</th>
<th>Blade Proj-area (cm²)</th>
<th>No. of Blades</th>
<th>Power Req'd (Watt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>14.34</td>
<td>28.68</td>
<td>196.90</td>
<td>13.34</td>
<td>6.67</td>
<td>71.95</td>
<td>4</td>
<td>2.21</td>
</tr>
<tr>
<td>20</td>
<td>15.95</td>
<td>31.90</td>
<td>227.36</td>
<td>14.95</td>
<td>7.48</td>
<td>89.06</td>
<td>4</td>
<td>4.77</td>
</tr>
<tr>
<td>25</td>
<td>17.31</td>
<td>34.63</td>
<td>254.20</td>
<td>16.31</td>
<td>8.16</td>
<td>104.91</td>
<td>4</td>
<td>8.78</td>
</tr>
<tr>
<td>30</td>
<td>18.50</td>
<td>37.00</td>
<td>278.46</td>
<td>17.50</td>
<td>8.75</td>
<td>119.82</td>
<td>4</td>
<td>14.55</td>
</tr>
<tr>
<td>35</td>
<td>19.56</td>
<td>39.13</td>
<td>300.77</td>
<td>18.56</td>
<td>9.28</td>
<td>133.97</td>
<td>6</td>
<td>32.56</td>
</tr>
<tr>
<td>40</td>
<td>20.53</td>
<td>41.06</td>
<td>321.54</td>
<td>19.53</td>
<td>9.76</td>
<td>147.52</td>
<td>6</td>
<td>47.64</td>
</tr>
<tr>
<td>45</td>
<td>21.42</td>
<td>42.83</td>
<td>341.05</td>
<td>20.42</td>
<td>10.21</td>
<td>160.54</td>
<td>6</td>
<td>66.72</td>
</tr>
<tr>
<td>50</td>
<td>22.24</td>
<td>44.48</td>
<td>359.49</td>
<td>21.24</td>
<td>10.62</td>
<td>173.13</td>
<td>6</td>
<td>90.23</td>
</tr>
</tbody>
</table>

Conclusion

Under this laboratory experiment, churning with inclined paddle agitator (Type A) that spun at 200 rpm rotational speed performed best with average maximum butterfat recovery of 87.6% and average minimum churning time of 6.7 min. Highest fat recovery was observed persistently for inclined paddles rather than being shaped or bored in the direction of flow which shows that shearing force is more important in churning operation. Straight paddle wheel (Type C) at a rotational speed 150 rpm performed the least in terms of fat recovery and churning time for the whole experiment.

Statistically, both the agitator rotational speed and shape affected butterfat recovery where as only the speed affected churning time significantly. It was observed that butter making operation could be accomplished satisfactorily with inclined rotary paddles that cut the churning time to less than 10 min while maintaining a higher butterfat recovery. This study suggests that a better result can be achieved in small butter making processing, once the optimum degree of agitation is determined.

Standardizing the design parameters of churning equipment that suits small dairy processors will have a greater advantages among many stakeholders engaged in the sector. First, small dairy farmers will be benefited by possessing efficient technology which help to sell fresher and quality product to the local market. Secondly, manufacturers who desirous of multiplying the technology can easily adopt the ready made information to their fabrication scheme. Thirdly, development organization can provide sound and appropriate butter making technology to the end user. Generally, it facilitates a wider adoption of the technology addressing the demand and capacity of small dairy processors while supporting community development programs in the country.

References

FAO. 1990. The technology of traditional milk products in developing countries. FAO Animal production and Health Papers 85. FAO, Rome, Italy.

DEVELOPMENT OF MULTI-CROP THRESHER

Seyoum W/Senbet, Laike Kebede and Girma Mogos

Ethiopian Agricultural Research Organization (EARO), Melkassa Research Centre (MARC), P.O.Box 436, Nazareth, Ethiopia

Abstract

A cleaning type multi-crop cereal thresher was developed through modification of concave-drum assembly of the IAR non-cleaning wheat and barley threshers, IITA multi-crop thresher, Chinese thresher and assessment of the Assela maize Sheller. A comparative test was conducted on four selected prototypes; from the test results, Assela maize Sheller was found superior to all others in most of the performance parameters. Farmers too appreciated the Sheller. The IAR non-cleaning thresher stood second next to the Assela maize Sheller in terms of field capacity and percentages of threshed grain. The performance of the newly developed thresher was tested at different speed and moisture content on wheat and maize for its threshing capacity, cleaning efficiency and seed...
The test results revealed that the thresher recorded a high maize shelling capacity of 2106.33 Kg/hr at a cylinder speed of 720rpm and grain moisture content of 14.35%. A threshing capacity of 116.89 Kg/hr with an efficiency of 98.44% was recorded at 14.10% moisture content on wheat. Lower percentage of grain breakage was observed at higher moisture content and lower cylinder speed.

Introduction

In the agricultural production process mainly practiced by small-scale framers, the harvesting system for many of the crops mainly consists of manual cutting (uprooting), threshing by either beating with stick or treading with animals or sometimes riding tractors over a platform. These traditional threshing techniques are, labor intensive, time consuming, have a lot of drudgery and cause high losses. Crops, after harvest are mostly transported to the threshing and shelling site where they are stacked or stored till the threshing or shelling season. The threshing floor has a diameter of 10-15 meters. It is usually made by smearing the ground with cow dung and left to dry for some time. During threshing, the harvested crop is laid on the floor and several oxen tread on it. The oxen go around the threshing floor over the crop for some time and are taken out to turn the unthreshed crop from the bottom up and spread again for threshing and this operation will continue until the whole grain is detached from the straw. Depending on the variety and condition of the crop there can be 7-11 treadings for 0.5-2hrs [1].

Threshing with animals need skill and energy to keep the animals moving around the threshing floor. Usually the best-trained animal is used as the pivot in the center of the ring while other animals circle around. During the operation care is taken not to under thresh or over thresh, crack or break the kernels. The threshing season normally lasts 2-3 months, but when production is high, threshing may not be completed within the threshing season. The failure to complete the threshing operation within the safe period will expose the crop to unfavorable weather, and this will result in quality deterioration, insect and rodent attack [1]. Oxen not in good condition will be exposed to danger during the threshing season. Animal powered machines have been in and could save labor time but the mechanism of converting animal power to mechanical action to attain the necessary speed is complicated and expensive. Power threshers play an important role as the forerunners of farm mechanization in the Western world. The same was true of Japan and is proving to be the case yet again in nations of the developing world. Therefore, for many reasons engine driven threshers and shellers are favoured [3]. Traditional crop production techniques demand the time and high energy of the farmer, especially during threshing. This has triggered the interest to develop a more effective means of threshing to keep up with this increased production. Different threshers were made to address the challenges by different organization. Arsi Rural Development Project (ARDP) took the first initiatives to develop cereal crop thresher. The first thresher developed by ARDP was an eight-hp diesel engine driven non-cleaning type wheat-barely thresher. Later on, the Institute of Agricultural Research (IAR) took over this thresher and improved the concave assembly and managed to reduce the breakage to 2.1% and 4.6% for wheat and barley respectively (9). These multi crop threshers showed good performance in some parameters for some cereals. Some of the problems encountered were considerable seed brakeage, low capacity for some cereals, as the threshers were only originally meant for wheat and barley. In addition, no data regarding the working condition like cylinder speed, moisture content were available. Therefore, in order to alleviate these problems and facilitate the threshing operation it was necessary to develop a new multi crop thresher to go along with the demand.

Objective

To develop a cleaning type multi-crop thresher.
To test the performance of the developed thresher.
Materials and methods

Materials
Sheet metal, angle iron, corrugated bar, metal rods, bearings, belts and square pipe were used to develop the thresher.

Methodology
In the first phase, recent information regarding farmers' practice in threshing was collected. Different thresher prototypes were also collected and their designs were thoroughly examined to identify which of their designs best meet the requirements. The problems of the collected improved practice were further identified and quantified.

In the second phase, after collecting the four types of threshers, the problems and shortcomings of each were identified. Modifications were made on the drum-concave of IAR non-cleaning wheat and barley threshers, IITA multi-crop thresher and Chinese thresher as shown in the pictures below.

Figure 1 Rasp bar type drum of IAR non-cleaning thresher.
Figure 2 Triangular shaped sheet metal fitted on the threshing drum of Chinese thresher.

Figure 3 Bar type drum of Assela maize Sheller.
Figure 5 Peg type drum of IITA original multi-crop thresher.

Finally, a comparative test was conducted on the four prototypes. The test was conducted in CRD with maize as a test crop. To drive all the threshers, one engine was used. Shelling
capacity and efficiency (percentage of shelled and unshelled grain), percentage of breakage and percentage of blown grain were the parameters considered.

In the last phase, based on the data generated from the comparative test, a new cleaning type, multi-crop thresher was developed by combining the best design features of the best performing threshers and pegs and bars were made exchangeable on the same drum for different crops to reduce the breakage to an acceptable level. The new thresher was operated by engine. Three speeds were used during the test. These speeds were obtained by varying the fuel throttle of the engine. Three levels of moisture were used i.e. 15.58%, 14.35% and 14.07%. The moisture content of the grain was determined by oven method. For each test, the time was fixed. The shelled grain, unshelled grain and blown grain were collected and their respective percentages were calculated. Breakage was evaluated by thoroughly examining the kernels cracks or breaks.

<table>
<thead>
<tr>
<th>Performance parameter</th>
<th>Type of thresher</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chinese thresher</td>
</tr>
<tr>
<td>Shelled grain (%)</td>
<td>91.32 (c)</td>
</tr>
<tr>
<td>Unshelled grain (%)</td>
<td>2.89 (c)</td>
</tr>
<tr>
<td>Blown grain (%)</td>
<td>5.79 (b)</td>
</tr>
<tr>
<td>Broken grain (%)</td>
<td>0.9 NS</td>
</tr>
<tr>
<td>Capacity (Q/hr)</td>
<td>37 (c)</td>
</tr>
</tbody>
</table>

**Table 1 Comparative field performance of different threshers.**

**Result and Discussion**

From the results shown in the table above, Assela maize Sheller was found superior to all others in most of the performance parameters. Its output is three fold than IITA thresher and almost two fold than Chinese thresher. Percentage of Unshelled grain and blown grain was minimum and breakage was to the required level. The IAR non-cleaning thresher stood second next to the Assela maize Sheller in terms of field capacity and percentages of threshed grain. However, farmers complained about IAR non-cleaning thresher for its inconvenience they faced while trying to move the shelled maize away from the thresher. The IITA thresher was found poor in performance in most of the parameters. Based on the good design features of the four threshers a new multi-crop thresher prototype shown below was designed and fabricated (Figure 6).

**Figure 6 Newly developed IAR cleaning type multi crop thresher multi-crop thresher.**

efficiency, cleaning efficiency, percent seed damage and unshelled grain as summarized in table 2. The thresher capacity varied from 992.07kg/hr to 2663.86kg/hr at different speed. The highest capacity was recorded at a drum speed of 705rpm. Figure 1 shows the effect of drum
speed on the capacity of the thresher. As indicated in the figure, the higher the speed, the higher is the capacity. Figure 2 shows that the maximum breakage occurred at a drum speed of 705rpm and it further confirms that the higher the drum speed, the higher is the breakage. The capacity and shelling efficiency of the machine is increased as the speed of the drum is increased but the breakage was high beyond 633rpm. The reason for the increase in shelling efficiency and capacity of the thresher with increase in drum speed is that the impact force required for the threshing increased as the drum speed is increased.

![Figure 7 Effect of drum speed on capacity](image1)

![Figure 8 Effect of drum speed on grain damage](image2)

Table 2. Test results of newly developed multi-crop thresher on shelling Maize

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Test No. 1</th>
<th>Test No. 2</th>
<th>Test No. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed with out load(rpm)</td>
<td>Drum</td>
<td>500</td>
<td>633</td>
</tr>
<tr>
<td></td>
<td>Blower</td>
<td>1015</td>
<td>1285</td>
</tr>
<tr>
<td>Speed with load(rpm)</td>
<td>Drum</td>
<td>475</td>
<td>623</td>
</tr>
<tr>
<td></td>
<td>Blower</td>
<td>960</td>
<td>1250</td>
</tr>
<tr>
<td>Moisture content</td>
<td>Grain</td>
<td>15.58</td>
<td>14.07</td>
</tr>
<tr>
<td></td>
<td>Cob</td>
<td>15.84</td>
<td>14.71</td>
</tr>
<tr>
<td>Grain cob ratio</td>
<td></td>
<td>1:0.35</td>
<td>1:0.38</td>
</tr>
<tr>
<td>Shelling efficiency (%)</td>
<td>58.84</td>
<td>88.93</td>
<td>88.38</td>
</tr>
<tr>
<td>Cleaning efficiency (%)</td>
<td>99.88</td>
<td>99.99</td>
<td>99.75</td>
</tr>
<tr>
<td>Broken grain (%)</td>
<td>0.12</td>
<td>0.13</td>
<td>0.25</td>
</tr>
<tr>
<td>Out put capacity (kg/hr)</td>
<td>992.07</td>
<td>2106.33</td>
<td>2663.86</td>
</tr>
<tr>
<td>Hundred grain weight (gm)</td>
<td>219.92</td>
<td>202.76</td>
<td>208.76</td>
</tr>
<tr>
<td>Fuel requirement (lit/hr)</td>
<td>1.86</td>
<td>3.55</td>
<td>-</td>
</tr>
</tbody>
</table>

To determine the capacity and to see the smoother operation of the machine, it was evaluated for an extended period of about 40hours on hybrid maize variety (BH 660). The capacity was 36qt/hr and there was no any considerable stoppage due to stacking or failure of any parts.

**Conclusions**

The Assela maize Sheller was found superior to all others in most of the performance parameters.
Farmers also appreciated the Sheller in terms of its capacity and comfortably during operation. The IAR non-cleaning thresher stood second next to the Assela maize Sheller in terms of field capacity and percentages of threshed grain. However, its cleaning efficiency was very low creating extra work for farmers to separate blown grain from the cobs and chaffs. Farmers also complained about the inconvenience they faced while trying to move the shelled maize away from the thresher. The IITA multi-crop thresher performed less as far as threshing is concerned and resulted in higher breakage when shelling maize. This higher breakage resulted due to the radial pegs welded on the periphery of the drum, resulting in higher impact on the crop. However, the pegs were found effective in separating tef grain, and chopping the straw. Where as, the bars of the Assela maize Sheller produced the least breakage of maize and much smoother flow of the threshed material but it was not effective in threshing tef. Therefore by combining the two best features of the two peg type drums, a hybrid good enough for tef, barely and wheat; and bar type for maize were developed. Therefore, using exchangeable bars, pegs and pulleys on the same drum was found to be good to solve the breakage by using bar for maize and peg for tef, barely and wheat.

The newly developed thresher gave the highest performance at a speed of 705rpm with higher but within the acceptable breakage limit. The optimum drum speed for threshing maize was determined to be between 633rpm and 705rpm. The threshing and cleaning efficiency of the thresher were 88.93% and 99.99% respectively.

Recommendations

- To improve the threshing capacity, easy of feeding and to accommodate different crops, the feed inlet of the thresher should be modified
- The thresher should be extensively tested for different crops and machine conditions to compare its performance.
- To make transportation easy, it should be mounted on wheels.
- The economics of the thresher should be studied with to compare with other improved threshing mechanism and traditional one.
- Study should be made on the cleaning unit of the thresher.

Reference:

3. Chilalo Agricultural Development Unit 1969. Implements Research section progress Report No.1 Chilalo Agricultural Development Unit
ON - FARM VERIFICATION OF MANUAL OPERATED MILK CHURNS

Abu Tefera

Associate researcher & Post-harvest Research Program Coordinator
Bahir Dar Agricultural Mechanization Research Center, Bahir Dar
P.O. Box 133
Tell 0582200631

Abstract

Milk production by the smallholder farmer has increased in the Amhara Region due to access to modern breeding service and interests on milk processing. However, only a minor portion of the locally produced milk enters the commercial sector owing to marketing constraints and lack of processing technologies suitable for the smallholder or dairy farmers. A comparative study was conducted to investigate the performance of three manual milk churns with partial modification. The modified revolving churn showed considerable advantages over the traditional and the improved versions. The improvement is simple, cheap and equally effective compared to the imported one. The trials and analysis of data indicated that as much fat could be recovered from sour milk in considerably shorter churning time and low labour input compared to the traditional and the other improved churns. The statistical analysis showed that the mean difference is significant at the .05 level among churns regarding productivity. Even though, all churns were capable of making butter, the revolving one was more efficient. Generally, the improved technology if employed could increase the income of smallholders.

Introduction

Milk is an important product in most parts of the region. In the smallholder farming systems in areas with high human population density, milk is one of the staple foods, providing vital nutrients as calcium, protein, phosphorus and lipids, and, in many instances, is a major source of cash for the family. Milk fat or butterfat is the second largest component of milk and has a major commercial value. It serves as an energy source and supplies essential fatty acids. (1)

Farmers close to main roads and towns have no marketing problems they can sell their milk directly to consumers or to traders, as well as to an established milk collection stations. However, most farmers living away from towns have poor access to such markets and they change the milk to products like butter, which have greater storability (5). Income from sale of dairy products is usually used to purchase food grains, clothing and other household items.

Most of the milk produced by farmers, who are isolated from market areas, is consumed by their families as fresh or coagulated milk. However, as some church members abstain from milk and animal products for approximately 150 days per year, all the milk produced during this period is usually converted into butter and cottage cheese.

Traditionally, in the region, milking and processing are the affairs of each family. The milk for processing can be collected either from a single milking animal or from a larger number of animals. The milk thus accumulated is processed into different products by each household. In making butter from sour milk, irda, the objective is to extract the maximum amount of fat from the milk. Buttermilk, the liquid that remains after the butter is made is used to produce a type of cottage cheese, called ayib in Ethiopia. Since there is a big difference between the price of...
butter and that of cottage cheese, any butterfat remaining in the buttermilk is usually considered as an economic loss to the smallholder.

Efficient butter-making can be measured by the length of time it takes to churn the milk and by the amount of fat remaining in the buttermilk or the amount of fat extracted from the milk. However, the traditional methods of churning are time consuming, and take more than two hours (2). Observations made on traditional butter making by smallholders indicated that the efficiency should be improved to save time and increase the economic return.

The current trend of dairy farming indicates an increase in milk and milk products due to:

- Modern breeding service given for users by governmental and non-governmental sector.
- Increased interest in milk production and processing
- Increased dairy production activities from day to day

To support this positive trend, it is time to demonstrate the existing model churns,

**Objective**

The objective of this study was to overcome the problem in the traditional butter making practice and support existing dairy progress by availing different kinds of small scale improved butter churns for farmers

**Description of Churns and Butter making**

Traditional butter making practice and equipments

Traditional butter (*kibe*) is always made from sour milk (*irgo*); cream is not used. The churn is smoked with *Olea African*, that gives a distinct flavor to the butter and this practice has a bacteriostatic effect, may reduce processing time by heating the churn. (ILCA BULLETIN No. 22-October 1985). The sour milk (*irgo*) is placed in a churn (Figures 1a, b, and 2a, b). After filling, the churn is stopped with a plug, a false banana leaf or a piece of skin or leather stretched over the mouth and securely tied. The churn is then agitated in different way of agitation as shown in the pictures. (Figure. 1 and 2).

![Figure 1b.](image1)

![Figure 2a.](image2)

The churn is placed on the lap (Figure. 1a) or on the floor, (Figure. 1b) on a soft pad of material such as sheep skin or straw, tilted at an angle of about 75° to the horizontal, and rocked back and forth. On the other hand the churn is hung on a tripod or doorpost and swung or shaken with both hands back and forth (Figure 2a). Women usually put about 10-15 litters sour milk (*irgo*) in to the local chumer and are churned until the break point, i.e. the point when butter starts to form. It can be detected by a change in the sound of the milk. Many women dairy farmers also insert a straw into the churn through the vent and adherence of small
butter grains to the surface of the straw indicates that the break point has been reached. If the straw is clean, this indicates that the butter granules have coalesced into larger grains. The churn is then rotated on its base; the grains, which collect in the centre, form lumps of butter, which are skimmed off. The butter is then kneaded in cold water and washed to remove visible residual buttermilk.

**Improved milk churns and butter making**

**Horizontal Butter Churn**

The horizontal butter churn is modified at Bahir Dar Agricultural Mechanization Research Center. It is made of aluminum sheet and hard wood. It looks more cylindrical in shape, (Figures a and b) has four fixed beaters located in different position at 45° degree on beater holder, which has aluminum ring casing at both ends. The aluminum rings are used to pass on rotating action coming from the handle through its square holes. The agitator is driven by square iron bar through handle and has wooden leg. The lead or cover of the churn has an eyeglass at the center for inspecting butter grain formation during processing. It has also ventilation holes used for releasing air from inside, which is created during operation. Working capacity of the churn is 10 litters and it weighs 12 kg.
**Vertical Butter Churn**

The imported vertical butter churn is made of aluminum sheet and hard wood, it looks cylindrical in shape, (Figure c) has fixed box type agitator (beaters) located in parallel position on the beater holder shaft (Figure d). A hand-operated revolving round iron bar through bevel gear drives the beater. The driving mechanism and the upper part of the lead or cover are attached with two bolts and the beater is rigidly fixed on the round shaft (figure, d). Working capacity of the churn is 10 litters and it weighs 15 kg.

**Revolving Butter Churn**

The Revolving butter churn was modified at Bahir Dar Agricultural Mechanization Research Center. It is made of metals and plastics (Figure e). It is cylindrical in shape, has two fixed flat type beaters located at the center on opposite side of the central shaft. A hand-operated revolving round iron bar through ball bearing at each opposite side drives the beater. The ring is made of round iron and sheet metal, grips tightly the plastic container and the ring is tightly adjusted by a pair of bolts. The driving mechanism and the cylindrical plastic container are attached together through the ring shaped attachment. It is easy to assemble and disassemble the plastic container from the ring attachment and frame. Working capacity of the churn is 10-15 litters and weighs 15 kg.
Materials and methods
Three different models of chums designated as imported vertical chum with box type beater, horizontal paddle type beater chum and cylindrical body revolving chum were selected for the study. Except the vertical chum, the others two models, the designs were carefully worked out, and manufactured from imported items using reverse engineering at Bahar Dar Agricultural Mechanization Research center workshop. All churns were of 10 liters capacity each and were checked for proper functioning in the center using 10 litters of irgo.

After checking the proper functioning of all churns, criteria were set for selecting participant farmers and testing sites. Number of milking cows, awareness about the improved technology, and potential of the area for milk production, market access and distance from the main road or nearest town were some of the criteria used in the selection. The actual test sites were selected through discussion about the objective and merits of the study with the respective wereda Agriculture and Rural Development office experts, development agents and farmers. Based on the criteria and discussion, the trial sites and participant farmers were selected from Bachema Kebele in Mecha wereda West Gojjam zone and from WerkAmba Kebele in Dejjan wereda East Gojjam zone. Three participants were selected from each trail site. The selected farmers were given practical training on operation and handling of improved butter chum. The performance of the traditional and the improved chums was observed side by side. Since the study was based on farmer’s evaluation, the objectives of the study and expectation form the participant farmers were discussed.

For each farmer one type of improved chum model with full accessory (manuals, wrench and data sheet) was supplied. The rest of the models were rotated among farmers each month, so that each participant farmer utilized all models of churns within three months. Besides, the full functionality of the churns was periodically assessed and, difficulties in operation and information on farmers’ reactions were gathered using data collecting sheets.

Finally, in all the trail sites, discussions were held among farmers, development agents and wereda experts on the merits and demerits of the churns relative to the local butter making practice and the performance of churns. Information was collected on farmers’ perception towards the effectiveness and suitability of the supplied churns. Farmers at the trial sites also provided their opinion regarding improvements required and some indicated their choice by placing orders.

Results and discussion
The performance of the three improved churn models were compared with the locally made churns and practices. Farmers did the evaluation on site over a 3-months period. Summary of results obtained from Dejjen wered at Worek Amba kebele trials sites are indicated in Table 1.

Table 1 shows that the amount of churned sour milk, Erigo was between 7-10 liters, which was enough for all churn in order to collect the required data. Normally for proper functioning, churns should be filled to a half level of their volumetric capacity. Filling to more than half the volumetric capacity increases churning time considerably but does not reduce fat recovery. (1)

In approximately 4-6 days, under normal storage conditions the milk becomes sour in 4 to 5 hours. The souring of milk has a number of advantages. It retards the growth of undesirable
microorganisms, such as pathogens and putrefactive bacteria, and makes the milk easier to churn. Manpower required for driving each churns were almost similar.

![Diagram of butter churns](image)

**Figure 1** Average churning time of churns in Dejjine wereda at Worke Amba kebela

The results of the trials clearly indicated that churning efficiency was considerably improved and depended on the agitator and its types. In these experiments, the length of the average time required for churning was 135 minutes for the traditional method and 31 - 37, 21 - 31, and 26.4 - 49 minutes for the horizontal, revolving and vertical churns respectively (Figure 1). This indicates that even though traditional churn is capable of churning milk, but the time taken for butter to form is considerably longer. All improved churns speeded up butter making, in addition to increasing the quantity of butterfat recovered and required less labour than the traditional churn, which is attributed to the effective agitation systems. Even though, all tested churns were equipped with agitators, the types and method of operation brought differences in performance among them. Figures 1 and 2 show that, revolving churn took less butter extracting time than the others. The average churning times were 26 and 21 minutes at both trial sites. More over, participant farmers in both trial sites forwarded their opinion about all improved churns; they ranked the churns in their order of performance. Based on their evaluation, revolving; vertical and horizontal churns were given the first second and third place respectively. They mentioned that working with the revolving one was very easy, had less butter loss. As its body is made of plastic, the butter did not stick on it and was easy to remove butter by hand. The container can be used for other purpose during the slack period, needs less churning time, easy to assemble and disassemble, has no leakage and is convenient for cleaning during operation. Table 1 shows that, beyond farmer’s opinion, there is a significant mean difference in productivity among the churns at the .05 level. The farmers commented that attention be given during batch production and the price of the churn to be within the range of the farmer’s purchasing capacity.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Statistical analysis of churning time of different churns at Werke Amba kebele.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multiple Comparisons</strong></td>
<td></td>
</tr>
<tr>
<td>(I) Milk Churn (J) Milk Churn</td>
<td>Mean Difference (I-J)</td>
</tr>
<tr>
<td>L.S.D Horizontal Vertical Revolving</td>
<td>-1.2020</td>
</tr>
<tr>
<td>Vertical Horizontal Revolving</td>
<td>7.7980*</td>
</tr>
<tr>
<td>Vertical Horizontal Revolving</td>
<td>9.0000*</td>
</tr>
<tr>
<td>Revolving Horizontal Vertical</td>
<td>-7.7980*</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the .05 level.
Abu Tefera

Figure 2 Average churning time in the trial site at Werke Amba kebele.

Conclusions

The modified improved churn has considerable advantages over the traditional churn. The improvement is simple, cheap compared to the imported one. Observation and test results indicated that as much fat could be recovered from sour milk in considerably shorter churning time and with less labour input than with the traditional methods. This indicates that improved technology could help in increasing the incomes of smallholder farmers and milk processing cooperatives.

Therefore, as the study show that all improved chorns capable of churning milk, have advantage over the traditional churning equipments, but the revolving one performed better than the others with respect to less butter losses, high output and labour productivity. These advantages make the revolving milk churn to be preferred by farmers and should be promoted further.

References

1. Frank O'Mahony 1988. ILCA Manual No. 4, rural dairy technology Experiences in Ethiopia (International Livestock Centre for Africa) Addis Ababa, Ethiopia
4. Ruth Ryoba and R.L. Kurwijila, Milk processing requirements for satisfying the demand for various dairy products in Tanzania Dairy Technology Laboratory, Department of Animal Science and Production. Sokoine University of Agriculture, Morogoro, Tanzania.
5. Tsehay Redda Small-scale milk marketing and processing in Ethiopia Ministry of Agriculture, Addis Ababa, Ethiopia
DEVELOPMENT OF HORIZONTAL MODERN BEEHIVE

*Hussen Abbagissa
Jimma Rural Technology Research Center P.O.Box 358 Jimma, Ethiopia
Tel (047)1110855, E-mail:jirtrc@telecom.net.et Fax (047)111-53-96

Abstract

In Ethiopia there are about 10 million bee colonies out of which, 7.5 million are confined in traditional hives and the rest exist in the forest and crevices. Having such a huge amount of bee colonies and surplus honey sources of flora, the amount of honey harvested per hive is very small (8 kg/hive). As the traditional hives are hanged on the trees, the harvesting system by itself is full of hazard. The objective of the study was to develop an efficient horizontal beehive that could be made from locally available cheap materials. Accordingly, the beehive was made from bamboo mat plastered with cow dung and was tested in comparison with Langstroth modern beehive. Data on construction cost and ease, management condition, bee-absconding, internal temperature variation, quantity and quality of honey and users feedback were collected. The results showed that the cost of this hives ranged between 100-150 Birr (at shop level), which is by far lower than cost of Langstroth (472-550 Birr) with simple construction, ease, better management condition and less absconding rate. No significant difference was observed in internal temperature variation and the quantity and quality of honey harvested was almost the same. Thus, proper popularization of this hive will help poor farmers to exploit the natural and abundant resources that would otherwise be wasted.

Introduction

Ethiopia’s wide climatic and forest variability has endowed the country with diverse and unique flowering plants, a large number of bee colonies and a long established practice of beekeeping. Bee keeping is an important activity for many rural men and women and is also carried out in home gardens and even around the house in many parts of the country. Honeybees obtain their protein source from pollen and carbohydrate from the honey they make from nectar. In most cases, human beings keep honeybees in improved hives and by providing proper management contribute to increased production of honey and as a result, they benefit from the big sale of honey and wax. There is no nationality in Ethiopia, which does not have beekeepers and for some, beekeeping is a major economic activity. In Ethiopia, there are an estimated 10 million bee colonies, out of which about 7.5 million are confined in traditional beehives (FAO 2006).

The current honey production in the country is estimated to be 24,600 tons per year. This estimate is based on 65% and 75% efficiency of 7.5 million traditional hives and some 20 thousand frame type hives respectively (FAO 2006). This indicates that only 2.6 percent of the total beehives used by our farmers are modern types. Had more modern frame beehives been used, many folds of the current rate, both in terms of quality and quantity would have been harvested. Yet the high initial cost of the Langstroth beehive, has limited the farmers from using this improved tool and exploit this abundant natural resources that is currently being wasted. Thus, the horizontal beehive, which is easily made from local material at village level, can be the solution for the problem that has hindered the quality and quantity of the countries honey production.
Materials and methods

The horizontal beehive has the honey area next to the brood chamber, not on the top, as that of Langstroth beehive. This hive has 25 cm and 23 cm external and internal heights respectively and 2 cm thick floor, which is made from bamboo mat plastered with cow dung. It also has two partitions, which can be separated by movable plywood after every 40 cm or after every 10 frames. It has a slot, which helps to keep the movable plywood to create a convenient environment for the early transferred bees. Moreover, this slot also helps to keep stand queen excluder when necessary. The external and internal width was 50 cm and 46 cm respectively and its length varied from 44 cm - 124 cm and even more (Figure 1). The new model movable frame of horizontal beehive is made of lumber, which has a 2 cm thick and 3 cm width, and its dimension is the same to that of Langstroth hive frame (Figure 2).

The experiment was conducted in Jimma, purposively selected four districts, namely Gera, Gomma, Manna and Karsa. Twelve low cost 124 cm X 50 cm X 25 cm horizontal beehives with 30 new model frames were manufactured at Jimma Rural Technology Research Center. From each site, one farmer was selected and given three low cost horizontal beehives with the new model frames to under take the experiment and three Langstroth beehives as a check. Data like internal temperatures, bee absconding, quantity and quality of honey harvested; any unusual condition and user's feedback were collected and analyzed.

Results and discussion

The horizontal beehive has the honey area next to the brood chamber, not on the top, as that of Langstroth beehive. It has different length, which can accommodate 10-30 frames and even more, depending on the potential capacity of the area. For areas, where there is a large amount of honey flora and large number of bee colonies, it is possible to use a horizontal beehive, which can accommodate 30 frames and even more. This hive has 25 cm and 23 cm external and internal height respectively and 2 cm thick floor, which is made from bamboo mat or any thin sticks and plastered by cow dung or mud. The thickness of all parts of this hive can be varied according to the environmental condition. It also has two partitions, which can be separated by movable plywood after every 40 cm, or every 10 frames there will be a slot, which helps to keep the movable plywood to create a convenient environment for the early transferred bees. Moreover, this slot also helps to keep stand queen excluder when necessary. The external and internal width is 50 cm and 46 cm respectively and its length varied from 44 cm - 124 cm and (Figure 1).

The new movable frame model has an advantage such that its bee spacer can be made easily by attaching a spacer of 0.5 cm - 1 cm thick and 5 cm height to its one face. It is also more durable than the Langstroth frame because of its uniform width unlike the Langstroth frame, which has two cm width at its two upper ends (Figure 2).

Construction ease

This beehive has no sophisticated joints and it can be easily manufactured even at village level. The new model movable frame of the horizontal beehive is preferred to the frame of Langstroth beehive because of ease of construction, uniform width and durability.
Management of the beehive
As observed from fieldwork and gathered feedback, handling this beehive was by far easier than that of Langstroth because:

A. It has no different movable parts as that of Langstroth so it can be handled easily, especially during supervising and harvesting
B. It is very convenient to take any necessary action, since all frames can be seen at once,
C. It reduces the number of bee-killed during harvest and supervision
D. It can also be hanged on trees like the traditional beehive
E. It has a great advantage of resisting wind and any other side pressure, because of its 21 cm height, as compared to that of Langstroth, which has 100 cm height.

Bee transfer
Transfer of bee from local beehive can be done in the same manner as that of Langstroth.

Bee Absconding
Bee absconding is the running away of transferred bee from their hives because of different reasons and the test result showed that absconding rate in horizontal beehive was about 8.3% and 33.3% of the Langstroth beehive (See Table 1)

Temperature
There was almost equal average internal temperature in both types of beehives (Table 2).

Quality of Honey
The term quality refers to the extractability of honey using the extracting machine. As this horizontal beehive uses movable frame and the same extraction technique as that of Langstroth, the quality honey harvested is taken to be the same as that of Langstroth.

Quantity of Honey Harvested
The test result showed that on average the percentage share of Langstroth beehive is 51% while that of Horizontal beehive is 48.9%, thus the honey production of Langstroth beehive exceeds by 1.1%. (See Table 3)

General Feed Back
The people, residing around the selected farmer in each site, visited the Horizontal Beehive. All visitors admired and preferred this beehive, even if the yield from this beehive were by half less than that of Langstroth, because of its low cost and ease of management.
Table 1  Registered absconding from each site.

<table>
<thead>
<tr>
<th>Site</th>
<th>Kind of Distributed B.H</th>
<th>Registered Absconding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gera</td>
<td>Horizontal Beehive 1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Long Stroh Beehive 1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 3</td>
<td>0</td>
</tr>
<tr>
<td>Gommaa</td>
<td>Horizontal Beehive 1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Langstroth Beehive 1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 3</td>
<td>0</td>
</tr>
<tr>
<td>Manna</td>
<td>Horizontal Beehive 1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Long Stroh Beehive 1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 3</td>
<td>1</td>
</tr>
<tr>
<td>Kersaa</td>
<td>Horizontal Beehive 1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Long Stroh Beehive 1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&quot; &quot; 3</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2  Registered Temperature at Different sites.

<table>
<thead>
<tr>
<th>Site</th>
<th>Horizontal Beehive</th>
<th>Langstroth Beehive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Gera</td>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td>Goma</td>
<td>14</td>
<td>32</td>
</tr>
<tr>
<td>Mana</td>
<td>12</td>
<td>31</td>
</tr>
<tr>
<td>Kersa</td>
<td>13</td>
<td>32</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>121</td>
</tr>
<tr>
<td>T.Average</td>
<td>12.25</td>
<td>30.25</td>
</tr>
</tbody>
</table>
### Table 3 Quantity of Honey Harvested at Different Site in kg

<table>
<thead>
<tr>
<th>No</th>
<th>YEAR</th>
<th>Site</th>
<th>No of HBH distributed</th>
<th>No of LBH distributed</th>
<th>Average honey harvested from HBH in Kg</th>
<th>Average honey harvested from LBH in Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1997</td>
<td>Gera</td>
<td>3</td>
<td>3</td>
<td>12/hive</td>
<td>11.5/hive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Goma</td>
<td>3</td>
<td>3</td>
<td>8/hive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mana</td>
<td>3</td>
<td>3</td>
<td>12.5/hive</td>
<td>13.5/hive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kersa</td>
<td>3</td>
<td>3</td>
<td>22/hive</td>
<td>22/hive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total 67.5</td>
<td>69</td>
</tr>
<tr>
<td>2</td>
<td>1997</td>
<td>Gera</td>
<td>3</td>
<td>3</td>
<td>13/hive</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1998</td>
<td>Gera</td>
<td>3</td>
<td>3</td>
<td>22/hive</td>
<td>22/hive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Goma</td>
<td>3</td>
<td>3</td>
<td>13.5/hive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mana</td>
<td>3</td>
<td>3</td>
<td>20/hive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kersa</td>
<td>3</td>
<td>3</td>
<td>Total 9.64</td>
<td>9.85</td>
</tr>
</tbody>
</table>

**Note:**
- **H.B.H** - Horizontal beehive
- **L.B.H** - Langstroth beehive

**Figure 1** Horizontal beehive.
Conclusion

As the test result showed, there is no significant difference between Horizontal Beehive and Langstroth beehive in the quantity and quality of honey harvested and the Horizontal Beehive is found to be better than Langstroth beehive because of the following advantages:

- It could be constructed at village level or small workshops with locally available and cheap materials.
- It avoids complicated joints.
- It reduces the cost of queen excluder by half.
- It decreases the consumption of lumber by 72% when compared with Langstroth.
- It can be constructed at different length according to the environment.
- Its internal temperature can be maintained by varying the thickness of plastered material.
- It can also be hung from a tree, or from a pole, as it consists of single box. This protects it from ants, toads and brush fire.

This hive is by far cheaper than the Langstroth hive.

Popularization of this hive is therefore recommended to enable the farmers harvest better quantity and quality honey from abundant natural resource that otherwise be wasted. Further research is also recommended on this area to come with still cheaper and easily manageable hive.

References


TECHNICAL EVALUATION OF TREADLE PUMPS FOR ABILITY TO LIFT WATER IN MICRO-IRRIGATION SCHEME

Oumer Taha
Oromia Agricultural Research Institute, P.O. Box 81265, Finfinne

Abstract

Review of the performance of different pump models working in Africa revealed wide range of discharge and pressure though built around the same principle using similar materials. Similarly, treadle/pedal pumps working on the same principle, manufactured by different organization were introduced to Oromia for water lifting purpose, but none of the pumps has complete information on their hydraulic performance. Thus, this experiment was conducted to evaluate different pressure treadle pumps manufactured by different institutions for their hydraulic performance. It was carried out at Asella, 2400 m.a.s.l. Four model pressure treadle pumps: OARI, Selam, Appro TEC and Rope and Pulley types were used in the study. A test tower of 10 meters height divided into 2 meters testing plat form compartment was erected to vary the suction and delivery heights. Three levels of weight (45-50kg, 55-60kg and 65-70kg ), three levels of suction lift or depth (2, 4 and 5m ) and three levels of delivery height (6, 8 and 10m ) were arranged in split plot design, where weight was assigned to the main plot, suction lift and delivery height were split over sub plots. The result showed that among the four treadle pumps tested OARI type was superior in the amount of water discharged (l/min) followed by Selam pump up to a total head of 10m (2m suction plus maximum 8m delivery height) recording 1.46m³/hr, 2m³/hr and 2.3 m³/hr for weight groups of 45-50kg, 55-60kg and 65-70kg, respectively. On the other hand, for the same weight category Selam model recorded 1.2m³/hr, 1.3m³/hr and 1.74m³/hr, indicating preference for OARI at lower suction lift. However, at suction lift greater than 4m, for lesser weight groups of 45-50kg and 55-60kg Selma showed a better performance. However, in sustainable discharge of one working day for all pumps using 59kg person at 4m suction and 4m delivery height OARI delivered 1.8m³/hr followed by Selam 1.5m³/hr with the least delivery by the Pulley and rope pump model, 0.75m³/hr. Hence, deciding which pump is best is not a question of technical performance; judgment must be based on wide range of factors including: circumstances in which the pump will be used, cost and benefits, reliability, maintenance and availability of spare parts.

Introduction

In order to reduce poverty and increase food security, the government of Ethiopia has designed and launched food security strategy through development and implementation of water harvesting schemes. In Oromia alone, 83,400 ponds with 127m³ capacity each and 6100 hand dug wells were planned in 2002/2003 and the achievement was 44,149 and 3452 ponds and hand dug wells, respectively. Though the achievements were about half of what was planned, in the fiscal year of 2003, the plan for the next fiscal year for pond was more than double (196,070) and that of well was about five fold (31,260) according to Rural and Agriculture Development Supreme office of Oromia (RADSO 2003). The main aim of this water harvesting scheme was to ensure food security at household level by making water available to supplement natural rainfall through irrigation of field crops and backyard gardening during off season.

Harvested water has to be transported for intended purpose, i.e. to irrigate the fields. However, methods employed to convey water to the field for irrigation in the country and in Oromia too are mostly traditional. The water is transported to the field with the help of bucket using human labor. This method of water extraction is extremely laborious and hectic, especially where
water points and area to be irrigated are far apart. For shallow wells of the type under construction by the food security program, watering using human labour and buckets instead of pumping, limits the area that can be irrigated.

To overcome the problem of water lifting, treadle/pedal pumps, which originated in Bangladesh during the late 1980s, have been introduced to some regions of the country including Oromia since 2002. This low speed, foot operated reciprocating pump is designed to overcome problems of small scale farmers. The device can be operated by standing on two treadle levers and depressing them alternatively using the feet (Annex 1 - figure A). The introduced pump types have two main design features (suction pumps and pressure pumps). The suction pumps are designed to lift water from shallow wells (3-6m deep) and release it to the furrow. The introduced pressure pump can be used for suction lifts up to 6m and a delivery head of 8m high. The pressure pumps are used when water sources are deeper than 4m and there is a need to deliver water under pressure to irrigate undulating or steeply sloping land (Kay 2000).

Different organizations distributed pumps working on the same principle manufactured by different organization to support the food security program. The initiation is highly appreciable and acknowledged as the intervention of this kind is vital for developing countries that are frequently affected by recurrent drought. However, none of the pumps has complete information on its hydraulic performance.

On the other hand, review of the performance different pump models, including the two types of pumps available in the country and in other parts of Africa revealed wide range of discharge and pressure despite that the pumps were built around the same principle using similar materials. According to Kay, pressure pumps of similar piston diameter (100 mm) and stroke length (290-300 mm) recorded maximum total head of 13m in Zambia and 8m in Zimbabwe. On the other hand, the Protect pressure pump with a piston diameter of 121 mm and 73 mm stroke length gave a similar discharge to the 121 mm piston diameter and 121 mm stroke length suction pump. The data, showed different results, for the pumps built around the same principle with similar materials as opposed to the expectation of getting similar results. The conclusion to be drawn from this is that much of the variation could be a result of the methods of testing. Some of the tests were conducted in the laboratory and some in the field. There is also the question of the operators in terms of weight, number and treadle speed. On the other hand, as treadle pump was first developed for flat topography, it is legitimate to expect lower efficiency in Oromia, where the topography is undulating. The ground/river water is at deeper position and the catchments to collect the water in ponds are mostly at a lower elevation than the command area to be irrigated. Therefore, the water must be pushed much further from its source to the point of use. The aforementioned basic information and as well performance evaluations of these pumps under different condition (weight, depth and height) was lacking. Therefore, this study was designed to select the appropriate pumps for a given set of conditions in terms of hydraulic performance as this indicates the discharge and pressure that can be expected for the effort or power input. Thus, in 2005/06 this research activity was conducted to evaluate the hydraulic performance of different pressure treadle pumps manufactured by different institutions.

Materials and methods
The experiment was carried out at Asella Rural Technology Research Center, 2400 meter above sea level, 175 km southeast of Addis Ababa. Four models of pressure treadle pumps
Proceedings of the first Agricultural Mechanization Completed Research Forum

namely Oromia Agricultural Research Institute model (OARI model), Selam, Appro TEC and Rope and Pulley types (Figure-2) were used in the experiment. Different size containers; barrel, buckets and container with 6000 liters capacity, measuring tape of 30m length, stopwatch and balance with a measuring capacity of 200kgs were used in the experiment. The treatments were three weight groups: 45-50kg, 55-60 kg and 65-70 kg representing child and women, average adults and above average or heavy weight groups of the community, respectively. The other two treatments were three levels of suction lift or depth (2m, 4m and 5m) and three levels of delivery height (4m, 6m and 8m). The experimental design used was split plot design arrangement weight assigned to main plot and depth and height split over weight in sub plot with three replications. A test tower of 10m height, divided into two meters test compartment, to vary suction lift and delivery heights was constructed and erected at Asella rural technology research center (Figure-2).

Two types of experiments were carried out. The first one was short duration test- using all levels of treatments in three replications to pump 1/3 of barrel (about 73 liters of water) and recording time taken in minutes. The second experiment, sustainable discharge test, was carried out after facing a difficulty in reaching a conclusion, especially on the suction lift of 4m depth with two of the three alternate delivery heights at 4m and 6m suction, where all pumps revealed the same result for short duration test. For this test, the weight of operator was 59kg. suction lift was 4m depth, delivery height was 4m, the operator pumped continuously for 20 minutes on average and the rest time between successive operations was 20 minutes. One
The following graphical representation shows the relationships among the RPM of the turbine, discharge, input power, output power, angular velocity, load (weight) and efficiency. The graphs were plotted from the data obtained from the experimental.

![Graph 1: Torque vs Power](image1)

**Figure 1** The effect torque on power.

From the graph, the maximum power obtained from 17.95 l/s discharge and 1.5m head was only 126.3 watt.

![Graph 2: Power vs Efficiency](image2)

**Figure 2** Efficiency

Here it can be seen from the graph that the maximum output power obtained with 47.84% turbine efficiency was only 126.3 watt. An ever increasing of any input with the given efficiency could not give any significant change on the power output; rather with an increasing input the power output declined.
As it can be seen from each table, the output power mainly depends on the torque developed as a result of moment and angular velocity of the turbine. Output power has also direct relationship with available net head and flow rate of the water. Output power increases with increase in discharge rate and head, but after the maximum limit it diminished due to the increment of load. With the above described discharge rates, other parameters kept constant, the maximum output power to be expected from the turbine is depicted in Figure 4 below.

Figure 4 shows that speed and torque have inverse relationships. This is attributed to the fact that the torque has direct relationships with the load and intern the maximum load harness the RPM of the turbine other parameters kept constant.

Figure 3 the change in RPM as related to torque.
Table 1: Effect of weight of operator and pumping head (suction lift + delivery head) on discharge of some pressure type treadle pumps.

<table>
<thead>
<tr>
<th>Weight of operator</th>
<th>Pressure head</th>
<th>OARI</th>
<th>Selam</th>
<th>Appro TEC</th>
<th>Pulley and rope</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2sl+4dh(6m)</td>
<td>0.48</td>
<td>0.42</td>
<td>0.40</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>2sl+6dh(8m)</td>
<td>0.40</td>
<td>0.27</td>
<td>0.35</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>2sl+8dh(10m)</td>
<td>0.34</td>
<td>0.32</td>
<td>0.26</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>4sl+4dh(8m)</td>
<td>0.34</td>
<td>0.31</td>
<td>0.27</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>4sl+6dh(10m)</td>
<td>0.30</td>
<td>0.26</td>
<td>0.22</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>4sl+8dh(12m)</td>
<td>0.28</td>
<td>0.24</td>
<td>0.13</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>5sl+4dh(9m)</td>
<td>0.23</td>
<td>0.31</td>
<td>0.24</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>5sl+6dh(11m)</td>
<td>0.19</td>
<td>0.26</td>
<td>0.19</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>5sl+8dh(13m)</td>
<td>0.16</td>
<td>0.20</td>
<td>0.15</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>2sl+4dh(6m)</td>
<td>0.61</td>
<td>0.51</td>
<td>0.44</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>2sl+6dh(8m)</td>
<td>0.51</td>
<td>0.34</td>
<td>0.40</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>2sl+8dh(10m)</td>
<td>0.55</td>
<td>0.41</td>
<td>0.37</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>4sl+4dh(8m)</td>
<td>0.39</td>
<td>0.38</td>
<td>0.38</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>4sl+6dh(10m)</td>
<td>0.37</td>
<td>0.37</td>
<td>0.34</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>4sl+8dh(12m)</td>
<td>0.34</td>
<td>0.32</td>
<td>0.25</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>5sl+4dh(9m)</td>
<td>0.36</td>
<td>0.38</td>
<td>0.37</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>5sl+6dh(11m)</td>
<td>0.31</td>
<td>0.33</td>
<td>0.31</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>5sl+8dh(13m)</td>
<td>0.26</td>
<td>0.29</td>
<td>0.26</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>2sl+4dh(6m)</td>
<td>0.71</td>
<td>0.60</td>
<td>0.53</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>2sl+6dh(8m)</td>
<td>0.62</td>
<td>0.42</td>
<td>0.47</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>2sl+8dh(10m)</td>
<td>0.61</td>
<td>0.43</td>
<td>0.45</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>4sl+4dh(8m)</td>
<td>0.45</td>
<td>0.56</td>
<td>0.38</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>4sl+6dh(10m)</td>
<td>0.42</td>
<td>0.42</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>4sl+8dh(12m)</td>
<td>0.41</td>
<td>0.37</td>
<td>0.32</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>5sl+4dh(9m)</td>
<td>0.43</td>
<td>0.43</td>
<td>0.43</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>5sl+6dh(11m)</td>
<td>0.40</td>
<td>0.37</td>
<td>0.38</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>5sl+8dh(13m)</td>
<td>0.38</td>
<td>0.33</td>
<td>0.33</td>
<td>0.19</td>
</tr>
</tbody>
</table>

F value for treatments

<table>
<thead>
<tr>
<th></th>
<th>Weight of operator (W)</th>
<th>27.9**</th>
<th>24.46*</th>
<th>27.2**</th>
<th>16.55**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Section lift (sl)</td>
<td>652.64***</td>
<td>113.13***</td>
<td>236.22**</td>
<td>514.08***</td>
</tr>
<tr>
<td></td>
<td>Delivery head (dh)</td>
<td>16.12***</td>
<td>6.99**</td>
<td>6.5**</td>
<td>16.42***</td>
</tr>
<tr>
<td></td>
<td>Weight (W) x suction lift (sl)</td>
<td>73.96***</td>
<td>187.47***</td>
<td>145.28***</td>
<td>210.8***</td>
</tr>
<tr>
<td></td>
<td>Weight (W) x delivery head (dh)</td>
<td>0.67</td>
<td>6.9**</td>
<td>2.46</td>
<td>13.38***</td>
</tr>
<tr>
<td></td>
<td>Section lift (sl) x delivery head (dh)</td>
<td>4.8**</td>
<td>18.89***</td>
<td>0.74</td>
<td>15.63***</td>
</tr>
<tr>
<td></td>
<td>Weight (W) x Section lift (sl) x delivery head (dh)</td>
<td>1.49</td>
<td>2.41*</td>
<td>1.89</td>
<td>9.06***</td>
</tr>
</tbody>
</table>

C.V (%) 6.06% 6.17% 5.2% 5.10%

Key to treatments codes:
sl = suction lift (depth of water table)
dh = delivery height (height above ground level to which water was pumped)
W = weight group category, (W1 = Operators weighing 45-50kg, W2 = Operators weighing 55-60kg W3 = Operators weighing 65-70kg)
As weight of operator increased by 10 kg i.e. from 55-60kg to 65-70 kg, the average difference between the competing pumps, OARI and SELAM was pronounced at shallower depth of 2m, delivery heights of 4m, 6m and 8m. It was 0.65 l/sec for OARI and 0.48 l/sec for SELAM model pumps (Table 1). Again, as the suction lift increased from 2m to 4m, the total discharge remained the same (0.43 l/sec) on aggregate for both OARI and SELAM pumps. However, it is only in this weight group the discharge of OARI model pump registered higher value than its competitor SELAM at deeper suction lift greater than 4m (Figure-5). On the other hand, the pulley and rope type pump recorded low in all treatment levels especially at increased weight category.
From the Figures 4 and 5, the discharge for the pumps under consideration was inconsistent especially in the short period test of delivering of 1/3 barrel of water. This inconsistency result triggered the idea of sustainable discharge test.

**Sustainable discharge test**

This test was conducted with the same operator pumping from constant depth and height for one working day on the same pump by having equal rest time between successive operations. The result of this test is summarized below (Figure 6). This result was obtained by an operator of 59kg continuously pumping for 20 minute and getting rest for 20 minutes between successive pumping with a total rest period two hours in day. As seen from the graph, sustainable discharge in a given day for the same operator working the same working hour, OARI model delivered more water 28.5 l/min or 1.7 m³/hr from a suction lift of 4m and delivery height of 4m (total head of 8m) followed by SELAM 21.6 l/min or 1.3 m³/hr, Appro. Tec 16.2 l/min or 0.97 m³/hr and 12.6 l/min or 756 m³/hr. The operator pumped for a total time of 3 hours and delivered 5130 liters, 3888 liters, 972 liters and 756 liters of water by OARI, SELAM, Appro. Tec and rope and pulley pump models, respectively. However, Orr et al 1991 reported that a healthy adult male could work comfortably for 5-6 hours a day pumping continuously for 20 minutes and then resting for 10 minutes. The OARI model pumps manufactured by four centers of Oromia Rural Technology Research Centers (Asella, Bako, Harar and Jimma) were used for in the sustainable test. Though attempt was made to
standardize this model pump at regional level, their sustainable discharge result was ranging from 1.44 m³/hr to 2 m³/hr showing variation in workmanship and other factors such as material selection. The result used for comparison is the mean of four pumps produced by respective centers.

As seen from this report OARI model, pumps more water (5130 liters) in a given period of time as compared to the other pump types. This could attributed to the higher mechanical advantage of OARI model, 3.9 as compared to SELM which was 3.2 and also higher stroke length of OARI model, 110 mm (Anex.2)

To see the suitability of these pumps for micro irrigation let strong man convey water with 20 liter capacity bucket from a gorge of a river having 4m depth or from a shallow well having 4m depth along a sloppy land having 4m vertical height to irrigate his farm. At ambitious working speed, this could take him about 12 minute to accomplish one round conveying. If the man rests 12 minutes in one working hour, he only conveys 20 liters x 4 that is 80 liters of water. However, using treadle pump delivering mechanism in sustainable way (pumping for 20 minutes and resting for 20 minutes) a 59 kg man conveyed 855 liters of water from 4m suction and to 4m delivery height. This increased efficiency of pumping about 8.5 times in OARI model and 6.5 times for SELAM as compared to bucket conveying method to irrigate farmlands.

**Figure 6 Sustainable discharge of 59 kg person for one working day.**

To see the suitability of these pumps for micro irrigation let strong man convey water with 20 liter capacity bucket from a gorge of a river having 4m depth or from a shallow well having 4m depth along a sloppy land having 4m vertical height to irrigate his farm. At ambitious working speed, this could take him about 12 minute to accomplish one round conveying. If the man rests 12 minutes in one working hour, he only conveys 20 liters x 4 that is 80 liters of water. However, using treadle pump delivering mechanism in sustainable way (pumping for 20 minutes and resting for 20 minutes) a 59 kg man conveyed 855 liters of water from 4m suction and to 4m delivery height. This increased efficiency of pumping about 8.5 times in OARI model and 6.5 times for SELAM as compared to bucket conveying method to irrigate farmlands.

**Conclusion and recommendation**

Attempts were made as seen above to evaluate the technical feasibility of four pressure treadle pumps manufactured by different institutions for their ability to lift water for irrigating small holder farms, though it is difficult to compare pumps from different suppliers because of differences in design, materials used, dimension of components and workmanship. From the
above evaluation test, one can clearly notice that during the first short duration test, up to 4m depth, OARI model pump performed better (Figures 3 and 4). For the lighter group category of 55kg -60kg at suction lifts greater than 4m, SELAM model pump showed a better water lifting ability, suitable and preferred by children and women groups. This could be due to shorter stroke length (75mm) of SELAM model, which requires less effort as compared to 110mm stroke length of OARI model pumps.

In the second test, sustainable discharge test, at 4m suction lift and 4m delivery height, which is common for most shallow, wells and river gorges, OARI model pump delivered more water per unit of time (1.71m³/hr). The net working hour was about 3 hours, which is in agreement with other workers (M. Kay and T. Brabben 2000), which underlined that pressure pumps are operated for 3.03 hours per day in Kenya. Rope and pulley model pump was not only recording the least result (0.7m³/hr) but also show inconsistent flow and at higher weight category. Water leakage through the base due to cracking of the wooden base was observed, the treadles (wooden treadles) were broken during operation, flow interrupted, while the pump was in operation, constant stroke length was not maintained as the rope started stretching while pump was and there was difficulty to start smoothly (priming problem) revealing the inferior quality of this pump.

Delivering 5130 liters of water in three working hour from a depth of 4m to 4m above its working place is a great achievement for a person who fetches about 20 liters of water from a well having 4m depth or a river with the same depth and carrying it to command area along to equivalent of 4m vertical height. Survey of different African country on the use of treadle pumps revealed that treadle pumps can increase area cultivated in bucket irrigation (0.03 ha) to 0.27 ha in Appro Tec pressure pump models. If more than one operator is working the pump, the irrigated area can be much greater (M. Kay and T. Brabben, 2000). Therefore, OARI and SELAM pumps, which can deliver more than Apron Tec, can satisfy small-scale farmer irrigation schemes technically. Deciding which pump is best is not a question of technical performance only, judgment must be based on wide range of factors including: circumstances in which the pump will be used (is it from shallow wells or deeper river gorges along slope, who is mostly working with my pump?), cost and benefits, reliability, maintenance and availability of spares.

As observed from this experiment, pumps produced within the same institute vary in their performance (1.44m³/hr -2m³/hr) due to various reasons of which over look of important design parts such as foot and piston stroke length, seal selection and in general absence of accurate workmanships. Hence, it is imperative to have agreed up on standard jigs and fixtures to manufacture to the precise dimension, to standardize and make possible interchangeability of parts to fit to all and in order to minimize variability due to welding distortion, incorrectly dimensioned stock, and human error.

References


Annex-1

Figure 1: Treadle pump operating principles

Annex-2

Specification of pumps

<table>
<thead>
<tr>
<th>Parts</th>
<th>OARI</th>
<th>SELAM</th>
<th>Apro-Tec</th>
<th>Pulley type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piston ø (mm)</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Cylinder Height (mm)</td>
<td>200</td>
<td>200</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>Foot stroke length (mm)</td>
<td>430</td>
<td>240</td>
<td>240</td>
<td>160</td>
</tr>
<tr>
<td>Piston stroke length (mm)</td>
<td>110</td>
<td>75</td>
<td>55</td>
<td>80</td>
</tr>
<tr>
<td>Inlet pump ø (inch)</td>
<td>¾</td>
<td>¾</td>
<td>¾</td>
<td>¾</td>
</tr>
<tr>
<td>Outlet pump ø (inch)</td>
<td>¾</td>
<td>¾</td>
<td>¾</td>
<td>¾</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>29</td>
<td>17.5</td>
<td>18</td>
<td>33</td>
</tr>
</tbody>
</table>
DEVELOPMENT OF HUMAN OPERATED MICRO-IRRIGATION PUMP

Zewdu Ayalew, Associate Researcher,
Bahir Dar Agricultural Mechanization Research Center
P.O.Box 133 Baher Dar
Tele 0582200631/0918762835

Abstract
Successive attempts were made to develop and test human powered water pumping unit suitable for small scale irrigation application. The pump was aimed to be owned by individual poor farmers. Besides, it has to be easy to operate and maintain by the owners themselves, and has a higher discharge to use for irrigation application. Working principals of reciprocating pumps with direct action and rower pump arrangement were selected. Preliminary investigations on direct action pump model showed that it had a lower discharge rate and hence efforts were directed to development of suitable components for rower type pump. Consequentially a pump was developed which can lift water from a depth below 4 meters. It was made from standard G.I. pipe, standard pipelining, scrape rubber, round bar, and aluminum rod. After sufficient on-station evaluations, the pump was tested on farmer’s field around Geriby, Oromya Zone in Amhara region by pumping water from a depth of about 4.36 m. Four farmers within different weight categories and two different sized seals were used during the final on-farm trials. Average performance values using two different sized seals were; water discharge rate (28.8 & 45.6 l/mi), power requirement (19.65 & 32.8 Watts), power use efficiency (47.78 & 66.57), volumetric efficiency (57.19 & 77.40%), and slip (42.81 & 22.60%). Power requirement was observed to be within the capacity of a single farmer and even his grown up child (45 kg weight) was able to operate the pump. Participant farmers, being satisfied with the pumps performance, forwarded encouraging comments. Even though the recorded results were better than obtainable by most other hand pump types, additional works of refining some pump components and standardizing products may still be required.

Introduction
A pump is a mechanical device used to increase the pressure energy of a liquid in order to lift it from lower to higher level. Pumping is usually achieved by creating a lower pressure (suction) at the inlet side and high pressure at the outlet (delivery) side of the pump. There are various types of pumps used for lifting water from various sources, out of which positive displacement pumps are most widely known. There are also different ways in which positive displacement pumps can be used depending up on the requirement in mode of operation, available power, and the required capacity. Positive displacement pumps, especially those with reciprocating piston type, are more commonly used for small scale water pumping purposes in rural areas for pumping water for community water supply uses. There are also some successful designs, which can be used for pumping water for irrigation water application too.

The highlands of Ethiopia, especially those in the northeastern part of the country, have irregularly patterned rainfall, which result in frequent drought. However, these highlands are also endowed with different sub surface and surface water resources, which are mainly found in low laying areas and valley bottoms. Gravity overflow springs can be found on the bottom of farmlands and ground water table can be found just a few meters below the surface. Harvesting and utilization of these water resources is technically possible, but need an efficient
mechanical pumping device for lifting sufficient water to the level of the farms for irrigation purposes. This pumping unit, in turn, should satisfy some technical and social requirements to be acceptable and utilized. It should have lower cost to be owned by resource poor farmers individually. Besides, it should have high discharge rate, be easy to handle and maintainable at rural levels and be less complex to minimize rapid wear and tear resulting in ultimate failure of the pump. Cognizant of the potentials of the highlands of Wollo for micro-irrigation application and the trends of the farmers towards production of cash crops and high value vegetables, attempts were made to develop a high discharge water pumping unit suitable for resource poor farmers.

Materials and methods

Pump development
The pumps were selected guided by the pump selection criteria developed by the UNDP and World Bank (Arlosoroff et al., 1987) and other relevant literatures. A rower arm and direct action type models were primarily selected for pump model and suitable components were developed for each. Each pump was then manufactured using 2in G.I. pipe for rising main and air-chamber, 8mm diameter round bar for pump rod, and standard 2 in Nipple shaped with lathe for foot valve (Fig. 1). Piston was manufactured from aluminum shaft shaped with lathe to perform pumping operations. Scrape rubber ringed to appropriate diameter was used as a seal. Two different dimensions of seals were tested. A number of engineering testing were made on-station, until an acceptable discharge level (taken as 0.45lt/se) was achieved. The final prototype, which passed this level was taken further evaluated at a farmer’s field around Kemisse area in the presence of other farmers. Two pumps, direct action type and rower type, were developed.

Test sight
Available hand dug wells used for irrigating coffee and some vegetables were found at Gerbi area, near Kemisse town. Water table during testing time was in the range of 4.2-4.36 m bellow the water reservoir made by the farmer.

Testing conditions
The pump was tested after it worked for about two months on the farm’s field. Three farmers and one technical investigator having different body weights (45kgs, 53kgs, 57kgs and 63 kgs) operated the pump during data collection. Pumping head was kept constant (4.2m-4.36 m) by re-admitting the pumped water to the well. Data was taken while each man pumped water to fill a 9.5 liters container. The following formulas were used for the data analysis (Arlosoroff, 1987; CTA, 1992; Stern, 1994):

1. Actual discharge rate (Qa)
   \[ Q_a = \frac{\sqrt{t}}{l} \]

2. Theoretical Discharge rate (Qt)
   \[ Qt = \frac{A \times S \times N}{1000} \]

3. Volumetric Slip (S)
   \[ S = \frac{Qt - Q_a}{Qt} \]
4. Volumetric efficiency (\( \eta_v \))
\[ \eta_v = 100 - \frac{S}{V} \]

5. Power utilized for pumping (\( P_a \))
\[ P_a = Qa \times H \times \gamma \]

6. Power input (\( P_i \))
\[ P_i = F \times V \]

7. Power use efficiency (\( \eta \))
\[ \eta = \frac{P_a}{P_i} \times 100 \]

Where:
- \( V \) - Volume of water pumped (lt)
- \( t \) - Time taken for pumping (sec)
- \( A \) - Cross-sectional area of pump cylinder (cm\(^2\))
- \( S \) - Stroke length (cm)
- \( N \) - Stroke frequency (sec\(^{-1}\))
- \( H \) - Pumping head (m)
- \( \gamma \) - Specific weight of water (N/m\(^3\))
- \( F \) - Hydraulic force - force required to lift the water and all moving components (N)
- \( V \) - Working rate (m/sec)

**Results and discussion**
The mean performance values obtained using two different sized rubber seals (50mm and 52mm diameter) are summarized in Table 1 and Table 2. The result indicates that the rower pump developed performed good for both the two seal types. However, the pumps capacity, volumetric efficiencies, power requirement and power use efficiencies vary depending on the type of seal used and the weight of the man working on the pump.

![Figure 6 Developed rower pump.](image)

**Discharge rate**
Discharge rate is the most important criterion for the selection of a pump for irrigation purpose. Mean values of recorded discharge rate were indicated to be 0.46lts/sec, 0.44lts/sec, 0.48 lt/sec, and 0.53 lt/sec using the smaller seal size and pumping men weight of 45kgs, 55kgs,
57kgs, and 63kgs respectively. Values recorded by the same group, using the larger seal size were 0.62lt/sec, 0.67lt/sec, 0.82lt/sec and 0.94 lt/sec respectively. The mean discharge obtained by the second seal type showed an increment of 34.78%, 42.55%, 70.83%, and 77.36% as compared to the discharges of the pump using small sized seal for each operator weight. Thus, it is confirmed that the developed pump can perform well above the minimum discharge, set during the initial stages of the design process. As the output is also related to the seal size, the use of the second size seal will be more appropriate if higher discharge rate is required.

Figure 2 shows the weight and discharge relationship. The graph indicates that the operators weight is directly related to the pumps output capacity, but with a higher correlation in the case of the first seal ($R^2=0.97$) than the second seal ($R^2=0.7$). Figure 3 shows the relationship between the actual power input for pumping (watts) and corresponding discharge using the two seal types.

**Volumetric efficiency** - The on farm experimental results showed that volumetric efficiency of the pump was unacceptably lower when using the smaller type seal. Acceptable volumetric efficiency was set to be above 80% (Stem 1994) prior to the experiment and hence the results obtained by using the smaller seal are below the acceptable range.

### Table 4 Performance values (mean ± standard deviation) of rower pump using seal type 1.

<table>
<thead>
<tr>
<th>Mean weight of operator (kg)</th>
<th>Stroke frequency (str./sec)</th>
<th>Actual Discharge (lt/sec)</th>
<th>Theoretical Discharge (lt/sec)</th>
<th>Volumetric efficiency (%)</th>
<th>Power utilized (watt)</th>
<th>Power use efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45.00</td>
<td>1.04±0.07</td>
<td>0.46±0.03</td>
<td>0.81±0.05</td>
<td>56.80±0.00</td>
<td>19.07±1.25</td>
<td>48.45±0.00</td>
</tr>
<tr>
<td>53.00</td>
<td>0.99±0.08</td>
<td>0.44±0.03</td>
<td>0.78±0.06</td>
<td>56.80±0.00</td>
<td>18.21±1.40</td>
<td>48.45±0.00</td>
</tr>
<tr>
<td>57.00</td>
<td>1.02±0.05</td>
<td>0.48±0.04</td>
<td>0.80±0.04</td>
<td>59.16±2.05</td>
<td>19.60±1.69</td>
<td>50.47±1.75</td>
</tr>
<tr>
<td>63.00</td>
<td>1.19±0.10</td>
<td>0.53±0.10</td>
<td>0.94±0.10</td>
<td>55.99±4.80</td>
<td>21.71±3.96</td>
<td>47.76±4.10</td>
</tr>
</tbody>
</table>

### Table 5 Performance values (mean ± standard deviation) of rower pump using seal type 2.

<table>
<thead>
<tr>
<th>Mean weight of operator (kg)</th>
<th>Stroke frequency (str./sec)</th>
<th>Actual Discharge (lt/sec)</th>
<th>Theoretical Discharge (lt/sec)</th>
<th>Volumetric efficiency (%)</th>
<th>Power utilized (watt)</th>
<th>Power use efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45.00</td>
<td>1.04±0.05</td>
<td>0.62±0.00</td>
<td>0.82±0.04</td>
<td>76.44±3.49</td>
<td>26.69±0.13</td>
<td>65.32±2.98</td>
</tr>
<tr>
<td>53.00</td>
<td>1.24±0.05</td>
<td>0.67±0.03</td>
<td>0.97±0.04</td>
<td>68.97±0.00</td>
<td>28.74±1.23</td>
<td>58.94±0.00</td>
</tr>
<tr>
<td>57.00</td>
<td>1.34±0.04</td>
<td>0.82±0.03</td>
<td>1.05±0.03</td>
<td>76.40±3.57</td>
<td>35.24±1.10</td>
<td>67.00±3.05</td>
</tr>
<tr>
<td>63.00</td>
<td>1.36±0.06</td>
<td>0.94±0.04</td>
<td>1.07±0.05</td>
<td>87.78±0.00</td>
<td>40.04±1.79</td>
<td>75.01±0.00</td>
</tr>
</tbody>
</table>
The volumetric efficiencies, as indicated in table 1 were 56.80%, 56.80%, 59.16%, and 55.99% for smaller seal and rose to 76.44%, 68.97%, 76.40% and 87.78% by using the larger size. These values showed the importance of increasing the seal size more than any other variable.

The size of the seal, which is slightly lower than the bore of the cylinder, permits the back flow of water through the clearance. This, in turn, results in excessive decline in the volumetric efficiency. However, clearance between the cylinder and the seal is not the only thing, which affects the percentage reduction in discharge volume per stroke. This can be understood by seeing the results when the largest seal, which completely close the clearance, is observed. Thus, the percentage increase in volumetric efficiency observed under similar working conditions may indicate the importance of using as minimum seal clearance as possible, but other factors as the stroke frequency, valve stroke length should also be considered to further reduce leakage.

![Graph](image)

**Figure 7** Weight-discharge relationship using the two seal sizes.

![Graph](image)

**Figure 8** Power input discharge relationship using the two seal sizes.

3-Power expenditure

The average power output of a normal sized adult is about 30 watt (CTA 1992), but it will differ from person to person depending, among others, on age, experience, health status, working environment and nutrition conditions. The operational conditions, specially the ergonomic conditions will also affect the power output and the length of time the power can
be sustained sufficiently. The test result indicated that the mean power expenditures were 19.07 watts, 18.21 watts, 19.60 watts and 21.71 watts, while operating on seal type one; and rose to 26.69 watts, 28.74 watts, 35.24 watts and 40.04 watts, using the larger seal type for the four persons operating the pump. Power expenditure was lower for the first case, which resulted from the reduced pumping rate. The power expenditure in the second case was observed to rise above 30 watts, assumed optimum at the outset. However, corresponding increase in output was observed to offset the increased power requirement as the farmers commented as long as the discharge is appreciably increased, they are willing to increase their efforts within a reasonable maximum limit. This limit was not passed, since no farmer was heard complaining on 'heaviness' of pumping operation.

![Figure 9: Stroke frequency vs volumetric efficiency](image)

![Figure 10: Relationship between the weight of operator and power use efficiency](image)
Farmers' comment

Participant farmers commented that the pump's performance was satisfactory. They gave special emphasis for operational simplicity and liked the ease with which main components are accessed and fast wearing parts can be replaced. They showed willingness to buy the pump if sold on manufacturing price. However, they also indicated that frequent priming after a short stopping, knocking sound, which will be heard at faster operation rate and inclusion of stroke limiting devise on the pump rod are problems to be solved.

![Figure 11 power use efficiency-discharge relationship](image_url)

Conclusion and recommendation

The on farm test results of the developed rower pump and the actual farmers comment collected indicated that the pump could perform under conditions it is planned to work. The discharge rate, power requirement, and other pertinent variables are acceptable, especially for larger seal type than for smaller one. The manufacturing complexity were relatively simple but can further be simplified to minimize the use of large workshop machines as lathe. The cost to own the pump, as estimated from the production cost, is acceptable even for a farmer with low income and willing to participate in intensified and irrigated farming business. The maintenance and other technical requirements are comparatively good. Thus, it can be said that the planned objective for most parts was successfully achieved. However, it should be admitted that more works focusing in improved efficiency, reducing cost, increased pumps working reliability, and refining parts design for standardization may still be required.

References


Abstract
Enset is an important perennial crop, used as a staple food by more than ten million people in Ethiopia. The plant has an upper part, a pseudo stem and a root, which is usually called amicho. The processing of both the root and the pseudo stem has been a backbreaking exercise that imparts physiological stress on the operators, who are usually women. To overcome these problems a number of efforts have been made by individuals and organizations like the former Ministry of Rural Development, Ministry of Agriculture and the former IAR, EARO and the current Ethiopian Institute of Agriculture (EIAR) and Debub University. Among many, the Agricultural Mechanization Research division of EIAR started the current improvement work, based on a survey conducted at Endeber. Accordingly, major improvements were made on the, amicho pulverizer. The newly improved amicho pulverizer has dramatically cut down the time to less than an hour for the whole corn compared to three hours taken in squatting position in the traditional way of pulverizing. Different generations of devices were developed in the process. The first generation was tested at Weliso and Endeber, the second was tested at Chencha, and Areka, and the necessary modifications were made based on the feedback collected. The last version was tested at Kofele and Butajera. Four manufacturers from the last two places were trained for one week at the Melkassa Agricultural Mechanization Research Center workshop. These improved devices will lessen the drudgery on the rural women, who are responsible for the processing work. It will also help in creating rural employment in manufacturing and processing as observed in the case of the grain mills or animal drawn cart operators.

Introduction
Enset is a banana like plant and is a major source of food for a substantial number of the population. It is widely grown mainly in the highlands of South, Central and Southern Ethiopia supporting more than ten million people. The Gurage zone is one of the important Enset growing areas and Enset covers about 81,000 hectares. In Cheha, Eja and Gumero, it is predominant and crops like tef especially in Cheha are recent introductions through the extension package program.

Enset has three major parts; the leaves, pseudo stem and corm. The pseudo stem and the corm pulverized and decorticated are buried to ferment in a pit lined with the leaves for few days. The fermented product is processed into various types of food and its fiber is used in the manufacturing of ropes. It is a very suitable crop for human consumption; and by using a simple technology, it can be made into a number of traditional products either in moist or dried form. The two main food products are locally known as kocho and Bulla. Kocho is the fermented product obtained from the corm and pseudo stem. Bulla is made by dehydrating the juice collected during the decortication of the pseudo stem and grating of the corm.

Traditional method of processing
Enset harvesting in Endeber and most parts of the country begins at the end of October and continues until January. For processing, the whole plant is uprooted with the help of a special knife and brought to the processing site, which is an open place in the plantation. A wooden plank at an angle of about 40° is placed against a pole (Figure 1). A woman sits in front of the plank keeping a pseudo stem piece with its convex side against the plank securing it in position by putting her foot on it as high as possible (Kielbasa Urga, et.al., 1996).
plank keeping a pseudo stem piece with its convex side against the plank securing it in position by putting her foot on it as high as possible (Kielbasaj Urga, et.al., 1996).

In the past efforts were made by different individuals and organizations to come up with different improved processing devices. Taye Bzuneh, Ataro Adare Milton Dayass and the Awassa Community Development Center made different attempts in the early 70s. The Engineering Department of IAR started its work on Enset in May 1977. During the 1984 and 1985 research season, efforts were made to improve the traditional decorticating devices. The project came up with an inclined plank/ clamp pseudo stem decorticator, corn graters and bulla squeezers. All these were meant to improve the ergonomics, with simple clamping mechanisms at a normal position and efficiency. After a number of iterations both were achieved. Most of these are currently taken up by the Sodo Rural technology center and are distributed among the users in the Sidama region. According to Liyuwork Zewde, 1984, these devices were very much accepted by the women in her study area, because they increased efficiency, reduced wastages and were found comfortable for operation.

The second device of corn grater had some resemblance to that of the carpenter’s jackplane and comprised a set of thin plates in front of the main blade. The efficiency of this device was three times that of the traditional tool, but the sliced material varied in size, which made pulverization difficult. Further effort was made to refine the operation and finally an adjustable rotary type blade pulverizer was developed, which was much better than its predecessors. The Awassa Agricultural College Departments of Agricultural Mechanization and Food Science conducted a study on processing tools. The group finally managed to develop a handy equipment made from local wood without any metallic attaching material (nail). The equipment has three major fitting parts that are assembled for the operation. It has a decortication board with a clamp at the upper end, a pulverization chamber at the lower, a sit with a provision for placing a kneading tray on the other side, fitted at 45 degree angle in slots made on both sides of the main stand (Mehtzu Tedla and Yewelsew Abebe 1994). Despite efforts by different groups, still there was urge to come up with better processing equipment.
The women involved in the operation still recommended improvement of the overall *kocho* processing methods to save energy, time as well as to make it more hygienic. Thus, the research work on the improvement of processing devices at the Agricultural Mechanization Research Center (AIRC) at Melkassa was reinitiated in the year 2000 to address the above problems.

**Objective**

The overall objective of the current study was to develop an improved corm pulverizer, which is within the economic reach of the end user.

**Materials and methods**

The study comprised a survey followed by development and testing of prototype including demonstration and training of artisans in the manufacturing of proven prototype.

**Survey**

A survey was conducted in the year 2000 in two *weredas* to learn about the culture with a major focus on the processing of *Enset*. The study started with a structured questionnaire where discussion was held with farmers and the *wereda* agricultural bureaus were consulted in depth.

At Yefenzige and Bulcha mender, survey was conducted at the household level at the time when the processing operation was actually taking place. Questions related to their main means of livelihood, farm power, crops grown, crop production techniques, means of processing and problems encountered in the processing methods and farm income were raised. Finally, the priority area that needed serious consideration was determined.

**Improvement works**

The first pulverizer model was designed and fabricated based on the IITA design of cassava grater (Figure 2). The basic material for this specific design was wood. The device had a feeding mechanism and a rotating grater fabricated from galvanized steel. The rotating part was originally made from sheet metal, but later on was replaced with animal horn. The basic material was wood and mild steel with the understanding that it will be replaced with corrosion free material in the final prototype. The grating chamber was fabricated from galvanized iron sheet. This device used a feed chopped in a rectangular for ease of handling. A wheel sprocket drive was added to overcome the drive force requirement.

*Whole Corm Pulverizer*

Despite the different designs forwarded to the users, farmers opted for a machine that takes up the whole corm in one piece. The farmers argued that such a method very well fitted to their system and there will be minimal loss. Finally, a whole corm pulverizer was designed and fabricated by modifying the feeding mechanism of the late Araya Kebede’s design. According to the studies conducted, the major problems were on the feeding rate during grating, which usually burdens the operator and lowers the durability of the cutting part. A thorough study was conducted to set the optimum feeding rate, which lessens the load on the operator. A feeding mechanism that delivered a feed at a rate of 2 mm per revolution of the cutting disc was designed. The equipment was fabricated in the workshop. Later on, this was modified to accommodate the whole corm, which minimized losses based on the feedback collected from field visits.
Efforts were also made to reduce the weight; and the size was increased to accommodate bigger size corms as well.

**Testing**

At first corm was brought from Weliso and sliced to manageable size and was tested in the laboratory. Later, the testing material was planted in the research center. The material was ready for use in two years after planting. The material was cut, removed and cut in rectangular form to fit into the grating chamber. Data on time taken, efficiency, and degree of pulverization and down time were taken.

**Results**

**Survey**

From the survey and field observation, the areas from Welkite to Endeber were dominated by eucalyptus plantation and open grazing land and hardly any oxen. Hoe culture dominated the area rather than oxen cultivation, which limited cultivation to perennial crop like Enset, which is partly attributed to the existence of tsetse fly. As a result, the Endeber woreda population is mainly dependent on cultivation. The Endeber woreda depends totally on Enset for food and as a means of income for buying necessary goods. At Endeber, Yeferenzeige Keble, it was witnessed that in one house hold, the owner had hired about six women to decorticate the pseudo stem and the Amicho at a rate of two birr per pseudo stem and two birr per three corms. The owner was responsible for providing the necessary daily maintenance, food, coffee for the operation day on top of the two birr she was paying per head. At the time of the study, this practice was the accepted norm in the community. The operators complained that it was indeed a back breaking exercise as the women had to squeeze in a cramped position for the whole day and there was no question on the needed improvement on the decorticating devices. The pseudo stem-decorticating device was a split bamboo beveled at one end, though looked inefficient, there was reservation on the user’s side to replace this device with a metallic one. They reported that this might not enable them to recover the fiber, which fetched them substantial amount of money. The Amicho grating device, Gebangeba was reported to be tiresome and in efficient. The ladies said that any improvement on the devices should have a provision for sitting arrangement during operation.

At Endebir in a community called Bucha Mender, the ladies had the chance of using improved decorticating devices, pseudo stem decorticator and Bulla squeezer introduced to them from the Sodo Rural Technology Center. They commented that the clamping arrangement on the decorticator was time taking, which at times could not be done from the lady’s sitting position and was not efficient in fiber recovery. There was mixed filling on the bulla squeezer, some said it produced finer quality bulla, which could be a luxury but reduced volume, which meant less money from selling the product. The others commented that it did not totally extract the whole bulla and did not get comparable volume to their traditional practice. Finally, they said that improvement be done on the above short comings and a corm pulverizer be developed, as they have not seen any device in this area. Similar comments were received from the areas visited at Welkite and Weliso.
Development work

Three kinds of corm pulverizer were developed. The first pulverizer model was designed and fabricated based on the IITA’s cassava grater design, which required the amicho to be cut into a rectangular shape feed form, but required a higher input of power.

A pedal operated prototype with a sprocket chain arrangement was the second option, but farmers complained about the wastage, as this also required the feed material to be arranged in a rectangular, but the loss was unaffordable to the farmer. The last version was a whole corm pulverizer, which handled the whole corm in one go.

Testing and Evaluation

At first, corm was brought from Weliso and sliced to manageable size and was tested in the laboratory. Later, the testing material was planted in the research center. The material was ready for use in two years after planting. The material was cut, removed and cut in rectangular form, which fits into the grating chamber. Data on time taken, efficiency, and degree of pulverization and down time were taken.

The first design required relatively higher force, which gave a lower output. A second generation corm pulverizer had a higher force requirement observed in the first design. This was more efficient compared to the first generation. With the new design, it was possible to pulverize at a rate of 0.6 kg/min compared to 0.1 kg/min with the previous generation. It was found efficient and comfortable for the operator. Still the work was further refined and a better result was obtained as indicated in the above tables.

The results were as shown in the table.

<p>| Table 1 Performance of pedal operated corm pulverizer Nov 12, 2002. |
|------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Weight (gms.)</th>
<th>St. time</th>
<th>Stoppage (min)</th>
<th>Finishing time</th>
<th>Total</th>
<th>Output (gms.)</th>
<th>Rate (kg/min)</th>
<th>Unpulverized (gms.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2267</td>
<td>2:05:03</td>
<td>-</td>
<td>2:06:04</td>
<td>1.02</td>
<td>1314</td>
<td>1.28</td>
<td>790</td>
</tr>
<tr>
<td>3235</td>
<td>2:30:47</td>
<td>4.78</td>
<td>2:36:47</td>
<td>1.22</td>
<td>1951</td>
<td>1.59</td>
<td>719</td>
</tr>
</tbody>
</table>

<p>| Table 2 Performance of hand operated corm pulverizer. |
|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Weight (gms.)</th>
<th>St. time</th>
<th>Finishing time</th>
<th>Total</th>
<th>Output (gms.)</th>
<th>Rate (kg/min)</th>
<th>Unpulverized (gms.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3953</td>
<td>9:46:45</td>
<td>9:48:45</td>
<td>2</td>
<td>2470</td>
<td>1.25</td>
<td>572</td>
</tr>
<tr>
<td>3216</td>
<td>1:47:28</td>
<td>1:49:17</td>
<td>1.82</td>
<td>2399</td>
<td>1.32</td>
<td>628</td>
</tr>
</tbody>
</table>
During testing on farmers' field, the farmers complained about the wastage and reported that amount, which failed to be pulverized was unacceptable. Thus, there was a suggestion to come up with a device that could accommodate the whole corm in one operation.

**Whole corm pulverizer**

The equipment was tested on station and at Areka Research Center in collaboration with the Research team. It was also demonstrated at Chencha in collaboration with World Vision Ethiopia. It was found operational and acceptable. The equipment was able to handle a corm up to 45 cm in diameter and of 60 kg weight in less than an hour.

At Chencha, the corm was found to be as large as 80 cm in diameter and 100 cm in length. Observation was made, that it required to be splitted in to two as the diameter becomes larger, but was found acceptable for the major diameter and weight classes of corms.

The equipment was further tested at Koefele (Figure 7) and Butajira and favourable responses were received from the farmers. A sample weight of 20.798 kgs. was pulverized in 11.5 minutes.
Manufacturing

Four local manufacturers were selected from Butajera and Kofele area in May 2006 and were trained at AIRIC workshop on the manufacturing of the corm pulverizer. As part of the training program, they were able to manufacture one prototype in a group (Figure 4).

Figure 3 Testing of corm pulverizer at Kofele.

Figure four Trainees at work.

Discussion

The first corm pulverizer design required relatively higher force, which gave a lower output. A second generation corm pulverizer had a higher force requirement observed in the first
design. The second model was fabricated by adjusting the cutting clearance and using galvanized steel as the cutting material. A wheel sprocket drive was added to meet the force requirement observed in the previous design. This was more efficient compared to the first generation. With the new design, it was possible to pulverize at a rate of 0.6 kg/min compared to 0.1 kg/min with the previous generation. It was found efficient and comfortable for operator, but the farmers complained because of the wastage and time required to prepare the rectangular sample pieces. Taking the above into account a whole corm pulverizer was designed and fabricated using the late Araya Kebede’s design with a major modification on the feeding mechanism which delivers a feeding rate of 2 mm per revolution of the cutting disc. The equipment was tested and demonstrated at different sites. The equipment was able to handle as big as 45 mm diameter and 60 kg weight in less than an hour and an acceptable fine product was produced. Farmers raised issues related to the weight, the change of role it could induce between men and women, the provision of adjustment to effect pulverization to the the required degree of fineness. They even suggested it to be motorized. Other feedbacks on some left over corm due to the various size of the corm at different sites were also reported. Finally, effort was made to reduce the weight and the size was increased to accommodate bigger sizes of corm as well. This was tested at Kofele and Butajira. It has now a provision for engine as well, which makes it versatile to kick start cottage industry in the growing rural community. This will give chance for manufacturers, individual operators like the flour mill and maintenance people who will do maintenance work and parts replacement as well.

References

Agricultural Engineering Department Research programme. 1977/78. IARp13


Mehtzun Tedla and Yewelsew Abebe. 1994. Study of processing and Development of Processing Tools in the Southern Region of Ethiopia. ACA/NORAGRIC research collaboration project

DEVELOPMENT OF TOMATO SEED EXTRACTOR

Friew Kelemu and Amdom Gebrmedhin
Agricultural Mechanization Research Project
Melkassa Agricultural Research Center
P.O. Box 436, Nazareth

Abstract

Vegetable seeds in Ethiopia are made available through imports. They have high overhead costs and because of the poor storage condition, seed vigor and viability are usually low. To overcome these problems, a low power tomato seed extracting equipment was designed and fabricated at AIRIC. The equipment working units were fabricated from galvanized and stainless steel, whereas the load-bearing frames were fabricated from mild steel. The equipment has a wet pulping and seed extracting unit similar to a drum concave assembly, a pulverizing unit to mash the non-seed part of the tomato into tomato puree or juice. The two operations are handled simultaneously. The development work started with a generation of the design data, using a small model extractor attached to a variable speed motor. About 2 kg of ripe tomato was fed into the bucket and extraction rate was recorded at different speeds of rotation. The seed extractor was tested in the workshop and at the horticulture department, using different amounts of tomato throughput. About 11 gms of seed on the average was extracted from 3 kg of tomato in a retention period of 34.96 seconds. In a different set of comparative tests against the traditional manual extraction technique, 2 kg of tomato was extracted in 35 seconds, compared to 8 minutes taken using the traditional technique. From a throughput of 12 kg, 41.2 gms of seed was recovered using the machine, while manually about 70.5 gms was extracted. The time taken was 20 minutes and 2.3 minutes respectively for the manual and the extractor. The difference in recovery could be attributed to the poor welding and fabrication techniques employed in the production of the prototype. The seed extractor is efficient and labor-saving and has a provision to make the pulp usable in a form of tomato puree. It is a potential input to start a cottage industry in vegetable processing.

Introduction

Vegetables are important sources of food and essential in the diet, providing fiber, trace minerals and vitamins. They are high value export crops and are used as break crops in crop rotation. Today, vegetables are widely used in towns, have become good sources of income for the growers, and have helped them improve their livelihood. The problem to date has been getting good seeds at a reasonable price to the farmer.

Vegetable seeds in this country are made available through imports from countries like the Netherlands and South Africa, incur high transport and other overhead costs like storage and handling, which makes the seed expensive when it gets to the end user. Tomato seed costs between 600 and 650 birr/kg. As the storage condition is poor and very likely to stay on shelf for a long time before being sold, by the time it gets to the farmer, the viability of the seed decreases and farmers are penalized in lower rate of seed germination and emergence. Areas around the Melkassa Research Center and in the Rift Valley are suitable for growing horticultural crops like tomato. If seed with high vigor and low cost could be made available to the farmer, the crop could be grown cheaply and made available at a reasonable price to the consumer. To make this a reality, it will be wise to make available low cost extracting equipment at the disposal of the seed farmer.

The term seed processing is used by the seed industry to include a wide range of operations to improve or upgrade seed lots after threshing or extraction. The processing may include removal of plant debris, non-plant material and other seeds. The separation of seeds from other
materials is based on physical differences such as relative size, shape, length, density and surface texture.

Generally, tomato extraction is done either purely as tomato seed extraction or as an additional product during the processing of tomatoes for puree or juice. In the process, the harvested tomato is put in the crusher. The crusher squashes or crushes the fruit and the resulting mixture of the gelatinous seed, juice and fruit residue is passed through a screen to separate off the gelatinous from the bulk of the remaining material. The crushed material is passed in to a revolving cylindrical screen which allows the seed and juice to pass through the mesh, while the fruit debris pass the cylindrical screen to drop in the field. The debris is collected later on, while the fruit and juice is collected in separate container. The separated mixture is left to ferment at 21°C for 96 hours, which is possible under the Melkassa condition. The seed extracted as such is washed in a series of sieves smaller than the mean weight diameter of the tomato seed in a gradient of 1:50. They are dried on trays (George 1985).

Objective
The objective of the study was to make tomato seed available through the development of low cost seed extracting equipment.

Materials and methods

Survey

Attempt was made to record the conventional practice of seed extraction. The main source of our information was the Melkassa Research Center, Horticulture department. According to the department staff, tomato meant for seed extraction need to be ripe and their usual practice is to select, healthy ripe and red fruit from the second and third pick. Ripe and red tomato fruit are collected, healthy, appealing fruit among the ripe are selected, and the process of extracting begins. If some fruits are found to be at the turning stage, the usually wait until they totally become ripe. Knives, plastic buckets are used for this process. If there are no knives, the seeds can be squeezed out by hand. Using a knife, the tomato fruit is cut and the gelatinous material containing the seed is spooned out and collected in the bucket. The pulp and other debris are collected in a different container. The seed material in the plastic bucket is left for two to three days to ferment and eventually the seed separates from the mucilage. After three days this material is washed out using sieve. The cleaned seed is left in the shade to dry. This is the practice still followed at Melkassa center.

Generation of design data

A simulated study was conducted to select material and the kind force needed to be applied to detach the fruit from the pulp. The study was conducted on tomato fruits collected from the vegetable research section. The tomato fruit was extracted mechanically and manually. Energy input and time taken to detach the seed using these different methods was documented. A small model of seed extracting equipment was fabricated in the workshop. This equipment was attached to a variable speed motor. About 2 kg of ripe tomato was fed in to the bucket and extraction rate was recorded at different speed of rotation, which was recorded using the graduated scale on the variable speed motor. After each trial, the degree of extraction was
analyzed. This was done by recording and weighing the throughput, pulp weight, and seed remaining in the pulp. After repeated trial the speed of rotation was selected and the corresponding torque was calculated. The test showed that tomato seed could be extracted using human power by rotating an extracting unit at an average speed of 450 rpm in a chamber of 300mm diameter. These input data was used in the design of the equipment.

Design and development of the first prototype

The required power and revolution needed to effect the extraction was determined using the model extractor and a provision was made to retain the pulp, which was a by product of the process. The fabrication was made using mild steel at the beginning. Thirty millimeter rectangular hollow section (RHS) was used for the base frame. The concave part was made from 1mm sheet metal with drilled holes of 10mm diameter at 20mm distance. The separator had triangular blades welded to a 30mm diameter shaft on to which is welded a conveying and cutting unit arranged in an auger fashion. The equipment had a provision for pressured water, to help wet pulping; a seed collecting unit, a water trough, a pulp pulverizer and mashed pulp collecting units. The driving unit had a handle and a sprocket chain assembly to vary speed and torque.

Testing

The equipment was tested using tomato secured from the Horticulture Department. The equipment was placed near a water source. A water hose was attached to the water inlet pipe of the equipment. The tomato was fed in to the pulping unit after the operator had started rotating the pulping unit and the water system turned on and directed into the chamber. About 30kgs of tomato was fed, the test time, throughput, weight of the pulp, weight of seed extracted were recorded during the testing. The weight of the pulp, which remained after the operation, was also determined. After the operation, the machine was thoroughly cleaned. The extracted seed was dried and germination rate was determined.
Results and discussion

Prototype development

The first prototype was fabricated from RHS and standard sheet metal with a provision for water application during pulping (Figure 2). The final prototype frame was made from standard RHS and the pulping unit and other parts in contact with the food material were fabricated from stainless steel and aluminum. The prototype has provision for pulverizing and collecting the pulp (Figure 3).

![Figure 2. the first version tomato extractor](image1)

The final prototype
From our first observation, modification on the design, fabrication and selection of appropriate material were seriously considered and the following prototype was produced.

![Figure 3. The final tomato extractor](image2)

Testing and Evaluation

The prototype was tested using the material collected from the horticulture department. A comparative test was conducted between the original prototype and the traditional method using two kgs of tomato (table 1). The final prototype was tested with a smaller thorough put
of 3kg and a higher throughput of 18-30kgs. The results were as shown in the following tables.

Table 1. Comparative test on seed extraction using the mechanical and the traditional (manual) extraction method

<table>
<thead>
<tr>
<th>No.</th>
<th>Sample</th>
<th>Manual</th>
<th>Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>3kg</td>
<td>39.4</td>
<td>9.5</td>
<td></td>
</tr>
<tr>
<td>3kg</td>
<td>38.23</td>
<td>8.45</td>
<td></td>
</tr>
<tr>
<td>3kg</td>
<td>40.49</td>
<td>8.63</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Seed extracted during testing on Oct 21/2005 using the improved final prototype.

<table>
<thead>
<tr>
<th>Test no.</th>
<th>Throughput (kgs.)</th>
<th>Extraction time (secs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>manual</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>480</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>420</td>
</tr>
</tbody>
</table>

Table 3. Seed extracted using a higher throughput using the improved final prototype compared to the trampling practice using two people.

<table>
<thead>
<tr>
<th>No sample</th>
<th>Time (min)</th>
<th>Extracted seed (gms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manual**</td>
<td>Machine</td>
</tr>
<tr>
<td></td>
<td>Manual</td>
<td>Machine</td>
</tr>
<tr>
<td>30kg</td>
<td>6</td>
<td>4.95</td>
</tr>
<tr>
<td>30kg</td>
<td>6.5</td>
<td>5.06</td>
</tr>
</tbody>
</table>

**Two operators trampling by foot

Table 4. Comparison of seed extraction using the improved version against the conventional practice using one person

<table>
<thead>
<tr>
<th>No sample</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manual</td>
</tr>
<tr>
<td>12kg</td>
<td>20</td>
</tr>
<tr>
<td>12kg</td>
<td>20</td>
</tr>
<tr>
<td>12 kg</td>
<td>20</td>
</tr>
<tr>
<td>Mean</td>
<td>20</td>
</tr>
</tbody>
</table>

The results showed that even in the older version the machine was ten folds faster in the operation. With the improved version still it was ten times faster. Currently the manual practice at Melkassa has changed to trampling. The machine in this case too is much faster than the traditional practice. Besides, the pulp that remains, after trampling cannot be used because of the unhygienic condition of the pulping action. With the new machine the pulp is
Friew kelemu and Amdom G/medhimm

not only conserved, but is pulverized and converted to juice which can be some source of income for the farmer as well. A lower seed recovery rate is observed in the machine compared to the traditional practice, which is attributed to some problems of fabrication observed due to the escaping of the some tomato materials through some non tight fitting parts, which needs serious attention during fabrication.

The new equipment was found satisfactory in terms of seed recovery and pulverization of the non seed material for other uses. The equipment is manually operated, which makes it versatile to work any where in the country. There is minimal loss; the equipment also pulverizes the pulp and other non seed debris, it has the potential to kick start a cottage industry in tomato producing areas.

References

TRADITIONAL CHOPPING PRACTICES IN ETHIOPIA: TECHNICAL CONSTRAINTS AND METHODS FOR IMPROVEMENT

Workineh Abebe* and Seyoum W/senbet1

1 Ethiopian Institute of Agricultural Researches, Melkassa Agricultural Research Center P.O.Box 436 Adama. E-mail: narc@ethionet.et

Abstract
Forage chopping increases the quality of feed and minimizes feed loss by reducing selective consumption. Survey was conducted around Holleta, Arsi-Negele, and Messo to identify the ways of forage chopping and implement related constraints faced by farmers. The survey revealed that the farmers use sickle, machete, mencha and small axe to chop feeds. Green maize and green sorghum are the main forages, which are chopped by the farmers. However, since the process is labor intensive and time taking, they prefer to feed the animals without chopping. Comparative test was also conducted between the most common cultural practices (using sickle and using machete) on wet maize, wet sorghum, elephant grass, oats, tegesaste and vilicia spp. (forage vetch). A similar assessment was also performed between a hand operated Indian chaff cutter introduced by the International Livestock Research Institute (ILRI) and a simple chopping device developed at Melkassa Agricultural Research Center. Significant variation (p<0.05) was observed between the chop lengths of the two cultural practices, i.e., using machete (9.08cm) and sickle (15.33cm). No significant difference (p>0.05) was observed between the capacities of machete (0.06t/hr) and sickle (0.09t/hr). The Indian chaff cutter (0.13t/hr and 2.43cm) was considerably superior (p<0.05) to the developed simple device (0.06t/hr and 6.83cm) both in capacity and product chop length. However, as the major parts of the Indian chaff cutter are complicated and made by casting, development of a chopper within the economic reach of the local farmers by seeking different options is commendable.

Introduction
Ethiopia is well endowed with its livestock population and yet livestock productivity is very low due to various factors among which malnutrition and under nutrition are the major once (FAO, 1973). Traditionally, ruminant’s feed in the country are based on pasture grazing. The size of grazing land is shrinking with increase in human population. For each added person, 0.32 hectares of grazing land is being converted to crop land to seek additional grain in securing food (Amaha and Asfaw 1998). On the other hand the cattle population increasing at the rate of 1.2% (ILRI, 1993) imposes a heavy burden.

Due to the aforementioned man-animal competition for land and the association of more than 70% of the livestock populations with mixed crop livestock system, farmers in the densely populated part of Ethiopia have to depend on crop residue for their livestock feed (ILCA 1983). In Ethiopia each year 9 to 10 million tons of crop residue is produced on dry matter basis, which is much higher than estimated from grazing (3.757 million tons) (ESAP 2000). In terms of total area among the cereals produced in the country, maize and sorghum stand second and third next to tef. They cover 1.1 million hectares and 0.9 million hectares, producing 3.022 million tones of maize stock and 1.695 million tones of sorghum stovers on DM basis (ESAP 2000). Thinned out plants and green leaves stripped from cereal plants such as maize are also utilized as feed. Some cereal species, such as millet, sprout again after harvest, taking advantage of residual moisture in the soil and are used as forage. However, because of the toughness and roughness of the stovers of these crops, animals, select only the leaf part and this is below half of the quantity of feed that could have been consumable to the animals. Therefore, feeding ruminants with chopped forage is more economical than free self-grazing (ILCA 1983).
Silage is more nutritive than dry stock of the same crop, palatable and needs very little space for storage. The abundant unexploited forage available in Ethiopia during the rainy season can be used as silage to enhance the dry matter intake and digestibility, which will help to increase body weight gain and the animals’ productivity. Obviously, silage making with out size reduction (chopping) is unthinkable.

Reduced particle size of stovers and other fibrous feeds may take the form of simply reducing long forage into shorter pieces of a few centimeter lengths or it may mean grinding into a fine powder. Chopped forage is readily mixable with oil seed cakes, molasses, chemicals and other more nutritive feeds. Making the particle smaller has two effects on digestion. It increases the efficiency of rumen degradation. It also increases the overall surface area of the food so that more microbes can act on the food (Cheworth 1992). As the result, feed intake of animal increases. The process of reducing the particle size of feed is carried out using several mechanical and simple hand operated tools of varying capacity. Field forage chopper harvester is also available in tractor drawn, tractor mounted and self-propelled models. They have combination of plant cutting and chopping unit. The chopped material is blown directly into a trailer that is towed behind the chopper or pulled alongside with a separate power source, or into a truck driven behind the chopper. The disadvantage of this method is that it involves investment in equipment. Thus, it is economically practical only where a considerable tonnage of material is to be chopped each year (FAO 1977). Because of this, it is not practically applicable for resource poor small-scale farmers.

In Ethiopia though hand chopping is the common practice by farmers, there is little information on the details of forage chopping technique. This study was undertaken to identify the shortcomings and suggest improvements on the implements used by the farmers.

Materials and methods
The study was undertaken into two phases. A preliminary survey was conducted in the first phase and the most common cultural practices and improved hand operated equipments were evaluated in the second phase.

Preliminary survey
Based on the agro ecology they represent Welmera (Western Shewa), Arsi –Negele (Southern Shewa) and Messo (located in the central rift valley) were selected for the preliminary survey. The farming system in all the locations is mixed type (cropping and animal husbandry). From each woreda two kebele’s (villages) and from each kebele, ten farmers were randomly selected. A semi-structured individual (household head) interview was the main technique used in the survey. Key informants like researchers working on improvement of forage crops, development agents and woreda MOA officers were also involved. Information on major feed sources, forage types being chopped, problems on chopping devices and methods, and steps taken to alleviate the problem were collected.

Comparative study
Based on the survey result, a comparative test was conducted among the most common cultural practices (using sickle and machete), a hand operated Indian chaff cutter introduced by the International Livestock Research Institute (ILRI) and a simple chopping device developed
at the National Agricultural Mechanization Research Project (NAMRP) workshop. Wet maize (Katumani), wet sorghum (Teshale 24-45), and elephant grass, oats, tegesaste and *viticia spp.* (forage vetch); were used as test materials.

The hand operated chaff cutter (Figure 1) is popular among Indian farmers and has been tried at experimental level in Kenya. The implement has a flywheel with a two blades spoke assembly. The simple chopping device developed at NAMRP (Figure 2) has an angle iron, a knife fixed on a slotted log. Both implements employ shear force while cutting the forage. These implements were selected because they are hand operated relatively of lower cost and simple in operation.

Comparative tests were undertaken both at Holeta Agricultural Research Center (for elephant grass, oats, tegesaste and *viticia spp.*) and at Melkassa agricultural Research Center (for elephant grass, wet maize and wet sorghum). The average lengths of the forages before chopping and after chopping were recorded. Minimum and maximum diameters of the stems or stocks of the forages and their moisture contents were taken before chopping. Comparison of the cultural practices was done by simulating the field conditions and using the expertise of experienced farmers.

Randomized complete block design (Gomez and Gomez, 1984) in three replications was used for the study. ANOVA was performed using SAS (SAS Institute, 1999). Means were then compared at $p<0.05$ using Student Newman Keuls test.

Figure 12 the hand operated Indian chaff cutter.
Result and discussions

Preliminary survey

In all the areas under the study, crop residue was the feed source for animals. The importance of the crop residue varied in the three locations. As presented in Table 1, crop residue from sorghum, maize and beans were the main sources in Messo, while residues from wheat, barely and teff were the most important feed sources in Arsi Negelle and Wolmera, while residues from maize and sorghum were also important sources of feed in Arsi Negelle. However, since their stovers are very strong the animals selectively feed only the leaf part. Senar was an exception to Welmera and the farmers claimed that it was an important feed source resistant to adverse conditions.

The survey revealed that nearly all the farmers in Messo, 43.2% of the farmers in Arsi Negelle and only 19.3% at Welmera practice forage chopping. Almost all the farmers know some of the advantages of forage chopping. However, since the process is labor intensive and time taking they prefer to feed the animals with out chopping or leave the crop residues on the field for grazing. In all the three areas, forage chopping is done by all the house hold members. Green maize and green sorghum are the main forages, which are chopped by the farmers. Plants removed when crop stand is thinned and green leaves stripped from maize and sorghum and sorghum after math are included in the feed source list. Farmers in Messo reported that using the leaves and stovers of failed sorghum and maize as a main feed source is one of the draught coping mechanisms in this erratic rainfall area.

The farmers use sickle, machete, mencha and small axe to chop feeds. However, as shown in Table 1, mencha is widely used in Messo, and in the remaining two woredas the order of importance of the tools is similar. Mencha is a sickle like tool having an eye for holding its wooden handle. It is a versatile tool used for land clearing, harvesting maize cobs and sorghum ear heads and protecting oneself against predators and other potential enemies. Capitalizing on low labour productivity of these tools, farmers requested for improvement within the reach of their purchasing power.

Reports by the researchers working in forage improvement revealed that elephant grass and oats from grasses, vetch from herbaceous legumes and tagasate from tree legumes were very
productive and well adapted to the highlands of Ethiopia. Farmers are utilizing these forage crops and their importance is expanding. However, for forage crops like elephant grass and tagasseate, hay making is very difficult due to their thick stem structures. The problem of selective feeding of leaves on stems of the forage from these crops was also reported. Vetch has a huge loss during hay making while collecting, hauling, transporting and storing. Hence, conservation of these grasses and legumes in mixture as silage was recommended and different activities were being undertaken in optimizing the mix by the researchers working in improvement of forage crops. However, lack of low cost improved size reducing equipment is one of the main bottlenecks for introducing silage technology to the farmers.

Table 1 Preliminary survey result on traditional chopping practices.

<table>
<thead>
<tr>
<th>Major crop residue feed source (ranking down ward)</th>
<th>Messo</th>
<th>Arsi Negelle</th>
<th>Wolmera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum</td>
<td>Wheat</td>
<td>Wheat</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>Barely</td>
<td>Barely</td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td>Teff</td>
<td>Teff</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>Oats</td>
<td>Beans</td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td></td>
<td>Maize</td>
<td></td>
</tr>
</tbody>
</table>

| %age of farmers practicing forage chopping         | 98.4  | 43.2  | 19.3   |

<table>
<thead>
<tr>
<th>Major forages being chopped (ranking down ward)</th>
<th>Green maize</th>
<th>Green maize</th>
<th>Green maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green sorghum</td>
<td>Green sorghum</td>
<td>Green sorghum</td>
<td>Green sorghum</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tools used for forage chopping (ranking down ward)</th>
<th>Mencha</th>
<th>Sickle</th>
<th>Sickle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sickle</td>
<td>Machete</td>
<td>Machete</td>
<td></td>
</tr>
<tr>
<td>Small axe</td>
<td>Small axe</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparative study

The conditions of the forages before chopping are given in Table 2. The result of the evaluation of the selected traditional chopping tools is shown on Table 3. There was no significant difference in chopping capacity between machete and sickle (p>0.05). However, the chop lengths of the outputs from the two tools significantly (p<0.05) varied. The chop length of the sickle (15.34cm) was higher than that of machete (9.08cm). Hence, machete gives relatively finer forage.

Table 2 Conditions of the test materials before chopping.

<table>
<thead>
<tr>
<th>Test material</th>
<th>Moisture content (%)</th>
<th>Stem/stover minimum-maximum diameter (mm)</th>
<th>Average length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet maize (Katumani)</td>
<td>73.54</td>
<td>12.0-19.6</td>
<td>179.8</td>
</tr>
<tr>
<td>Wet sorghum (Teshale 25-45)</td>
<td>66.76</td>
<td>12.2-16.6</td>
<td>175.1</td>
</tr>
<tr>
<td>Elephant grass</td>
<td>78.5</td>
<td>10.2-14.91</td>
<td>182.8</td>
</tr>
<tr>
<td>Oats</td>
<td>64.4</td>
<td>1.2-5.3</td>
<td>141.5</td>
</tr>
<tr>
<td>Tegesaste</td>
<td>61.1</td>
<td>3.17-4.83</td>
<td>58.5</td>
</tr>
<tr>
<td>Vicia spp.</td>
<td>79.6</td>
<td>1.5-3.8</td>
<td>*</td>
</tr>
</tbody>
</table>

*Was difficult to measure.
Table 3 Outputs of the cultural forage chopping tools.

<table>
<thead>
<tr>
<th>Chopper type</th>
<th>Chopping capacity (tones/hr)</th>
<th>Average chop length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machete</td>
<td>0.062±0.008</td>
<td>9.08±3.84</td>
</tr>
<tr>
<td>Sickle</td>
<td>0.09±0.021</td>
<td>15.34±4.05</td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td>37.47</td>
</tr>
</tbody>
</table>

Values within the same column with different letters are significantly different (p<0.05).

Information from the operators involved and observations made on the two hand tools are summarized as follows:

- There is high risk of cutting one's finger;
- Both require a lot of energy leading to chest muscle pains making it very difficult to undertake together with the other field works;
- Scattering of chopped feed, which needs additional labour to windrow;
- Inability to cut the feed to the recommended 2.5cm size;
- Regular replacement of the wood on which cutting is done;
- Regular sharpening of the cutting edges (as the tools mainly use impact force for cutting) leading to additional labour and replacement cost.

The chopping capacity of the Indian chaff cutter (0.133t/hr) is considerably (p<0.05) higher than the developed fixed knife cutter (Table 4). The chop length of the Indian chaff cutter (2.43cm) is significantly lower and very close to the recommended size (2.5cm). Therefore, the Indian chaff cutter is better than the developed fixed knife chopper both in capacity and in product quality. The average working speed of the machine was 50 rpm.

In both implements, the following benefits and advantages were observed:

- Less risk of finger bruising or cutting;
- Less noisy;
- Chopped pieces do not scatter;
- Less cumbersome to the operator as less energy is used.

The main technical shortcomings of the developed fixed knife chopper were blocking of the aperture through which the knife moves with bits of forage as it cuts and inability to reduce the chop length closer to the recommended size. The major parts of the Indian chaff cutter are made by casting and they are complicated.

Table 4 Outputs of the Indian chaff cutter and the developed fixed knife chopper.

<table>
<thead>
<tr>
<th>Chopper type</th>
<th>Chopping capacity (tones/hr)</th>
<th>Average chop length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developed fixed knife chopper</td>
<td>0.058±0.012</td>
<td>6.83±3.84</td>
</tr>
<tr>
<td>Indian chaff cutter</td>
<td>0.133±0.065</td>
<td>2.43±4.05</td>
</tr>
<tr>
<td>CV (%)</td>
<td>32.69</td>
<td>25.89</td>
</tr>
</tbody>
</table>

Values within the same column with different letters are significantly different (p<0.05).
Conclusions and recommendations

The findings of the preliminary survey and the comparative study showed that the cultural practice (using sickle, machete, mencha and small axe), besides its low output and lack of uniformity in cut length; the method is tedious, time consuming and dangerous to the operator. These are some of the reasons, which forced the farmers to feed the animals with out chopping. The outputs of these tools are also by far greater than the recommended size. Lack of low cost improved size reducing equipment is one of the main bottlenecks for introducing silage technology to the farmers.

The developed fixed knife cutter, though less cumbersome, has many advantages over the traditional implements and cheaper compared to the Indian chaff cutter, has still low capacity and the chop length of the out put is relatively higher than the recommended size. The performance of the Indian chaff cutter is better both in capacity and in product chop length. However, its major parts are complicated and made by casting. This makes the implement costly to acquire and run sustainably by the local farmers. Therefore, development of a chopper within the reach of the local farmers by improving the fixed knife chopper or seeking different options is commendable.

References


EVALUATION OF HAND OPERATED WINNOWER

Kamil Ahmed*, Mitiku Kinfe, Yosef Asafa, Abira Jara

Oromia Agricultural research institute, Bako Rural Technology Research Center
P.O.Box 07 West Shoa, tel. (057)6650045/55, E-mail: brtrc@telecom.net.et fax (057)665-00-42

Abstract

Efficient post-harvest system has the potential to reduce loss, which is estimated to 25% of the total production. Winnowing is one of the post harvest activities that cause much of the losses. It is mostly done by tossing the grain and chaff into a natural breeze and catching the grain, while the chaff is blown away using local implements such as darba, afarsa, gundo*, sieve and others. There are some improved winnowers in the country, having the potential to reduce the problems observed in the above methods, though they are not widely transferred and used by farmers. A test was conducted at Bako R/T/R/Center on a manual winnower that has a blower and replaceable sieves stored in the center for a long time. The results indicated that the machine had a capacity of 509.1 kg/hr, 1855.7 kg/hr 666.7 Kg/hr 285.7 kg/hr at a cleaning efficiency of 88.66% 99.8% 81.5% and 84.2% on wheat, maize, teff and Niger seed respectively. In all the crops the machine performed better, with insignificant grain loss and ease of operation. It also conserved, time and energy, gave better clean grain and controlled the air blast. The equipment can be operated by women and children. However, it is recommended to add some force multiplying mechanisms for further ease of operation.

Introduction

In Ethiopia, several agricultural production constraints are encountered at different crop growth stages. Energy and timeliness are the major practical problems encountered in crop production activities, mainly due to lack of appropriate technologies. Post harvest losses are estimated to be about 25% of the total production (FAO 1976). Developing the post-harvest systems will reduce the huge production losses. It has a great contribution to food security, raises the living standards in rural and urban areas. In urban areas it makes food available, more efficiently and at lower cost and in rural areas it can benefit the poor members of the society in particular through its contribution to the generation of farm and non-farm income (Golob et al 1988).

In wide-ranging view, the post-harvest activities comprise threshing, winnowing, grading and storing/transporting.

The winnowing operation, commonly known as grain cleaning is traditionally practiced in most parts of the country, using local equipment such as darba, afarsa, korbi, gundo, hatola, sieve and other accessories. Problems like timeliness, high energy requirement, high losses while blowing and removing larger chaff/straws fallen on the clean seed; seed and chaff mixing are encountered while using this local equipment. Since the activity is dependent on the natural wind, at times the threshed crops is left in the hogdi for 1-2 days in the absence of wind and when the wind speed is high, the seed can be taken away with the straw/chaff.

The average threshing and cleaning output per man-hour for wheat, sorghum, millet, groundnut and maize is 5.5, 6.5, 4.0, 1.5 (expressed in kg/man-hour) respectively (R.N.Kaul et al., 1994).

However, on the contrary to the above facts, literatures show that multi purpose post harvest farm equipment constituting winnowing, cleaning and grading capabilities are now available at global level in a wide range performance levels (George Acquah, 2002). Similarly in some parts (institutions) of our country, though not widely promoted and used by farmers, there are some improved winnowers, which can help alleviate the operational problems encountered in winnowing. 
Proceedings of the first Agricultural Mechanization Completed Research Forum

Like wise, at Bako's Rural Technology Research Center store, there was an imported winnower, stored, without being tested, evaluated and transferred to the users. Therefore, this experiment was undertaken to evaluate the machine against one of the commonly used methods called Gundo winnowing method using wheat, teff, maize and Niger seed, which are commonly produced in the area.

Materials and methods
The experiment was conducted during the 2007 crops threshing season at Guder and Ano. An imported winnower stored in the Bako Research Center's store was used for the test. The machine is manually operated, has three different size replaceable sieves (2mm, 6mm & 12mm) used for different grain size crops. It has also a fan (blower) fitted in a suitable housing used to create an air blast, equipped with outer chip wood board for delivering the specified volume of air that carries away the lighter material (chaff/straw) and deliver the clean grain on one side when the threshed crop mixture was dropped from a hopper. The experiment was laid out in a randomized complete block design in a factorial arrangement with the crops as main plots, the winnowing machine and the traditional "gundo" as sub plots. Small cereals like teff, niger seed and larger ones like maize were used for the test. Six kilograms of crop was used in each case and the same persons (farmers) operated both the machine and the Gundo to generate comparative performance data. Time taken to winnow the given weight of the grain, weight of the chaff blown and that remained with the grain, weights of grain blown together with the chaff were recorded. Percentage of purity of the grains, winnowing capacity per man hour and losses caused by the different methods were analyzed. Required amount of air pressure to winnow the grains by the machine were randomly (approximately) adjusted by using the regulator board designed for the purpose. The collected data were analyzed using MSTAT-C (Freed et al., 1989) statistical packages. Mean separation was done using least significant difference (LSD) at 5% probability level (Steel and Torrie, 1980).

![Diagram](image)

**Figure 1** Schematic arrangement of the main components of the winnower.
Results and discussion

The mean squares of the time taken (man-hours) to winnow the sample grain using the machine was significantly (p<5%) different across all crops except in the case of wheat and tef. The time recorded was 9.5, 24.25, 33.75, and 56.75 for maize, tef, wheat and Niger seed respectively where as in the case of the gundo, the time range was 45.25, 132.5, 140.0, 277.5 for the crops respectively, which shows the comparative timeliness advantage of the machine to the gundo. (Table1). The capacity of winnowing (kg/man-min) for the machine was in the order of 37.33, 11.18, 8.330, 2.677 for maize, tef wheat, and Niger seed respectively and for the gundo it was in the order of 7.586, 1.648, 1.640, 0.4625 for maize, wheat, tef and Niger seed respectively. The purity percentage of winnowed grain by the machine was 99.87, 97.24, 94.92, 77.83 for maize, wheat, tef and Niger seed respectively, while in the case of gundo, the record was 97.74, 86.61, 84.18, 68.38, for maize, tef, wheat, and Niger seed in that order. The percentages of grain blown together with the chaff by the machine was 0.00, 4.181, 9.894, 25.07 for maize, wheat, tef, and Niger seed respectively while in the case of gundo the loss was in the order of 1.488, 14.08, 21.02, 40.49 for the above crops respectively. According to other workers (R.N.Kaul et al. 1994,) the average threshing and cleaning output (expressed in kg/man-hour) was 5.5 and 1.5 for wheat and maize respectively. The combined mean of winnowed grain were significantly different (p<5%) across all crops for the machine and for the gundo but was not for the maize and Niger seed in both winnowing methods. The winnowing capacities (kg/man-min) for the machine were significantly different (p<5%) across all crops where only maize was significantly different from others in the gundo winnowing and no significant differences were recorded between Niger seed and wheat in the machine; and between tef and Niger seed in both methods. The purity percentages of the machine were also significantly different across all crops, except for wheat and tef and in the case of the gundo and for the wheat and maize in both methods. The mean loses of the machine were significantly different for tef and Niger seed, but was significantly different across all crops in the gundo.
Table1: Combined mean square of considered winnowing performance parameters due to different grain size crops and the two winnowing methods.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Winnowing methods x crops grain</th>
<th>Winnowing performance parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time Taken (sec)</td>
<td>Winnowed grain (kg)</td>
<td>Chaff blown (kg)</td>
</tr>
<tr>
<td>Machine X Tef</td>
<td>24.25EF</td>
<td>3.950C</td>
<td>1.375BC</td>
</tr>
<tr>
<td>Machine X Niger seed</td>
<td>56.75C</td>
<td>2.187E</td>
<td>2.150A</td>
</tr>
<tr>
<td>Machine X Maize</td>
<td>9.500F</td>
<td>5.868A</td>
<td>0.1300E</td>
</tr>
<tr>
<td>Gundo X Wheat</td>
<td>140.0B</td>
<td>3.825CD</td>
<td>0.9125D</td>
</tr>
<tr>
<td>Gundo X Tef</td>
<td>132.5B</td>
<td>3.575D</td>
<td>0.9500D</td>
</tr>
<tr>
<td>Gundo X Niger seed</td>
<td>277.5A</td>
<td>2.138E</td>
<td>1.688B</td>
</tr>
<tr>
<td>Gundo X Maize</td>
<td>45.25CD</td>
<td>5.650A</td>
<td>0.1250E</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>15.52</td>
<td>0.3662</td>
<td>0.3662</td>
</tr>
<tr>
<td>CV%</td>
<td>11.73</td>
<td>6.22</td>
<td>23.42</td>
</tr>
</tbody>
</table>

Note: Means with the same letter are not significantly different.
Conclusion and recommendation

The experiment confirmed that the machine carried away the lighter material such as straw/chaff and collected the clean grain on one side and the time taken (man-hours) to winnow the sample grain was less than that of the gundo. The winnowed grain was better in quality, quantity and had minimal loss compared the gundo practice. The winnowing time increased in the order of maize, tef, wheat and Niger seed respectively. The winnowed amount /time increased in the order of Niger seed, tef, wheat and maize, purity percentages was high in the order of maize, wheat, tef and Niger seed respectively and an loss percentage increased in the order of maize, wheat, tef, and Niger seed respectively.

The results indicated that the time required for winnowing using the machine was highly variable and depended on crop factors (such as moisture content, variety, etc...), and on worker attitude and supervision. The above results could be attributed to a lower chaff volume in the maize and much of it in the later during the winnowing time and the same was true in an increasing orders for other crops, where results of the winnowed amount of the grain out of the grain chaff mixture were also shows due to the above reasons where the crops with much volume of the chaff tends to blown out of the sieve together with the chaff. This in turn increases the loss caused by the machines as well as with the gundo methods and decreases their resulted winnowing capacity. In addition to this, it was seen that the machine performed better, with ease of operation, conserved time and energy controlled the amount of air blast and also can be operated by women and children. The performance of the machine can be increased by reducing the amount of chaff load in the grain using other ways like reducing the chaff using sweepers carefully. It is also at times necessary to re winnow the grains that might blown away together with chaff especially in the smaller size and lighter weight grains such as the teff and the Niger seed in order to decrease losses and get better clean grains. It is also recommended that as it has to be made as simple as possible by addition of some force multiplier mechanisms. As the machine can perform the activity in a better way than the traditional methods, effort must be done to make the machine for resource poor farmers.

References

DEVELOPMENT OF NATURALLY VENTILATED
ONION BULB STORAGE STRUCTURES
Laike Kebede and Shimelis Aklilu
Melkassa Agricultural Research Center

Abstract
Three naturally ventilated onion storage structures, structure I, II and III (control) constructed from locally available materials with different roof and wall design and of approximately 9 quintals capacity each, were tested using, Adama Red onion cultivar as a test crop over two consecutive storage seasons at Melkassa Agricultural Research Center. The study showed that there was considerable variation in the internal atmospheric condition between structures and that of the outside atmospheric condition, particularly during night times. The average minimum temperature in structure I and II ranged from 20°C to 25°C while it ranged between 10°C and 18°C in the control structure. In all the structures the average maximum temperature was similar to the outside maximum atmospheric temperature and mostly higher than the optimum range during the dry season, while it was close to the lower margin within the optimum range during wet season. Relative humidity (RH) in all structures varied from 45% to 65%, much less than the optimum range during the dry season. During the wet season, RH higher than the optimum level was recorded in rainy days and at cool night-times. Comparison of bulb losses due to sprouting and loss in weight indicated a significant variation (p<0.05) among structures. Overall losses after four months of storage were 54.8%, 63.6% and 68.5% during wet season and 35.8%, 43.8% and 67.8% during dry season for structure I, II and III respectively. Generally losses increased with increase in storage period, the highest loss recorded during the wet season. During the dry season the extent of weight loss was higher than sprouting losses in structure I and II while sprouting loss was higher in structure III. During the wet season sprouting loss was higher in all the structures after one month of storage. On the whole, structure I is the best of the three structures followed by structure II. Hence small-scale commercial farmers can use them to prolong the shelf life onion, for a storage period of three to four months with a relatively minimum loss.

Introduction
Bulb onion/Allium Cepa.L/ is a major crop throughout the world and contributes a significant nutritional value to the human diet. It has long been growing in Ethiopia for flavoring of local foods. It is a cash source for farmers and also many people make their living by trading the crop. High losses incurred during storage are a major problem encountered in onion trade and year round consumption. The total storage losses comprise physiological loss in weight, sprouting and rotting. Worldwide, post harvest losses in fruits and vegetables range from 24-40% (Raja and Khokhar, 1993) or even reach up to 50% in developing tropical countries (Anon 1989). A comprehensive statistics for such losses is not available for Ethiopia. However, it has been estimated that in the Upper Awash Agricultural Development Enterprise, which used to store bulbs in sacks of 25kg each on prepared shelves, 40% to 70% of the stored bulbs were lost during storage periods of 30 to 45 days respectively (Ketema, pers. com). Most farmers do not have proper storage facilities and they directly bring onion to the market immediately after harvest. Fearing losses, farmers usually unload their entire stock within a month after harvest. As a result, during this period prices are very low due to glut situation. Thereafter, the rise in prices is quite rapid and sometimes-wide fluctuations occur leading to dissatisfaction amongst the producers as well as consumers.

Every agricultural commodity is required to be stored properly to prolong the availability with minimum qualitative and quantitative losses. Onion is not an exception. The principal aim of storage technology is to maintain the bulbs for as long as possible in an unchanged and sound condition. For effective storage, maintaining of desired temperature and humidity conditions in the store are essential. Therefore it is necessary to counter the above losses by proper
monitoring of internal environment. Bulb onion storage is possible at two distinct temperature regimes: either low (0 °C -5°C) or high (25 °C -30°C) temperatures. In each case the relative humidity must be 65% to 75% (Gubb and Tavish 2002). Storage options at low temperature involve controlled temperature and humidity in refrigerated or motorized stores. At subsistence local farm level and in many countries of the tropics, it can not be considered and generally not practical because of cost implications and the technical support needed to sustain refrigerated technology. In the absence of refrigerated stores in tropical climates, cheaper systems based on high temperature regime, that employ natural ventilation could extend the shelf life of onions for at least some time with out much loss.

In most climate zones of Ethiopia, prevailing ambient temperature makes it possible to use naturally ventilated onion stores in a wide range of conditions, provided that the basic principles of store design, operation and management are followed. However, other than the use of delayed harvesting, farmers in our country store their shallots in sacks, huts and on prepared shelves under their roof for marketing. However, stored products in such structures may not last more than two weeks as the shallots sprout and in some instances decay. Farmers also hang shallots in bundles, in their houses at elevated positions, to get them well cured for planting.

Therefore, considering the absence of efficient storage methods at the farm level and in the trading sector, simple onion stores that employ natural ventilation, low energy input and economical under Ethiopian condition were developed and tested with the aim of extending the shelf life of bulb onions with minimum storage losses.

Materials and methods

Experimental location
The experiment was conducted at Melkassa Agricultural Research Center (MARC), which is located at an altitude of 1650 m above sea level. The mean annual rainfall is 780mm and average annual minimum and maximum temperatures are 17 °C and 31 °C, respectively.

Bulb source and general requirements
The cultivar, Adama Red, bulbs used for this trial was obtained from Upper Awash Agro-industry. The bulbs were harvested when 50% to 60% of the onion tops had fallen down. After removing the bulb necks, at approximately 3 cm length, the bulbs were cured by spreading on concrete flour under shade for two days. Splitted, thick-necked, damaged and infected bulbs were graded prior to loading in the stores.

Storage structures design
Three naturally ventilated storage structures, with different roof and wall design and of approximately 6 quintals capacities were constructed from locally available materials (Figure 1). The walls of structures St-I and St-II were made of 20 cm thick mud bricks, while that of St-III (control) was a slated wall structure covered with sorghum stock erected side by side. The roof of St-I was constructed using corrugated iron sheet under laid with 5cm to 7cm thick straw as a ceiling. On the other hand thatched grass was used as roofing for St-II and St-III. About 500kg bulb was stored in each store. The performance of the structures were measured for two dry (January –May, 2001) and wet (July –October, 2001) seasons over a storage period of 4 months in each case.
**Data collected**

1. **Temperature and Relative Humidity conditions**
   Relative humidity (RH), daily maximum and minimum temperature in degree Celsius (°C) inside and outside the stores were monitored using analog type hygrometer and dry bulb mercury thermometers respectively for the entire storage period.

2. **Quantitative loss**
   
   *Number of bulbs sprouted (%)*
   Percentage sprouted bulbs was determined by counting the number of sprouted bulbs at monthly intervals during the storage period. The sprouted bulbs were discarded after each count to avoid double counting.

---

*Figure 1 Naturally ventilated onion storage structures.*
Lake Kebede

Weight loss of bulbs (%)
Weight loss of bulb was determined based on the difference in weight of bulbs placed in sample net bags each containing 50 bulbs. During loading six samples were positioned on three rakes of the two shelves in each structure. The measurement was done in monthly interval and the difference between the initial weight and successive weights gave the weight loss percentages.

\[ WL(\%) = \frac{W_i - W_f}{W_i} \times 100 \]

Where,
- \( W_i \) = initial weight
- \( W_f \) = final weight

Number of rotten bulbs (%)
The incidence of rotting was determined by counting the number of rotted bulbs and was based on monthly storage period. The rotted bulbs were discarded after each monthly count to avoid double counting.

Results and Discussions

1. Storage internal environment
Store room temperature and relative humidity affect the length of storage period.. The overall temperature effect in this trial indicated an increased daily minimum temperature within structure I and II compared to the temperature occurring in the control structure and that of the prevailing ambient condition. As indicated in Figures 2 and 3, the bi weekly average daily minimum night temperature in the control structure ranged from 16 °C to 18.6 °C during the dry season and 13.35 °C to 16.54 °C during the wet season. In the case of structure I and II the biweekly average daily minimum night temperature within the stores showed an increment of 5 °C to 6 °C during the dry season and 3.8 °C to 6.4 °C during wet season. Relatively, a bit higher night temperature was detected in structure I. The reduced night temperature in the control structure was because of free air movement through the porous slated walls, which caused temperature equilibrium with that of the ambient condition. The maximum day temperatures maintained in all stores were generally above the desired critical temperatures during the dry season while it remained within the optimum range during wet season. In both seasons internal daily maximum temperature conditions closely followed that of the out side air condition with slight variation among structures. Relatively a higher daily maximum temperature was observed in structure I because of higher heat conductance property of the corrugated iron sheet roofing.

In all stores biweekly average relative humidity (RH) ranged from 41.2% to 50.8% during the dry season and 60.3% to 72.5% during the wet season. The general recommendation for relative humidity in onion stores is 60% to 75% for onion bulbs desired to be stored for a long time. Relatively a bit higher RH was recorded in the slatted wall structure due to lower inside temperature during night time. Except for very few rainy days, the RH records during the dry season were below the desired limit, while higher than the optimum limit occasionally occurred during wet season. Under high RH conditions, ventilation must be carefully applied
inside the store to achieve the required humidity levels. Excessive humidity in-store will lead to the development of roots and promote rotting (Thompson 1982).

Fig 2. Dry season minimum temperature (a) and maximum temperature (b)

Fig 3. Wet season minimum temperature (a) and maximum temperature (b)

2. Sprouting loss
Onion bulb sprouting percentage during the two storage seasons is presented in Table 1. For the same length of storage period significant (p<0.05) variation in the monthly percentage bulb sprouting was observed between the control and the main structures. The maximum bulb sprouting percentage observed during the dry season was 4.0% in Structure-I at the end of the fourth month, 8.67% in Structure-II at the end of fourth month and 20.66% at the end of third month in Structure-III. The monthly maximum bulb sprouting during wet season were 14%, 19.33%, and 27.33% in structure I, II and III respectively and appeared at the end of the second month in all structures. The difference in bulb sprouting between structure I and II was not significant up to the end of the third month. During the dry season, and for the entire storage period during the wet season, structure I consistently gave lowest percent of sprouted bulbs in both seasons. This is attributed to its ability to maintain internal temperature very close to the optimum range of high temperature onion storage regime (Table 1).
Generally, the incidence of bulb sprouting increased with the increase in storage period. Cumulative percentage of sprouted bulbs following four months of storage period were 12%, 18% and 52% during dry season and 38.0%, 43.8% and 47.9% for wet season storage of bulbs stored in structure I, II and III respectively (Fig 3a & b). The rate of bulb sprouting was affected by variation of the storage season with a highest loss during wet season. This is clearly shown by the behavior of the curves on the two graphs (Figures 3a and b). As can be seen in Figure 3a, losses due to sprouting in all structure were lowest for the first month and from there on bulb sprouting shot up sharply at a relatively higher rate in the control structure while it appeared at lower rate after a storage period of two months in the case of the main structures. During the wet season losses, due to sprouting in all stores showed a similar trend but a relatively higher rate was observed in the control structure (Figure 3b). Though the same cumulative percent of bulb sprouting was observed in the control structures at the end of the forth month, high percent was observed after the fourth and second months in dry and wet season storage periods respectively.

Temperature within the store influences the amount of sprouting in stored onions. In a temperature range of 5 °C to 20 °C, dormancy ceases early and causes higher sprouting to occur. In this study the control store minimum temperature range remained favourable for sprout induction during the entire storage period in both seasons while it appeared out side the critical range in the main stores. However, temperature increment in the main stores was still slightly less than the optimum temperature level (25 °C -30°C) for high temperature onion storage regime.

<table>
<thead>
<tr>
<th>Table 1 Influence of storage design and storage period on the monthly percentage number of bulb sprouting.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Storage period number of bulb</strong></td>
</tr>
<tr>
<td>(Month)</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>Mean</td>
</tr>
</tbody>
</table>
b) Wet season

<table>
<thead>
<tr>
<th>Storage period (Month)</th>
<th>Storage structure</th>
<th>n</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00b(a)</td>
<td>6</td>
<td>2.66c(a)</td>
<td>2.66c(a)</td>
<td>1.78</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>14.00a(b)</td>
<td>6</td>
<td>19.33a(b)</td>
<td>27.33a(a)</td>
<td>20.22</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>12.00a(a)</td>
<td>6</td>
<td>13.33b(a)</td>
<td>14.67b(a)</td>
<td>13.33</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>11.33a(a)</td>
<td>6</td>
<td>9.33b(a)</td>
<td>8.67bc(a)</td>
<td>9.78</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>9.33</td>
<td>24</td>
<td>11.17</td>
<td>13.33</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Letters inside the bracket indicate mean separation test within the row (between storage designs). Letters outside the bracket indicate mean separation test within a column (length of storage time); Means followed by the same letter within a column or row are not significantly different at p<0.05; n = number of sample net bags in each stores;

Figure 4 Percentage number of bulb sprouting during dry season (a) and wet season (b)

3. Weight Loss
There was no big difference in weight loss of stored bulbs due to variation in storage design. However, at the end of the storage period (the last month), significantly higher percentage weight loss was observed in bulbs stored in structure-I during the dry season and in structure II during wet season (Table 2). In all the structures the monthly rate of weight loss varied with increase in storage time for both seasons (Figures 5a and 5b). During the dry season, high percentage of weight loss was observed within the first month of storage period and then showed a drastic decrease in the second months followed by an increasing trend during the rest consecutive months. Higher weight loss at the initial stage followed by drastic decrease in the second month of the storage period was accounted mainly due to loss in moisture as a result of high temperature and low relative humidity. This is due to the fact that during early storage period, the thin outer layers of the bulb needs to be dried to form one or more complete dry skins, which act as a barrier to water loss. The neck of the bulbs also dries and makes them tightly closed. Freshly harvested onion bulbs contain 80%-90% water and removal of water from the outer skins causes a rapid loss of weight (Currah and Rabinowitch 2002). Gradual increase in the following consecutive months was due to loss of moisture, losses in dry matter content, sprouting or bulbs respiration process. Similar trends were observed in the wet season but maximum weight loss appeared after storage for three months due to the resumption of higher incidence of sprouting which utilizes the dry matter content of bulbs for re-growth. In
the wet season, lower cumulative percent of weight loss was recorded in all the structures compared to the dry season. Onions can be stored at high temperatures of over 25°C at a range of relative humidity (75%-85%), which is necessary for minimizing water loss. Hot and dry temperature was observed during dry season storage, particularly in the month of May and caused a higher weight loss due to excessive drying and skin loss. However, excessive weight loss and desiccation of bulbs, which occur at high temperatures and dry humidity, make the system uneconomic for long periods of storage that is required for successful onion marketing (Thompson et al. 1972; Stow 1975).

![Fig. 5 Percentage weight loss of bulbs during dry season (a) and wet season (b)'](image)

**Table 2. Influence of storage design on monthly weight loss of bulb onions**

<table>
<thead>
<tr>
<th>Storage period (Month)</th>
<th>n</th>
<th>Storage structure</th>
<th></th>
<th></th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>I</td>
<td>11.25a(a)</td>
<td>11.18a(a)</td>
<td>10.95a(a)</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>II</td>
<td>2.05d(a)</td>
<td>2.37c(a)</td>
<td>3.16b(a)</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>III</td>
<td>4.81c(a)</td>
<td>4.34b(a)</td>
<td>3.64b(a)</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td></td>
<td>7.42b(a)</td>
<td>6.09b(ab)</td>
<td>4.35b(b)</td>
</tr>
<tr>
<td>Mean</td>
<td>24</td>
<td></td>
<td>6.31</td>
<td>5.6</td>
<td>5.59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Storage period (Month)</th>
<th>n</th>
<th>Storage structure</th>
<th></th>
<th></th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>I</td>
<td>4.79a(a)</td>
<td>4.46b(a)</td>
<td>4.38b(a)</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>II</td>
<td>3.68b(a)</td>
<td>3.88b(a)</td>
<td>3.32c(a)</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>III</td>
<td>5.56a(b)</td>
<td>7.57a(ab)</td>
<td>6.51a(a)</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td></td>
<td>2.84b(a)</td>
<td>3.64b(ab)</td>
<td>4.05b(a)</td>
</tr>
<tr>
<td>Mean</td>
<td>24</td>
<td></td>
<td>4.21</td>
<td>4.89</td>
<td>4.56</td>
</tr>
</tbody>
</table>

Letters inside the bracket indicate mean separation test within the row (between storage designs). Letters out side the bracket indicate mean separation test within a column (length of storage time); Means followed by the same letter within a column or row are not significantly different at p<0.05; n = number of sample net bags in each stores.
Summary and conclusion

- Structure I and II achieved daily minimum temperature increment of 5°C to 6°C during dry season and 3.8°C to 6.4°C during the wet season, which appeared to be outside the critical range for sprout induction.
- For each season, bulbs stored in the main treatment store sprouted less than those stored in the control structures and the incidence of sprouting was higher during the wet season than the dry season.
- Structure I increased the shelf life of bulb onions up to two months with an overall loss of 17.9% and 22.36% during the dry and wet seasons respectively. In the same order total losses in structure II was 20.17% and 27.64%. Therefore they are recommended for popularization.
- Further improvement should continue to reduce weight losses due to excessive drying as a result of high temperature and low relative humidity particularly during the dry season.

References


TESTING AND EVALUATION OF WATER POWERED FLOUR MILL

Habtamu A, Mitiku K. Gutu B and Ashabir H.
Oromia agricultural Research institute, Bako Rural Technology Research Center
P.O.Box 7, West Shoa Tel (057)665004/5/5171, Fax: - 057, 6650242, E-mail:- brtcr @eth net.et.

Abstract

The energy scenario of the country could not satisfy the demand of the community. To fill the gap the, Bako Rural Technology Research Center fabricated a model turbine and brought to Addis Ababa University of technology faculty for test. To proceed with the test, the experimental set up was made to suit the geometry of the turbine to be tested. Meanwhile the test set up that suit the geometry of the turbine was bolted to the existing experimental set up. Finally the test was carried out repeatedly in the hydrology laboratory of the faculty. The test result depicted that the maximum output power obtained from 5m head and 58.32 l/s discharges, keeping other parameters constant, was 762 Watts. The output power generated was very small and below the expectation. The absence of draught tube in the test set up, the wrong arrangement and angle of the runner blade and fabrication error might be the principal factors prone to the insufficiency of the output power boosted. If efforts be made to improve the manufacturing error, this turbine can have the capacity to provide electricity for at least one rural community or for one rural peasant association, which is far from the main grid line.
Introduction
Oromiya is endowed with different natural renewable energy sources. Particularly Western Oromiya has large rivers, which can generate high hydropower. Even though these resources are abundant, they are not effectively utilized as to solve the problem of drudgery and energy demand of the rural community. Consequently, the energy demand and supply gap has been experienced all over the rural community; even though the degree of severity varies from place to place. All countries of the world are now actually experiencing "Energy Crisis" and are busy formulating methods and devices to explore the various possibilities of energy generation for satisfying the growing demand. The world energy consumption by the year 2003 was estimated to be four times that of year 1970. However, man has been practicing on different natural renewable resources and tried to exploit it for welfare of mankind in this aspect (Dandekar; 1997).

In many countries micro-hydropower schemes do not generate electricity. Grain mills, for instance, are often driven directly from the turbine shaft. This modern milling machines using water as a source of power will greatly reduce the drudgery of turning a flourmill by hand. Where there is access for flourmill, women must rise early during the planting time and harvesting and often work at night, to prepare grains for the family's meals, while still contributing a full day labor in field. Thus, there is an increasing power supply need in many countries for rural areas, partly to provide mechanical energy for driving grain mills during the day and illumination at night. Government authorities are faced with the high costs of extending electricity grids. Often micro hydro-power provides an economic alternative to the grid, as independent micro hydro schemes save on the cost of grid transmission lines, which often have very expensive equipment and staff costs. In contrast, micro hydro power schemes can be designed and built by local staff and smaller organizations following less strict regulations and using "off-the-shelf" components or locally made machinery (Harvey 1993). They also solve the problem of energy supply, for example in isolated houses, alpine refuges and pastures, missions and small villages. Ecowatt water turbines permit energy saving and provide green energy, which is quite a considerable contribution to ecology. They minimize the burning of vast fuel and hydrocarbons, which are widely responsible for air pollution, acid rain and the so-called green house effect. (http://WWW, irem.irem. il/en/Mhp/MHP intro. Htm)

As stated earlier to fill the gap between energy demands and supply and also to address the energy problems of the rural community much would have to be done to utilize the abundant, water resources of the country to produce green energy. Green energy-Ecowatt turbines resulting from years of experience in the field, transform the energy of small streams into precious electricity, in a clean way and in full respect for the experiment, (http://www.irem.ile/en/Mhp/MHP intro. htm.)

Hence the Bako Rural Technology Research Center realizing the problems pertained, had introduced and verified the GTZ-GATE cross flow turbine by installing at three different rural areas.

The objectives of the experiment were:
- to determine the basic operating parameters and working condition of the installed mills;
- to test, evaluate and investigate the overall performance and the efficiency of turbine by measuring discharge, the inclination of penstock and effective heads,
To recommend appropriate mill size and specific speed in particular for the generation of rural electrification according to the local condition

Material and methods

The center installed three flour mills at different places, to verify whether the GTZ-GATE design is working or not under the local specific conditions.

To proceed with the realization of the above stated objectives, the following methods and procedures were employed. The experiment was conducted in series of steps as stated below.

Experimental set up

A modified test set up that fit the dimension of the turbine was prepared in the workshop and was attached to the existing experimental set up in the laboratory. The output shaft of the turbine was attached to torque speed measuring devices. During the execution of the experiment, taco meter, digital flow meter, balance, burden gauge and a tube manometer were used.

Power and efficiency computation

Data on rotational speed, flow velocity, static pressure and torque were taken repeatedly and recorded. Based on the recorded data, the power output was calculated. The power output of the turbine was obtained by multiplying the torque by the angular velocity from the data recorded during the experiment. The efficiency of the turbine was defined as the ratio of the power output to the available input power obtained from the water with out any loss. The available water head was calculated from the static pressure measured during the experiment. Similarly the flow rate of the water was calculated from the flow velocity. The head and flow rate were used to determine the input power from which the efficiency of the turbine was calculated by using the following formula:

\[
\eta = \frac{\text{Output power}}{\text{Input power}} \times 100
\]

\[\text{Output power} = G \cdot J \cdot T\]

\[\text{Input power} = Q \cdot T \cdot H\]

\[T = \text{specific gravity} = \rho g = 9810 \text{ kg/m}^2\text{s}^2\]

\[H = \text{static pressure}\]

\[\tau = \text{torque in N-m, } \omega = \text{angular velocity in rad/s}\]

\[\eta = \frac{\text{Output power}}{\text{Input power}} \times 100\]

Data collection, entry and analysis

Data on efficiency of the turbine head, discharge, RPM of the turbine at different valve adjustments were collected. The data were analyzed using Excel. The output power was calculated from the torque and angular velocity and the efficiency of the turbine, was computed using the above formula.
Results and discussion
The effects of head (H), RPM, discharge (Q), weight (Load) on the power output generated and the efficiency of the turbine have been thoroughly evaluated in the laboratory. The results displayed in the following tables show the major parameter's of the turbine taken at different points in order to determine the optimum value of the turbine at local conditions.
Table 1: the effects of head (H), RPM, discharge (Q), weight (Load) on the power output generated at low speed

<table>
<thead>
<tr>
<th>Revolution (RPM)</th>
<th>Weight (kg)</th>
<th>Velocity (m/s)</th>
<th>$P$ (Kp/cm²)</th>
<th>Pressure (N/m²)</th>
<th>Head (m)</th>
<th>Torque (N.m)</th>
<th>Power (W)</th>
<th>$Q(M^3/s)$ (s)</th>
<th>$Q(L/s)$</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>420</td>
<td>0.1</td>
<td>0.4</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>0.5946</td>
<td>26.14</td>
<td>0.0179</td>
<td>17.94623</td>
<td>0.09898</td>
</tr>
<tr>
<td>389</td>
<td>0.2</td>
<td>0.4</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>1.1892</td>
<td>48.42</td>
<td>0.0179</td>
<td>17.94623</td>
<td>0.183349</td>
</tr>
<tr>
<td>365</td>
<td>0.4</td>
<td>0.4</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>2.3784</td>
<td>90.86</td>
<td>0.0179</td>
<td>17.94623</td>
<td>0.344075</td>
</tr>
<tr>
<td>320</td>
<td>0.5</td>
<td>0.4</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>2.973</td>
<td>99.58</td>
<td>0.0179</td>
<td>17.94623</td>
<td>0.377068</td>
</tr>
<tr>
<td>301</td>
<td>0.6</td>
<td>0.4</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>3.5676</td>
<td>112.4</td>
<td>0.0179</td>
<td>17.94623</td>
<td>0.425616</td>
</tr>
<tr>
<td>*290</td>
<td>0.7</td>
<td>0.4</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>4.1622</td>
<td>126.3</td>
<td>0.0179</td>
<td>17.94623</td>
<td>*0.478405</td>
</tr>
<tr>
<td>232</td>
<td>0.8</td>
<td>0.4</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>4.7568</td>
<td>115.5</td>
<td>0.0179</td>
<td>17.94623</td>
<td>0.437399</td>
</tr>
<tr>
<td>203</td>
<td>0.8</td>
<td>0.4</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>5.3514</td>
<td>113.7</td>
<td>0.0179</td>
<td>17.94623</td>
<td>0.430565</td>
</tr>
<tr>
<td>120</td>
<td>1.0</td>
<td>0.4</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>5.946</td>
<td>74.68</td>
<td>0.0179</td>
<td>17.94623</td>
<td>0.282801</td>
</tr>
</tbody>
</table>

Table 2: the effects of head (H), RPM, discharge (Q), weight (Load) on the power output generated at medium speed

<table>
<thead>
<tr>
<th>Revolution (RPM)</th>
<th>Weight (kg)</th>
<th>Velocity (m/s)</th>
<th>$P$ (Kp/cm²)</th>
<th>Pressure (N/m²)</th>
<th>Head (m)</th>
<th>Torque (N.m)</th>
<th>Power (W)</th>
<th>$Q(M^3/s)$ (s)</th>
<th>$Q(L/s)$</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>365</td>
<td>0.1</td>
<td>0.6</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>0.5946</td>
<td>22.72</td>
<td>0.0269</td>
<td>26.91935</td>
<td>0.057346</td>
</tr>
<tr>
<td>352</td>
<td>0.2</td>
<td>0.6</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>1.1892</td>
<td>43.81</td>
<td>0.0269</td>
<td>26.91935</td>
<td>0.110607</td>
</tr>
<tr>
<td>322</td>
<td>0.4</td>
<td>0.6</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>2.3784</td>
<td>80.16</td>
<td>0.0269</td>
<td>26.91935</td>
<td>0.20236</td>
</tr>
<tr>
<td>287</td>
<td>0.5</td>
<td>0.6</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>2.973</td>
<td>89.31</td>
<td>0.0269</td>
<td>26.91935</td>
<td>0.225455</td>
</tr>
<tr>
<td>269</td>
<td>0.6</td>
<td>0.6</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>3.5676</td>
<td>100.4</td>
<td>0.0269</td>
<td>26.91935</td>
<td>0.253578</td>
</tr>
<tr>
<td>223</td>
<td>0.7</td>
<td>0.6</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>4.1622</td>
<td>97.15</td>
<td>0.0269</td>
<td>26.91935</td>
<td>0.245251</td>
</tr>
<tr>
<td>165</td>
<td>0.8</td>
<td>0.6</td>
<td>0.15</td>
<td>14715</td>
<td>1.5</td>
<td>4.7568</td>
<td>92.15</td>
<td>0.0269</td>
<td>26.91935</td>
<td>0.207387</td>
</tr>
<tr>
<td>Revolution (RPM)</td>
<td>Weight (kg)</td>
<td>Velocity (m/s)</td>
<td>Pressure (KPa/cm²)</td>
<td>Head (m)</td>
<td>Torque (N.m)</td>
<td>Power (W)</td>
<td>Q(M³/s) (s)</td>
<td>Q(L/s)</td>
<td>Efficiency</td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------</td>
<td>----------------</td>
<td>-------------------</td>
<td>----------</td>
<td>--------------</td>
<td>-----------</td>
<td>-------------</td>
<td>--------</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td>575</td>
<td>0.1</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>0.5946</td>
<td>35.79</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.014079</td>
<td></td>
</tr>
<tr>
<td>569</td>
<td>0.1</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>0.5946</td>
<td>35.41</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.013932</td>
<td></td>
</tr>
<tr>
<td>560</td>
<td>0.2</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>1.7838</td>
<td>104.6</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.041135</td>
<td></td>
</tr>
<tr>
<td>548</td>
<td>0.4</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>2.3784</td>
<td>136.4</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.053671</td>
<td></td>
</tr>
<tr>
<td>537</td>
<td>0.6</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>3.5676</td>
<td>200.5</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.07889</td>
<td></td>
</tr>
<tr>
<td>517</td>
<td>0.7</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>4.1622</td>
<td>225.2</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.088611</td>
<td></td>
</tr>
<tr>
<td>496</td>
<td>0.8</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>4.7568</td>
<td>246.9</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.097156</td>
<td></td>
</tr>
<tr>
<td>476</td>
<td>1.0</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>5.946.9</td>
<td>296.2</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.116548</td>
<td></td>
</tr>
<tr>
<td>462</td>
<td>1.1</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>6.5406</td>
<td>316.3</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.124432</td>
<td></td>
</tr>
<tr>
<td>447</td>
<td>1.2</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>7.1352</td>
<td>333.8</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.131337</td>
<td></td>
</tr>
<tr>
<td>435</td>
<td>1.3</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>7.7298</td>
<td>351.9</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.138462</td>
<td></td>
</tr>
<tr>
<td>420</td>
<td>1.5</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>8.919</td>
<td>392.1</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.154255</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>1.7</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>10.1082</td>
<td>423.2</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.166498</td>
<td></td>
</tr>
<tr>
<td>363</td>
<td>1.8</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>10.7082</td>
<td>406.6</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.159985</td>
<td></td>
</tr>
<tr>
<td>296</td>
<td>2.0</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>11.892</td>
<td>368.4</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.144951</td>
<td></td>
</tr>
<tr>
<td>245</td>
<td>2.4</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>14.2704</td>
<td>365.9</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.143971</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>2.6</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>15.4596</td>
<td>325.2</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.127958</td>
<td></td>
</tr>
<tr>
<td>141</td>
<td>2.8</td>
<td>1.65</td>
<td>34335</td>
<td>3.5</td>
<td>16.6488</td>
<td>245.7</td>
<td>0.074</td>
<td>74.0282</td>
<td>0.096667</td>
<td></td>
</tr>
</tbody>
</table>
Table 4: the effects of head (H), RPM, discharge (Q), weight (Load) on the power output generated at higher speed

<table>
<thead>
<tr>
<th>Revolution (RPM)</th>
<th>Weight (kg)</th>
<th>Velocity (m/s)</th>
<th>P (KPa/cm²)</th>
<th>Pressure (N/m²)</th>
<th>Head (m)</th>
<th>Torque (N.m)</th>
<th>Power (W)</th>
<th>Q(M³/s)</th>
<th>Q(L/s)</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>689</td>
<td>0.6</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>3.5676</td>
<td>257.3</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.089931</td>
</tr>
<tr>
<td>641</td>
<td>0.8</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>4.7565</td>
<td>319.1</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.111554</td>
</tr>
<tr>
<td>624</td>
<td>1</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>5.946</td>
<td>388.3</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.135745</td>
</tr>
<tr>
<td>604</td>
<td>1.1</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>6.5406</td>
<td>413.5</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.144553</td>
</tr>
<tr>
<td>594</td>
<td>1.2</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>7.1352</td>
<td>443.6</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.155062</td>
</tr>
<tr>
<td>530</td>
<td>1.4</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>8.3244</td>
<td>461.8</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.161414</td>
</tr>
<tr>
<td>524</td>
<td>1.6</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>9.5136</td>
<td>521.8</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.182385</td>
</tr>
<tr>
<td>520</td>
<td>1.8</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>10.7028</td>
<td>582.5</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.203617</td>
</tr>
<tr>
<td>514</td>
<td>2</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>11.892</td>
<td>639.8</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.223636</td>
</tr>
<tr>
<td>500</td>
<td>2.2</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>13.0812</td>
<td>684.6</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.239293</td>
</tr>
<tr>
<td>466</td>
<td>2.6</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>15.4596</td>
<td>754.0</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.263571</td>
</tr>
<tr>
<td>435</td>
<td>2.8</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>16.6488</td>
<td>758.0</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.264963</td>
</tr>
<tr>
<td>404</td>
<td>3</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>17.838</td>
<td>754.3</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.263658</td>
</tr>
<tr>
<td>383</td>
<td>3.2</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>19.0272</td>
<td>762.7</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.266616</td>
</tr>
<tr>
<td>329</td>
<td>3.4</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>20.2164</td>
<td>696.2</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.243339</td>
</tr>
<tr>
<td>296</td>
<td>3.6</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>21.4056</td>
<td>663.2</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.23181</td>
</tr>
<tr>
<td>226</td>
<td>3.8</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>22.5948</td>
<td>534.5</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.186823</td>
</tr>
<tr>
<td>186</td>
<td>4.2</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>24.9732</td>
<td>486.2</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.169942</td>
</tr>
<tr>
<td>121</td>
<td>4.4</td>
<td>1.3</td>
<td>0.5</td>
<td>49050</td>
<td>5</td>
<td>26.1624</td>
<td>331.3</td>
<td>0.0583</td>
<td>58.32525</td>
<td>0.115818</td>
</tr>
</tbody>
</table>
The following graphical representation shows the relationships among the RPM of the turbine, discharge, input power, output power, angular velocity, load (weight) and efficiency. The graphs were plotted from the data obtained from the experimental.

![Torque Vs Power](image1)

**Figure 1** The effect torque on power.

From the graph, the maximum power obtained from 17.95 l/s discharge and 1.5m head was only 126.3 watt.

![Power Vs Efficiency](image2)

**Figure 2** Efficiency

Here it can be seen from the graph that the maximum output power obtained with 47.84% turbine efficiency was only 126.3 watt. An ever increasing of any input with the given efficiency could not give any significant change on the power output; rather with an increasing input the power output declined.
As it can be seen from each table, the output power mainly depends on the torque developed as a result of moment and angular velocity of the turbine. Output power has also direct relationship with available net head and flow rate of the water. Output power increases with increase in discharge rate and head, but after the maximum limit it diminished due to the increment of load. With the above described discharge rates, other parameters kept constant, the maximum output power to be expected from the turbine is depicted in Figure 4 below.

Figure 4 shows that speed and torque have inverse relationships. This is attributed to the fact that the torque has direct relationships with the load and internally the maximum load harness the RPM of the turbine other parameters kept constant.
The optimum discharge that gives maximum power output in this particular condition was rectified on the graph being other parameters kept constant.

Earlier it has been thought that the load and RPM had inverse relationships. This fact was depicted clearly on the graph.

Generally the following general facts depicted from the graphical representation of the given parameters:
As it can be seen from the graphical representation of the two parameters (i.e. Torque and RPM) they have inverse relationships. Consequently as the torque increases the angular velocity of the turbine shaft decreases.
From the experiment it was observed that, the output power increased as the torque developed increased. i.e. torque and load have direct relationships. The angular velocity decreased when the load increased; since they have inverse relationships. As observed through out the experiments, the out put power increased as the torque generated increased synonymously to a certain limit and started to decrease after a certain limit. That peak point in the graph indicates the maximum power and efficiency respectively.

Further the graph indicates that, the output power and efficiency of the turbine increased, when the load increased to a certain climax point and then declined even if the load increased. Based on the above general observation from the graph the following general facts were displayed vividly.

At low head of 1.5m, low speed of 290 rpm, and modest load of 0.7kg; a relatively significant efficiency of 47.8% was attained (tables 1 and 2). At these points the velocity of fluid flow, the discharge and head of the fluid are small as compared to the remaining experiments. As a result, the power output and the input power generated by the flowing water turned to be very small. The corresponding efficiency of the turbine at these points was significantly high as compared to the remaining experiments (\(\eta_1=47.84\%, \eta_2=25.4\%, P_{out.1}=100.4w\)). This might be due to the low velocity of flow and the effective head employed in this particular experiment. This intern made the input power insignificant, because the input power is the function of the parameters mentioned above (velocity of flow & effective head). Here it was observed that the RPM of the turbine and the torque generated were insignificant, which in turn affects the power output. Thus the magnitude of input power and output power became close together.

In experiment 3 (table 3), the velocity, discharge and head were doubled to see their effect on the output power and efficiency of the turbine. From this particular experiment it was perceived that the increase in output power was insignificant; despite the significant increase in input power. This shows that the power conversion efficiency of the turbine is very low. Here the maximum output power obtained was 423.2w and the corresponding maximum efficiency of the turbine was 16.65%. In actual case it is natural that as the discharge increased the input power and rotational speed of the turbine increased synonymously keeping other parameters constant. The larger the magnitude of the RPM of the turbine means the larger could be the output power. Here in this particular experiment, the reverse fact was observed. This might be because of the design problem, the laboratory setting problem and manufacturing error.

In the 4th experiment (table 4) at relatively high head (5m), relatively high discharges, the output power generated was relatively significant (762.7 watts) but the efficiency of the turbine was observed to be very low (26.67%). This is attributed to the fact that the efficiency of cross flow turbines depend on the sophistication of the design. A feature such as vacuum enhancement is necessarily expensive as it requires the use of air tight casing. Part flow efficiency down to less than a quarter of full flow can be maintained at high
values by the arrangement for flow partitioning. Some designs maintain high efficiency down to 50% of full flow with out the inclusion of a portioning device, but standard guide vane. However, the technology faculty of Addis Ababa University hydrology laboratory setting employed to test the turbine lack the attachment of draft tube, which is pertinent for the formation of negative pressure, which has a significant effect on the general performance of the turbine.

Conclusion and Recommendation

Two major attraction of the cross flow turbine have led to a considerable interest in this turbine. Firstly, it is a design suitable for a wide range of heads and power ratings; secondly, it lends itself to simple fabrication techniques, a feature that is of interest in developing countries. It also offers an excellent solution that reconciles quality, performance and price. The runners and mechanical parts can be made of from local materials. They are suitable for heads from 7m to 60m and effective flow rates ranging from 20 l/s to 8001/s.

Even if years of experience showed the vitality of the turbine to transform small streams into precious electricity sources, from the test result it was revealed that it lacks to perform to its intended duty. The amount of output power generated could not satisfy the intended need. From the output of the experiment it was concluded that the electric power to be boosted from this turbine was estimated to be at 0.68kw (at 5m head and flow rate of 58.3 l/s) by considering mechanical efficiency of the generator to be 90%, which is very small to perform the goal. The factors, which attributed to the insignificant power generated during the experimentation were numerous. To pinpoint out some of them for clarity:

The experimental set up did not have enough places to bolt the draught tube with the turbine casing. The enclosure of the draught tube was meant to maintain a column of water between the turbine outlet and the downstream water level and the other purpose is to recover velocity energy or kinetic energy in the water leaving the runner. Since water has to leave the turbine runner at a relatively high velocity in order to exit from the turbine, it still possesses a substantial proportion of the available kinetic energy. Thus the absence of draught tube from the experimental set means water would jet out of the turbine outlet in to the tail race and energy would be lost as turbulence in the tail race (Adams Harvey et al.). This intern play a significant role in the reduction of the output power obtained from the turbine. It could be recommended that at present performance of the turbine it could not be proposed for rural electrification or for milling any grain.

Finally to optimize the efficiency of the turbine, it is necessary to rework on the fabrication of the turbine. From visual observation the runner blades were not attached as required. The improper arrangement of the runner blade and angles involved in turn effect the efficiency of the turbine. Hence it will be prone to improve all the manufacturing errors observed in the work shop of the center for the best of the turbine performance. With the improvement of all
these remarks the popularization of the turbine can be persuasive to alleviate the problem of energy demand and rural electrification of the rural communities.

References


RELATIVE FUEL CONSUMPTION RATE OF WOOD SAVING STOVES AT HOUSE HOLD LEVEL

Tilahun Tefera
Oromiya Agricultural Research Institute, Harar Rural Technology Research Center

Abstract

Evaluation was undertaken to compare performance of traditional and improved cooking-stoves at household environment. The tests were conducted at Bilisuma village/Kombolcha woreda over a two weeks period.
A three stone traditional stove, Modified version of GTZ "Mirt" stove and improved metal stove, were compared in five replicates. The result indicated significant differences in specific daily wood consumption among the three stoves. The entire mean specific daily consumption were 2.189, 1.286, 1.214 kg/day/adult equivalent for the traditional, GTZ and metal stove respectively. The two improved stoves, namely modified version of GTZ "Mirt" and improved Metal reduced fuel wood consumption by 41.25% and 44.34% respectively, when compared with the traditional stove.

Introduction

Fuel wood is the primary source of energy for over 90% of the households in the developing countries (Timoty S.wood, 1992). In many areas, population pressure have consistently led to demand exceeding supplies, which in turn has led to higher costs in terms of money and labour. Women bear the burden of this increased cost by spending a greater proportion of their time and energy collecting firewood (Aprovecho Institute, 1980). The ecological consequences are equally grave: reduced soil fertility, desertification severe flooding and soil erosion.

Most of this wood is burned in open fires or in inefficient stoves. When wood is simply too expensive or too far away, animal manures and crop residues formerly returned to the soil as fertilizers frequently are burned as fuel instead. This practice, increasingly common in
many parts of Africa and south Asia, adds to a downward spiral in soil fertility (Dennis et al., 1980). Once the trees and vegetation on hillsides are removed, soil erosion proceeds rapidly with rainwater run off and flooding and the land can be turned into a desert. Current patterns of daily firewood consumption around the world are thus important factors in an advancing environmental crisis (David and Patricia, 1982).

Dependence on traditional fuel will long remain a reality. It is not so much their use that is wrong, but the manner in which they are being managed and used. Inefficient technologies and appliances mean that precious wood fuel resources are wasted. The burden of this traditional energy use falls disproportionately on women (Robert Lou Ma 1982).

It is likely that wood and other biomass will continue for some years as the most important fuel for majority of people in developing countries. In the long term reforestation and silviculture programs need to be extended and new programmes initiated present supplies of wood need to be used more efficiently (Gerald Foley and Moss 1984). A wide spread introduction of more efficient wood stoves could potentially reduce the demand on biomass fuel and extend the time available for the long term measures to take effect. (Dennis wood et.al 1980)

The amount of heat lost from a stove depends on the outer wall temperature of the stove and the speed of the air flowing past the stove. The closer the stove wall temperature is to the surrounding air temperature, and the lower the speed of air flowing past the stove, the lower are the losses. Since the late 1980s, much work has been done on the design and dissemination of simple, low-cost improved cooking stoves. Such stoves can save up to 40% of the wood fuel normally consumed in open fire, and 25%-35% of the fuel consumed in typical traditional stoves (Stephen Joseph and phillipassrick 1984). The Harar Rural Technology Research Center in its Rural Energy and Small Industry research program, has trained rural women, modified and disseminated different types of improved wood saving stoves in cooperation with different NGOs, particularly in East Harargie, Konbolcha wereda, where fuel wood scarcity has the worst devastating impacts. The women were given the necessary training and access to technologies to build their own improved stoves. This has helped them to come up with their own modern versions and has indirectly created jobs in stove building. (Harar Rural Technology 1996 E.C). Women produce much of the pottery in the Kombolcha area and it is believed that the wide diffusion of stoves here could be attributed to the skills of the women and their perception in anticipating the fuel crisis.

Despite the fact, that a number of efforts are under way to develop and disseminate wood saving cooking stoves, little efforts have been made to evaluate their performance compared to the traditional, which has deterred the diffusion of the technology in the region. This paper presents the results of a study on specific daily wood consumption rate of improved stoves related to local- traditional stoves conducted at household environment. The objective of this research was to investigate the advantages and limitations of particular stove models. Its primary aim was to help identify the most efficient and desirable stoves for a specific social and economic context.

Materials and methods

1. Improved metal stove:

This is a portable metal non-chimney wood stove made of sheet metal with a single pothole modified to fit the rural Hararghe small "Mitad" (Injera pot) by HRTRC
II. The modified version of GTZ "MIRT" Mortar stove

This is a two-pot-hole cook stove, where one hole is used as a chimney and or for warming small-pot meals, while Injera is cooked in the main. It is a progressive modification of the GTZ "Mirt" stove to smaller and simpler stove, better matched to local cooking patterns. It can be constructed from cement-sand or clay soil mud mix.

Testing and evaluation

The tests were conducted over a two weeks period during which time the house-hold cooks were asked to alternately use traditional and improved cook stoves every other day each replicated five times, according to the following schedule:

Day 1: Traditional stove
Day 2: Improved stove (mortar)
Day 3: Improved stove (metal) again
Day 4: Traditional stove ...
... etc.
Procedures

Five modified version of GTZ "Mirt" Mortar stoves and five small sized metal stoves were used in the study. Fuel-wood of the same species (sorghum stalk, sun dried) was used for all households during the tests. Ten willing house holds were selected based on their similarity in their:

- economic status
- use of the same type and size "Mitad" of local installed use of three stone traditional stove.
- variety of fuel wood they usually use.
- cooking and firing techniques.

A preliminary survey was conducted for ten days to gather data on the cooking environment of each household of interest. The number of persons cooking done for was converted in to standard Adult equivalent. The make-up of a house hold, i.e. the number of women and children compared with the number of men, can have influence on household's level of fuel wood consumption, based on the assumption that the lower caloric in take meant a lower consumption of fuel wood. For the purpose of this test, the "Standard adult" conversion formula was defined according to a signified version of the widely used UN formula (Guide lines for wood-fuel surveys, for FAO by Keith open Shaw). Then the specific daily wood consumption on the local stove was collected. Information at a household level was collected without complicated apparatus or calculation. The preliminary survey elicited information on the amount of fuel-wood (sorghum-stalk) consumed by each house hold for fifteen days and the type of cultural cooking practice which is intermittent cultural cooking practices often conducted more than two times per day.

A sufficient amount of wood of the same species to be used for fifteen days was weighed and set aside for each household according to the preliminary survey information result. Then cooks were instructed to use only this fuel wood for cooking on the stoves according to the schedule. Each household was visited twice each day. During these visits the remaining fuel wood was weighed and reminded the cooks, which stove to use for the following day's meals preparation and also recorded the number of persons the meal was prepared for. These tests directly compared the amount of fuel wood used for cooking by traditional versus improved cook-stoves. Then data obtained was analyzed using Randomized complete Block Design.

Experiments data collection and parameters measured

In each house hold, the amount of fuel wood used for baking "Injera" on a particular stove for the daily meal and the number of persons the meal was prepared for was recorded every day according to the schedule. After recording the daily fuel wood consumption on each stove for 15 days (five replicate for each stove); the total wood consumed by each stove was calculated and with the daily average person the meal prepared for, was converted to "standard adult equivalent".
The specific daily wood consumption was calculated using the formula:

\[
\text{Specific daily wood consumption} = \frac{\text{Total wood consumed}}{\text{Test duration} \times \text{Adult equivalent}}
\]

Careful efforts were made to maintain the following quality control plan: Pilot experiments were run to develop the protocols and become familiar with the system operation. For each stove, a number of preliminary experiments were conducted to standardize the burn cycle and minimize the natural viability due to differences in cook’s behavior.

**Results and discussion**

The level of fuel wood savings achieved by a household through the use of improved stoves depends on how well the users apply the cooking and firing techniques. The users motivation to save fuel wood naturally also plays a role. The savings achieved in a given case also depends on the technical condition of the stoves to gain the socio-cultural acceptance of the women and whether the "Mitad" (pots) fit the stove. The results of the field tests are summarized in Table 1 (for short and intermittent cooking tasks). The test results showed that the massive stove (A modified version of GTZ "Mirt") saved fuel wood by 41.25% relative to traditional three-stone stove where as the light weight portable metal stove save fuel by 44.54% relative to the traditional stove. As (Georges Yameogo, et.al., 1983) investigated that, all improved stoves, laboratory tested and compared with performance of an open fire saved 40%-50% of the wood. The results show that both improved stoves perform better than the traditional stove.

**Table 1 Mean Consumption and saving of fuel-wood in kgs.**

<table>
<thead>
<tr>
<th></th>
<th>Hb1 (SAE=1.8)</th>
<th>Hb2 (SAE=4.1)</th>
<th>Hb3 (SAE=5.4)</th>
<th>Hb4 (SAE=4.3)</th>
<th>Hb5 (SAE=7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total fuel wood consumption in kg with traditional stove 1</td>
<td>21.8</td>
<td>42</td>
<td>64.3</td>
<td>4.6</td>
<td>68.5</td>
</tr>
<tr>
<td>Total fuel wood consumption in kg with modified version of GTZ &quot;Mirt&quot; stove 2</td>
<td>13.9</td>
<td>26</td>
<td>34.3</td>
<td>32.7</td>
<td>29</td>
</tr>
<tr>
<td>Total fuel wood consumption in kg with modified Metal stoves</td>
<td>8.7</td>
<td>23.1</td>
<td>44</td>
<td>26.6</td>
<td>39</td>
</tr>
<tr>
<td>Fuel wood savings in kg by using stove 2</td>
<td>7.9</td>
<td>16</td>
<td>30</td>
<td>13.3</td>
<td>39.5</td>
</tr>
<tr>
<td>Fuel wood saving in kg by using stove 3</td>
<td>13.1</td>
<td>18.9</td>
<td>20.3</td>
<td>19.4</td>
<td>29.5</td>
</tr>
<tr>
<td>Fuel wood saving efficiency of stove 2</td>
<td>36.24%</td>
<td>38.09%</td>
<td>46.4%</td>
<td>28.91%</td>
<td>57.66%</td>
</tr>
<tr>
<td>Fuel wood saving efficiency of stove 3</td>
<td>60.09%</td>
<td>45%</td>
<td>31.57%</td>
<td>42.17%</td>
<td>43.06%</td>
</tr>
</tbody>
</table>

* Mean efficiency of modified version of GTZ "Mirt" stove .............41.46%
* Mean efficiency of Modified Metal stove............................44.3%

SAE = Standard Adult Equivalent, Hh = House hold.

The modified version of GTZ "Mirt" stove, which is a poor conductor of heat took much longer time to heat up and thus requiring larger fuel wood. On the other hand, the lightweight metal stoves showed the potential of good wood economics, portability and ease of quality control during construction due to it being done in centralized facilities. However, very high costs, use of imported materials, difficulty in construction were some of the drawbacks. From the test result as shown in Figure 2., the light weight portable metal-stove had the least specific daily consumption for the Kombolcha Rural area where short, and intermittent cooking are practiced. However, over a longer period of cooking time, like in a
larger household family size, average fuel wood consumption for metal stove increased while for the improved version of GTZ "Mirt" mortar stove decreased (Figure 1).

Cooks opinion

The assessment of improved stoves by their users and survey conducted to determine the level of acceptance for the two modified versions of improved stoves (Metal and GTZ "Mirt") showed that both stoves save fuel wood. The metal stove required less fuel wood than "Mirt" and also the light weight metal stove was found good for its:

- quicker cooking
- Shielding against the wind
- Transportability

<table>
<thead>
<tr>
<th>stoves</th>
<th>Mean specific daily consumption</th>
<th>LSD value at alpha = 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stove 1</td>
<td>2.189A</td>
<td>0.5716</td>
</tr>
<tr>
<td>Stove 2</td>
<td>1.286B</td>
<td></td>
</tr>
<tr>
<td>Stove 3</td>
<td>1.214C</td>
<td></td>
</tr>
</tbody>
</table>

Figure 14 Specific daily consumption in relation to standard adult equivalent (1.8, 4.1, 5.4, 4.3, 7, respectively).
Proceedings of the first Agricultural Mechanization Completed Research Forum

The amount of fuel wood needed in kg to heat the stove body to reach its most efficient operating temperature and to cook the entire meal within time.

![Graph](image)

Figure 15 Cumulative Wood consumption of different stoves over continuous use time.

Conclusion and recommendation

Due to limitations of time and funds, the study was limited to a single location with only one type of locally used stove and only “specific daily wood consumption” was evaluated which is not enough to draw a general conclusion.

Although the results are not applicable to all area of the region with different cultural cooking practices and local stoves, I believe they provide valuable insights into the comparative technical advantages of the two improved stoves. For short and intermittent cooking tasks the metal stove performs well and its low mass is an advantage to reduce the amount of energy needed to heat the stove body itself. On the other hand, the test for a longer period shows a definite difference in performance. Apparently the heavier “Mirt” stove takes longer to reach its most efficient operating temperature, but does transfer more heat to the “Mitad” (local pot used for baking injera) after it has warmed up with minimum requirement of fuel wood. For areas where cooking periods is long and frequent throughout the day, the modified version of GTZ “Mirt” stove perform better than lightweight metal stove.

With this basic information further investigation is needed to come up with general conclusion. Moreover both improved stoves are saving fuel wood relative to traditional three-stone open fire, so it may be important to spread these improved stoves to these areas to the hundreds of thousands of households which could benefit from their use.

References


PERFORMANCE EVALUATION OF FIVE CHARCOAL STOVES

Abdujalil Mohamad* and Wandiye Gezahegn
OARI Asella Rural Technology Research center, P.O.Box 06 Asella

Abstract

Five different types of lamps: Asella, Indian Imported, Indian Modified, Jimma and Modified Masho were tested for their illumination intensity, pressure and gas use efficiency on floating and fixed type of biogas plants in a factorial RCB design in three replications. The results showed that there is a very high significance difference (p<0.01) among types of plants and types of biogas lamps, in the interaction between the biogas types and the lamp types, between illumination intensity and distance, between biogas lamps. Moreover, there was a very high significant difference on two type of biogas plant, between lamps. The Imported Indian type biogas lamp gave more luminous intensity on floating type of biogas plant with minimal pressure and small amount of gas than all the tested biogas lamps on small family size biogas plant, which could be easily constructed by a poor farmer with minimum construction cost. It is advisable to use this type of lamp for a resource poor farmer. If there is no imported Indian type biogas lamp, one can use the modified Indian type of lamp on floating type biogas plant instead as it is the next choice. If one wants to get more luminous intensity with more pressure and more amount of gas on large size of biogas plant, it is advisable to use Jimma type lamp provided that leakage that results in wastage and bad smell can be avoided especially for beneficiaries sensitive to this smell as observed during testing.

Introduction

Rural energy planning requires choices among energy technologies. Until recently, the choices have been confined to centralized energy supply technologies, power plants based on hydroelectricity, coal, oil, or natural gas. Increasingly, however, centralized energy sources face two major and probably insurmountable difficulties: a) shortages of capital, and b) public opposition focused on local and global environmental degradation. It has, therefore, become
essential to extend the list of technological alternatives for energy decision-making to include decentralized sources of supply.¹

Potentially, one of the most useful decentralized sources of energy supply is biogas². Two types of biogas plants namely fixed type model (the Chinese type) and floating type model (the Indian type) have been constructed by Rural Technology Research Centers. There are various sizes of fixed type as well as floating ones. The maximum pressure is found in fixed type biogas plant, whereas the minimum amount of pressure is found in floating type of biogas plant. Arsis, Bale and East Showa have large cattle herds whose considerable wastes have much energy potential. Traditionally, these wastes are carefully collected, made into dung cakes and burnt as cooking fuel especially in Bale and Arsis. In some places, they are used as fertilizer. Asella, Harar, Jimma and Bako Rural Technology Centers constructed 150 biogas plants in different years (in different zones) for individuals and farmers’ groups. Some of these biogas plants are functional and are used for cooking and lighting purposes. The above condition of the region (country) forced to introduce family size biogas plant with appropriate lamps to farmers and other individuals involved in dairy production. They alleviate the women’s drudgery and create spare time for other activities, which contribute to the family’s income and enable children to read under biogas illumination.

Now a days, the Ethiopian government has given a great attention for the electrification of rural areas with the motto of “light for all” in order to improve the lives of the majority of the rural people in many different ways. To fulfill this objective, in general, the improvement of bio gas lamps with the existing large number of live stock population is very important as the best alternative option to start the policy of rural electrification to supply them with appropriate facilities enhancing rural development.

In doing this, the rural technology centers and other governmental and non governmental organizations tried to develop different cooking and lighting appliances pertinent to the rural population. In order to enhance rural electrification with small scale appropriate technology namely known as biogas plant, different types of biogas lamps have been made and used in different parts of the country. About five different types of biogas lamps known as imported Indian, modified Indian/modified energy/, Asella, Jimma and modified Masho/modified Lantern/ are being used with out the users having any information about the efficiency of each type of lamp and having no clue to select the best among them. More over, farmers making use of bio gas lamps available in our mandate areas frequently ask for the best bio gas lamp that gives more illumination than Asella type biogas lamp that they are using at present. Furthermore, there is no any basic data on these and other lamps regarding their types, efficiency, etc., of the existing different types of bio gas lamps available in the country. There are also no data on biogas lamps that show the type, efficiency, quantity available in the country that can help to select the best among the existing ones for lighting purposes. Hence taking all the above facts into account, this study was launched to generate basic data on the efficiency of two types of biogas plants, referred as fixed and floating types under the same environmental conditions to select the best lamp in order to carry out further improvement on the lamp. The study further aimed to rank lamps based on their efficiency for easier selection and promotion, so that bio gas users can reliably make use of the existing lamps based on the results of the experiment.

Objectives
- To select best high luminous intensity biogas lamp using smallest amount of gas and lowest pressure on the biogas plants
To enable farmers use small family size biogas plant with low construction cost optimum luminous intensity

Materials and methods
The experiment was conducted at Adaa and Lume districts of East Shewa zone characterized as low land, taking 2m³ floating type of biogas plant at Debre Zeit and 4m³ fixed type of biogas plant at Sirba area. The experiment was carried out in randomized complete block design in three replications using five types of biogas lamps, namely Asella, Jimma, modified Indian, Imported Indian and Modified Masho. The lamps were selected randomly and tested for an hour for every experiment. The data was collected and analyzed using ANOVA and Duncan Multiple Range Test was used to see differences among means.

Materials
Five different biogas lamps, biogas plants, luxemeter, manometer, Gate valve/ball valve/, spanners, hoses, clamps, pipe wrenches, pipe vice, water pipes paper, stop watch, gasometer measuring tape, stick, sealing tape, pipe thread maker, flash light, dry cells, plugs, unions, elbows, T’s, sockets, water, digital thermometer reflectors, match and mantle were used in the experiment.

Methods
Before conducting the experiment on each type of biogas plants, the plants were checked for sufficient amount of gas needed to conduct the experiment. Each plant was filled with sufficient amount of dung mixed with recommended proportion of water regularly at the required time. The gas line/pipe line/ was cut into two around the biogas lamp area and manometer was connected to the two ends of cut pipe line with pipe line fittings. Similarly, the gas line around gas holder was cut into two and digital gas meter was connected to it with pipe line fittings. After the installation of the manometer, before conducting the experiment, its line was closed with ball valve, filled with the required amount of water. Initial pressure reading was taken before starting the experiment at zero time and its pressure readings were taken during running the experiment at 15, 30, 45 and 60 minutes for each experiment. Like wise, after the installation of the gas meter, before conducting the experiment, its line was closed with ball valve, filled with the required amount of water, initial amount of gas reading was taken before starting the experiment at zero time and its gas reading was taken during running the experiment and finally, at 60 minute for every experiment. A stop watch was employed to measure each required time. A measuring tape was used to measure horizontal and vertical distances. Luxe meter was used to measure luminous intensity of each type of biogas lamps at 50cm, 100cm, 150cm and 190cm horizontal and vertical distances at 15, 30, 45 and 60 minutes for each experiment on floating and fixed type of plants. Finally, the data was analyzed using ANOVA. And Duncan Multiple Range Test.

Result
Luminous Intensity
There is a very high significant difference (p<0.01) between two tested types of biogas plants that is all lamps give more luminous intensity on fixed type of biogas plant. There is a very high significant difference (p<0.01) between five types of biogas lamps that is all lamps give different luminous intensity on different types of biogas plants. The interaction between the biogas types and the lamp types is a very high significance difference (p<0.01). There is a very high significant difference (p<0.01) with luminous intensity with distance on two of types of biogas plants. There is a very high significant difference (p<0.01) between
biogas lamps with distance. There is a very high significant difference ($p<0.01$) between biogas lamps, distance and types of biogas plants.

**Pressure**

There is a very high significant difference ($p<0.01$) in pressure on type of biogas plant. There is a very high significant difference ($p<0.01$) in pressure between lamps on type of biogas plant. There is a very high significant difference ($p<0.01$) in pressure between time and biogas plants.

**Amount of gas consumed**

There is a very high significant difference ($p<0.01$) in amount of gas on type of biogas plant. There is a very high significant difference ($p<0.01$) in amount of gas used by different lamp types. There is a very high significant difference ($p<0.01$) between biogas lamp and types of biogas plants in amount of gas consumed.

**Conclusion and recommendation**

The imported Indian type biogas lamp gives more luminous intensity on small family size, 2m$^3$ floating type biogas plant, with small amount of pressure and small amount of gas than all the tested biogas lamps. It could easily be constructed with a minimum cost and helps in wider adoption of biogas plants. It also gives good luminous intensity on 4m$^3$ fixed type of plant, compared to other lamps. A beneficiary with whom biogas lamps were tested, preferred the imported. Indian lamp from all lamps tested at his house even on the 4m$^3$ fixed type of biogas plant having high pressure. If there is no imported Indian type biogas lamp, one can make use of the modified Indian type on 2m$^3$ floating type biogas plants. This has the second best luminous intensity operating with small amount of pressure and small amount of gas than all the tested biogas lamps on 2m$^3$ small family size biogas plants, which could be easily constructed by a poor farmer with minimum construction cost. If one wants to get more luminous intensity, with more pressure and more amount of gas on large size biogas plant, it advisable to use Jimma type of lamp, if the wastage and bad smell due to gas leakage during operating can be avoided.

**References**

PERFORMANCE EVALUATION OF FIVE CHARCOAL STOVES

Abdujalil Mohamad and Wandiy Gezahegn

Asella Rural Technology Research Center
P.O.Box 06 Asella

Abstract

Different kinds of charcoal stoves have been produced and are available on the local market. However, their fuel saving efficiency has not been well studied. Experiment was conducted to evaluate their performance under controlled condition. Five charcoal stoves, namely Asella type, Sheet metal type, White sheet metal and Clay type, Black sheet metal with Clay type and Clay type were tested at the Ethiopian Rural Energy Development and Promotion Center. Data on their efficiency and drawbacks were collected, to identify the best stove in terms of fuel saving. The collected data was analyzed using “Water Boiling Test” and “Controlled Kitchen Cooking Test.” According to these tests the Asella type had the least fuel consumption rate of 0.1032 KJ/gm and the smallest percentage of fuel used, 43.13%. It also cooled down slowly, showing its highest heat retaining nature, which later can be used for another cooking or boiling purpose. This stove is energy saving and should be popularized among the rural population.

Introduction

Energy is one of the most important components of any community’s activities. Economic development of any community cannot succeed without sufficient and appropriate energy production. The main categories of energy consuming activities in households are cooking, water heating, space heating and in some cases lighting in agriculture and small industries, etc. Normally, more than 70% of the energy in rural areas is used for household activities. (1) One of the most energy consuming activities, which is increasing with increase in human population in urban as well as rural areas is cooking. The open fire “three stone” stove is the most common method of cooking in developing world and is used by some of the population virtually in all countries. The other types of cooking methods are traditional, many of which are modifications of the open fire types. Currently, fuel wood saving stoves, unlike the ones wasted by open fire and traditional cooking stoves are being promoted in developing countries. They are increasingly being incorporated into the national energy strategies and energy program of the international technical assistance and development agencies. They have now become an accepted part of response to the worsening fuel shortages being experienced in many countries now a days including developed nations like America, etc., due to the fact that other alternatives of solving ever increasing energy problems are not easily achievable in the world. (2) More over, it has been strongly agreed that well designed and carefully selected stoves can help people obtain fuel saving, reduce rate of deforestation and get other benefits. In Ethiopia, different kinds of charcoal stoves have been made. However, their fuel saving efficiency has not been determined and there was no information on the amount of charcoal saved by each stove.

Objectives

Hence taking the above mentioned facts into account, this study was conducted to:

- generating basic data on the efficiency of different charcoal stoves,
- select the best efficient charcoal stove
Materials and methods

The experiment was conducted at the Ethiopian Rural Energy Development and Promotion Enterprise. Five cooking stoves approximately having the same shape and size were randomly selected for controlled kitchen cooking test. To conduct controlled kitchen cooking test, 121 gm of oil, 30 gm of pepper, 107 gm of onion, 14 gm of salt, 118 gm of shiro, about nearly the same amount of water were taken as ingredients. Pan, three dists, charcoal, stirring stick, volumetric cylinder were used for cooking as recommended by a well experienced cooks of the Ethiopian Rural Energy Promotion Enterprise. Cooking time was recorded in each case. Finally the amount of charcoal remaining after cooking was weighed. The cooked food was taken out of the stove recording the time at which it was taken out of the stove. Finally the specific energy consumption of the stoves using controlled kitchen cooking test was calculated, to determine the best stove among the tested ones.

Results

The results were as shown in the following table

<table>
<thead>
<tr>
<th>Type of stove</th>
<th>charcoal burnt</th>
<th>charcoal remained</th>
<th>Specific energy consumption KJ/g</th>
<th>Specific fuel consumption g/g</th>
<th>Power in KW</th>
<th>%age of charcoal remained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asella Charcoal Stove (1)</td>
<td>160</td>
<td>211</td>
<td>0.1032</td>
<td>2.9926</td>
<td>1.13</td>
<td>56.87</td>
</tr>
<tr>
<td>White Sheet Metal and Clay Type (2)</td>
<td>230</td>
<td>216.67</td>
<td>0.1363</td>
<td>3.9334</td>
<td>1.2</td>
<td>51.49</td>
</tr>
<tr>
<td>Black Sheet Metal and Clay Type (4)</td>
<td>204</td>
<td>244.33</td>
<td>0.1331</td>
<td>3.8595</td>
<td>1.43</td>
<td>54.50</td>
</tr>
<tr>
<td>Sheet Metal Type (3)</td>
<td>243.67</td>
<td>222.67</td>
<td>0.1583</td>
<td>4.5908</td>
<td>1.73</td>
<td>47.75</td>
</tr>
<tr>
<td>Clay Type (5)</td>
<td>235</td>
<td>231.33</td>
<td>0.1469</td>
<td>4.2605</td>
<td>1.0</td>
<td>49.61</td>
</tr>
</tbody>
</table>

NB. Specific Fuel Consumption g/g is grams of wood burned per gram of baked food
Specific Energy Consumption KJ/g is KJ of wood energy per gram of baked food

Conclusion and recommendation

The test results indicated that, the Asella charcoal saving stove was better than the other tested stoves in charcoal saving, low fuel consumption rate, (0.1032 g/g) in grams of wood burned per gram of baked food, and high heat retaining capacity. Because of these advantages and the favourable comments responses from users this stove is recommended to be widely used by the resource poor farmers.

References


2. Ken Darrow and, Mike Saxenian. 1986. Appropriate technology source book. USA.
EVALUATION OF COOKING BANANA VARIETIES FOR FOOD MAKING QUALITY

Mulugeta Tamir1, Admassu Fanta2, Shimelis Admassu3, Tiringo Tadesse4

1 Melkassa Agricultural Research Center E-mail: muteasta@yahoo.com 2 Bahirdar University, 3 Addis Ababa University

Abstract
Cooking bananas are one of the cheapest food crops to produce. Cooking bananas may be prepared in a variety of ways—boiled, roasted, fried, steamed, baked or sun-dried and ground to flour. The cost of production of 1 kg of plantain (and of 1000 kcal) is less than that for most other staples, including sweet potato, rice, maize and yam. Consequently cooking banana is usually a very cheap food to buy and hence is an important food for low-income groups. In order to promote cooking banana as alternative food crop in Ethiopia, 11 cooking banana varieties were subjected for traditional food making qualities. Matoke, Wondo genet-4, Kitawira and Wondo genet-3 varieties have the best pulp to peel ratio. Cachako, Saba, Matoke and Kitawira performed well for chips making. Nijuru, Kitawira, Wondogenet-4 and Matoke are good bread makers (in blends with wheat flour in ratio). Nijuru, Kitawira, Kibungo and Cachako are suitable for thick porridge making. Cachaco, Saba and Kibungo varieties perform well for fried products, where as matoke and kitawira are good for boiling.

Introduction
Bananas originated in Asia. The species of banana known as Musa acuminata is the one, which originated in Malaysia while the species, Musa balbisiana originated in India. In banana growing regions of the world, table and cooking bananas have the greatest nutritional significance, being key staple food in much of Uganda and parts of Tanzania. They are also major components of the diet across much of central and western Africa and in parts of South and Central America (Gowen, 1995).

Cooking bananas may be prepared in a variety of ways like boiled, roasted, fried, steamed (Matoke), baked or sun-dried and ground to flour. Moreover cooking bananas can be processed in to industrial or medicinal alcohol (ethanol), crisps or chips on commercial scale, Jams and jellies, powder, flour, puree, ketchup, dried banana flakes, starch, wine and vinegar (Adams et al., 1982; Tewari et al., 1985 Wilson, 1975 and Stover et al., 1987). Cooking bananas grow vigorously, more drought-resistant, not easily attached by diseases, their fruits have a lot of starch and a little sugar even at ripening and are not soft upon cooking. Moreover according to Johnston (1958) cooking bananas are one of the cheapest food crops to produce. The cost of production of 1 kg of cooking banana (and of 1000 kcal) is less than that of most other staples, including sweet potato, rice, maize and yam. Consequently it is a very cheap food to buy and hence is an important food for low-income groups.

The nutritional value of any food depends on the variety, ripeness, climatic conditions and the soil under which it is grown. In addition, important differences result from the method of preparation (INIBAP, 1999). Generally, the cooking bananas are cheap sources of energy, vitamin A, C and B6. They are low in protein and iron, which must be obtained from other parts of diet. Besides, bananas are low sodium and high potassium contents. While the mean level of sodium is less than 1 mg/g, and that of potassium is about of 3800 mg/g. Therefore the trace level of sodium in the banana makes it a good candidate for low sodium diets. In spite of the above advantages, little attention was given to this nutritionally fruit except the breeding aspect.
Taking the above into account, the present study was undertaken to study the food making quality of cooking banana varieties for added value products and to fulfill the research gap in the food science and post-harvest technology aspect of the fruit research.

**Objective**
- To evaluate cooking banana varieties for added value food products by preparing with different recipes
- To select the best cooking banana varieties for a given food products by comparing their food making quality.

**Materials and methods**
The experiment materials for the project were 11 cooking bananas varieties: Cachaco, Saba, Matoke, Kitawira, Wondogenet-3, Chibulangombe, Nijiru, Wondogenet-4, Kibungo, Caradaba and Ikimago-1 grown at the Melkassa Agricultural Research Center fruit program. Potatoes and wheat flour were bought from super markets in Nazareth. The design for the experiments was CRD in three replications. The sensory analysis for different food recipes from the varieties was conducted according to ISO 6658:1985 sensory analysis methodology. Analysis of variance was conducted using JMP 5 software.

Data were taken on color, taste, texture and flavor. Most important of all, general acceptance of chips, bread, thick porridge and boiled products from cooking banana varieties and control check products were measured.

Semi-trained judges from the center community conducted sensory evaluation using a 9-point hedonic scale rating for color, flavor, taste and overall acceptability. The range method of statistical analysis was applied for the test of significance to find the preferences.

Semi-trained judges from the center community conducted sensory evaluation using a 9-point hedonic scale rating for color, flavor, taste and overall acceptability. The range method of statistical analysis was applied for the test of significance to find the preferences.

Cooking banana varieties were sliced 5-10 mm thickness with a stainless steel knife, suns dried then milled to fine flour with Udy cyclone mill and were used as composite with wheat flour for making bread and thick porridge.

**Results and discussions**
Matoke, Wondo genet-4, Kitawira and Wondo genet-3 have the best peeling ratio in both conditions (Figure 1) and easy to peel. This indicates, from varieties with best peeling ratio either in raw or ripe conditions more edible pulp can be harvested compared to those with poor peeling ratio. According to the results indicated in Table 1, Cachaco, Saba, Matoke and Kitawira performed well for chips making. Chips from these varieties were preferred than chips from potato. Nijiru, Kitawira, Wondogenet-4 and Matoke were good bread makers in blends with wheat flour in ratio 85 percent wheat flour and 15 percent cooking banana flour. Nijiru, Kitawira, Kibungo and Cachaco were superior for thick porridge making in blends with wheat flour in ratio 85 percent wheat flour and 15 percent cooking banana flour. Cachaco, Saba and Kibungo varieties performed well for fried products, where as Matoke and Kitawira were good for boiling (they were more firm after boiling than other varieties and tastes were better.

Cooking banana chips, as acceptable snack food, has good storability when packed with polyethylene bags. We observed that chips made of the selected cooking banana varieties retain their crispiness and other important attributes. Therefore cooking banana chips can be used as competitive commercial snack food generating income. Flour prepared from sun-dried slices of cooking banana can be used to make bread and genfo (thick porridge).
Figure 1  Pulp to peel ratio.
Table 1 Mean value of variety qualities for different food making

<table>
<thead>
<tr>
<th>Variety</th>
<th>Chips</th>
<th>Bread</th>
<th>Thick porridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cachaco</td>
<td>7.85a</td>
<td>5.72g</td>
<td>5.54d</td>
</tr>
<tr>
<td>saba</td>
<td>7.27b</td>
<td>5.99f</td>
<td>4.79h</td>
</tr>
<tr>
<td>Matoke</td>
<td>7.13c</td>
<td>6.8d</td>
<td>4.99g</td>
</tr>
<tr>
<td>Potato*</td>
<td>7.04dc</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Kitawira</td>
<td>6.93d</td>
<td>6.97c</td>
<td>5.81c</td>
</tr>
<tr>
<td>Wondogenet-3</td>
<td>6.75e</td>
<td>6.46e</td>
<td>5.18e</td>
</tr>
<tr>
<td>Chibulangombe</td>
<td>6.64e</td>
<td>5.54h</td>
<td>4.48i</td>
</tr>
<tr>
<td>Nijiru</td>
<td>6.32f</td>
<td>7.94b</td>
<td>5.92a</td>
</tr>
<tr>
<td>Wondogenet-4</td>
<td>6.01g</td>
<td>6.86d</td>
<td>4.51l</td>
</tr>
<tr>
<td>Kibungo</td>
<td>5.79h</td>
<td>4.75l</td>
<td>5.78e</td>
</tr>
<tr>
<td>Caradaba</td>
<td>5.54l</td>
<td>5.92j</td>
<td>5.26e</td>
</tr>
<tr>
<td>Wheat*</td>
<td>--</td>
<td>8.53a</td>
<td>7.96a</td>
</tr>
<tr>
<td>Ikimago-1</td>
<td>--</td>
<td>4.95l</td>
<td>5.06l</td>
</tr>
<tr>
<td>P =</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>CV</td>
<td>1.18</td>
<td>0.86</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different

Conclusions and recommendations

The cooking banana varieties, which are grown at the Melkassa Agricultural Research Center (MARC) can be used as alternative foods crop, using different preparation styles either from traditional recipes or by adopting from countries where cooking banana is a staple food. Chips from cooking banana can be done in a small scale processing level in order to generate income for growersprocessors. Nutritional composition, bioavailability, digestibility of cooking banana varieties and uses for industrial processing are not given due attention and should be studied further.

References


STUDIES ON THE NUTRITIONAL COMPOSITION OF LOWLAND PULSES

Mulugeta Teamir1, Shimelis Admassu2
1 Melkassa Agricultural Research Center, E-mail: muteas@yahoo.com
2 Addis Ababa University

Abstract

Lowland pulses provide variety to the human diet and are an economic source of protein for the larger sector of the population in developing countries. Though more than a dozen varieties were released by the Low Land Pulse project, but no nutritional studies were conducted on these varieties. Fifteen haricot bean and three cowpea varieties were assessed for their nutritional compositions. Generally cowpea varieties recorded higher crude protein level than haricot bean varieties. Black eye bean, TVU-197 and WWT varieties contain 23.08%, 21.65% and 23.18% of protein respectively. Gofta, Ayenew, Melke, Beshbesh and Red wolatta have higher Zinc and energy value content than other haricot bean varieties. The WPB (navy bean) types are high in crude protein but low in Zn content (1.52-1.79mg/100g.) compared to the colored food type beans. According to the study results there are significant differences among varieties on nutrients of haricot bean and cowpea varieties.

Background and justification

Pulses are consumed all over the world. Consumption is higher in those parts of the world, where animal protein is scarce and expensive like in South East Asia and Africa (COPR, 1981). In these parts of the world, they provide a large proportion of the protein required for adults and children. In general, about one fifth of the protein available to humans comes from pulses in the developing countries (Reddy et al., 1986).

Lowland pulses are predominantly grown for cash and dry beans (Phaseolus Vulgaris) constitute 32 percent of the total world legume production (FAO, 1982), but in some parts of the region it is a major staple food supplementing the least expensive protein source for the poor farmers who cannot afford to buy meat. Although bean protein is not complete because of a deficiency in sulphur bearing amino acids like cystine and methionine, it is exceptionally rich in lysine, can compensate for the deficiency of lysine in animal proteins, and is an ideal complement to cereal based diets (Wismer-Pedersen, 1979, Bressani et al, 1980). Consumption of lowland pulses has nutritional advantage and helps to prevent anemia and protein energy malnutrition (PEM) diseases (Grasbeck et al, 1982).
The area of research in food science so far focused on survey of bean consumption, acceptable cooking time and popularization and promotion of haricot bean dishes. However, nutritional compositions of lowland pulses also require more research attention. As part of the crop improvement effort, breeder materials must be tested for quality in terms of physical, organoleptic and chemical composition parameters (Senayit, 1995). The nutritional composition of lowland pulses need to be studied to address the food science and post-harvest aspect and deliver a complete package of technology to the end user.

Objectives
The objectives of this study were;
- To determine the nutritional composition of lowland pulses.
- To select the best lowland pulse cultivars by comparing their nutrient composition.

Materials and methods
The experiment was conducted in CRD (Completely Randomized Design) in three replications using fourteen haricot bean and three cowpea released varieties, 1kg of sample from each obtained from Melkassa Agricultural Research Center Lowland Pulses Improvement Project (Table 1). In order to determine the quantitative chemical composition the following analytical test methods and equipments were employed:
- KS 05-164:1979 Sec.7,
- MS3: 1982 sec, 6,10,12
- Atomic absorption spectrometer AA,
- Flame photometer
- AOAC 1984
- Micro kjeldahl
- Muffle furnace
- Oven

The mineral composition (Ca, Fe, Zn, Cu, Cr, Mg, Mn and P (mg)) of each variety was determined using the atomic absorption spectrometer and flame photometer method. Crude protein (%) was determined using micro kjeldahl method. Moisture (%) was determined using convection oven at 105 °C until constant weight was attained. Ash (%) was determined using muffle furnace at 525 °C. The sample analyses were undertaken in the biochemical laboratory of the Quality and Standard Authority of Ethiopia in 2002.

Analysis of variance (ANOVA) using JMP 5 software was applied in order to test the mean difference among the different varieties in the composition of the stated minerals.

Results and discussions
Mean of the crude protein content in 18 lowland pulse varieties ranged from 17.32% to 23.18%, which was similar to different lowland pulse varieties as stated by various people (Bresani et al., 1980, FAO, 1981, Nassratullah, 1985 and Fashakin et al., 1988). These protein levels in lowland pulses are twice as cereals and many times than in root and tubers. This can help to improve the protein intake, if cereals and root tubers are consumed in combination with pulses (Kushwah et al., 2002). Generally cowpea varieties exhibited better crude protein than haricot bean varieties and the WPB (navy bean) types are high in crude protein than the colored ones (Table 2).
The fat contents of the varieties ranged between 1.28% and 3.46%. The ranges were within the
that found by Akpapunam and Markakis 1979. The carbohydrate content ranged from 51.72% to 64.71%, which was similar to the one
reported by Ofuya et al., 2005. According to Ofuya a large percentage of carbohydrates is
starch and about 1.8%-18% of carbohydrate occurs as oligosaccharides. These
oligosaccharides are made up of raffinose, stachyose verbacose that cause gas production in
humans. Presently according to Hayakawa et al, (1990) it is believed to have some beneficial
effects of oligosaccharides like promotion of growth of bifido bacteria and helping reduction
of colon cancer risk.
Regarding mineral contents in the tested low land pulses varieties, iron ranged from
5.14mg/100g to 8.41 mg/100g; Phosphorus from 7.81mg /100g to 25.55 mg/100g; Calcium
ranged from 64.21mg/ 100g to 220.61mg/100g and zinc ranges from 1.34mg/100g to 2.90
mg/100g. Gofta, Ayenew, Melke, Beshbesh and Red wolaita showed higher Zinc value than
the other haricot bean varieties (Table 3).
Energy is required for all metabolic process. The energy comes from the nutrients supply
of protein, fat and carbohydrate The energy content of haricot bean and cow pea varities
ranged between 292kcal/100g and 350.14kcal/100g respectively, which are similar to the
figures found by others (Woleung et al., 1968 and Gopalan et al 1980). Significant differences
in chemical composition were observed among the different haricot bean and cowpea
varieties (Tables 2 and 3).
Conclusion
Legumes supply essential components for human diets by providing the amino acid balance
needed for normal growth and the maintenance of health. They contain twice as much protein
as in cereals; and except the sulphur amino acids, the legumes contain a sufficient,
complementary pattern of amino acids to add to those of cereals (Fashakin et al., 1988). This
shows that they are very important to the low income groups in terms of nutrition value.
However, the biological availability, net protein utilization, starch properties and other
parameters have not been studied. Hence, researchers should focus on these varieties, in order
to improve the nutritional status of the population.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Variety</th>
<th>Seed color</th>
<th>Seed shape</th>
<th>Yield (on station), Q/ha</th>
<th>Seed size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Roba-1</td>
<td>Cream</td>
<td>Elongate</td>
<td>21</td>
<td>Small</td>
</tr>
<tr>
<td>2</td>
<td>Awash- Melka</td>
<td>White</td>
<td>Round</td>
<td>25</td>
<td>Small</td>
</tr>
<tr>
<td>3</td>
<td>Awash- 1</td>
<td>White</td>
<td>Round</td>
<td>24</td>
<td>Small</td>
</tr>
<tr>
<td>4</td>
<td>Mexican-142</td>
<td>White</td>
<td>Round</td>
<td>21</td>
<td>Small</td>
</tr>
<tr>
<td>5</td>
<td>Atendaba</td>
<td>Carioca</td>
<td>Round</td>
<td>24</td>
<td>Medium</td>
</tr>
<tr>
<td>6</td>
<td>Ayenew</td>
<td>Cream</td>
<td>Round</td>
<td>25-30</td>
<td>Large</td>
</tr>
<tr>
<td>7</td>
<td>Red wolaita</td>
<td>Red</td>
<td>Elongate</td>
<td>22</td>
<td>Small</td>
</tr>
<tr>
<td>8</td>
<td>Beshbesh</td>
<td>Cream</td>
<td>Round</td>
<td>25-30</td>
<td>Small</td>
</tr>
<tr>
<td>9</td>
<td>Melke</td>
<td>Red Speckled</td>
<td>Elongate</td>
<td>20-25</td>
<td>Large</td>
</tr>
<tr>
<td>10</td>
<td>Gobe Rash</td>
<td>Red Speckled</td>
<td>Elongate</td>
<td>25-30</td>
<td>Large</td>
</tr>
<tr>
<td>11</td>
<td>Gofta</td>
<td>Cream</td>
<td>Round</td>
<td>25-30</td>
<td>Medium</td>
</tr>
<tr>
<td>12</td>
<td>Brown Speckled</td>
<td>Brown Speckled</td>
<td>Elongate</td>
<td>11</td>
<td>Large</td>
</tr>
</tbody>
</table>
Table 2. Mean values of chemical composition of lowland pulse varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Crude protein % DWB</th>
<th>Crude fat % DWB</th>
<th>Crude fiber % DWB</th>
<th>Carbohydrate % DWB</th>
<th>Energy value Kcal/100gr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Roba-1</td>
<td>20.55bcde</td>
<td>2.44abcd</td>
<td>7.36bc</td>
<td>54.72g</td>
<td>309.36n</td>
</tr>
<tr>
<td>2. Awash- Melka</td>
<td>17.32h</td>
<td>1.67abcd</td>
<td>8.76ab</td>
<td>55.50fg</td>
<td>292.44o</td>
</tr>
<tr>
<td>3. Awash-1</td>
<td>21.95abc</td>
<td>1.44bcd</td>
<td>10.13a</td>
<td>51.72h</td>
<td>294.71i</td>
</tr>
<tr>
<td>4. Mex-142</td>
<td>22.06ab</td>
<td>2.62abcd</td>
<td>7.35cd</td>
<td>56.17efg</td>
<td>322.46k</td>
</tr>
<tr>
<td>5. Atendaba</td>
<td>20.40bcde</td>
<td>2.99abc</td>
<td>6.19c</td>
<td>56.60def</td>
<td>320.76l</td>
</tr>
<tr>
<td>6. Ayenew</td>
<td>20.50bcde</td>
<td>2.82abcd</td>
<td>3.41ef</td>
<td>64.21a</td>
<td>348.17b</td>
</tr>
<tr>
<td>7. Red wolaita</td>
<td>19.37efg</td>
<td>2.66abcd</td>
<td>3.27ef</td>
<td>64.70a</td>
<td>344.05d</td>
</tr>
<tr>
<td>8. Beshbesh</td>
<td>20.44bcde</td>
<td>3.02abc</td>
<td>2.94ef</td>
<td>64.32a</td>
<td>350.14a</td>
</tr>
<tr>
<td>9. Melke</td>
<td>20.47bcde</td>
<td>2.80abcd</td>
<td>2.75ef</td>
<td>64.03a</td>
<td>347.19c</td>
</tr>
<tr>
<td>10. Gobe Rasha</td>
<td>17.95fgfh</td>
<td>2.81ab</td>
<td>3.36ef</td>
<td>64.71a</td>
<td>339.75c</td>
</tr>
<tr>
<td>11. Cofa</td>
<td>20.07de</td>
<td>2.80abcd</td>
<td>4.22de</td>
<td>64.61a</td>
<td>347.77bc</td>
</tr>
<tr>
<td>12. Brown Speckled</td>
<td>19.91e</td>
<td>1.38d</td>
<td>3.40ef</td>
<td>61.73b</td>
<td>323.55j</td>
</tr>
<tr>
<td>13. Tabor</td>
<td>19.62ef</td>
<td>1.28d</td>
<td>3.40ef</td>
<td>63.10ab</td>
<td>326.63h</td>
</tr>
<tr>
<td>14. Zebra</td>
<td>20.59cde</td>
<td>1.73bcd</td>
<td>2.70ef</td>
<td>60.97bc</td>
<td>326.57h</td>
</tr>
<tr>
<td>COWPEA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Black eye bean</td>
<td>23.08a</td>
<td>1.67bcd</td>
<td>2.40f</td>
<td>59.22cd</td>
<td>329.43g</td>
</tr>
<tr>
<td>16. TVU-1977</td>
<td>21.65abc</td>
<td>3.46a</td>
<td>3.21ef</td>
<td>57.84de</td>
<td>334.64f</td>
</tr>
<tr>
<td>17. WWT</td>
<td>23.18a</td>
<td>1.50cd</td>
<td>3.90def</td>
<td>58.29de</td>
<td>324.81i</td>
</tr>
<tr>
<td>P &lt; 0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV</td>
<td>5.08</td>
<td>40.93</td>
<td>24.22</td>
<td>2.19</td>
<td>0.13</td>
</tr>
<tr>
<td>LSD</td>
<td>1.7162</td>
<td>1.567</td>
<td>1.8</td>
<td>2.18</td>
<td>0.7009</td>
</tr>
</tbody>
</table>
Table 3 Mean value of mineral contents of haricot beans and cowpea.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Variety</th>
<th>Phosphorus, mg/100g</th>
<th>Calcium, mg/100g</th>
<th>Iron, mg/100mg</th>
<th>Zinc, mg/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Roba-1</td>
<td>15.75d</td>
<td>90.56m</td>
<td>6.34bcd</td>
<td>1.59ab</td>
</tr>
<tr>
<td>2</td>
<td>Awash-Melka</td>
<td>12.49h</td>
<td>154.03f</td>
<td>7.13abcd</td>
<td>1.52ab</td>
</tr>
<tr>
<td>3</td>
<td>Awash-1</td>
<td>16.58cde</td>
<td>163.17e</td>
<td>6.96abc</td>
<td>1.72ab</td>
</tr>
<tr>
<td>4</td>
<td>Mex-142</td>
<td>16.44cde</td>
<td>165.41de</td>
<td>6.43bcd</td>
<td>1.79ab</td>
</tr>
<tr>
<td>5</td>
<td>Atendaba</td>
<td>20.33b</td>
<td>198.05b</td>
<td>7.40ab</td>
<td>1.35ab</td>
</tr>
<tr>
<td>6</td>
<td>Ayenew</td>
<td>17.22cd</td>
<td>116.73i</td>
<td>8.32a</td>
<td>2.38ab</td>
</tr>
<tr>
<td>7</td>
<td>Red wolaita</td>
<td>16.50cde</td>
<td>126.69h</td>
<td>8.41a</td>
<td>2.82ab</td>
</tr>
<tr>
<td>8</td>
<td>Beshbesh</td>
<td>16.14cdef</td>
<td>112.66j</td>
<td>6.27bcd</td>
<td>2.80ab</td>
</tr>
<tr>
<td>9</td>
<td>Melke</td>
<td>25.55a</td>
<td>108.85k</td>
<td>6.35bcd</td>
<td>2.90a</td>
</tr>
<tr>
<td>10</td>
<td>Gobe Rasha</td>
<td>17.40c</td>
<td>133.10g</td>
<td>7.93ab</td>
<td>2.39ab</td>
</tr>
<tr>
<td>11</td>
<td>Gofta</td>
<td>16.79cde</td>
<td>167.85d</td>
<td>6.21bcd</td>
<td>2.76ab</td>
</tr>
<tr>
<td>12</td>
<td>Brown Speckled</td>
<td>15.77cdefg</td>
<td>132.08g</td>
<td>5.14d</td>
<td>1.55ab</td>
</tr>
<tr>
<td>13</td>
<td>Tabor</td>
<td>14.73fg</td>
<td>220.61a</td>
<td>6.18bcd</td>
<td>1.54ab</td>
</tr>
<tr>
<td>14</td>
<td>Zebra</td>
<td>15.18ab</td>
<td>90.66l</td>
<td>5.40cd</td>
<td>1.52ab</td>
</tr>
<tr>
<td></td>
<td>COWPEA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Black eye bean</td>
<td>16.18cdef</td>
<td>65.72n</td>
<td>5.28bcd</td>
<td>1.68ab</td>
</tr>
<tr>
<td>16</td>
<td>TVU-1977</td>
<td>7.81i</td>
<td>66.45n</td>
<td>6.38bcd</td>
<td>2.05ab,</td>
</tr>
<tr>
<td>17</td>
<td>WWT</td>
<td>14.26g</td>
<td>64.21n</td>
<td>5.26cd</td>
<td>1.77ab</td>
</tr>
<tr>
<td></td>
<td>P&lt; 0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CV</td>
<td>6.2</td>
<td>1.16</td>
<td>16.31</td>
<td>47.63</td>
</tr>
<tr>
<td></td>
<td>LSD</td>
<td>1.66</td>
<td>2.51</td>
<td>1.76</td>
<td>1.56</td>
</tr>
</tbody>
</table>

References


FAO, 1982. FAO year book, FAO, Rome, Italy


Abstract
In Ethiopia, the livelihood of most of the rural population is based on agriculture, and the production does not go beyond subsistence level, despite the growing population is a serious concern of the country. The primary objective of this study was to assess the farming system and identify the existing tools and implements used for different farm operations in Jimma and Ilubabor zones. Accordingly, survey was conducted in the different agro-ecology of the zones. The results showed that agriculture of the area is characterized by crop-livestock production activities at a subsistence level. Almost all the households in the study area owned traditional farm tools and implements. Most farmers carry heavy goods ranging from 10kg-30 kg on their back/shoulder specially while transporting from field to home. The common storage structure used by 83% respondents is gombisa, which is simple and poor in construction and grains can be easily susceptible for different weather conditions, wild animals attack and theft. They also lacked service stations to repair and maintain farm implements. Generally they have very little accesses to improved farm tools and implement, which are not only instrumental in increasing production and productivity, but comfortable for operation.

Introduction
The primary aim of this survey was to assess the farming system and identify the existing tools and implements used for different farm operations of the study area. The area is distinguished by different agro-ecologies of temperate, semi-temperate and tropical having varied relief mainly inclined, hilly and rolling type of land topography. Its altitude varies from 800m to 3360m where the mean annual rainfall varies from 1200mm to 2650mm, late April to September being the main rainy seasons. The soil of the area is predominantly Nito soil, which is mainly clay, porous and well drained. Vegetation of the area is continuously devastating due to excessive land utilization for cultivation, house and other construction purposes. The agriculture of the area is characterized by crop-livestock production activities at a subsistence level. Maize, teff, sorghum, coffee, wheat, barley and faba bean are the major preferably grown crops. Animal production trend is decreasing mainly due to prevalence of animal disease, shortage of feed and lack of initial capital. Obviously oxen are the main sources power using traditional plowshare although about 23% of the household farmers lacked, 32% owned one and only 45% of them have a pair of oxen and above.

Almost all the household frames of the study area owned traditional farm tools and implements. The most commonly used hand tools for land clearing is gejera100% and axe 99% except 41% of the farmers use additional tools such as zapa, hoko, and sickle and even fire some time. The great number farmers (92%) used traditional plow except some others (8%) practiced hoe culture by using lemi for tillage activities. Planting method is commonly by broadcasting, weeding is done by using tools likes cheki, koto/gaso, babaqu using plow). Herbicide is used for some crops. Sickle is the popular harvesting tool though hand picking, harvesting by using tools such as gejera, hoe and sticks.
Proceedings of the first Agricultural Mechanization Completed Research Forum

(for fruits) is practiced. Likewise, threshing and shelling of the crop is very challenging activities at the rural localities where improved farm tools and implements are totally lacking. Threshing activity by the sample farmers is generally performed by biting with sticks (96%) and trampling by oxen (43%).

The means of transportation for most farmers (72) is by caring heavy goods ranging from 10-30 kg on their back/shoulder specially while transporting from field to home. The common storage structure used is *gombisa* (83%) with simple and poor construction that grains can easily be susceptible for different weather conditions, wild animals attack and theft. Similarly underground storage structure (for qocho), sack and bag in partition room are also used. Because the farmers live in the remote rural areas they totally use traditional farm tools and implements either made by themselves or purchased from the local markets. They also lacked service station to repair and maintain the farm implements when damaged and, generally they have no or very little accesses to improved farm tools and implements.

Understanding of the existing farming level of the mandate area was a necessity for the center, which is recently engaging in research activities to identify the research priority areas in the agricultural technical farm practice and verify merit and appropriateness of the recommended improved technologies on farm operation. Therefore this survey was conducted with the aim of providing information to researchers for better understanding of the environment and properly designs their research projects.

**Objectives**

The objectives of the study were

- To assess the farming system to understanding the farming level of the area.
- To identify the existing farm tools and implements used for agricultural operations.
- To collect data and generate information and researchable agenda for further improvement, demonstration and adoption of farm tools and implements.

**Methodology of the study**

*The study area*

This diagnostic survey was conducted in seven representative districts: three from Illubabor Zone; Metu, Yayu and Bedele and four from Jimma Zone; Dedo, Nada, Sokoru and Mana by considering the three target groups *Beda, Beda-dere*, and *Gamoji* (temperate, semi-temperate, and desert) of the area under the Jimma Rural Technology Research Center mandate area.

*Sampling techniques*

Secondary information was collected from district agricultural offices and Zonal agricultural affair representatives. Structured questionnaire was used to interview the household farmers for gathering the primary data. The interview was conducted by a team of researchers assigned from the research center.

The sampling technique involved two stages. The first stage was purposive selection. Seven representative districts (three from Illubabor and four from Jimma zones) and three peasant associations were selected from each district. In the second step, five representative household farmers from each peasant association had been taken and 105 sample farmers were interviewed.
Data Analysis
Descriptive statistics such as percentage, mean, and standard deviation was used for the analysis.

Result and discussions

Tools and implement used in different farm operations
Land preparation and tillage activities
The household farmers stated that normally lands that newly assigned for crop cultivation and forest lands need land clearing tools to avoid scrub, bushes and trees to make ready for cultivation. On average almost all sample household farmers mentioned that now days there is no forest or any other new land is assigned for crop cultivation. However some local tools are used for land clearing purpose. The most commonly used hand tools are gejera (100%) and axe (99%) to cut and remove small trees and crop residues. Zapa, hoko and sickle are utilized by 41% of the household respondents. Zapa is used for cutting roots, leveling ground, and digging (plowing). Sickle is mostly used for cutting grass and crop residues remaining on farmland. Very few numbers of the households mentioned that they use spade and fire to clear and prepare their land for cultivation.

Primary tillage
The sample household farmers in the surveyed area practiced land preparation operation in two ways. The first and commonly used primary tillage by the majority of the sample farmers is traditional oxen plowshare with its frame which is made by the farmers themselves or available in local market. Most sample household farmers (92%) used traditional plow for primary tillage activities. In fact all farmers owned the farm equipment including farmers with no oxen since they can obtain oxen either from owners by crop sharing method or borrowing from friends. The second method of primary tillage but practiced by relatively less members (8%) of the sample household is hoe culture or using lemi. Lemi is a name given to the special hoe derivated from Oromo language lama (two). It is a simple frame farm tool made of two materials one wooden handle and its two fingers attached with two special metal plows used for cultivating the farmland. This hoe-culture is normally adopted in the areas where animal disease is very serious.

Secondary tillage implements
Normally there are no as different farm tools for primary and secondary tillage. However there was some variations in the adjustment of the different parts of the traditional plow. During the secondary tillage the maresha was sharpened plowshare and shorter wooden handle was used to increase depth. Similarly the wider wings for harrowing and lighter beam are also used to minimize load in different phases of the secondary tillage. However the non-oxen owning farmers practice hoe-culture in primary tillage followed by harrowing using fork. Moreover some sample household farmers mentioned that they also use zapa, qoto, cheki and hoe during the secondary tillage while spade is also utilized in some rare circumstances.
Tillage frequencies

Tillage frequency differs depending on the type of the farm tool and implements used and the crop cultivated by the farmer households. The larger proportion (92%) of the sample farmer household stated that they use traditional plow where as its tillage frequency ranged from 1 to 5 times. The maximum tillage frequency is for teff crop, which required average tillage of 4-5 times. This tillage frequency is less (2-3) where hoe culture is practiced.

Table 1 The distribution of tillage farm implement and its frequency.

<table>
<thead>
<tr>
<th>Type of Implements utilized</th>
<th>The household farmers (%)</th>
<th>tillage frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional plow</td>
<td>92</td>
<td>1-5</td>
</tr>
<tr>
<td>Hoe (lemi)</td>
<td>8</td>
<td>1-3</td>
</tr>
<tr>
<td>Improved implement</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

In this hoe-culture practicing, 8% household farmers tillage frequency ranged from 1 to 3 times. In hoe cultivation practice the heavy work is performed during primary tillage activity by complete cutting down of the roots after digging into more depth of the ground. Consequently the remaining major task of secondary tillage is more of harrowing and leveling the ground to make it ready for planting.

Planting

No farm household suggested the utilization of planter for any of his crop. All farmers planted their crops by broadcasting method except manual row planting machine is widely adopted for maize crop.

Weeding and cultivating

The sample households illustrated that almost all the crops cultivated were weeded ranging from one to three times depending on the types of the crops they cultivated. The majority of the crop fields in the sample households were hand weeded using hoe (geso or cheki). Cultivation (babaqu or shilshalo) using local oxen-drawn implement (maresha/qota) were reported in 98%, 97% and 95% of the total respondents respectively for every used weeding mechanisms. The first phase of weeding was done usually using local hoes commonly known as geso and cheki.

In addition, sickle and gejera were also used for weeding grain and coffee crops together with hand pulling methods during the 3rd phase of weeding.

Table 2 Tools and implement used for weeding.

<table>
<thead>
<tr>
<th>Weeding method</th>
<th>Farmer households (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Hand weeding</td>
<td>98</td>
</tr>
<tr>
<td>2-Weeding by cheki and or qoto/geso/</td>
<td>97</td>
</tr>
<tr>
<td>3-Babaqu (using plow)</td>
<td>95</td>
</tr>
<tr>
<td>4-Using chemical</td>
<td>31</td>
</tr>
</tbody>
</table>
Weeding by cultivation (shilshalo or babaqu) practice is mainly used for maize and sorghum crops in the second phase of weeding. Weeding by using herbicide chemical is used mainly for teff and some times for grains such as wheat and barely. The shortage of chemical supply forced the household farmers to apply it only for few grains selectively. Generally the entire sample households stress that they have faced series chemical shortage for their crop weeding. Consequently only 31% of the total sample respondents are using even some times for their crops selectively. Hence the local farm tools and implements used for weeding are helping much in the areas where chemical weeding is less or totally absent. Therefore it needs mare attention for improvement of those simple frame tools in both quality and supply regard.

Pruning tools
The sample household farmers indicated that previously rural farmers had been using gejera and axle to prune their coffee crop though extension workers did not recommend it. However presently all farmer households have been convinced its disadvantage and used only band saw for coffee pruning.

Watering can
Utilization of the watering cane practice is not common and very few sample households (3%) used it to water vegetables during the dry seasons.

Chemical sprayer
Chemical sprayer device is a common problem to the farmers in addition to the great shortage of chemical supply itself. One sample household farmer complained that the sprayer was made of plastic substance, which was not found in the local market. The only available alternative was renting it from other farmers who owned the device at a cost of 10 to 15 birr/ha. Among the sample household farmers interviewed 42% use herbicides for weed controlling, but none owned the tool. Therefore, either developing the device from locally available materials or facilitating mechanism of easily obtaining from market recommends intervention of appropriate technology

Harvesting
The popular harvesting tool in the surveyed area was sickle. Most crops like tef, sorghum, wheat, barley, horse bean and the like are harvested by using sickle. The other means of harvesting is handpicking up of the crops. Other crops such as coffee and maize were totally hand picked and collected in sacks or basket. Gejera is used to cut the stock of maize and sorghum to make it suitable for harvesting at proper height. Hoe was the other tool used for harvesting. Hoe with different size was used for harvesting beetroots mainly potato and godere. Fruit harvesting mechanism is really challenging problem resulting in damage of produce and the branch of the trees biting by sticks while harvesting. At the same time as the height of the tree increases the problem of harvesting fruits becomes even more serious since normally children climb the tree to collect fruits, which usually resulted in unexpected falling down from the trees.
Post harvest technologies

**Threshing and shelling**

The very popular means of threshing different types of grains and maize shelling in the rural areas of the sample household farmers is mainly by using either human or animal labor. Biting with stick is common for grains like maize, tef, sorghum, wheat, barely and etc. This method is used at least for one type of crop by 96.19% of the total farmer household either because the product is in small amount or because of the none availability of an alternative mechanism. This practice is performed by either putting unshelled/threshed grains in the sack and barrel, or on leveled ground using different size and shape of sticks prepared based on the type of the grains and mechanisms used. Another alternative for grain threshing was using by trampling of oxen. Tramping by oxen for at least one of their crops usually tef, sorghum, barely and wheat is practiced by 42.86% of the total sample household. The least option of threshing grain is using human foot trampling 1.91% where as finger-palm shelling is another option for maize shelling practiced by 4.76% of the total household farmers.

In fact farmers did not encourage animal foot trampling specially those whose produce is diversified but in small amount and have very few animals fearing that it increases load on their oxen where there is a great shortage of animal feed which accordingly have impact on plowing activity. Nevertheless the farmers have less awareness about improved sheller and thresher and at least only 2.86% of them have got chance to use by the device at least once.

Therefore further demonstration activities of grain thresher, maize sheller and other appropriate post harvest technologies are recommended.

**Table 3 distributions of crop threshing/sheltering methods**

<table>
<thead>
<tr>
<th>Threshing/Sheller mechanisms</th>
<th>Total HH Respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Biting with sticks</td>
<td>101</td>
<td>96.19</td>
</tr>
<tr>
<td>2- Foot trampling of oxen</td>
<td>45</td>
<td>42.86</td>
</tr>
<tr>
<td>3-Human foot trampling</td>
<td>2</td>
<td>1.91</td>
</tr>
<tr>
<td>4-Finger-Palm shelling</td>
<td>5</td>
<td>4.76</td>
</tr>
<tr>
<td>5- Using thresher/Sheller</td>
<td>3</td>
<td>2.86</td>
</tr>
</tbody>
</table>

**Transportation equipment**

Transporting different types of products from rural to the local market as well as farm inputs and construction material from urban to rural area is very challenging problem among the rural farmers.

**Table 16. Farmers’ goods transportation system**

<table>
<thead>
<tr>
<th>The possible means</th>
<th>Total household farmer</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caring on back/shoulder only</td>
<td>23</td>
<td>21.9</td>
</tr>
<tr>
<td>Using equine only</td>
<td>21</td>
<td>20.0</td>
</tr>
<tr>
<td>Using equine and caring on shoulder</td>
<td>53</td>
<td>50.4</td>
</tr>
<tr>
<td>Use wheel barrow</td>
<td>3</td>
<td>2.9</td>
</tr>
<tr>
<td>Use animal drown cart</td>
<td>5</td>
<td>4.8</td>
</tr>
<tr>
<td>Total</td>
<td>105</td>
<td>100</td>
</tr>
</tbody>
</table>
Storage
The common storage structure used was kasa, which is made from bamboo or other locally available trees and covered either by grass or corrugated iron sheet. Such type of storage is susceptible for different weather conditions, wild animals attack and theft.

Table 4. Distribution of different crop storages

<table>
<thead>
<tr>
<th>Type of storage structure</th>
<th>Stored food staffs</th>
<th>User h.h farmers %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gombisa</td>
<td>maize, sorghum, other grains</td>
<td>83</td>
</tr>
<tr>
<td>Gumbi</td>
<td>wheat, barley, other grains</td>
<td>2</td>
</tr>
<tr>
<td>Sack/bag</td>
<td>coffee and other grains</td>
<td>14</td>
</tr>
<tr>
<td>Underground</td>
<td>qocho</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

Other problem related with storage
Pestis and disease are common factors of grain problem affecting farmers' crop yield. The other equally important factor that damages farmers' crops yield is rat. The improved storage structure, which is appropriate for different weather condition with special rat guarding structure, is not widely introduced to the household farmers and hence it needs special emphasis to this regard. The poor quality of farmers' storage construction allows vertebrate pests to easily attack the crop yield. Birds, ape and monkey are among other wild animals that caused loss of the stored crops, which made some farmers (14%) store their crops in partition room inside the house in sack or bag.

General conditions of farm tools and Implement
Accessibility, repair and maintenance conditions
The traditional farm tools and implements that usually farmers used in rural areas are made of wood materials and metallic substances either made by local artisans or factory products. The later are costly and some times unavailable in the farmer's localities. Nevertheless no farmer household responded that he got farm tools on credit bases arranged by any concerned organization or from available farmer's technical service station.

Table 5. Access to farm tools.

<table>
<thead>
<tr>
<th>Supply of farm tools implement</th>
<th>Farmers response %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase from local market</td>
<td>67</td>
</tr>
<tr>
<td>Made by local artisans</td>
<td>38</td>
</tr>
<tr>
<td>Farmers' technical service station</td>
<td>-</td>
</tr>
<tr>
<td>On credit bases from organization</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>105</td>
</tr>
</tbody>
</table>

177
Improved farm tools and implements
Perceptibly the principal tillage implement that commonly utilized almost by all farmers is traditional plow with its frame and different hand tools, which are locally made. Most farmers have no enough information about improved technology though they stated that they either used at least one rural technology produced implement or have seen while other farmers using it.

Table 7 farmers’ suggestions concerning improved technologies.

<table>
<thead>
<tr>
<th>Why failed to use</th>
<th>Farmer households%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No access to know</td>
<td>50</td>
</tr>
<tr>
<td>No access to get</td>
<td>41</td>
</tr>
<tr>
<td>Lack of operating experience</td>
<td>-</td>
</tr>
<tr>
<td>High price of implement</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

Furthermore 9% of the sample household farmers also mentioned that some improved rural technology products are costly and unaffordable. However, no farmer household stated that he failed using appropriate technology because of experience and technical problem to operate the implements.

Repair and maintenance of farm tools and implements
It is obvious that repairing and maintenance are essential for tools and implement. Farmers perform simple maintenance repair or totally replace the damaged part. But sometimes when the repair and maintenance required special skill or hand tool especially for metal parts of the implement, the farmers get it repaired by taking it to the local artisans. However this problem is more challenging for the farmers at distant rural localities where the local artisans are either inefficient or totally absent. Therefore, to improve farmers' technical skills, train and community-level technical service station encouragement is recommended.

Major problems and possible responses

Problems and constraints of the farming system
Life is becoming challenging for the farmers whose family member is generally under fed because of low production and productivity under the existing traditional production system for both crop and livestock production. The farmland of the majority of the farmers (77%) is less fertile, while that of 8% is totally poor mainly because of continuous cropping and lack of maintaining mechanism for land fertility. The shortage of cash due to low price of produce and unavailability of inorganic fertilizer in the mean time is the limitation that farmers usually face in overcoming the problem of low soil fertility. Hence providing adequate and timely supply of fertilizer is required in such away that credit condition is facilitated. Encouraging farmers to apply organic manure, appropriate soil erosion control methods and using crop rotation system is another alternative. The shortage of draft animals is the critical issue in the study area. In spite of the fact that almost all (92%) of the farmers used traditional plow by exploiting oxen as farm power for plowing, only 45% of the household farmers owned a pair of oxen and above, 32% owned single where as the remaining 23% have totally lacked oxen for their farm operation. Consequently these farmers who have no oxen farm their lands either by crop sharing with oxen-owners or using hoe (lemi) culture practice.
The major causes for draft power shortage

Livestock disease

Gendi is the most serious problem (37%) among the factors that caused for decrease of animal production. This problem is serious in Sokoru district (Jimma zone) where 87% of the interviewed farmers raised the prevalence of the disease as the primary cause for loss of their draft animals. The farmers stated that their livestock died even after treatment is provided. This may be due to misuse of medicine against certain disease due to lack of knowledge, as some medicine are available at informal market or resistance developed against the medicine. Therefore provision of adequate veterinary service and improving the medicine supply can minimize the gap.

Animal feed shortage

The increasing demand for farmland is resulting in less availability of land for animal grazing. Only about 12.95% of the total land owned by the household farmers is reserved for grazing. Farmers do not have experience of growing forage crops for dry season. Even the crop residue is partially allocated mainly for fuel, fencing, house construction, etc. To overcome the feed problem, it is necessary to improve veterinary management, realizing the animal feed while allocating land and crop residues for different purposes and introducing forage seeds for dry seasons.

Shortage of improved far tools and implements

Improved and appropriate technologies are totally lacked in the study area. Farmers depend on traditional plow and simple local farm tools. The most commonly used tools for land clearing is gejera (100%), axle (99%), and some another additional tools such as zapa, hoko, spade etc. To avoid this problem improving the supply and upgrading the farmers technical skill is required providing that farmers’ technical service station is facilitated. Sickle is usually unavailable in the farmers’ locality. Harvesting beetroots and fruits also need improvement of harvesting mechanisms. Improved threshers and sellers are totally absent in the surveyed area. To combat the problem further demonstration works of improved grain threshes and shellers are desirable. Transportation is a big problem as well. The greater proportions of the interviewed farmers carry goods ranging from 10kg to 30 kg on their back/shoulder. Furthermore, the available road network is very poor. Therefore demonstration and introduction of different improved carts and improvement of road situation is advisable. Where as in storage, The locally used gombisa has poor storing quality and easily predisposes the crop for loss and damage. This problem can be solved through introduction of improved storage structure.

The sample household farmers have less awareness about improved farming technologies due to weak extension linkage. The majorities of them have no any information about improved farm tools and implement produced by Rural Technology Research Centers. The absence of credit facilities and technical station for repairing and maintenance of the farm tools and implements is challenging problem for the farmers living at distant rural localities who can not
afford high price of the tools and implements. Correspondingly in the areas where the rural artisans are either inefficient or totally absent the repair and maintenance service at the nearest town is also costly in terms of transportation, labor and time.

**Conclusion and recommendations**
The existing farming system is characterized by crop-livestock mixed farm production activities with the intention to have adequate food supply to meet their family food demand over the year. This can be achieved by enhancing the traditional mode of production through utilization of improved farm tools and implements. Nevertheless, almost all farmers in the study area are using traditional farm tools and implements for different farm operations, which have indirect impact on production. The available poor infrastructure at the farmers’ locality and lack of down payment and credit facilities for farm implement together with farmers’ lack of awareness about improved technologies have kept them back using traditional farm tools and implement yet. Similarly, the complete dependency of farming activities on using oxen as a draft power have adverse impact on farming activities especially in those areas where animal disease is serious problem and no any other alternative mechanism except using only human labor with the help of hoe. Thus, improved and appropriate technology intervention is recommended through:

* Undertaking further research activities in the area of pre harvest, harvest and post harvest technologies to improve the existing traditional farm tools and implements.
* Developing better extension system that can facilitate demonstration and introduction of improved rural technology out puts.