Trans-SEC

Innovating pro-poor Strategies to safeguard Food Security using Technology and Knowledge Transfer

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Title: Testing report on post-harvest processing upgrading strategies: Maize shelling and millet threshing; sunflower processing; optimized market oriented storage **(UHOH, SUA, ZALF**, **MVIWATA**, TFC, ACT, ARI)
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SUMMARY

This report provides an introduction to the Trans-SEC project with regard to testing of upgrading strategies under Task 6.1 in Work Package 6 and Task 7.1 under Work Package 7. It provides an overview of implementations in the period of January-December, 2015. The areas covered include maize shelling, millet threshing, sunflower oil processing, and storage as per the design of their respective UPSs. Most of these activities fall under Task 6.2 and the rest are under Task 7.1. Whereas maize shelling and millet threshing are exclusively implemented under field conditions in Tanzania, the work on sunflower oil processing and storage are also undertaken in the laboratory at the University of Hohenheim (UHOH) in Germany and under field conditions in Tanzania. Also presented in this report are the successes of the experimental work in the laboratory at UHOH on sunflower oil processing and storage. The results look promising for adoption if the technology will be made cheaply available. Maize shelling was well received and adopted in Changarawe village while very little work was done in Ilakala as there was insufficient maize to test the technology. Due to crop failure in Idifu and Ilolo villages in Chamwino district the work on millet threshing will be executed in the next season (June 2016 onwards). Finally the report provides lessons learned and adaptation strategies as well as some more parameters for close monitoring.

1. Introduction

The Trans-SEC project, with the title *Innovating Pro-poor Strategies to Safeguard Food Security using Technology and Knowledge Transfer* is implemented in Kilosa and Chamwino Districts in Morogoro and Dodoma regions, respectively. Formulation of the project went through various stages in German and Tanzania in dialogues and meetings that involved multi-stakeholders at governmental and institutional levels. The project is focused on Food Value Chains (FVC) in the two selected districts. It is run by a consortium of researchers, policy makers, and other implementation actors in Germany and Tanzania. All the chain segments and actors in crops and livestock production and the post-harvest chain were considered including processing for food and bioenergy production, waste products handling and utilization, and use of additional biomass (Trans-SEC, 2013).

During year one and year two of the project a number of activities were done to set the forward motion for implementation of the various activities. Just after the inaugural workshop an overall project baseline was conducted while at the same time experts in various fields of activities established some technical foundations. These together established benchmarks which in collaboration with the farmers generated strategies worth adapting in the target rural set ups. These were named Upgrading Strategies (UPS), identified and prioritized by the farmers, researchers and other stakeholders as the most suitable ones. As the project is multisector in nature as explained by the respective Work Packages, the selected UPS were specifically named as follows: UPS No.2: Byproduct for Bioenergy; UPS no. 3: Improved processing; UPS no.4: Improved Wood supply; and UPS no. 5: Improved stoves. UPS 2 is under Task 6.1, UPS 3 under Task 6.2 and UPSs 4 and 5 are under Task 6.3. This particular deliverable report is on Improved Processing which is directly under Task 6.1 (UPS No. 3) and overlaps UPS No. 6 (sunflower processing) and UPS No.7 (optimized storage).

2. Overview and Implementation of Improved Processing (UPS No.3)

2.1 Maize Shelling and Millet Threshing

2.1.1 Design Aspects

This section includes UPS Design, review of UPS approach and potential adaptations, reviewing minimum and maximum number of repetitions of trials for UPS implementation, reviewing UPS monitoring parameters/indicators and baseline information requirements, planning time schedule for monitoring activities, publications, milestones and roles and expectations in UPS team.

2.1.1.1 UPS Design

This UPS was designed to address the following problems: poor knowledge on processing technology, low availability of energy/human labour for processing, lack of awareness on better processing methods with regard to the crop harvest to be processed. The UPS are implemented in Idifu and Ilolo villages in Chamwino District on millet threshing and Ilakala and Changarawe villages on maize shelling. Implementation is through farmers groups specifically formulated in the respective villages with the intention of acquiring processing machines as a business.

2.1.1.2 Review of UPS approach and potential adaptations

a) Economic considerations
   - Availability of maize shelling and millet threshing machines was established
   - Based on tentative prices available, viability of diesel/petrol powered maize shellers and millet threshers was established for each of the CSSs.

b) Acquire funds to foster procurement of the machines
   - Advertise for donation of funds from each of the group members to enable procurement of the machines.
   - Arrange for alternative funding if necessary

c) Participatory selection of machines and procurement
   - MVIWATA leads the process

- Participatory selection of machines by farmers' groups, MVIWATA and technical people experienced in maize shelling/ millet threshing.
- Ordering machines after acquiring the requisite amount of funds.
- Supply of the machines to the respective groups of farmers.
- Training on operation and maintenance of the machines by the suppliers.

d) Use of machines for maize shelling or millet threshing

e) Publicity

2.1.1.3 Reviewing minimum and maximum number of repetitions

Continuous assessment of performance until the end of the project

2.1.1.4 Reviewing UPS monitoring parameters/indicators and baseline information requirements

Group management issues

i) Group Name.....

ii) Date of conducting monitoring .....

iii) No of members present .....Male .....Female.....

iv) From which sub villages are the members of the groups come from?.....

v) Is there any increase or drop out of members?

vi) Reasons for increase or drop out.....

vii) Does the group has still its leadership (chair person, secretary, treasurer) (Yes, No)

viii) How often do group members meet (intervals)?

ix) How many times did they meet since their inception?

x) What do they discuss when they meet?

xi) Do the group members keep record? If yes, which records?

xii) Does the group have a constitution?

xiii) Do all members have a copy of the constitution?

xiv) Does the group have a working plan? If yes, how far has their plan implemented?

xv) What is the status of the UPS group registration?

xvi) Who makes decisions for group activities?

xvii) What challenges are members facing in managing the UPS group?

(a) Technical and socioeconomic performance

Socioeconomic Performance

i) Who is operating the machine?

ii) Where is the machine located?

iii) Availability of maize to shell/ millet to thresh (high, medium, low)

iv) Time (hrs *per week*) spent on operating the machine

v) What is the benefit of operating the machine versus manual shelling?

vi) Number of operators for the machines and their roles

vii) Number of bags shelled/crashed per day/week

viii) Price charged per bag

ix) Operation costs per day/week (including wages, fuel, etc)

x) Returns to the group per week

xi) How much is the group paying back

xii) Type of farmers receiving service (male/female)

xiii) Total number of farmers and days served

xiv) Time spent in moving machines from one location to another; average distance between locations

xv) Means and cost of moving the machines

xvi) Additional costs incurred if any

xvii) Suitability for marketing the grain (with or without additional winnowing).

Technical Performance

i) Estimate maize/millet harvested (No. of bags*)* ……. maize shelled/ millet threshed (No. of bags*)…… (Amount shelled to be obtained from the group operational records versus estimated total production from village statistics if any*).

ii) Amount of fuel used…….cost of fuel…….; is there any additional cost of acquiring fuel?

iii) Processing losses incurred: shatter losses (%) ……., amount that is lost with the cobs (%)…….

iv) Shelling quality: presence of chaff and broken grains (good, medium, bad):……

v) Problems faced on using the maize sheller

vi) Any issues of environmental concern……..

vii) Down time due to breakdown……..

viii) Time for fixing minor faults……

(b) Gender issues

UPS Participation and Control

i) Is there a difference in male and female participation in a) implementation……., b) training……, c) meetings for UPS……..?

iii) What is the influence of the UPS on social issues (conflicts, relationships, meetings)?

iv) What influences the male, female, youth participation on UPS?

v) Are there differences in decision making for a) men b) women regarding UPS income and expenditure?

vi) Regarding investments in the UPS are there affordability differences? Which ones for a) male…….. b) female…….. c) youth……..

Changing Gender Roles and Relations

i) Are there any changing roles during and after UPS implementation?

ii) Has there been change of traditional roles after implementation? ……

iii) Are there non-traditional roles changing? ……..

iv) What is the change of workload related to UPS? Is the overall workload increasing…… (on whom) or decreasing…….(on whom)?

d) Status of implementation

i) Has the group started implementation of UPS? YES/No. If YES, when was the UPS implementation started?.....

ii) If the group has started UPS implementation,

- How many farmers were trained on the UPS implementation?.....
- How many farmers participate in UPS implementation……?
- What is the level of UPS implementation among the group members.....?
- How is the UPS being implemented ?.....

iii) Do trained farmers train others in their villages, YES/No. If yes, how many?

iv) Are there farmers who have changed the UPS groups? YES/NO. If YES, why.....

v) What are the challenges faced during UPS implementation.....

vi) Have members of the group allocated time or other requirements for UPS implementation as was agreed during group formation? .....

vii) Have the groups received any support from the project? YES/NO. If YES, what is the support received from the project.....

e. Economic analysis will be covered by the business model establishment

- Since acquisition of the machine was based on calculations of return on investment, the true income per season will be estimated.

*2.1.1.5 Planning time schedule for monitoring activit*ies

Since there was no appreciable amount of millet to be threshed, this activity has been shelved to next year (May-July 2016). However, the millet threshers that were received had some technical problems which were later on solved by the supplier in collaboration with MVIWATA.

- Maize shelling was scheduled to start from August each year and will be continued next years (between July and August 2016) in both Changarawe and Ilakala.

2.1.1.6 Milestones

Millet threshing machines are tested and availed to the respective group members in Ilolo and Idifu villages ready for use in the next season (starting from May 2016) – MVIWATA to facilitate.

- Farmer training on group management and operation of millet threshing machines.
- Report on maize shelling in Changarawe and Ilakala

2.1.1.7 Publications

No sufficient data yet to warrant publication

2.1.1.8 Roles and expectations in UPS team

There are no changes on roles from the initial project set-up.

2.1.1.9 Other issues

Although this report is on Task 6.1, more or less similar monitoring indicators will apply to sunflower oil processing under WP7 except for the marketing aspect.

2.1.2 Methodology

2.1.2.1 UPS location

This UPS was implemented in Ilakala and Changarawe villages in Kilosa district on improved maize shelling and Idifu and Ilolo villages in Chamwino district on millet threshing. Implementation started from the time the farmers chose this processing UPS in the respective villages. This was anticipated to be done in groups of farmers ranging between 15 and 30 in each village. Implementation activities were subdivided into five steps, namely: formation of a business oriented farmers group, project planning and feasibility, ordering and purchase of one unit of machine, training of farmers on operations and management, and conduct business with the machines by the UPS groups in the respective villages.

2.1.2.2 Implementation steps in the field in Tanzania

(a) Establishment of business oriented farmers group

In a two days workshop that was organized in the case study sites by MVIWATA, farmers who were willing to establish processing business self-selected to be organized into the respective UPS groups. The groups were sensitized to organize themselves to seek for credit or self-contribution to acquire processing machines, a process that followed after the indication of positive business viability. The purpose was to avoid free donation that always make farmers lack the sense of ownership.

(b) Project planning and feasibility

A business feasibility for investing in threshing and shelling was done by both project economists and farmers who considered all the essential factors for investing in rural set-ups. Factors which were looked at included:

- Collection and analysis of data on price of the machine and fuel/diesel
- Current maize shelling cost,
- Estimated availability of maize to shell
- Distances between one farm to storage of maize
- All other feasibility study items.
- Cost-Benefit ratio/analysis

(c) Ordering and purchase of machinery

Prior to purchase of the machines, representatives from the maize shelling and millet threshing UPS groups visited various manufacturers in Morogoro and Dar es Salaam. This was facilitated by MVIWATA, the aim being to make the farmers choose what they perceived as good to meet their demands. After the farmers made their choice ordering and purchase was done by MVIWATA.

(d) Training of farmers on operations and management

This activity was designed to be implemented by the equipment suppliers on delivery. This was meant to give the farmers skills on operations, routine maintenance, and troubleshooting. These were regarded as essential factors for sustainability of these mechanical technologies.

(e) Use of the machines by the UPS groups

It was planned to use maize shellers in Ilakala and Changarawe and millet threshers in Idifu and Ilolo villages pending supply of the machines at the right time and availability of crop produce for shelling or threshing. This was expected to be done after the UPS groups were trained on how to operate and maintain the machines by the suppliers.

(f) Monitoring

Monitoring was done by a group of experts from ARI and MVIWATA on the basis of indicators mentioned in 2.1.1. The following means were used for information collection:

- Informal and formal surveys by members of the consortium
- Data gathering by students and researchers
- Telephone communications
- Daily monitoring and supervision by on-station personnel

2.2 Controlled Testing on Sunflower Processing at UHOH (Part of UPS No. 6)

Sunflower seeds of high oleic hybrid *PR65H22* were obtained from Würzburg, Germany. The oil content of the raw material was 48.5±0.3 %-m/m on dry matter basis. Currently experiments for the optimization of sunflower oil extraction via a mechanic screw press are conducted at the University of Hohenheim (UHOH). Since the experiments have not been finished yet, below we mention only the material and method part of the study.

Oil press CA59G (IBG MonfortsOeketech GmbH, Mönchengladbach, Germany) was used to press sunflower seeds. The speed of the motor, $\omega_{m,}$ and the screw press speed, $\omega_{s,}$ were measured using digital tachometer DT-2234 (Fa. ZEITECH, Berlin, Germany). The correlation between ω_m and ω_s was fitted into linear equation, as shown in Eq. 2.1 (R^2 = 0.989).

$$\omega_s = 0.092 \cdot \omega_m \quad (2.1)$$

In order to optimize the mechanical extraction in terms of oil obtained, process factors such as press cylinder, nozzle, and rotational speed of the screw were taken into account. Press cylinder with 1-mm holes diameter was carried out in this study. The experimental design consists of experiments at different speed and nozzle diameter (see Table 2.1).

Table 2. 1 Level of Process Factors

Level	Screw speed, ω_s (rpm)	Nozzle diameter, $Ø_N$ (mm)
Low	18	4
Middle	28	5
High	40	6

Measurement of the temperature of press cylinder (T_1), press head (T_2), crude oil (T_3) and press cake (T_4) was conducted using thermocouple type K (Greisinger electronic, Regenstauf, Germany).

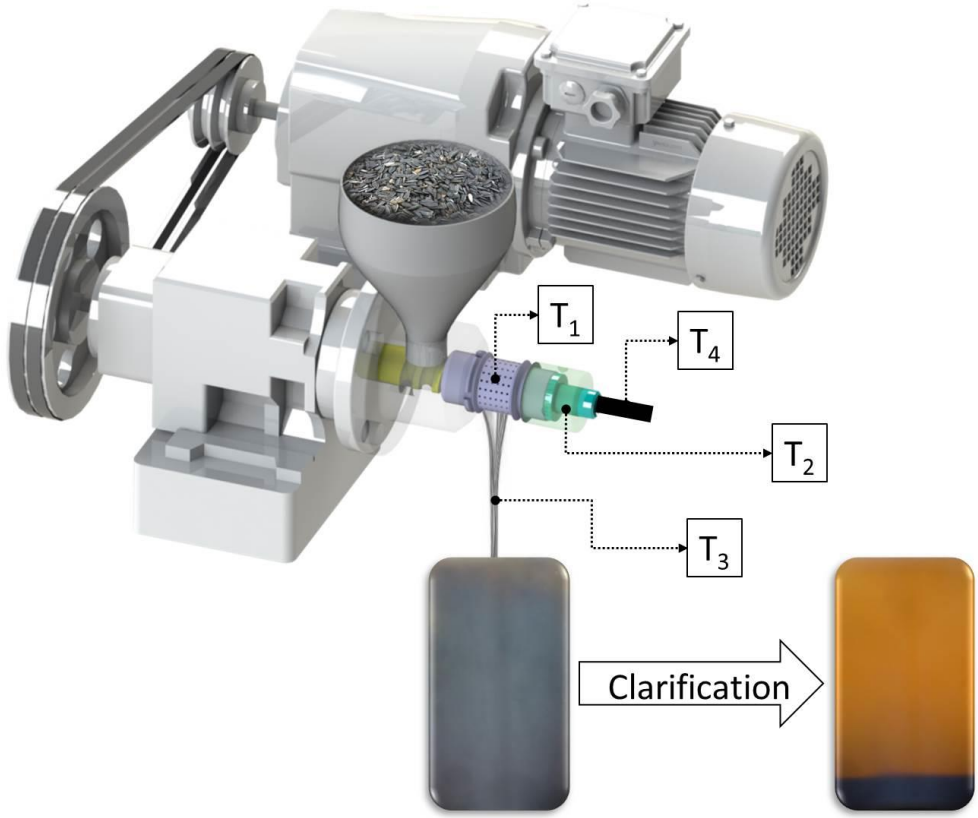

Fig. 2.1 Mechanical extraction using IBG MonfortÖkotec CA59G and oil clarification for seven days

The crude oil was collected and sealed in plastic containers and the clarification process was conducted at room temperature. Clear oil was separated manually after seven days of sedimentation. An i200 AC current clamp (Fluke, Glottertal, Germany) was used to measure power used by the motor. Power *P* (watt) of the pressing machine was calculated using Eq. 2.2.

$$P = \frac{3 \cdot 400 \cdot I \cdot 0.85}{1.73} \quad (2.2)$$

where *I* is measured current in Ampere as electricity outlet of the motor.

Oil recovery efficiency of the extraction process was calculated based on oil content of the raw material, and the pressed cake as described by Beerens (2007). The oil content was extracted using automatic extraction system SOXTHERM 2000 (C. Gerhardt GmbH & Co. KG, Königswinter, Germany). After the experiment, weight of the press cake, $m_{p,}$ and crude oil, m_c (kg), were also measured to estimate mass balance of the whole process. Throughput, S (kg/h), was estimated using Eq. 2.3.

$$S = \frac{m_s}{t} \tag{2.3}$$

where m_s was total mass of sunflower seeds (kg), and t was time of the extraction (h).

2.3 Optimized Market Oriented Storage (UPS No. 7)

2.3.1 Maize Storage in Ilakala and Changarawe Village

According to the UPS formulation table in deliverable D 6.1.1 last year, physical implementation and monitoring of UPS No. 7 was earmarked for Ilakala in Kilosa and only training will be pursued in the rest of the villages in Kilosa and Chamwino Districts. However, it was not feasible to conduct field experiments at Ilakala due to insufficient amount of maize grain in the last season; instead this experiment was conducted in Changarawe village. This is a slight change of activity plan but nevertheless the results will be extended to Ilakala through training. It is also worth noting that millet which is a priority crop in Idifu and Changarawe does not succumb to storage pests other than rodents. Therefore this storage UPS will be implemented only for Ilakala and Changarawe.

Maize storage at farmers' premises in Changarawe was done in four types of bags namely Super Bag (IRRI bag), PICS, polyethylene bag with insect treatment, and plain polyethylene bags in Changarawe CSS. The experiment was done in six different households and monitoring was planned to be conducted at zero, three and six months. Table 2.2 provides the experimental design and the parameters of interest. Note that the term sulfate refers to polypropylene bags. Parameters of interest include dry matter loss, moisture content,

germination, and proximate analysis. Aflatoxin test will be done at the Tanzania Food and Drug Agency in Dar es Salaam.

Table 2.2 Experimental Design of Improved Storage Bags for Six Months

	3 months duration to store				6 months duration to store			
Farmer A	1	2	3	4	1	2	3	4
Farmer B	2	1	3	4	2	1	3	4
Farmer C	4	2	1	3	4	2	1	3
Farmer D	1	3	4	2	1	3	4	2
Farmer E	3	2	4	1	3	2	4	1
Farmer F	2	4	1	3	2	4	1	3

Key: 1= IRRI bags, 2= PICS (Pardue improved crop storage) bags, 3= Polypropylene bags with pesticide (sulfate + pesticide), and 4= Polypropylene bags only (sulfate bags without pesticides). Each farmer is a replication where all 4 types of storage are into two durations (3 and 6 months

2.3.2 Hermetic Storage at UHOH

Nine steel pipes of volume 0.13m³ with flange to blind flange closure were tightly sealed and tested for their tightness. Each blind flange held a controller unit connected to a pressure sensor (BMP180, Robert Bosch GmbH, Gerlingen-Schillerhöhe, Germany, 300 – 1100±1 hPa), a relative humidity and temperature sensor (SHT15, Sensiron, Staefa, Switzerland, 0 – 100±2 % RH, -40 – 60±0.4°C) and a CO2sensor (CO2-Engine BLG, Senseair, Delsbo, Sweden, 0-30±0.2 %vol. CO2). The pressure was corrected to a temperature of 20°C by Eq. 2.4, the CO_2 value is corrected to the actual pressure by Eq. 2.5.

$$\frac{P}{t + 273.15} * 293.15 \qquad (2.4)$$

Where *P* is pressure in kPa and *t* is temperature, ^{o}C

$$\frac{CO_2}{4.026 * 10^{-3} * P + 5.780 * 10^{-5} * P^2} \qquad (2.5)$$

Where CO_2 concentration is measured in ppm and *P* is pressure in kPa

High oleic sunflower seeds (PR65H22, obtained in October 2015 from Kitzingen, Germany) were then conditioned to water activities (a_W) of 0.4 and 0.8 in a climate chamber (Typ C, CTS GmbH, Hechingen, Germany). Three repetitions of 3.50 ± 0.05 kg seeds per a_W-group were filled in the tightly sealed steel pipes; three control samples per a_W-group of the same mass were filled in unsealed sheet steel hob bocks. All samples were analyzed for their dry matter, oil content, oil-extractability and oil quality (acid value, FFA, peroxide value, iodine value, saponification value and fatty acid composition).

Figure 2.2 Conditioning of HO sunflower seeds in CTS climate chamber

3. Achievements made / Results

3.1 Maize Shelling and Millet Processing (UPS No.3)

3.1.1 Establishment of Business Oriented Farmers Group

In a two days workshop that was conducted in each village involving the 150 HHs and beyond, UPS groups of 22, 29, 12 and 19 HHs were formed towards the end of September 2014 in Ilakala, Changarawe, Ilolo, and Idifu, respectively. Decision to join the group was voluntarily achieved by the individual HHs themselves. One of the criteria for joining the group was the ability to contribute to the purchase of the equipment and construction of a processing unit.

Note: The small number of HHs in groups was allowed expecting that the size of the group will expand in future.

3.1.2 Feasibility Study

From a detailed feasibility study the decision to invest was made as summarized in Table 3.1.

Table 3. 1 Investment and Profitability Analysis on Processing Machines

SN.	Type of Machine	Case Study Site (village)	Capital Investment (T. Shs)	RoI	RoC
1.	Maize sheller	Ilakala	5,100,000	1.69	4.3
		Changarawe	5,200,000	1.47	5.53
2.	Millet thresher	Ilolo	3,600,000	1.22	1.93
		Idifu	3,650,000	1.44	1.72

With positive RoI and RoC it it was found worth investing on maize shelling and millet threshing in the respective CSS.

3.1.3 Ordering and Purchase of Machinery

- It was proved difficult for the UPSs groups to raise funds from their own sources to procure the machines.

- Based on positive business viability report, the UPS groups were credited with cash from the Innovation Fund (managed by MVIWATA) to acquire the machines.
- With the guidance of MVIWATA a few UPS group members visited various manufacturers and suppliers in Morogoro and Dar es Salaam to make their own choice on purchase on behalf of the group.
- Eventually, maize shellers were procured in Morogoro while millet threshers were procured in Dar es Salaam.

3.1.4 Training of Farmers on Operations and Management

- **Ilakala and Changarawe:** On the day of delivery the supplier conducted a quick training on use and maintenance of maize shellers. However, there is a need to make a simple operations manual that farmers can follow for service and routine maintenance.
- **Ilolo and Idifu:** Training of farmers was not done because there was not sufficient material to process. Moreover, the threshers had some technical problems with the pulleys which were supposed to be rectified. These problems have been solved by MVIWATA and training on threshing will be conducted towards the coming harvesting season.

3.1.5 Use of the Machines by the UPS Groups

Due to problems mentioned in section 3.1.4 above the millet threshers have not been used. In Ilakala the maize sheller could not be put into full use because there were not economic quantities of maize to be shelled. In Changarawe village the maize sheller was used although the machine was supplied towards the end of the normal shelling period.

3.1.6 Group Performance Monitoring

3.1.6.1 Maize shelling

(a) Group management issues

Ilakala CSS

From the monitoring that was conducted on 10 – 15th December 2015, the group had 8 (4 males and 4 females) out of 21 members who were initially recorded. The current membership is distributed as follows: three males and one female, two males, and 1 male

from Shuleni, miembeni, and Kempu sub-villages, respectively. Reasons for the drop out of membership are not known although the group has an established leadership. However, ability to contribute to purchase and operate the maize sheller might have caused this problem but this is yet to be substantiated. Since its inception the group was supposed to meet once every month but so far it has met only six times out of the estimated 12 meetings. When they meet they discuss four main issues, which are contribution of fees and shares, construction of machine shed, construction of constitution, and group registration. The group members keep records especially on finances, which is done by the accountant. The group has constitution and is striving for registration. However, the group has no work plan due to inability to prepare it.

Decision making was done by both men and women but there was a challenge of group management, which the project must address. These challenges are poor participation of members on internal meetings, poor geographical location of group members, delay in contribution, and poor leadership.

Changarawe CSS

From the monitoring session that was conducted on 10-15th December 2015 the group had 16 (12M males and 4 females) out of 27 members who were initially recorded. The current membership is distributed as follows: six males and one female, four males and one female, two males, and two females from Estate, Madizini, Iyanda and PWD/Dinima sub-villages, respectively. Reasons for the drop out of membership is so far not known but ability to contribute to purchase and operate the maize sheller might have caused it but this is yet to be substantiated. However, the group's leadership is still there and performing well. Since its inception the group was supposed to meet once every month and so far it has met 10 times out of the 12 meetings that were envisaged. When they meet they discuss four main issues, which are contribution of fees and shares, construction of machine shed, construction of constitution, and group registration. The group members keep records especially on finances, which is done by the accountant. The group has constitution and is striving for registration. However, the group has no work plan due to inability to prepare it.

Decision making is done by both men and women but there is a challenge of group management, which the project must address. These challenges are poor participation of members on internal meetings, poor geographical location of group members, delay in contribution and poor leadership.

(b) Technical and socioeconomic performance

Ilakala CSS

Due to lack of economic lot size to process there was not sufficient data on technical and social-economic performance. However, they made a trial run at the beginning of August 2015 and realized that they will need some mechanism to move the maize sheller from one location to another. As full use of the maize sheller is expected in the next harvesting season next year there is need to train the UPS group on routine service and maintenance so as to be able to pay the debt to the project which assisted them to acquire the machine through the Innovation Fund that is managed by MVIWATA.

Changarawe CSS

Although the maize sheller was received late into the harvesting season it was used to perform the maize shelling operation in a number of households with a number of observations made on both socioeconomic and technical performances, as shown:

Socioeconomic performance

- From its very nature the maize sheller is mainly operated by men; women participated in rather lighter activities of its operation, for example collection of cobs and shelled grain.
- The machine is located in one place but during the season it was moved from one place to another to offer shelling services.

- Although the machine was supplied late into the season there were still a lot of maize cobs requiring shelling. However, the exact amount could not be estimated.
- Due to the challenge of translocation to provide the shelling service it was difficult to estimate the actual processing time per week. As it is expected to start shelling early in the next season more data will be gathered. However, a figure of 70 bags per hour was estimated.
- The maize shelling activity was beneficial to the group and to its members as well as to the community. For the group it generated income and simplified the shelling operation whereas for individual group members it was a source of income as laborers and reduced time for shelling. For the entire community it reduced time for shelling and reduced losses compared to hand shelling. These benefits will be extended beyond the village in the 2015/2016 harvesting season.
- The machine is operated by seven males from the group sometimes women are also involved in light activities like clearing of shelled cobs from the machine surroundings. In the actual operations at least six people are involved, two on top and four on the ground.
- Maize shelling is performed between July and August. In the lowest availability 12 bags per day can be shelled whereas in the highest availability 100 bags per day can be shelled. These capacities are higher than 2 bags per day estimated for manual shelling and 10 bags per day when shelling is done on a slated platform at a fully fledged speed of these operations.
- The group can process in four days per week during peak seasons for the whole month and one day per week in the lowest season. However, direct extrapolation of this data to obtain the actual maize shelled per day may not be realistic; more data collection is required.
- The group charges 3,000 Tanzanian shillings for a bag of grains during the highest season and 2,000 during the lowest season; out of this 1,000 goes to personnel who operated the maize sheller.
- Assuming that there is no translocation of the machine, cost of operation is mainly on fuel. Three (3) litres of diesel is sufficient to shell 100 bags of cobs at high speed

operation and if there is no idling. Calculations on human labor are based on the amount of grain shelled (i.e., 1,000 shillings per bag).

- Analysis on actual returns to the group per week and the rate of loan repayment has not been completed. The RoC and RoI data used to convince farmers to venture into this business may not match with the practice.
- The grouped has paid back only 600,000 shillings but this is yet to be redistributed per week; the exercise will be done in the next season.
- The maize shelling service was rendered to everybody irrespective of gender for as long as there was economic lot size to shell. However, a minimum of 50 bags of maize cobs per station was recommended unless otherwise there was a preferntial treatment.
- Four (4) male farmers and two (2) female farmers were served. It took 1 farmer per day and 2 farmers per day during peak operations for female and male customers, respectively.
- It took about 2-2.5 hours to move the machine manually in a distance of 2-3 km. However, this depended on the road or path through which the maize sheller was transported.
- The maize sheller was manually moved when need for a service arose. This required 10 people on a smooth road and 15 people on rough road/paths. The cost is about 1,900 per person. Some members of the UPS group proposed 40,000 shillings for transportation of the machine (taking it to the site and back) for one trip. An alternative was to hire a tractor each time the machine is moved was an afterthought. However, these options are yet to be agreed upon.
- Compared with quality of manually shelled maize grain the quality of grain shelled by using the machine visually looked good and did not necessarily required additional winnowing.

Technical performance

- Exact data on maize harvested could not be accounted for; reliance on village statistics will be used. However, a total of 576 bags of grains were obtained (about 57600 kg).
- The amount of fuel used was 63 litres of diesel, at an average cost of 2000 shillings per litre (amounting to 126,000 shillings); additional cost is on transportation, and in this season 15,000 shillings were spent.
- Shatter losses were estimated less than 1% with grain moisture content being more than 10% w/w, whereas the amount that was lost with the cobs was estimated at 1.4%.
- With regard to the shelling quality the grain produced was good. However, more investigation is required.
- Some challenges were observed in this maize shelling technology, the main one being on dust emission followed by transportation. The group is considering purchasing dust masks to curb dust emission. With regard to transportation there is no firm solution that has been reached although thinking of locating the machine at one station expecting customers to follow or search for tractor transportation have been given a thought. The project scientists will also consider coming up with a design for improvising the machine with a single rear tyre with a universal joint. From the researchers point of view the machine is also relatively tall and difficult for women and the old to operate safely and comfortably.
- During the last season operations two breakdowns occurred. These were on the roller bearing and the welded parts, which caused the process to delay for five days while searching for the bearing in Morogoro town and replacement.
- It took one hour to fix the parts where one of the group member also participated; the overall repair cost plus labor was about 50,000 shillings.

(c) Gender issues

UPS participation and Control

- The maize sheller is operated by men; women provide other support such as fetching water for cooling the machine. However, there is no gender segregation on training and meetings.
- The UPS has influenced the good relationship in the society since through the UPS group members chance of knowing each other and working together.
- Male, female and youth participated in the UPS due to the benefits that were expected, for instance knowledge gain, improvement in the living standard and employment in running the maize sheller.
- With regard to UPS income and expenditure no difference in decision making between men and women was identified.
- With regard to the affordability there was a difference between men and women on investments whereby men were more financially capable.

Changing Gender Roles and Relations

- During and after implementation operating the maize sheller turned to be a men's activity.
- Workload has increased to men only as they are now responsible for the machine operation.

(d) Status of implementation

- Implementation of this UPS started in August 2015
- The UPS group provides the shelling service to the members and non-members within the same village. However, the group members have not been officially trained on management and maintenance of the machine. From the nature of this job only the seven men in the group operate the machine. Transportation of the machine from one area to another is done by pushing by all.
- All the members met the requirement for the UPS implementation and nobody has moved from this UPS to another.

- There was no challenge communicated to the researchers from the farmers except the issue of transportation.
- Time management seems to be among the challenges although it was not mentioned.
- The group failed to contribute funds to buy the machine, which led to seeking for a credit from MVIWATA under the auspices of the "Innovation Fund".

(e) Economic analysis

From the last season's data the following prevail:
Although the average selling price was 3,000 per bag of grain, the actual price ranged from 2,000 to 3,000. In the last season 43, 94, and 439 bags of grain were obtained at the shelling price of 2,000; 235,000; and 3,000 shillings, respectively. This amounted to gross return of 1,638,000 shillings. The expenditure was distributed as follows: 576,000 as shelling labor (1,000 per bag), 15,000 on transport, 126,000 on fuel (63 liters of diesel), 50,000 on repair and maintenance, 99,000 on construction of machine shed, and 160,000 to cover meeting allowances, which sum up to 1,026,000. Therefore, the gross margin was 612,000. The group has spent 600,000 to service the credit that was provided by MVIWATA.

3.1.6.2 Millet threshing

(a) Group management issues

Idifu CSS

From the monitoring that was conducted in December 2015 a new member had joined the group to make a total of 13 members for the millet threshing group. The groups had maintained its leadership, which is comprised of Chairperson, Secretary and Treasurer.
Just as for many other groups, this group does not have a tendency of meeting regularly unless there is a special issue to be addressed. Since August 2015 the group met three times and mainly discussed on new rates of share and introducing a new member to the group. The sunflower processing group met 15 times (every Saturday) and dwelt more on activities

regarding construction of a machine house. In the previous meetings, however, the group's meeting agenda were mainly on development of the constitution, making of the group bylaws and discussion on implementation of group activities. Note that there were no significant activities conducted after procurement of the machine as very little millet was harvested and also the machines had technical problems.

The group has a constitution which favors everybody in the group. However, the group is not yet registered with the District Council and does not have a Work Plan. Despite these setbacks decision making in the group is done in a participatory way involving members of the group during the meetings.

Ilolo CSS

Monitoring done at December 2015 has shown that a new member had joined the group to make a total of 14 members. The group has also maintained its leadership, which is comprised of Chairperson, Secretary and Treasure. However, the group does not have a tendency of meeting regularly unless there is a special issue to be addressed and since August 2015 the group met five times, the main agenda being members' contribution for the machine. During other meetings in the past the group discussed development of the constitution, making of the group bylaws and implementation of group activities. Note that there were no significant activities conducted after procurement of the machine as very little millet was harvested and also the machines had technical problems.

Just as in the case of Idifu CSS the group has a constitution which favors everybody in the group. However, the group is not yet registered with the District Council and does not have a Work Plan. Despite these setbacks decision making in the group is done in a participatory way involving members of the group during the meetings.

(b) Technical and socio-economic performance

It has to be noted that millet threshing in both Idifu and Ilolo has not been done. This is partly because the machines were delivered late into the harvesting season but above all there could not be economic lot size of millet worth threshing by using a machine.

(c) Gender issues (in Idifu and Ilolo)

- Male members in the group have shown to have higher affordability than female members; the nature of this UPS requires contributions in which some of the women did not afford. Most of the youths ran away from the project because they didn't see if it was important for them.
- There were no change of roles between men and women observed

(d) Status of implementation (in Idifu and Ilolo)

Implementation has not yet started. However, demonstration was done by the expert but implementation was not yet done by farmers; they are waiting for the season to start implementation.

(e) Economic analysis

This will be done after the end of use of the threshing machines next season in both Idifu and Ilolo villages.

3.2 Sunflower Oil Processing

3.2.1 Sunflower Oil Processing at UHOH

Fig. 3.2 presents the response surface of oil recovery efficiency and production of clarified oil with respect to different setups of rotational speed and nozzle diameter. The system was fitted into full-quadratic model and exhibited a good agreement. Clarified oil production ranged from 0.48 to 1.06 kg/h and was highly dependent on rotational speed of the screw. Oil recovery efficiency varied between 27.25 and 89.53%. The highest efficiency and lowest

oil production was achieved at nozzle diameter of 4mm and rotational speed of 18rpm. Smaller nozzle diameter and lower speed lead to higher efficiency. However, high intensity of blockage was observed at this setup. On the other hand, lower speed also resulted in lower oil production, which was not recommended in oil processing.

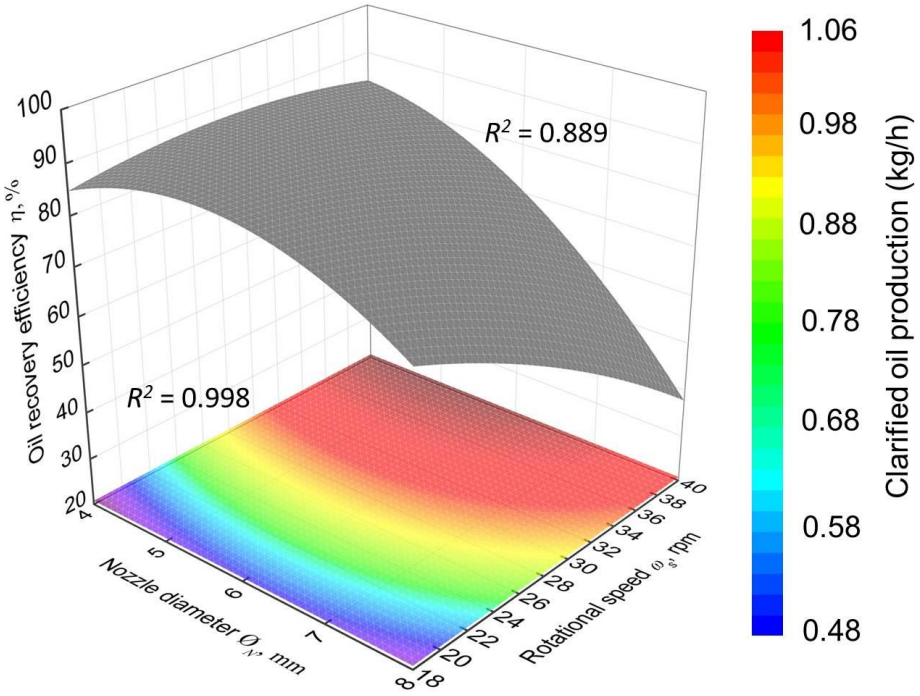

Figure 3.2 Oil recovery efficiency with respect to different rotational speeds and nozzle diameters

Fig. 3.2 shows the correlation of specific energy input and throughput where it was fitted well in an exponential model. The resulting throughput ranged from 1.15 to 2.91 kg/h. The lowest and highest specific energy input per one kg of raw material, crude oil and clarified oil were 0.16 and 0.37 kWh/kg, 0.45 and 0.79 kWh/kg, and 0.49 to 1.02 kWh/kg, respectively. The smallest nozzle and lowest speed lead to the highest specific energy input due to low mass flow rate. The yield of crude oil and clarified oil ranged from 0.53 to 1.15 kg/h, and 0.43 to 1.05 kg/h, respectively.

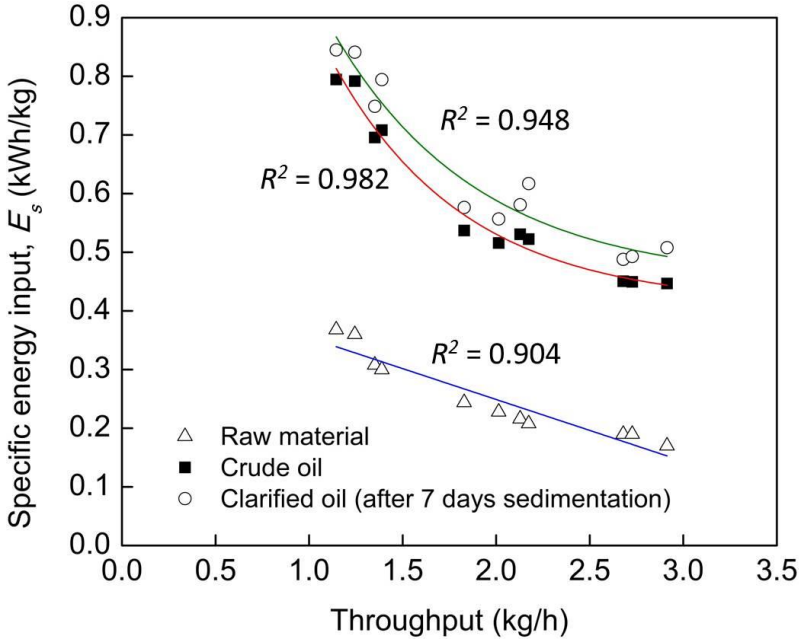

Figure 3.2 Specific energy input with regards to throughput

From Table. 3.2 high temperatures was corresponded to small nozzle and low screw speed. The highest press head, press cylinder, oil and press cake temperature was noted at 77.35, 55.32, 41.69 and 73.22 °C, respectively.

Table 3.2 4 Average Temperature under different Rotational Speeds and Nozzle Diameters

Setup		Temperature (°C)			
Nozzle (mm)	Rotational speed (rpm)	Press head	Press cylinder	Oil	Press cake
4	18	72.59	55.32	40.88	71.34
	28	74.87	54.86	41.69	71.86
	40	77.35	54.84	39.90	73.22
5	18	72.80	55.08	38.16	61.91
	28	68.38	52.95	39.65	64.74
	40	70.01	52.04	40.32	66.39
7	18	67.16	48.29	37.11	55.58
	28	62.12	49.48	36.54	55.13
	40	63.56	50.76	40.26	63.06
8	18	66.28	49.55	37.43	53.47
	28	67.52	46.99	38.77	53.46
	40	45.40	33.87	29.86	41.87

Minimum and maximum attained torque was 11.97 and 24.9 Nm, while power varied from 0.42 to 0.52 kW. Rotational speed played a major role in affecting the torque (Table 3.3).

Table 3.2.1 Power and torque under different rotational speeds and nozzle diameters

Nozzle (mm)	Rotationalspeed (rpm)	Power (kW)	Torque (Nm)
4	18	0.42	23.41
	28	0.45	15.94
	40	0.51	12.72
5	18	0.45	24.90
	28	0.46	16.40
	40	0.52	12.95
7	18	0.42	23.12
	28	0.46	16.41
	40	0.50	12.38
8	18	0.42	23.15
	28	0.45	16.15
	40	0.44	10.97

3.2.2 Sunflower Oil Processing in Idifu CSS

3.2.2.1 Status of implementation

- Sunflower processing machine was supplied late after the harvesting season and has not been installed yet. Furthermore, there was very little sunflower that was harvested in the season, thus the possibility of using was not there.
- A processing house where the machine will be installed has already been built and machine installation will be done before the full onset of the next harvesting season; as a regulatory requirement a modest toilet facility will need to be built on the site.

3.2.2.2 Socioeconomic and technical performance

This report will be provided once the facility is made operational.

3.3 Optimized Storage

3.3.1 Results and discussion at UHOH

After 30 days of tightness test, 7 out of 9 containers were considered as sealed tightly (< 5 hPa variation). Containers No. 3 and No. 9 had to be excluded from the experiments since tightness could not be achieved. Figure 3.3 shows the tightness-test data for all 9 containers, clearly showing the direct falling of ambient conditions in container 3 and container 9. The difference in pressure between the other containers was caused by sealing at different days.

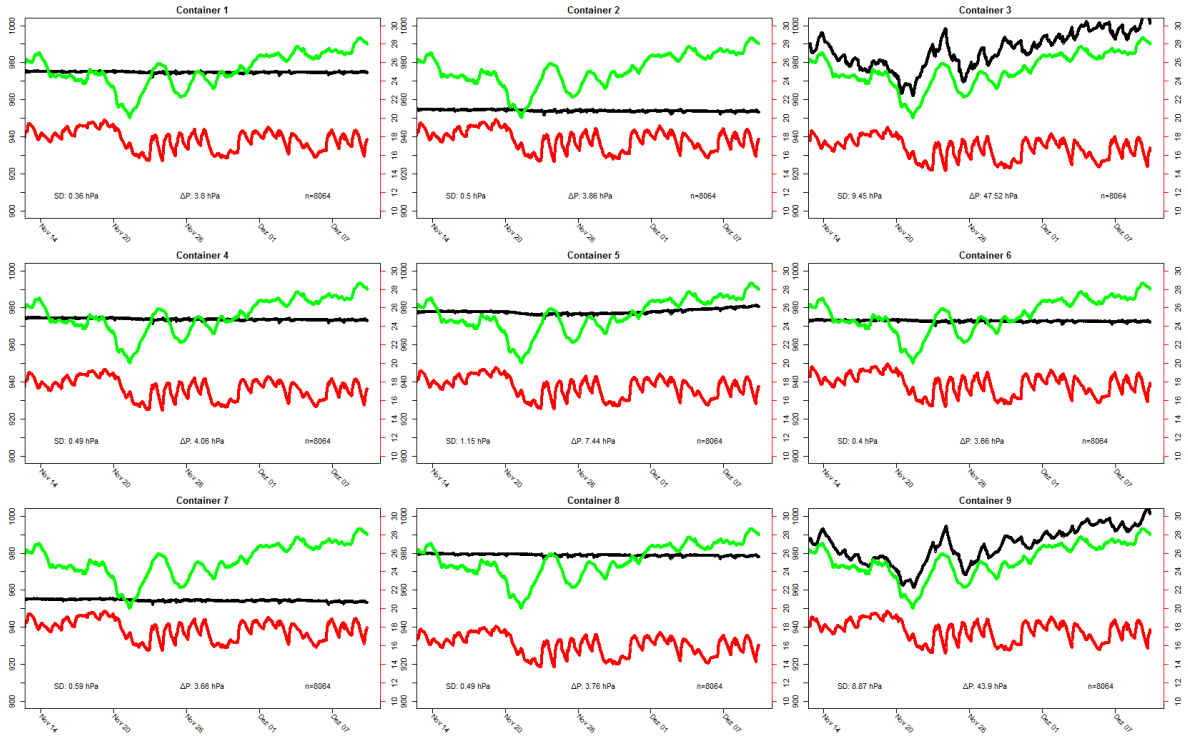

Figure 3.3 Tightness test: Red lines represent temperatures, green lines represent ambient pressure and black lines the corrected pressure for containers 1 to 9.

At the due time of this deliverable report, only the a_W 0.8 group had been stored long enough to show a proper trend. As the CO_2 content rises, the pressure is being reduced. The relative humidity equilibrates around the pre conditioned water activity. All the three repetitions (Figures 3.4, 3.5 and 3.6) show very similar development of the head space gas conditions.

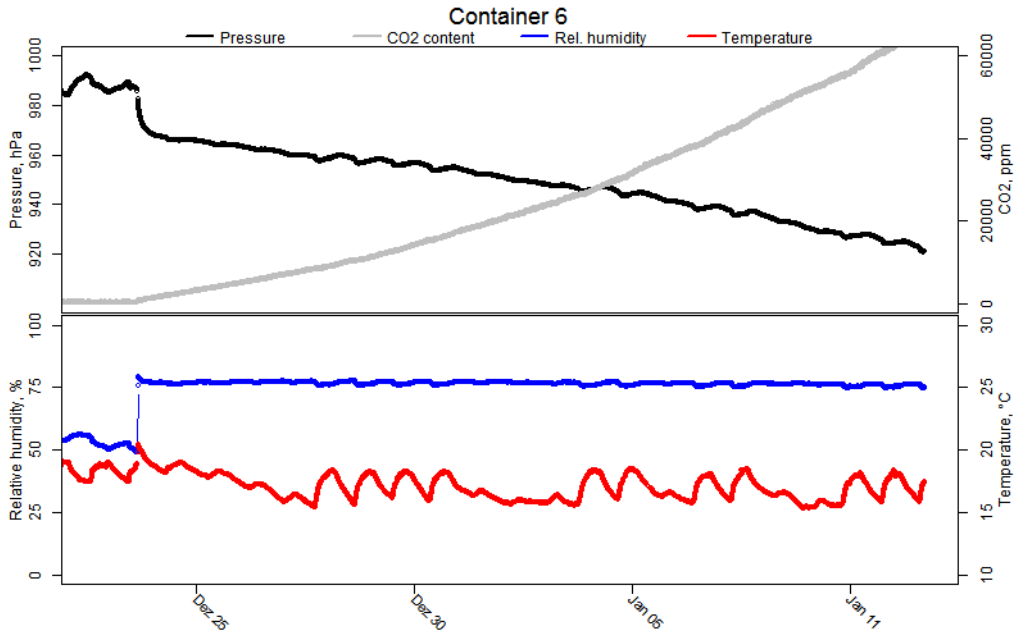

Figure 3.4. Head space gas conditions of repetition 1 for the a_W 0.8 group

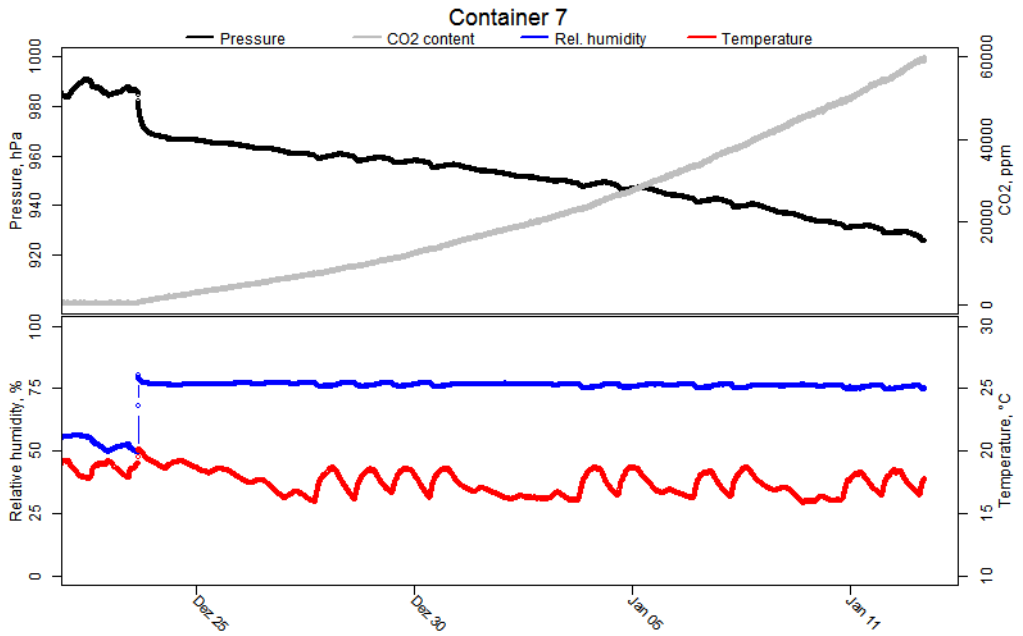

Figure 3.5 Head space gas conditions of repetition 2 for the aW 0.8 group

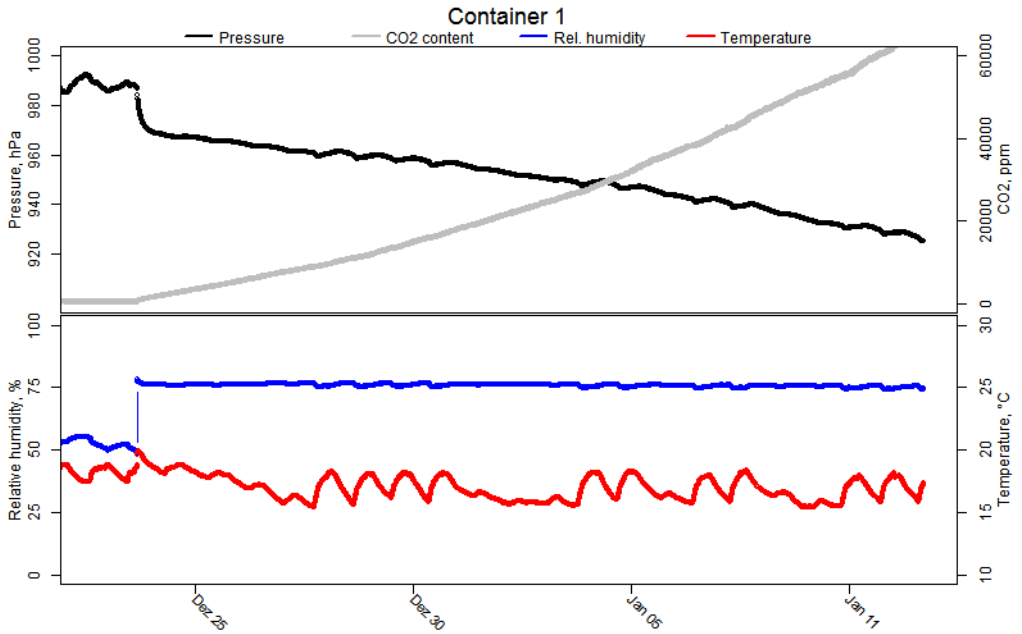

Figure 3.6 Head space gas conditions of repetition 3 for the aW 0.8 group

3.3.2 Storage in the Field in Tanzania

3.3.2.1 Technical and socio-economic performance

Ilakala CSS

- When the super bags were availed to the farmers, two were bought by members of the storage group and 10 by non-group members on cash. Seven were bought by non-group members on credit.
- One member of the group used traditional storage bag
- The members stored 3000 kg in both traditional and improved bags
- For the amount that was monitored the amount of stored grain in traditional bags was 300 kg.
- The storage period was from three months (July to September) through which the market price changed from 60,000 to 90,000 per bag of approximately 100 kg.
- During the storage period no pest damage occurred due to the presence of storage insecticide which was mixed with maize.

- Seventeen Super bags were bought by the group members and 121 by non-group members on cash. Only two bags were bought on credit by the group members.
- The number of members who used Super bags for the last season was three whereas 28 used the traditional storage bags.
- The amount of maize stored in traditional storage bags was 2300 kg while 1100 kg was stored in Super bags.
- For the amount stored in traditional bags (1100 kg) the envisaged storage period was between three and twelve months and the frequency of opening was once per week.
- In terms of quality of grain in the traditional bags majority of the farmers have reported the grain to be of good quality while a few farmers have reported damage of about 40%
- In terms of insect damage it was reported to be moderate probably because insecticides were used.
- As insect damage lead to losses some farmers have reported loss of about 3 tins per bag while others reported a loss of more than 30%. However, the period after which damage levels and eventual losses occurred could not be substantiated.
- The market price of maize at the beginning of the storage was 45,000 and at the end of storage it was 75,000 per bag. However, it is important to note that maize price fluctuates between years; in good years maize price gets low while in bad years maize price is high.
- For the amount stored in Super bags, inspection after 2.5 months has indicated that the grain quality was good; during this period the price changed from 50,000 to 75,000 per bag.

- From the good results that have been shown farmers will most likely need more of Super bags as well as the PICS. The main challenge is their high purchase price; some farmers are willing to buy them at a price not more than 4,000 shillings per bag.

3.3.2.2 Experimental results at farmers' premises in Changarawe village

These results will be available towards the end of May 2016.

4. Lessons Learned and Adaptation

4.1 Maize Shelling and Millet Threshing

Possession of a maize sheller is a great achievement in a place where a good harvest is realized. In addition to rendering the highly required service it can also make a good business to the owners. This is displayed in the high enthusiasm the farmers have despite the transportation problem caused by improper wheels design and its heavy weight. Provision with a wheel at the rear center might ease its transportation although cost may be prohibitive. The farmers might also need to be sensitized to keep the machines in a simple shed as they are not aware of the effects of weather hazards on machines.

From the problems observed on the maize shellers there is also a need to improvise easy transport mechanism for the millet threshers. Under the situation in Chamwino district use of oxen may be a better way of transport if proper harnessing mechanism is established.

4.2 Sunflower Oil Extraction

Proper selection of nozzle and rotational speed are vital for optimizing mechanical oil extraction of sunflower seeds with regards to oil production, extraction efficiency and energy requirement. Power and torque acquired from this study provides baseline knowledge in purchasing suitable motor to operate the mechanical screw press. On the other hand, temperature indicates good preservation of oil quality. Nozzle diameter of 4 mm and rotational speed of 40 rpm were recommended for the process with respect to oil recovery and energy required.

Optimization of mechanical oil extraction should take three elements such as oil production, extraction efficiency and energy requirement into consideration. The optimal process could be either based on maximizing oil production or specific energy input to produce one kg of oil. Based on this knowledge, up scaling the capacity of the machine or investigating the machine available in Tanzania using the similar method should be conducted in order to increase the oil yield while simultaneously maintain the oil quality.

4.3 Optimized Storage

Effective storage is obtained by increasing CO_2/O_2 ratio in storage containers. This depends on how tight the container is made, which is also directly related to high storage costs. This is evident from the field trial that was set in early November, 2015, with the containers that are expected to yield good results bearing high cost. This scenario will require economic analysis and will probably have policy implications.

5. Recommendations

In addition to the monitoring indicators the following aspects related to maize shelling, millet threshing and sunflower oil extraction in the field in Tanzania should be closely evaluated:

- The average moisture content at the beginning of the process
- The extent of grain damage by the machine (applicable to maize shelling and millet threshing only)
- The amount of chaff present in maize and millet grains.
- The effective and overall processing capacity in terms of kg per unit time and man-hours.
- Processing cost per unit weight of material obtained (grain or crude oil)

- Frequency and nature of breakdowns
- Profitability
- Preference to other methods and the prevailing reasons
- Factors limiting wide adoption