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Overcoming High Grain Moisture Content Prior to Storage in Poor Communities: The Case of Rungwe District, Tanzania

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Abstract - A study was conducted on a sample of 260 randomly selected farm households in Katumba ward, Rungwe district, Tanzania in 2009. Farm households were interviewed regarding maize grain moisture content at harvest, the effectiveness of maize drying methods in use the proportions of maize they normally lost to storage pests. The availability of biogas and its feasibility for maize drying prior to storage were investigated through studying the potential for the types of latrines used in the study area to accumulate biogas. Maize samples from a sub-sample of 130 farm households were collected at harvest and studied for moisture content using a moisture content tester. Another set of 130 maize samples were collected from the same sub-sample households after five months of maize grain storage and studied for insect infestation using the incubation method. Findings showed that farm households dried maize in the sun or in the roofs. Moisture content of maize at harvest was high, and the drying methods in use were inadequate to dry it fast and thoroughly, thus encouraging the infestation of maize by pests. Also, all of the farm households used latrines that have capacity to accumulate biogas. Thus it was concluded that the maize drying methods were not efficient, that the use of biogas for maize drying was feasible, and that the latter could be the most suitable grain drying technology for the climatic conditions in Rungwe district.

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I. Introduction

Grain moisture content is the percentage of water contained in the grain (Hagan, 2012). There are different opinions concerning specific moisture contents at which maize can be stored safely. However, the general understanding is that maize which is harvested at moisture content higher than 12.5 % would require the use of driers to reduce moisture content to the appropriate percentage before storage (CBH Group, 2006). High moisture content in maize does not only encourage the development of moulds and insect pests, but it could also lead to the effectiveness of insecticides on the maize being reduced (CBH Group, 2006).

The exchange of moisture between stored maize and the storage environment until equilibrium is reached is also known to occur (Metananda, 2001; Abba and Lovato, 1999). Thus, the exposure of dry maize to moist air would lead to the intake of more moisture from the air by the maize. The opposite can also take place until the air in the storage facilities is saturated. In view of this, in humid places also characterized with low temperatures, maize which has high moisture content at harvest would require appropriate technologies to ensure adequate dryness of the maize grain prior to and during storage. For preventing the growth of moulds in maize which is not dry enough at harvest, Reed *et al.* (2007) and Semple *et al.* (1989) recommended rapid drying or up to 48 hours, respectively, depending on drying conditions.

a) Climatic Conditions in Rungwe District

Rungwe district is characterized by rainfall throughout the year ranging from an average of 900 mm in the lowland zone to 2,700 mm in the highland zone and cool temperatures ranging from 18 - 25 ^{0}C (Administrator, 2010). Temperature in this district may drop to a minimum of 10 ^{0}C during the cold season. The indicated climatic conditions suggest that grain may have high moisture content at harvest, and it raises questions regarding the effectiveness of grain drying methods that farm households use in this district to dry maize prior to storage. Furthermore, temperatures between 20 - 40 ^{0}C are known to be most favourable for the development and growth of moulds (FAO, 1985). Likewise, the development and growth of most of insect pests occur at 10 - 40 ^{0}C. Thus temperatures in Rungwe district are within the range in which moulds and insect pests can easily develop in the presence of moisture. Consequently, high moisture content of maize gain at harvest and the indicated climatic conditions that characterize Rungwe district would encourage the deterioration of stored maize.

b) Subsistence farm households' socio-economic status

In 2011 Mboya reported that a farm household which consisted of five people in Katumba ward, Rungwe district, Tanzania lived on TS 319.20 or USD 0.21 per day, while those made up of six people lived on TS 267 or USD 0.17 per day (Mboya, 2011). In general, farm households in Rungwe district lived below the World Bank's poverty line, which is USD 1.25 per individual (Crocodila, 2010), and there is no imperical evidence to suggest that the status quo has changed. This reveals a great deal of low income and poverty in this area. It also suggests that expensive technologies are not convinient for the people in this area. This factor should be taken into consideration when introducing efficient grain drying technologies for improving subsistence farm households' storage output in this area. A suitable grain drying technology suitable for households with low income in a place characterized with wetness and prolonged rainfall such as Rungwe district should not only have the capacity to dry grain fast and thoroughly prior to storage, but it should also be affordable, durable and easy to manage.

c) The potential for bio - gas to be an effective source of fuel for subsistence farm households

Biogas is produced when organic matter decomposes anaerobically, that is in the absence of oxygen (Harris, 2010). It mainly consists of Methane (CH_4), and Carbon Dioxide (CO_2). However, depending on the source of its production, biogas may contain other gases such as Nitrogen (N_2), and Hydrogen Sulphide (H_2S) (Naskeo Environment, 2009). Moreover, biogas can be made from dead plants, sewage and from both animal and human waste products (Harris, 2010). It can be produced and used at household level, which is the case in many parts of Asia such as India and Nepal (Van Nes, 2006). Small scale units of biogas are said to be simple to build and operate (Harris, 2006). This makes the use of biogas cost effective, thus not only possible, but also beneficial and important for poor communities.

Pit latrines are known to be good sources of biogas (Buxton and Reed, 2010). Thus, in places where pit latrines are the norms, households could benefit in a number of ways, including: minimising fuel costs for domestic lighting and heating purpose and improving sanitation by burning it, thereby minimizing its accumulation in the environment. Most important for this paper is that farm households could harvest biogas for indoor rapid grain dying where climatic conditions make it difficult for grain to be dry enough for storage at harvest.

d) Hypotheses

1. \It was hypothesized that due to the climatic conditions in Rungwe district, farm households in this district could be facing difficulties in ensuring that maize is thoroughly dried prior to storage, which could encourage the development of pests in stored maize and to maize losses during storage.
2. It was also hypothesized that the use of biogas for grain drying in Rungwe district is feasible.

This study was conducted in order to test these hypotheses. Specifically, this study was conducted for the following objectives:

1. To investigate moisture content of maize at harvest and its association with maize loss to insect pests in Rungwe district, Tanzania,
2. To investigate the suitability of methods used for drying maize which is not dry enough at harvest and the length of time it takes for it to be dry enough for storage in Rungwe district, and
3. To explore the availability of sources of biogas and suggest the use of biogas for grain drying prior to storage in Rungwe district and other places with similar climatic conditions.

Due to financial constraints, coupled with the understanding that agricultural practices and climatic conditions in Rungwe district are the same, only one of the wards in this district, namely, Katumba ward was subjected to this investigation.

II. Materials and Methods

A sample of 260 farm households was randomly selected in Katumba ward using the procedure described by Mboya *et al.* (2011). A survey was administered to the sample households using structured face to face interviews and a guiding questionnaire to investigate their views on maize grain moisture content at harvest and to explore maize drying methods they use to dry maize when maize is not dry enough for storage at harvest. The questionnaire was also used to investigate the estimated amounts of maize that farm households harvested annually, the amounts of maize they use for consumption and non-consumption purposes and the proportions of maize they normally lose to pests. Data on the availability of biogas in the research area and the feasibility of using it for maize drying were also collected using the same questionnaire. Farm households were interviewed with respect to the types of toilets they have. This was done in order to investigate the capacity of the toilets used in the study area to accumulate biogas and to determine the possibility of using biogas for maize drying. In addition, 130 maize samples randomly collected at harvest from 130 farm households using the procedure described by Mboya (2011) were tested for grain moisture content to underpin the seriousness of high maize grain moisture content. After five months of maize storage, another set of 130 maize samples were collected from the same households and were tested for insect infestation using the incubation method described by Mboya (2011). The procedure involved randomly collecting 120 maize kernels from each maize sample incubating them in glass jars at room temperatures at 25 - 30 ^{0}C and 75 - 80 % relative humidity to allow growth of insect pests if any. The incubated maize kernels were observed for 90 days and insects that came out of the maize kernels were recorded. A larger proportion of the farm households grew improved varieties of maize, thus 66.9 % of the maize samples of the local varieties and 33.1 % of the improved varieties were studied. Furthermore, 67.7 % of the maize samples were collected from farm households that used the roof storage facilities to dry maize, and 32.3 % were collected from farm households that dried maize in the sun. A greater proportion of the sample household dried maize in the roof storage facilities as compared to those who dried maize in the sun, hence the variation between the proportions of maize samples collected. Moisture content in the maize grain was established using a moisture content tester.

III. Statistical Analyses

Data was analyzed using the Statistical Programme for Social Sciences (SPSS) version 15 by Pallant (2005). The amounts of maize that farm households lost to infestations and infections were obtained by subtracting the amount that farm households used for consumption and non-consumption purposes from the total estimated amount of maize that farm households harvested per year. T-tests were used to compare the average moisture content in the improved maize varieties and landraces at harvest and to compare the mean insect population density in maize dried in the sun and maize dried in the roof storage facilities. Pearson correlation was used to explore the association between grain moisture content at harvest and insect population density during storage, and also with the proportion of maize lost to pests.

IV. Results

a) Methods that farm households used to dry maize which was not dry enough at harvest and the length of time it took for it to dry

An estimate of 88 % of the farm households would put all of the maize in the roof storage facilities (Figure 1) as a means of drying and storing it at the same time, and about 12 % of them either dried maize exclusively in the sun or used both of the indicated methods. All of the farm households indicated that it took them more than two weeks to dry maize when it is not dry enough at harvest. On average, after five months of storage maize which was dried in the sun had 81 insect pest per 120 maize kernels and sun dried maize had 78 insect pests per 120 maize kernels. Standard deviation was 50.0 and 54.0, respectively. No statistically significant difference between the mean insect population density between maize dried in the sun and maize dried in the roof storage facilities was observed (Table 4). This implies that maize dried using the indicated drying methods was equally infested by insect pests and equally lost to pests.

b) Quantities of maize lost to pests

Farm households harvested an average of 0.88 tonnes of maize annually ranging from 0.1 - 6.33 tonnes per farm households. Farm households that participated in this study normally harvested an estimated total of 235 tonnes annualy, during a good year they harvested an estimate of 277 tonnes and during a bad year they harvested an estimate of 172 tonnes. Standard deviations for the indicated quantities of maize harvests were 6.912, 7.532 and 5.915, respectively. The mean for the total amount of maize that the 260 farm households harvested annually was 228 tonnes, Therefore, since there were 2649 farm households in the studied ward, it was estimated that a total amount of 2323 tonnes of maize were harvested in the ward per annum. Farm households used an estimate of 25 % of the harvested maize annually for consumption purposes, ranging from 0.08 - 0.4 tonnes with 0.2 tonnes mean per household, and used 40.4 % of the harvested maize for non-consumption purposes such as marketing for raising income. In general, farm households used about 65 % of maize for consumption and non-consumption purposes. The amount of maize that each farm household lost to pests ranged from 0 - 0.1 tonnes with $\pm$ 0.3 tonnes mean. The total amount of maize that the subsistence farm households lost to infestations per annum was estimated to be 78.8 tonnes. This amounts to an estimate of 800 tonnes of maize, equivalent to 34.4 % of the total harvests. However, an individual farm household could lose up to 80% of the maize harvest.

c) Maize grain moisture content at harvest

Moisture content in the tested maize samples ranged from 13 - 22.6 %, with 16.78% mean and 2.68 standard deviation. A total of 97.7 % maize samples had grain moisture content greater than 13 % (Table 1), and only 2.3 % had 13 % moisture content, indicating that for the majority of farm households maize had high grain moisture content at harvest. T-test results for comparing the average moisture content between the improved varieties of maize and landraces showed no significant difference between the two (Table 2), implying that the failure for maize to be dry enough for storage at harvest characteristized both landraces and improved variaies of maize alike. These findings corroborates with farm households' perspectives regarding maize grain moisture content at harvest. All of them indicated that maize was often not dry enough at the time of harvest.

Furthermore, the maize samples were found to be infested by either weevils only, or moths only, or both weevils and moths. The insect population density in the maize samples ranged from 0 - 52 per 120 maize kernels, the mean was 2.23 and standard deviation was 6.731. Pearson correlation revealed a positive association ($p = 0.316$, significant at $\alpha < 0.01$) between maize grain moisture content at harvest and insect pests population density during storage (Table 3). This implies that insect population during storage increased with increase in moisture content at harvest. This association indicated 10 % of shared variance. A weak, positive association ($p = 0.269$, significant at $\alpha = 0.01$) was also observed between grain moisture content at

Global Journal of Science Frontier Research (D) Volume XIII Issue IV Version I Year 2013

harvest and the proportion of maize lost to pests, indicating 7.2 % of shared variance. A strong, positive association (p = 0.685, significant at α < 0.01) was observed between insect population density during storage, and the proportion of maize lost to pests indicating 46.9 % of shared variance (Table 3). This implies that insect pests played a significant role in maize loss during storage. In addition, an average of 37.5 % of the maize dried in the roof storage facilities was lost to pests as opposed to an average of 35.5 % of the maize dried in the sun also lost to pest.

Standard deviations for the proportions of maize lost to pests were 19.99 and 17.99, respectively. The independent sample T-test revealed the absence of a significant mean difference between the proportions of maize lost to pests for the maize dried using each of the indicated drying methods (Table 4). This means that a high proportion of maize dried using the two drying methods was equally lost to pests during storage.

d) Types of latrines used

An estimate of 95 5 % of farm households were using pit latrines, and only 5 % had modern toilet facilities. However, there is no central sewage system in the whole of Rungwe district. Thus, farm households who had modern toilets built deep pits into which they flashed the toilets. There is no evidence to suggest that a central sewage system has been established in this district. This implies that all of the farm households in Rungwe district have toilet facilities that have capacity to accumulate biogas, and it suggests that the use bio-gas for maize drying could be made possible if farm households were empowered with the technology for harvesting and using it.

V. Discussion

a) The implications of high maize grain moisture content at harvest

The high moisture content in grain at harvest for both landraces and improved varieties of maize could suggest that the season during which maize is harvested is inappropriate, and that more research is required to identify the most suitable maize planting and harvest season in this area. However, the heavy rainfall that characterizes Rungwe district almost throughout the year, coupled with the poor capacity of the maize drying methods in use also suggest that a fast, most effective in- door maize drying technology for combating high grain moisture content at harvest in this place is required.

The fact that it took the farm households more than two weeks to dry maize indicates that the grain moisture content was too high for the maize drying methods used to effectively dry it within the shortest recommended time of up to 48 hours. Consequently, this would encourage the development and multiplication of insect pests in stored maize, and maize loss due to the insect pests (Williams, 2004), which findings in this study support. Moist grain is known to perspire faster than dry grain leading to increase in temperature and moisture content of the grain through condensation (Williams, 2004), which creates favorable conditions for pests especially insect pests, moulds and other micro-organisms. The contaminations associated with the pests would render the farm households vulnerable to illnesses. In this study, moisture content at harvest may have not been a strong determinant of the proportions of maize that farm households lost to pests, but it encouraged the multiplication of insect pests in maize during storage, which further led to maize losses. This further implies that food insecurity and vulnerability of farm households are inevitable due to the reduction in the amounts of maize as a result of insect pests feeding on the maize and due to the contaminations associated with insect pests. Thus an efficient alternative method for drying maize rapidly prior to storage is a basic need for the farm households in this ward.

However, the poor status of farm households suggests that an alternative technology for maize drying should be affordable to the farm households. The use of biogas from pit latrines for drying maize could offer farm households a fast and effective alternative in-door maize dying technology suitable not only for the weather, but also the socio-economic status of the farm households. Therefore, introducing a technology for harvesting biogas from pit latrines and encouraging farmers to build biogas driers using materials that are available to them is necessary for changing the status quo in relation to maize drying prior to storage in Rungwe district.

b) The implications of the quantities of maize lost to pests by farm households

The estimated 800 tonnes of maize lost to pests in Katumba ward per annum is quite huge especially considering the fact that the farm households are only subsistence farmers who produced an annual average of 877 kg of maize each. The estimate of 34.4 % of maize that the farm households lost to the infestations was within the estimated amount of maize that is lost to pests in Tanzania. Up to 34 % of on-farm maize loss due to insect pests has been reported to occur within three months of storage in the country (CIMMYT and Dubin, 2010). Considering that maize is the most preferred food crop in Rungwe district, the percentage of maize lost to insect pests reduces not only the amount of food, but also the length of time during which food can be available to farm households, thus, increasing their vulnerability. Ultimately, this scenario impacts negatively on the farm household's food security. The elimination of all conditions that encourage insect infestation, such as high grain moisture content, could contribute to improving the status quo.

c) Conclusion and Recommendations

This paper has shown that moisture content of maize grain at harvest in Rungwe district is high, that maize drying methods used by household farm households are inadequate in combating the high maize grain moisture content. Consequently, the indicated factors encourage the development and multiplication of insect pests in stored maize, rendering the quality of stored maize poor, and reducing the amounts of maize that could otherwise be available to the farm households. This paper has also shown that the use of biogas for maize drying prior to storage in Rungwe district is feasible. Thus introducing biogas driers made from materials that are available to farm households, and the use of bio-gas from pit latrines for maize drying are highly recommended.

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Table 1 : Maize grain moisture content in at harvest in katumba ward in 2009

Grain Moistwe content	Percent of farm households
13	2.3
13.1 – 13.5	6.9
13.6 – 14.5	10.0
14.6 – 15.5	26.2
15.6 - 17	18.5
17.1 - 20	21.5
>20	14.6

Table 2 : Comparing grain mean moisture content between the improved maize varieties and landraces

		t-test for Equality of Means					
		t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Average moisture content at harvest	Equal variances assumed	1.856	0.066	0.9195	0.4954	-0.0607	1.8997
	Equal variances not assumed	1.844	0.069	0.9195	0.4985	-0.0722	1.9111

Table 3 : Exploring the association between grain moisture content at harvest, insect population density during storage and the proportion of maize lost to pests in Katumba ward

Correlated variables	Pearson correlation	Significant level (2-tailed)
Grain moisture content at harvest and grain insect population density during storage	0.316**	0.000
Insect population density during storage and the proportion of maize lost to pests	0.269**	0.002
Proportion of maize lost to pests and insect population density during storage	0.685**	0.000

** = Correlation is significant at the 0.01 level

Table 4 : A comparison of the mean insect population and the proportion of maize lost to pest between maize dried in the sun and maize dried in the roof storage facilities in Kautmba ward

		t-test for Equality of Means					
		t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95%Confidence Interval of the Difference	
						Lower	Upper
Proportion lost to pests	Equalvariancesassu-med	0.547	0.585	1.9876	3.6329	5.2008	9.1759
	Equal variances not assumed	0.568	0.571	1.9876	3.4993	4.9655	8.9406
Insect population density	Equal variances assumed	0.301	0.764	2.900	9.629	-16.153	21.954
	Equal variances not assumed	0.293	0.770	2.900	9.902	-16.823	22.624

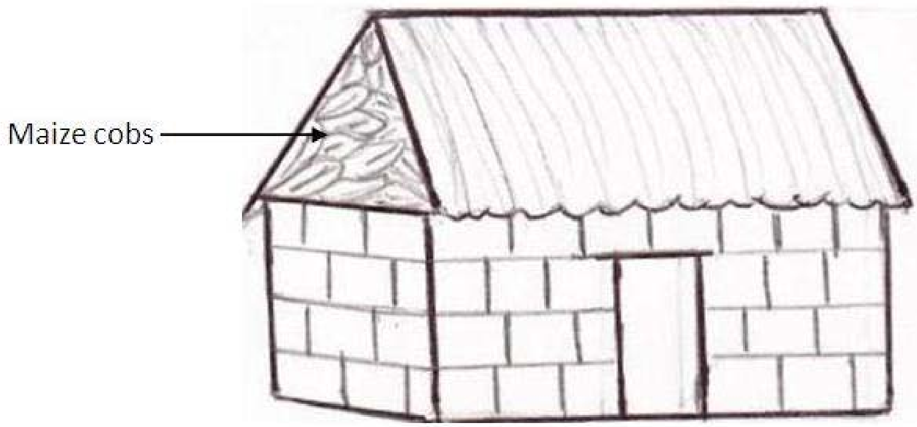

Figure 1 : Roof storage facility also used for maize drying in Rungwe distirct Tanzania