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The Characteristics, Importance and Usage of the Roof Storage Method for Maize Storage in Rungwe District, Tanzania

Rose Mboya

University of Zululand, Faculty of Science and Agriculture, Department of Consumer Sciences, Private Bag X1001, KwaDlangezwa, South Africa
Telephone: +2735902 4181
E-mail: MboyaR@unizulu.ac.za, mujilarose@yahoo.com

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ABSTRACT The importance and characteristics of the roof storage method for maize storage in Rungwe district, Tanzanian were studied using 260 randomly selected farm households. Data regarding the perceived importance and efficiency of the roof storage method was collected using the matrix for scoring and ranking tool and interviews. To enable probing, both face-to-face semi-structured and structured interviews were used. Literature was also used as a source of secondary data. It was found that farm households' perceptions of the roof storage method, the materials used to construct storage roofs and the manner in which farm households used the roof storage method encouraged the invasion of stored maize by pests. It was concluded that the roof storage method required improvement. Training and sensitization of farm households with regard to improving the roof storage method and adopting more efficient grain drying technologies for achieving maximum safety of stored maize was recommended.

INTRODUCTION

The characteristics of a storage method play a major role in determining a storage method's capacity to ensure safety of stored crops, and can therefore ultimately play a role in determining the quantity and safety of food available to the consumers. Depending on the technology and materials used to construct it, a storage facility may efficiently or inefficiently protect the stored produce from pests. The reduction of the quantity and quality of available food may occur as a consequence of using inefficient storage methods (Mboya 2011; Mboya et al. 2011; Inter-American Institute for Cooperation on Agriculture (IICA) 2014). The marketability of the infested or infected food crops may also become at stake (Food and Agriculture Organization of the United Nations (FAO) 2014). Insect activity in stored maize (Lewis et al. 2014), waste products produced by rodents (Mdangi et al. 2013; Stejskal and Aulicki 2014) and metabolic activities of fungi (Befikadu 2014) in stored grain are known to lead to serious contamination of grain. The contamination can further lead to the increase of consumers' vulnerability to diseases that are associated with the contamination (Mboya and Kolanisi 2014).

In Rungwe district farm households predominantly use the roof storage method for long term maize storage (Mboya et al. 2011). In the context of Rungwe district, the roof storage method requires pilling maize cobs in the space between the lower and the upper part of the roof, thus, is different from the roof-top storage method or the other roof storage method which requires hanging maize cobs on beams on the lower part of the roof, mainly used for drying and storing maize seeds (Mboya 2013 a). Roof storage method used by farm households in Rungwe district is constructed once, at the time of constructing the building in which the storage roof is located. This provides farm households with a facility that can last for as long as the roof lasts. Farm households can also store as much harvest as possible depending on the roof's size.

Rungwe district receives rainfall throughout the year in a range of about 900 mm in the low land areas and up to 2,700 mm in the areas with higher altitude (Meoweather 2009). On average, Rungwe district is characterized with cool temperatures and prolonged rainfall (Ndembwike 2009). A study conducted by Mboya (2013 b) in Rungwe district revealed that maize stored using traditional storage methods was highly infested by insect pests. High levels of mycotoxins in maize stored using traditional storage methods were also detected using Elisa Kits (Mboya et al. 2011). In general, a farm household in Rungwe district could lose to pests about 0.5 - 80 percent of maize in storage. It is estimated that a farm household could harvest an estimate of 0.88

tonnes of maize per annum in a range of 0.1 - 16.33 tonnes (Mboya 2011). Therefore the infestation of stored maize would naturally have negative implications on the quantities and quality of maize that can be available to farm households in this district.

Objectives

This study was conducted in order to characterize the roof storage method and investigate farm households' perceptions regarding the importance and efficiency of this storage method for maize storage. Specific objectives were as follows:

1. To characterize the roof storage method in Rungwe district in order to further understand the occurrence of high levels of insect infestations, fungal infections and mycotoxin contamination in maize stored using this storage method.
2. To explore the importance of the roof storage method to farm households in Rungwe district, Tanzania and determine the implications of farm households' perceptions regarding the efficiency of this storage method.

Hypothesis

Materials that are used for constructing buildings and in which maize storage roofs are located might be influencing the performance of the roof storage method in Rungwe district.

METHODOLOGY

Both qualitative and quantitative methods were used for studying a sample of 260 farm households in one of the wards in Rungwe district. The choice of the studied ward was based on the fact that its climatic conditions are similar to those which characterizes the rest Rungwe district, and that the residence in this ward are of the same tribe as the residence of the rest of Rungwe district, and that they follow the same practices. Research tools that were used include structured and semi- structured face to face interviews which were used to enable probing, and the matrix tool for scoring and ranking. Data collected include: types of materials used for constructing walls and roofs of buildings in which farm households stored maize, regarded as important for determining the quality of the roofs, as well as data concerning the perceived advantages of the roof storage method. Other data sets collected included the form in which maize was stored such as shelled grain or unshelled maize cobs and data with regard to factors or reasons that led farm households to store maize in the specified forms. Data with regard to farm households' perceptions in relation to the efficiency of the roof storage method were also collected. Where necessary the interviews were be re-scheduled in order to accommodate farm households that were unavailable at home when selected and visited.

Sampling

Sample size was determined using a sample size calculator at 95 percent confidence level, 6 percent precision and 100 percent response rate, following which a sample of 260 farm households was obtained. To get the interval at which a sample household should be selected, the total number of households in the studied ward was divided by the sample size. A sample household was then selected by walking through the study area and selecting every tenth household from the randomly selected.

The Procedure for the Scoring and Ranking Matrix

The matrix tool for scoring and ranking though simple, promotes discussion, thus, it is recommended for obtaining full participation of participants and to facilitate gathering their views (Chatty et al. 2003) of the group. Based on the participants' perceptions, the performance of the roof storage method with respect to protecting stored maize from invasion by rodents, insect pests and fungi was ranked as follows:

10 Scores : Excellent
8 - 9 : Very good
7 : Good
6 : Average
4 - 5 : Poor
< 4 : Very poor

The total scores were calculated and used to determine the importance of the roof storage method to the farm households.

Statistical Analyses

Data for this study was analysed using the Statistical Programme for Social Sciences (SPSS) version 15, by Pallant (2005) complemented by the STATA package. Farm households' perceptions regarding the performance of the roof storage methods were explored through calculating frequencies, performing cross tabulations and comparing means. The association between variables were explored by conducting dummy (linear) regression, chi square tests and Pearson correlations. t-tests and One way ANOVA were conducted to explore the proportions of stored maize that were normally lost to pests in relation to the materials that were used to build walls of buildings in which storage roofs were located. The practice of storing maize in the specified forms was correlated against the proportions of maize that farm households lost to pests in storage to investigate the association between them. Income, head of households' gender and number of years of farming experience were also correlated against the types of walls and roofs of the buildings in which storage roofs were located.

RESULTS

Farm Households' Income

Almost all of the farm households (98.8 %) stored maize in their main houses and only 1.2 percent of them stored it in the kitchens which were separate from the main houses. Farm households' annual earnings ranged from an equivalent of United States Dollars (USD) 10 - 4,603. The mean annual income was equivalent to USD 390 and standard deviation was 563.45. These findings show that the majority of farm households had very low income, thus would naturally have low purchasing power.

Farm Households' Years of Farming Experience

The majority (98.8 %) of heads of farm households that participated in this study had an estimated average of 24 years of farming experience, ranging from 4-60 years, at 12.92 standard deviation. This implies that farm households had several years of experience of using the roof storage method for grain storage.

The Importance of the Roof Storage Method to Farm Households

Several factors determined farm households' choice of the roof storage method for long term maize storage. However, the perceived capacity of the roof storage method to enhance the drying process and accommodate maize was the most important influencing factor (Table 1). The expectation was that heat from fire which was lit for routine cooking and heat from the sun would dry maize in the storage roofs (Mboya 2013a).

Table 1: Perceptions that influenced farm households' decision to store maize using the roof storage method

Perceptions regarding the roof storage method	*Percent of farm house holds (n=239)*
Its capacity to accommodate large quantities of maize	0.4
Its capacity to protect stored produce from infestations	1.5
Capacity to enhance the drying process and protect produce from insect infestation	5.8
To enhance the drying process and accommodate maize	78.8
Its capacity to accommodate maize and protect from insect infestation	0.8
Traditional storage method used for many years	1.9
Familiarity with the roof storage mthod	0.4
Being relatively cheaper than other storage methods	2.3

Responses are applicable to 239 out of 260 participants who responded to this question

Farm Households' Rating of the Roof Storage Method with Respect to its Capacity to Protect Stored Maize from Insect Pests, Rodents and Fungi

More than 50 percent of the farm households perceived the roof storage method as an excellent storage method for protecting stored maize against fungi (Table 2). More than 59 percent perceived it as lacking the capacity to protect stored maize from rodents. About 13.5 percent of the farm households had the view that the roof storage method did not offer stored maize protection against insect infestation.

The mean score for the general efficiency of the roof storage method was 7, which stood for

Table 2: Roof storage methods' capacity to protect stored maize against rodents, insect pests and fungi (n=260)

Ratin	*Protection from insect*	*Protection from fungi*	*Protection from rodents*
	Percent of farm households	*Percent of farm households*	*Percent of farm households*
Very poor	1.2	0.4	19.6
Poor	12.3	0.0	33.8
Good	45.0	8.9	33.1
Very good	33.0	31.5	11.6
Excellent	8.5	59.2	1.9

"good". However, different mean score values were obtained with regard to the roof storage methods' capacity to protect stored from the invasion by specific pests. Roof storage's capacity to protect stored maize against insects had a mean score value of 6.71 at 1.692 standard deviation, its capacity to protect stored maize against fungi had a mean score value of 8.98 and1.378 standard deviation. Also, roof storage's capacity to protect stored maize against rodents had a mean score value of 4.85 and 1.986 standard deviation. After rounding off, the indicated mean scores are equivalent to seven, nine and five, respectively, and as indicated in the procedure for the scoring and ranking matrix section, nine scores stood for 'very good', seven for 'good', six for 'average' and four - five for 'poor". Thus, in general, farm households perceived the roof storage method as very good for protecting stored maize against fungal infections and also perceived it as good for protecting stored maize against insect pests, but poor for protecting it from rodents.

The Mode in Which Maize Was Stored in the Roof Storage Facilities

Immediately after harvesting maize, 66 percent of the farm households would store unshelled maize cobs without husks in the roof storage facilities and 27 percent stored unshelled maize cobs with husks. About 27 percent of the farm households stored maize in the form of shelled grain using the sack storage method. Farm households that stored maize using the roof storage method could either use the roof storage method exclusively, or at some stage unhusk and shell maize and store it using the sack storage method. Farm households that stored maize in the form of unshelled cobs without husks stored it in that specific form in order to easily monitor infestations and to enhance drying of the maize in the roof storage facilities. The indicated reasons with regard to the storage of maize in the form of unshelled cobs had 13.1 percent and 65.4 percent scores, respectively. On the other hand, farm households that stored maize in the form of unshelled cobs with husks stored it in the specified form for several reasons, of which protecting it from smoke had the highest score (Table 3).

Table 3: Reasons for storing maize in the form of unshelled cobs with husks (n=260)

Reasons for storing unshelled maize cobs with husks	*Percent of farm households that stored unshelled maize cobs with husks*
To protect from insect infestations	5.40
To protect from smoke	12.70
It is a traditional method used for many years	2.70
To reduce the workload	2.70
To protect frm smoke and insects	3.50

Responses apply only to farm houseolds that stored unshelled maze cobs with husks

t-tests showed no significant difference between the mean proportions of maize lost to pests for farm households that stored maize cobs with husks and those that stored it without husks. Likewise, Chi- square tests revealed no significant association between form in which maize was stored and farm households' experience of losing maize to pests. These findings imply that farm households' lost stored maize to pests regardless of whether they stored it with or without husks, and that the proportions of maize lost to pests were not influenced by the practice of storing it with or without husks.

Types of Buildings Used by the Farm Households to Store Maize

More than half (64.2 %) of the farm households built their houses using mud bricks and roofed them with corrugated iron sheets (Table 4). An estimated total of 77.3 percent of the houses were built using mud bricks, 19.6 percent were built using baked (fire burnt) bricks and 3.1 percent were built using cement bricks.

Table 4: Types of walls and roofs of the main houses in Rungwe district (n=260)

Type of walls and roofs	*Percent of farm household whose houses had the specified walls and roofs*
Mud bricks thatched roof	13.1
Baked bricks (fire burnt) and thatched roof	4.2
Mud bricks (sun dried) corrugated iron sheets	64.2
Baked bricks corrugated iron sheets	15.4
Cement bricks corrugated iron sheets	3.1

Cross- tabulations revealed that 78 percent of the farm households whose houses were made of mud bricks lost maize to rodents as opposed to 53 percent whose houses were made of baked bricks and 62.5 percent of farm households whose houses were made of cement bricks (Table 5).

Findings in Table 5 reveal that farm households whose houses were made of mud bricks were more at risk of losing maize to rodents than those whose houses were made of baked or cement bricks. However, Pearson correlation revealed a small positive association (0.180 significant at $\alpha = 0.01$) between houses being made of mud bricks and farm households' experience of losing maize to rodents (Table 6), implying that farm households' experience of losing maize to rodents only slightly increased with the increase in the tendency for houses being made of mud bricks at 3.24 percent overlap. Farm households' experience of losing stored maize to rodents slightly decreased with buildings in which storage roofs were located. This association had Pearson correlation value of - 0.171, significant at $\alpha = 0.01$, presenting a 2.9 percent overlap. There was not much difference between the magnitude of the overlaps with regard to farm households' experiences of losing stored maize to pests in buildings made of mud bricks and buildings made of baked bricks, suggesting that farm households whose storage roofs were located in buildings made of mud bricks and in buildings made of baked bricks alike had encountered experiences of losing stored maize to rodents.

Also, households' experience of losing maize to insect pests and house being made of mud bricks slightly increased with houses being made of mud bricks. The association was observed at Pearson correlation value of 0.135, significant at $\alpha = 0.01$ and 1.82 percent overlap. No significant association was observed between houses being made of mud bricks and maize loss to fungi. This suggests that fungal infection of stored maize was not a major problem for farm households whose houses were made using mud

Table 5: Cross-taulations: The association between the types of bricks used to build walls of houses and farm households experience of losing maize to insects, rodents and fungi

Type of bricks used to build wall of house	*Percent of farm households' that experienced maize loss due to fungi*	*Percent of farm households' that experienced maize loss due to insects*	*Percent of farm households' that experienced maize loss due to rodents*
Mud bricks (n=198)	10.1	78.3	74.2
Baked bricks (n=52)	3.8	67.3	53.8
Cement bricks (n=8)	12.5	625	62.5

Table 6: Correlation results for the association between types of walls of buildings in which the roof storage facilities were situated and farm households' experiences of losing stored maize to pests

Type of wall	*Experience of losing stored maize to rodents*	*Experience of losing stored maize to insect pests*	*Experience of losing stored maize to fungi*	*Proportion of maize lost to pests*
Mud bricks	0.180**	0.135**	0..079NS	-0.227**
Baked bricks	-0.171**	-0.088NS	0.089NS	0.248**
Cement bricks	-0.028NS	0.023NS	-0.051NS	0.004NS

** Correlation is significant at the 0.01 level (2 tailed).
NS Correlation not significant

bricks. No significant association was observed between houses being made of baked bricks and farm households losing stored maize to insect pests or fungi, suggesting that insect pests and fungal infection of stored maize were not major concerns for farm households whose houses were made of baked bricks. Also, no significant association was observed between houses being made of cement bricks and farm households' experience of losing stored maize to insects, fungi or rodents, suggesting that farm households whose houses were made of cement bricks did not have much experiences of losing stored maize to insect.

In addition, the proportion of maize lost to pests slightly decreased with houses being made of mud bricks at Pearson correlation value of -0.227, significant at $\alpha = 0.01$, showing a 5.15 percent overlap. Contrary to this, the proportions of maize that farm households normally lost to pests slightly increased with houses being made of baked bricks at Pearson correlation value of 0.248, significant at $\alpha = 0.01$, showing a 6.15 percent overlap. No significant association was observed between buildings being made of cement bricks and the proportions of maize that farm households lost to pests.

One way ANOVA results showed that an average proportion of 36 percent of harvested maize was lost to pests in storage roofs located in buildings whose walls were constructed using mud bricks at 18.46 standard deviation. An average proportion of 47 percent of harvested maize was lost to pests in storage roofs located in buildings made of baked brick walls at 15.46 standard deviation and an average proportion of 33 percent of harvested maize was lost to pests in storage roofs located in buildings made of cement walls at 33.96 standard deviation. There was a significant difference between the average proportions of maize normally lost to pests in storage roofs located in buildings that were made of mud bricks and the average proportions of maize lost to pests in storage roofs located in buildings made of baked bricks at $\alpha = 0.05$. The effect size calculated using eta square was 0.6, implying that there was medium difference between the indicated maize proportions. On the contrary, there was no significant mean difference between the average proportions of maize lost to pests in storage roofs located in buildings made of cement walls and in buildings made of mud brick or baked brick walls. Therefore the average proportion of maize lost to pests was significantly higher in storage roofs located in buildings made of baked bricks compared to the average proportion of maize lost to pests in storage roofs located in buildings made of mud bricks.

The Association between Income and the Types of Bricks with which Farm Households Constructed Buildings in which Storage Roofs were Located

A small, negative association at Pearson correlation value of -0.153 was observed between income and houses being made of mud bricks, indicating a 2.3 percent overlap, and it was significant at $\alpha = 0.05$. At the indicated overlap, the tendency for farm households to build walls of houses using mud blocks decreased slightly as income increased. This finding also suggests that factors other than income more importantly influenced farm households' tendency to build houses using mud bricks than income did. A positive association at Pearson correlation value 0.350, significant at $\alpha = 0.01$ between wall of house being made of cement bricks and income was also observed, indicating that the tendency for people to build houses using cement bricks increased with increase in income at a 12.3 percent overlap between the two variables. No statistically significant association was observed between income and farm households' experience of losing stored maize to pests or with the proportions of maize lost to pests.

Materials Used for Constructing Bottom Parts of Storage Roofs

A total of 84.2 percent of the bottom part of the roofs of buildings in which farm households stored maize were constructed using heavy wooden logs, and 15.8 percent were constructed using light weight timber (Table 7). The highest proportion of roof storage facilities was constructed on mud brick walls with the lower constructed using heavy wooden logs (Table 7).

The heavy wooden logs were strategically placed from one side of the wall to the other side making it possible for the roofs to bear the heavy weight of maize and accommodate stored maize. The small spaces between the logs or timber served as entry points for the heat from cooking fire into storage roofs, and farm households that

Table 7: Materials used to construct lower parts of maize storage roofs

Materials used	*Percent of farm house hold that used the specified building materials*
Mud brick (sun dried)+ wooden logs	77.3
Baked bricks (fire burnt) + wooden logs	4.2
Cement bricks+wooden logs	2.7
Baked bricks+light weigh timber	15.4
Cement bricks+light weight timber	0.4

built their houses using baked or cement bricks used light weight timber to construct the bottom part of the roof. The proportion of maize lost to pests decreased with increase in the bottom part of roofs in which maize was stored being constructed using heavy wooden logs at $\beta = -0.215$, significant at $\alpha = 0.000$, showing a 4.6 percent overlap between the indicated variables. On the other hand, farm households' experiences of losing stored maize to pets slightly increased with bottom part of the roofs being constructed using heavy wooden logs at Pearson correlation value of -0.223. The association was significant at $\alpha = 0.01$, and it showed an overlap of 5 percent. No significant association was observed between farm households' experience of losing stored maize specifically to insect pests and fungi, and the bottom part of the roof being constructed using heavy wooden logs. This suggests that the loss of maize stored in the roof storage facilities of buildings that were constructed using heavy wooden logs was perhaps more due to rodents than insect pests or fungi.

Furthermore, farm households' experience of losing stored maize to rodents slightly decreased with the bottom part of the roofs in which maize was stored being made of light weight timber at Pearson correlation value of - 0.127, significant at and $\alpha = 0.05$. The indicated association showed a 1.81 percent overlap. t-tests showed that the overall mean proportion (48 %) of maize that farm households who built the bottom part of the roof using light weight timber lost to pests was higher than the overall mean proportion of maize lost to pests by farm households who built the bottom part of the roof using heavy wooden logs by 11.1 percent. The indicated mean proportion difference was significant at $\alpha < 0.01$. These findings reveal that larger proportions of maize were lost to pests in buildings whose bottom part of their roofs were made of light weight timber as opposed to maize stored in buildings whose bottom parts of their roofs were constructed using heavy wooden logs. Yet, farm households' experience of losing stored maize to pests was more prevalent in buildings whose roofs were constructed using heavy wooden logs.

Materials Used for Constructing Upper Parts of Storage Roofs

About 17.3 percent of the roofs were thatched and 82.7 percent were made of corrugated iron sheets. The mean proportion of maize lost to pests in storage roofs whose upper part was made of corrugate iron sheets and storage roofs that were thatched was 39 percent and 37 percent, respectively. t - tests showed that there was no significant difference between the mean proportions of maize lost to pests in thatched storage roofs and storage roofs made of corrugated iron sheets. In both cases, the mean proportions of maize lost to pests was high, indicating that maize would be lost to pests regardless of whether the storage roof is thatched or roofed using corrugated iron sheets.

DISCUSSION

The Importance of the Roof Storage Method to Farm Households in Rungwe District

Although the roof storage method is a traditional maize storage method in Rungwe district, farm households' main motivation for using it was to dry maize which is normally not dry enough at harvest and to accommodate it. Farm households believed in the capacity of storage roofs to dry stored maize, but they did not take into account the implications of the length of time that it took for maize to dry in the storage roofs. The inadequacy of the heat obtained from cooking fire and the sun resulted into this storage method failing to offer rapid/fast drying of stored maize (Mboya 2013a). This further resulted into conditions in the storage facilities that encourage insect infestations, fungal infections and mycotoxin contamination of stored maize (Mboya et al. 2011). Storage facilities that encourage the development and growth of pests,

have been widely acknowledged among factors that play a negative role on the quality and quantity of grain that can be available to consumers (Befikadu 2014; Chatta and Lee 2014). In this study, farm households' perceptions regarding the roof storage method were therefore misleading, and impacted negatively on the manner in which they used the roof storage method as well as on the safety of stored maize. Considering the importance of the roof storage method to farm households, it would be important that farm households be sensitized regarding the implications of its lack of capacity to offer fast drying of stored maize. Farm households should also be encouraged to find alternative maize drying methods or to be willing to embrace new ways of drying grain.

The fact that the roof storage facilities are constructed only once when a house is being built, and used for as long as a house exists makes the roof storage method conducive for use by small holder farm households whose income is low. Farm households' low purchasing power have been associated with the tendency for farm households to use cheap, yet inadequate storage technologies (Sarpong 2013). Considering the low income of farm households in Rungwe district, their preference of the roof storage method is therefore understandable.

Interestingly, farm households believed that the roof storage method has good capacity to protect stored maize from insect infestation and fungal infection, yet more than three quarters of the farm households reported having lost stored maize to insect pests. A contradiction between farm households' perceptions and the reality with regard to the efficiency of the roof storage method is thus obvious, and it further raises questions with regard to the driving force behind farm households' perceptions concerning this storage method.

Also, large amounts of insect pests (Mboya 2013 b) and high levels of fungal infection as well as mycotoxin contamination (Mboya et al. 2011) were reported with regard to stored maize obtained from the same farm households. Farm households' tendency to apply pesticides, traditional plant powders or ash to control insect infestation in stored maize (Mboya 2013b) also suggests that farm households were aware that pests could develop in storage facilities. However, farm households hardly fumigated or cleaned the roof storage facilities prior to maize storage. Pest would therefore have a good chance of developing and multiplying in the storage facilities. This also implies that the belief that the roof storage method was efficient with regard to protecting stored maize from insect pests and fungi was either based on farm households living in denial of this storage methods' inefficiency with regard to the former or it was a consequence of their incorrect understanding of what maize loss means.

More so, considering the large number of years during which farmers can use the roof storage method, the accumulation of insect pests and fungal species in the roof storage facilities would be inevitable. Sanitation of storage facilities and proper use of fumigants are highly recommended for reducing chances invasion of storage facilities by pests (Smith 2013). It is therefore important that farm households should be encouraged to clean and fumigate storage roofs on a regular basis to prevent the occurrence of fungal infection and insect pest infestation in the storage facilities.

It also seems that farm households were aware of the roof storage methods' lack of capacity to protect stored maize from rodents, hence they ranked it "poor" with regard to the latter. The invasion of stored grain by rodents is detrimental because rodents can seriously contaminate and reduce the amount of grain that can be available for consumption (Mdangi et al. 2013; Babber et al. 2014). It is therefore important that ways of ensuring that rodents do not get into storage roofs such as fitting structures around storage roofs for the indicated purpose should be explored. On the other hand, the importance of the capacity of the roof storage method to accommodate maize was unquestionable.

The Implications of the Mode in Which Maize was Stored

The practice of storing maize cobs without husks in the roof storage facilities to quicken maize drying was not effective in producing the expected results. This claim is based on the fact that it took a long time for maize to dry in the storage facilities (Mboya 2013 a), further allowing conditions in the storage facilities to be favourable for the development of pests. High moisture content in grain during storage have been found to promote post harvest grain losses by encouraging the development and growth

of insect pests, fungi and other micro-organisms in stored grain as well as germination (Befikadu 2014). Consequently, the contamination of stored grain by toxins that are associated with the indicated pests could also occur. This makes it necessity for farm households to adopt a better method of drying maize so that they can use the roof storage method for accommodating dry maize. The importance of introducing a better grain drying method in Rungwe district was discussed in detail in another paper by Mboya (2013 a).

It is also evident that the modes in which farm households stored maize in the roof storage facilities, namely, storing it with or without husks were not helpful with regard to protecting stored maize from invasion by pests. This claim is based on the fact that farm households that stored maize cobs with husks and those that stored it without husks alike lost stored maize to pests.

The Implications of the Type of Bricks that Farm Households Used to Construct Walls of Buildings in Which Storage Roofs were Located

Since the majority of the farm households that took part in the study that is being reported in this paper stored maize in houses that they lived in, the characteristics of walls of the buildings in which storage roofs were located would influence the capacity of the storage roofs to protect stored maize from pests. The majority (77 %) of the buildings in which storage roofs were located were made of mud bricks, it would naturally be expected that maize stored in buildings made of mud bricks would be at a higher risk of invasion by rodents as compared to maize stored in buildings that were made of baked or cement bricks. Unlike cement or baked bricks, rodents can easily make holes through mud bricks, thus, gaining access to maize stored in the roof storage facilities in the indicated buildings. One would therefore expect that houses made of cement and baked bricks would be less susceptible to the invasion by rodents. However, in the study being reported in this paper, farm households who stored maize in buildings made of mud bricks and those who stored maize in buildings made of baked bricks alike experienced the problem of rodents' infestation. Also, the facts that buildings made of baked bricks were infested by rodents, and that higher proportions of maize were lost to pests in storage roofs located in buildings mad of baked brick walls suggests the existence of other underlying factors that encouraged rodents' infestation of maize in the indicated storage roofs.

Furthermore, the noted significant association between farm households' tendency to construct buildings using cement bricks and income imply that farm households who stored maize in buildings made of cement bricks had high purchasing power. They therefore would have capacity to invest in ensuring safety of stored maize. However, the lack of statistically significant association between income and farm households' experiences of losing stored maize to pests, and between the former and the proportions of maize lost to pests shows that income was not a determining factor where the invasion of stored maize to pests is concerned. Therefore it is more the type of bricks used to construct buildings in which storage roofs were located that influenced the invasion of stored maize by rodents and insect pests than income.

The fact that very few farm households reported having lost stored maize to fungi may imply that fungal infestation of stored maize was not a serious problem in the study area. However, contrary to the latter, high levels of fungi and mycotoxins were detected in maize collected from the roof storage facilities of the same farm households (Mboya 2011; Mboya et al. 2011). Farm households' tendency to use fungal infected maize for food and feed in the studied area was also reported (Mboya and Kolanisi 2014). It is therefore evident that farm households did not regard fungal infection of maize as loss because they used it for food and feed anyway. It is also quite obvious that the lack of statistically significant association between farm households' experience of losing stored maize to fungi for maize stored in buildings that were built using mud bricks, cement bricks and baked bricks alike was a consequence of very few farm households reporting having had such experiences. Therefore although maize stored in buildings made of cement bricks may have been less susceptible to rodents' infestation compared to maize stored in buildings made using mud bricks or baked bricks, it was not safe from fungal infection and mycotoxin contamination.

The Implications of the Materials Used to Build the Bottom Parts of Storage Roofs

In general, it seems that materials used to construct walls and the bottom parts of storage roofs had some influence with regard protecting stored maize from rodents. The fact that more maize was lost to pests in roof storage facilities situated in buildings whose bottom part of roofs were constructed using light weight timber can in part be explained in that light weight timber can be easily chewed by rodents, making it easy for them to get access to stored maize. Light weight timber was used in combination with baked or cement bricks. This somehow explains the experiences of maize loss to rodents in storage roofs located in buildings made of baked and cement bricks. Although rodents could not chew through the walls made of baked or concrete bricks, they could chew through the light weight timber and gain access to stored maize. A combination of hard bricks and heavy wooden logs would possibly assist in preventing rodents from accessing stored maize in the storage roofs. In turn, this would also reduce chances for stored maize to be infested or infected by insect pests and fungi, respectively. Farm households' preference of mud bricks for constructing buildings should therefore be further investigated to understand the reasons behind this preference.

Also, where maize drying is concerned, the logs and timber used to build the lower parts of storage roofs would obviously block the heat from the fire sources. More so, the spaces between logs or timber would be inadequate for allowing heat into storage roofs even if adequate heat from the fire sources could be obtained. This, together with the high moisture content of stored maize implies that the manner in which the bottom parts of roofs were constructed would encourage fungal infections and insect infestations in stored maize.

The Implications of the Materials Used to Build the Upper Parts of Storage Roofs

The mean proportions of maize lost to pests were high for both, thatched storage roofs and storage roofs roofed using corrugated iron sheets. The lack of statistically significant difference between the mean proportions of maize lost to pests in thatched storage roofs and roofs whose upper part was made of corrugated iron sheets imply that farmers would lose stored maize to pests regardless of the storage roof being thatched or roofed using corrugated iron sheets. This suggests that thatched storage roofs and storage roofs that were roofed using corrugated iron sheets alike did not protect stored maize from pests.

Corrugated iron sheets are good conductors of heat, thus they would be helpful in increasing the temperatures in the roof space where maize is stored. This phenomenon has potential to enhance drying of maize stored in the roof space. However, considering that Rungwe district is characterized with rainfall and high humidity almost all throughout the year, heat from the sun would not be available on a constant basis. This, together with the fact that maize stored using the roof storage method is piled up in the roof space would make it impossible for fast drying of maize stored in the roof space to take place. The rise in temperatures in the roof storage facilities, together with high moisture content of maize grain would instead create favourable conditions for the development and growth of insect pests and fungi.

On the other hand, grass used to make thatched roofs is a poor conductor of heat. Thatched roofs would therefore create coolness in the roof storage facilities and help to cool stored maize. However, the indicated phenomenon would be useful only where maize is stored at the right moisture content. The fact that in Rungwe district maize is stored in the roof storage facilities while it still has high moisture content implies that maize stored in thatched storage roofs would be at high risk of developing fungal infection, insect infestation and rotting. It is therefore important that farm households should store maize in the roof storage facilities only after thoroughly drying it.

CONCLUSION

The roof storage method is important to farm households in Rungwe district because it provides them with a cheap, durable way of accommodating maize. Farm households' in Rungwe district believe in the capacity of storage roofs to dry maize which normally has high moisture content at harvest, and to protect it from insect pests. However, this storage method fails to meet the indicated most desired farm households' expectations. The manner in which the roof stor-

age is used as well as its characteristics allow rodents, insect pests and fungi to invade maize stored in storage roofs

RECOMMENDATIONS

The following recommendations were made:

- Farm households should be sensitized regarding the negative implications of the presence of pests in stored maize with regard to health and food security
- Farm households should be warned regarding the lack of capacity of storage roofs to offer rapid or fast drying of maize and be encouraged to ensure that maize is dried thoroughly before it is stored in the roof storage facilities.
- New ways of drying maize fast or rapidly after harvest should also be sought and farm households should be encouraged to adopt them.
- The Government of Tanzania and Agricultural Development organizations should prioritize training to raise farm households' awareness with respect to the negative implications of the presence of storage pests on stored maize, and
- Ways of ensuring that rodents do not gain access into storage roofs should also be sought.

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