Original Research

Quality of Grain Maize Stored in *Gombisa* and Sacks in Selected Districts of Jimma Zone, Ethiopia

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Abstract	Article Information
Quality of maize grains (Variety: Bako Hybrid-660, BH-660) stored in two storage containers (*Gombisa* and Sacks) for 180 days was studied in two agro-ecologies: intermediate (IAE)- and lowland (LAE) of Jimma zone, Ethiopia. Crude protein, crude fat, dry matter, total carbohydrate and ash contents were influenced significantly by storage periods in *Gombisa* (*p*<0.05). Crude fat under LAE and ash under both agro-ecologies were also influenced by storage days (*p*<0.05). There was a significant (*p*<0.05) effect of storage containers on dry matter and total carbohydrates in the IAE whereas in LAE appeared insignificant (*p*>0.05). Grains stored in *Gombisa* under IAE showed significantly lower dry matter and total carbohydrate contents than in Sacks. The study showed maize grain quality deteriorations in *Gombisa* because of favorable moisture, relative humidity and temperature conditions for maize weevil (*Sitophillus zeamais*) and angoumois grain moth (*Sitotroga cerealella*) attacks during 180 days of storage.	
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INTRODUCTION

Various studies undertaken in sub-Saharan Africa to estimate maize (*Zea mays* L.) grain losses in traditional storage practices have shown that the losses are generally high. From harvest to consumer market, maize grain postharvest losses in Africa are estimated to range 14 to 36% (Tefera *et al*., 2011a; Tefera, 2012). In Ghana, about 15 % of maize grains harvested are lost annually due to attacks by maize weevils (*Sitophilus zeamais*) (Baidoo *et al*., 2010). One in five kg of grain produce in sub-Saharan Africa is estimated to be lost by pest infestations and associated grain decays/spoilage of which maize grain loss remained the highest (FAO/NRI, 2011). In Nigeria, Kerstin *et al*. (2010) reported 10 to 12% loss of maize grains stored in traditional storage containers similar to *Gombisa* due to insect pests. Loss of about 18% was also reported by the same author in other African countries for maize grain stored in polypropylene sacks for the storage periods of six months.

Maize is one of the most important staple food and cash crops in Ethiopia providing calories for the consumers and income for the traders. In terms of grain volume productions (64.9 million quintals, 25.8%) and area of cultivation (1.99 million hectares, 16.1%) maize stands 1st and 2nd, respectively among cereal grains produced in Ethiopia (CSA, 2013/14). Traditionally, maize grain is stored both in- and outdoors by Ethiopian farmers for consumption and to sell in the later months of the year depending on the quantity produced per household. Survey conducted in three major grain producing areas of Ethiopia *viz*. Hetosa, Ada and Bako indicated that majority of farmers (93.3%) are using various traditional grain storage containers that expose their stored grains to be attacked by storage pests and other factors that contribute to deteriorations whereby per house hold grain losses of 12% was estimated from the total grain produced (Abebe and Bekele, 2006). Eticha (1999) reported an annual maize grain loss in Ethiopia in the range between 2 and 30%. In Jimma Zone, quantitative average maize grain storage loss of 41.0 to 80.0% and on average 64.5% of grain damage was estimated in 2004 from fifty traditional farm stores within three to six months of which maize

weevil (*Sitophilus zeamais*) followed by angoumois grain moth (*Sitotroga cereallela* (O), rice weevil (*Sitophilus oryzae*) and flour beetle (*Tribolium confusum*) were identified as major storage pests (Sori and Ayana, 2012).

In Jimma zone, like in other regions of Ethiopia, there have been some efforts to support post harvest grain management through promotion and demonstration of improved storage structures by the Office of the Ministry of Agriculture and Rural Development (Befikadu, 2011). However, the use of hermetic storage like metal silos (SDC, 2008; Tefera *et al*., 2011a; De Groote *et al*., 2013) is not promoted for use by subsistent grain farmers. Thus, grain deterioration problems (both quality and quantity) haven't been solved. Grain storage containers being used by majority of the farmers in the zone (more than 97%) are traditional ones (*Gombisa* for maize cobs and Sacks for shelled maize grains) that couldn't protect the stored grain from deterioration (Kemeru, 2007). Maize weevil and angoumois grain Moth were identified in this work as the major insect pests that attacks maize grains during 180 days of storages in both *Gombisa* and Sacks (Befikadu *et al*., 2012). In view of limited information, in this paper the extent of maize grain nutrient quality losses in the two traditional storage containers (*Gombisa* and Sacks) over 180 storage days for two maize growing agro ecologies (IAE and LAE) are reported.

MATERIALS AND METHODS
Description of the Study Area
This study was carried out in Jimma zone, Ethiopia which is found at about 345 km from Addis Ababa in South west and lies between 36° 10´E longitude and 7° 40´N latitude. The zone has an elevation ranging from 880 to 3360 masl. The area experiences annual average rainfall of 1000 mm for 8 to 10 months. The main rainy season extends from May to September and the small rainy season takes place in February, March and April. The temperature of Jimma zone varies from 8-28°C. The average annual temperature is 20°C (Haile and Tolemariam, 2008).

The agro-ecologies of the study area have an altitude range of 1000-1500 (lowlands), 1500-2500 (intermediate) and 2500-3360 masl (highlands) (FAO, 2009). Only two agro-ecologies (intermediate and lowlands) growing BH-660 maize variety were selected for the study since BH-660 maize variety is not produced in the highland agro-ecology of the study area.

Experimental Design
Factorial arrangement using Completely Randomized Design (CRD) was employed for the experiment in two replications. The factors were: traditional maize storage containers at two levels (*Gombisa* and Sack), agro-ecologies at two levels (intermediate and lowland) and storage periods at four levels (immediately after harvest, 60, 120 and 180 days after storage). Data were collected at every two months interval, including at the start of the study making up four levels for the factor storage period.

Experimental Materials
The experimental materials used for the study were BH-660 variety of maize grain harvested in December 2009 and two types of traditional maize storage containers; *Gombisa* and Sacks (Befikadu *et al*., 2012).

Sampling of the Grain for Evaluation
Initial sample of six cobs were randomly taken before the bulk was loaded in to storage container, *Gombisa*, shelled manually to make 1 kg and was then kept in an air-tight plastic bag. The initial maize samples from each storage containers were taken as a control at the beginning of the storage. Three cobs were drawn from each cage via the tube using strings, shelled manually and thoroughly mixed. Of these samples collected from each *Gombisa* and Sack, 200g were kept in clean airtight plastic bag in a refrigerator until required for analysis. For sampling grain from the Sacks, procedure described in AOAC (1995) was followed.

Chemical Analysis of Maize Grain
The chemical composition analyses on the maize grain samples collected was done using standard analytical procedures (AACCI, 2000): crude protein (AACCI Method 46-11A), crude fat (AACCI Method 30-25), dry matter (AACCI Method 44-15A), ash (AACCI Method 08-0) and free fatty acid (AACCI Method 02-01A). Total carbohydrate was determined by difference (Monro and Burlingame, 1996).

Data Analysis
Statistical analysis was performed on the chemical composition data collected over the storage periods using ANOVA and SPSS Version 16.0. Means were compared for the significant differences by LSD test, and significance was accepted at 5%.

RESULTS AND DISCUSSION
Effect of Storage Periods on Chemical Composition of Maize Grain Stored Under Intermediate (IAE) and Lowland (LAE) Agro-ecologies
The results on chemical composition (crude protein, crude fat, dry matter, total carbohydrate, ash and free fat acid contents) evaluated for BH-660 maize grains stored in *Gombisa* and sacks under intermediate and lowland agro-ecologies over 180 days (Tables 1, 2 and 3) are discussed below.

Crude protein: The crude protein content of maize grain stored in *Gombisa* was significantly influenced over the storage durations (*p*<0.05) (Table 1). Maximum crude protein content was observed at 60 days after storage which was statistically at par with initial storage period and 120 days after storage. Significantly different and minimum crude protein content was recovered at 180 days after storage. However, crude protein content was not significantly (*p*>0.05) different for grains stored in Sacks. The range of moisture (M), temperature (T) and relative humidity (RH) recorded (Befikadu *et al*., 2012) under IAE (*Gombisa*: M = 9.2 to 13.2%, T = 18.5 to 30.2°C and RH = 30.8 to 54.7%; Sacks: M = 11.7 to 13.5%, T= 15.0 to 28.8°C and RH = 29.3 to 65.2%) and LAE (*Gombisa*: M = 9.2 to 14.6%, T = 21.3 to 35.0°C and RH = 39.2 to 51.0%; Sacks: M = 12.3 to 13.6%, T= 16.6 to 29.0°C and RH = 29.8 to 62.3%) are suitable (Fleurat-Lessard, 2004) for grains attack by maize weevil (*Sitophillus zeamais*) and angoumois grain Moth (*Sitotroga cerealella*) during 180 days of storage. The difference in the crude protein content decrease could be due to maize weevils and Angoumois grain Moth attacks degree difference with the storage period increase. Both maize weevil (Tefera *et al*., 2011b; Osipitan *et al*., 2012; Keba and Sori, 2013) and angoumois grain Moth (Tefera

et al., 2011b) were known to cause substantial nutrient loss in maize grains on storages.

Crude Fat: The crude fat content of maize grain under intermediate agro-ecology in the two storage containers was found not significantly different over six months storage period (*p*<0.05) (Table 1). However, significant decrease in the crude fat content was observed for maize grain stored under lowland agro-ecology in both *Gombisa* and Sack (Table 2). Maximum crude fat contents were recorded from initial loading day samples and a decreasing trend in the crude fat content was observed as the storage period progressed from 60 to 180 days. Reduction in crude fat content with increased storage time could be due to attacks by maize weevils (*Sitophillus zeamais*) and angoumois grain Moth (*Sitotroga cerealella*) as observed in the study of Watson (1987).

Dry Matter: A significant differences on the dry matter contents was observed under both agro ecologies for grains stored in *Gombisa* than for grains stored in Sacks. The data for *Gombisa* remained unchanged up to four months but indicated a significant (*p*<0.05) reduction at six months of the storage period. Grains sampled from Sacks however showed no significant (*p*>0.05) difference over the six months of storage periods. Reduction in the dry matter content is at large due to consumption of parts of the grains by insect pests (Tefera *et al.*, 2011b; Befikadu *et al.*, 2012) that decreased the carbohydrate, crude protein and crude fat contents.

Free Fatty Acid: No significant (*p*<0.05) difference was observed in terms of free fatty acid values for grains stored in *Gombisa* and Sacks in both agro-ecology (Tables 1 and 2). An increase in the free fatty acidity is related to the degree to which fatty tissues (at large maize germ and aleurone layer) are attacked and release free fatty acids by hydrolysis due to pest actions and moist condition of the grain handling (Eldrid *et al.*, 1995; Sánchez-Mariñez *et al.*, 1997). The free fatty acids content in this work had remained not significant different from initial loading day is probably related to the decrease in the moisture contents of the grains as storage progressed to 180 days in both storage containers under both agro ecologies (Befikadu *et al.*, 2012) and by the relative limited fatty tissue attacks by pests.

Total Carbohydrate: For grains stored in *Gombisa* under both agro ecologies the total carbohydrate content had decreased significantly throughout the storage time (*p*<0.05) (Tables 1 and 2) (*p*<0.05). Whereas for grains stored in Sacks no significant difference were observed even though the result showed a decreasing trend. The difference between the two storages could be attributed to the fact that *Gombisa* was located out door and thus is more susceptible to insect attacks than the Sack which is stored in house. Moreover, *Gombisa* has high potential to favor suitable microclimate (temperature, grain moisture content, oxygen concentration and food availability) for maize weevil populations to increase (Fleurat-Lessard, 2004; Ileleji *et al.*, 2007) because of less dense grain packing nature into the *Gombisa* structure. For example oxygen concentration cannot be depleted fast as that for Sacks.

Ash content: The ash content of the stored grains under both agro-ecologies in both *Gombisa* and Sack were increased with increase in the storage period (Tables 1

and 2). The initial values were 0.96% and 0.93% for *Gombisa* and Sack respectively. The values increased significantly (*p*<0.05) to 2.45% and 2.42% for grains stored in *Gombisa* and Sacks respectively after two months and further rose to over 2.80% in the following two months. No significant increment was observed at the end of the last two months in both storage types. The explanation for rise in the ash content could be the cumulative effect of the reduction in the carbohydrate, protein and crude fat contents due to increase in the insect pests attacks (Befikadu *et al.*, 2012) and leaving mineral rich pericarp proportion of the grain proportionally to be large. The result obtained by Lemessa *et al.* (2000) is supportive to this study showing significant increment in ash content as storage period increased.

Effect of Storage Type on Chemical Composition of Maize Grain

Data on the effect of storage type on chemical composition of maize grain under intermediate and lowland agro-ecologies are presented in Table 3. Significantly (*p*<0.05) higher value in total carbohydrate content was obtained in Sacks than in *Gombisa*. The dry matter content in Sacks was also significantly higher than that in the *Gombisa*. The increase in the ash content was high in *Gombisa* than in Sacks. However, no significant (*p*>0.05) difference was obtained on the remaining chemical composition of the grain due to the differences in storage containers. The difference in the carbohydrate, dry matter and ash contents between the two storages could be attributed to the higher rate of insect infestation in *Gombisa* than in Sack (Befikadu *et al.*, 2012).

Maize weevil and angoumois grain Moth were reported as the major insects pest identified from maize samples under both storages (Befikadu *et al.*, 2012). The BH-660 maize variety is known to be susceptible to maize weevil attacks (Keba and Sori, 2013). The temperature, relative humidity and moisture recorded during the study period in both storage facilities under both agro-ecologies were not preventive to insect pests attacks of maize grains and this study have shown there is a maize grain nutrient losses. There is, therefore, a need to develop cost effective management methods for these insect pest control in maize producing areas of Jimma Zone. This also calls for a multi-directional approach in improving pre- and postharvest maize grain handling activities including harvesting, pre-storage drying, storage methods and their management. Identification and test of improved storage containers like hermetic grain storage facilities (rodent proof metal silos and impervious plastic drums) which were proved to be useful for subsistent maize farmers (SDC, 2008; Tefera *et al.*, 2011a; Yakubu, 2012; De Groote *et al.*, 2013) might be an alternative wayforward to extended maize grain storage periods and to preserve maize grain quality in the region. Currently the metal silo usage in Ethiopia are at the demonstration stages. Upgrading of farmers knowledge through education toward various grain quality management skills like adequate maize grain drying before storage, grain cleaning and inspection can also help to reduce the maize grain losses of the region and contributes toward elimination of mycotoxins risks and to improved food security. Such action also reduces the problem of pesticide residues of health risks, since the frequency of pesticide usage on maize storage can be at least minimized if not at all eliminated.

Table 1: Effects of storage periods on chemical composition of maize grain stored in *Gombisa* and Sacks under intermediate agro-ecology of Jimma zone

Storage period (days)	Crude Protein (%)		Crude Fat (%)		Dry matter (%)		Free Fatty Acid (as % Oleic Acid)		Total carbohydrate (%)		Ash (%)	
	Gombisa	Sacks	*Gombisa*	Sacks	*Gombisa*	Sacks	*Gombisa*	Sacks	*Gombisa*	Sacks	*Gombisa*	Sacks
ID	7.29±0.59[a]	7.59±0.74	3.07±0.31	3.42±0.33	89.30±0.75[a]	90.03±0.84	31.60±1.04	30.19±1.37	87.23±2.04[a]	90.03±0.84	0.96±0.03[c]	0.93±0.02[b]
60	7.82±0.32[a]	7.30±0.77	3.05±0.26	3.61±0.24	86.87±3.74[a]	88.21±3.21	30.50±0.75	30.00±0.77	86.87±3.74[a]	88.21±3.21	2.45±0.07[b]	2.42±0.14[a]
120	7.18±0.37[a]	6.99±0.39	2.72±0.18	2.72±0.21	80.64±3.08[a]	87.31±3.13	31.50±1.01	31.99±0.77	80.64±3.08[b]	87.31±3.13	2.84±0.07[a]	2.95±0.08[a]
180	5.29±0.22[b]	6.22±0.44	3.25±0.14	2.93±0.23	72.42±4.31[b]	84.26±3.92	33.70±0.19	32.09±0.95	72.42±4.31[b]	84.26±3.92	2.95±0.10[a]	2.71±0.16[a]
LSD (0.05)	1.89	NS	NS	NS	14.45	NS	NS	NS	14.44	NS	0.39	0.53

Results are means of twelve observations; ID= Initial loading day; Means ± standard error with different letters in a column are significantly different (*p*< 0.05) from each other. NS= not significant

Table 2: Effects of storage periods on chemical composition of maize grain stored in *Gombisa* and Sacks under lowland agro-ecology of Jimma zone

Storage period (days)	Crude Protein (%)		Crude Fat (%)		Dry matter (%)		Free Fatty Acid (as % Oleic Acid)		Total carbohydrate (%)		Ash (%)	
	Gombisa	Sacks	*Gombisa*	Sacks	*Gombisa*	Sacks	*Gombisa*	Sacks	*Gombisa*	Sacks	*Gombisa*	Sacks
ID	7.58±0.30[a]	7.51±0.23	3.70±0.22[a]	3.73±0.21[a]	88.82±1.03[a]	88.36±1.63	31.61±0.88	31.50±0.70	88.82±1.03[a]	88.36±1.63	0.90±0.03[c]	1.03±0.10[c]
60	7.29±0.37[a]	6.76±0.50	3.23±0.11[b]	3.67±0.32[a]	84.02±4.38[a]	85.07±5.01	32.00±0.54	31.50±0.16	84.02±4.38[a]	85.07±5.01	2.67±0.08[b]	2.70±0.09[b]
120	7.55±0.60[a]	7.22±0.42	2.77±0.09[c]	2.87±0.05[b]	82.24±1.84[ab]	89.25±1.09	32.48±1.90	32.50±2.85	82.24±1.84[ab]	89.25±1.09	2.97±0.10[a]	2.71±0.16[b]
180	5.76±0.46[b]	6.99±0.19	2.76±0.13[c]	2.81±0.17[b]	74.25±3.25[b]	79.59±5.08	35.40±0.62	34.70±0.70	74.25±3.25[b]	79.59±5.0	3.11±0.14[a]	3.08±0.10[a]
LSD (0.05)	1.53	NS	0.46	0.81	9.19	NS	NS	NS	9.76	NS	0.29	0.37

Results are means of twelve observations; ID= Initial loading day; Means ± standard error with different letters in a column are significantly different (*p*< 0.05) from each other; NS= not significant

Table 3: Effect of storage type (*Gombisa* and Sacks) on chemical composition of maize stored under intermediate and lowland agro-ecology of Jimma zone

Quality parameters*	Intermediate Agro-ecology			Lowland Agro-ecology		
	Gombisa	Sack	X ± SE	*Gombisa*	Sack	X ± SE
Crude Protein (%)	6.89±0.27	7.03±0.30	6.96±0.20	7.05±0.25	7.12±0.18	7.08±0.15
Dry Matter (%)	82.31±2.04[b]	87.45±1.47[a]	84.88±1.30	82.33±1.75	85.57±1.90	83.95±1.30
Free Fatty Acid (as % Oleic Acid)	31.82±0.45	31.06±0.51	31.44±0.34	33.37±0.59	32.55±0.80	32.96±0.50
Total Carbohydrate (%)	81.79±2.02[b]	87.45±1.47[a]	84.62±1.30	82.33±1.75	85.57±1.90	83.95±1.30
Crude Fat (%)	3.02±0.12	3.17±0.14	3.10±0.09	3.11±0.11	3.27±0.13	3.19±0.08
Ash (%)	2.30±0.17	2.25±0.17	2.27±0.12	2.41±0.19	2.38±0.17	2.40±0.13

*Means of twelve observations; Means followed by different letters across the row are significantly (*p*<0.05) different according to LSD (least significant difference) test

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CONCLUSIONS

The study showed that grain stored in *Gombisa* exhibited a significant ($p<0.05$) reduction in the dry matter and total carbohydrate contents with storage period increase. The dry matter and total carbohydrate content had decreased from 89.3 and 88.8% to 72.4 and 72.4%, respectively by the end of the six months storage period. Similarly the protein content of maize stored in *Gombisa* dropped from 7.58 to 5.29% in the same period which is also significant ($p<0.05$). The ash content showed an overall increase of 2% while in storage which is significant ($p<0.05$). Similar changes recorded in grains that were stored in Sacks under both agro-ecologies were all not significant ($p>0.05$). The study showed that there is a considerable nutrient losses for maize grains stored in *Gombisa*, particularly the losses are high after 120 days of storage. Both storage containers investigated in this study are not able to prevent maize grain damages as the storage period extends for more than four months. Therefore, maize grains should not be stored for more than four months under intermediate and low land agro-ecologies as nutritional quality progressively get reduced in such storage facilities. Adoption of improved storage facilities like metal silos and education of farmers on postharvest grain quality management skills will reduce maize grain losses, safe the resources (land, water, labor, seed, fertilizer and other inputs) required for maize grain production, minimizes: the maize nutrient quality deteriorations, mycotoxins and pesticide residues caused health risks and ultimately contributes to the improvement of food safety and food security of the region.

Conflict of Interest

Conflict of Interest none declared.

Acknowledgements

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