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Effect of storage conditions on quality and aflatoxin contamination of peanuts (*Arachis hypogaea* L.)

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ABSTRACT
Peanuts are prone to various types of deterioration during storage which renders them unsuitable for consumption and trade resulting in large economic losses. Peanut kernels of Homabay Local, Valencia Red, ICGV-SM 12991 and ICGV-SM 99568 varieties were stored for six months in jute, polypropylene and polyethylene bags to assess the effect of the storage bags, temperature and relative humidity (R.H.) on quality and aflatoxin contamination. Moisture content (M.C.), physical damage, rancidity and aflatoxin levels were determined before storage and after every 30 days during storage. Moisture content of the peanuts varied significantly ($p \leq 0.05$) from 3.3 to 6.9% with samples stored in different bag types recording mean values of: 5.1% - polypropylene, 5.2% - polyethylene, and 5.3% - jute. Physical damage – which ranged from 0.1 to 9.8% - was significantly influenced by storage temperature and R.H., and the type of storage bag. Rancidity ranged from 0.8 to 5.3 and increased with storage duration from a mean of 1.5 before storage to a peak of 2.5 after 5 months of storage. There was a significant variation in the total aflatoxin levels ranging from 0 – 47.8 µg/kg, where peanuts stored in polyethylene bags were 7.3 and 13.4% more contaminated than samples stored in polypropylene and jute bags, respectively. Dried peanuts should be packaged in a container that will impede critical increases in M.C. and aflatoxin contamination and stored in a well-ventilated dry room with adequate air circulation.

***Keywords*:** *Aflatoxin, bag types, peanuts, peanuts quality, rancidity*

INTRODUCTION
Peanuts (*Arachis hypogaea* L.) are a valuable source of protein and fats for humans and livestock. However, they are prone to various types of deterioration during storage which renders them unsuitable for consumption (Bulaong and Dharmaputra 2002) and trade, resulting in large economic losses (Williams 2008). Several of the deteriorations are caused by storage moulds which result in decrease of germination ability, loss in kernel weight, discoloration of kernels, heating and mustiness, chemical and nutritional changes, and mycotoxin contamination (Malaker et al. 2008). The moulds can also change fat

quality of peanuts by hydrolytic enzymes producing free fatty acids and glycerol (Bulaong and Dharmaputra 2002, Pomeranz 1992).

The quality and flavor of edible peanuts and peanut products can be affected by the fatty acid composition of the lipids (Ul-Hassan and Ahmed 2012). Although eight major fatty acids are present in peanuts, oleic acid (56.6%) and linoleic acid (26.7%) along with palmitic and stearic acids make up about 90% of total peanut triacylglycerols (Ahmed and Young 1982, Carrín and Carelli 2010). High oleic to linoleic acid ratio could confer a significant health advantage to the consumer and has the potential to greatly enhance the marketability of peanuts (Ul-Hassan and Ahmed 2012). However, strong negative correlation between oleic and linoleic acids has been reported in peanuts (Dwivedi et al. 1993).

Contamination of foodstuff with aflatoxin - one of the most potent mycotoxins - remains a challenge especially in developing countries where agricultural and food processing systems are poorly designed to handle food safety risks. Moreover, suboptimal postharvest conditions including handling, storage and processing have been suspect in playing a major role in aflatoxin accumulation in food crops within developing countries (Wu and Khlangwiset 2010). Peanuts and maize - the two crop substrates that are highly predisposed to aflatoxin contamination - are widely consumed in Kenya, thereby increasing the risk of aflatoxin exposure to consumers. Aflatoxin refers to a group of naturally occurring carcinogenic compounds which are mainly produced as secondary metabolites by *Aspergillus flavus* (Link), *A. parasiticus* (Speare) and *A. nomius* (Kurtzman et al.) (Pitt and Hocking 1997, Strosnider et al. 2006). These toxins are found in a wide range of commodities used for human and animal consumption (Shephard 2008). Aflatoxin B1 (AFB1) - the most toxic of the aflatoxins - has been classified by the International Agency for Research on Cancer as a group 1 human carcinogen (IARC 1993).

Within households in Kenya, peanuts are commonly stored for about five months during which time they are consumed or subsequently planted; while peanuts in trading premises are stored for an average of two months before selling (C. Mutegi, International Institute of Tropical Agriculture, Kenya, personal communication). In both commercial and household practice, polypropylene and polyethylene bags are commonly used to store peanuts, with less than 1% of the traders storing their products in the recommended jute bags (Mutegi et al. 2013). Jute bags easily absorb moisture but allow good airflow while polypropylene and polyethylene are non-absorptive but trap heat within (Kennedy and Devereau 1994). Improper drying, poor storage conditions such as excessive heat and moisture, insects and other pests make peanut kernels vulnerable to fungal infection and subsequent aflatoxin contamination during storage (Hell et al. 2000, Williams 2008). The packaging material for peanuts should have a water vapour transmission rate low enough to minimize moisture absorption from the environment (Bulaong and Dharmaputra 2002).

High aflatoxin contamination levels (above the 10 µg/kg limit set by the Kenya Bureau of Standards, KEBS) have been reported in raw and processed peanuts sampled from different regions of Kenya (Gachomo et al. 2004, Mutegi et al. 2012, Mutegi et al. 2013, Wagacha et al. 2013). The contamination occurs mainly post-harvest although infection by the aflatoxin producing moulds can occur at all stages in the peanut value chain (Novas and Cabral 2002). The objectives of this study were to i) assess the

effect of storage conditions on the quality and aflatoxin contamination of peanuts, and ii) assess the effect of storage/packaging bags – commonly used in households and markets in Kenya - on the quality and aflatoxin contamination of peanuts.

MATERIAL AND METHODS

Storage conditions and their rationale

This study was conducted under controlled conditions where temperature and relative humidity (R.H.) were maintained at two levels – 19°C and 64% R.H.; and 24°C and 56% R.H. - being average conditions in Nairobi and Homabay districts, respectively (Kenya Meteorological Department 2010). The annual temperature and R.H. data during 2009 for Nairobi (Kenya Meteorological Department Headquarters) and Homabay (Kisumu Meteorological Station) were obtained from the Kenya Meteorological Department (Fig. 1), which helped guide in the choice of temperature and R.H. for the storage experiment. A control entailed storage of peanuts at ambient temperature (22 ± 3°C) and R.H (55 ± 5%).

Homabay district in Nyanza province is a leading producer of peanuts in Kenya (Ministry of Agriculture 2004, Mutegi et al. 2012). Nairobi is a major market outlet of peanuts sourced from within Kenya and other countries, and has both large and small scale peanut processing enterprises. Both Homabay and Nairobi have a high demand for raw peanuts and processed peanut products.

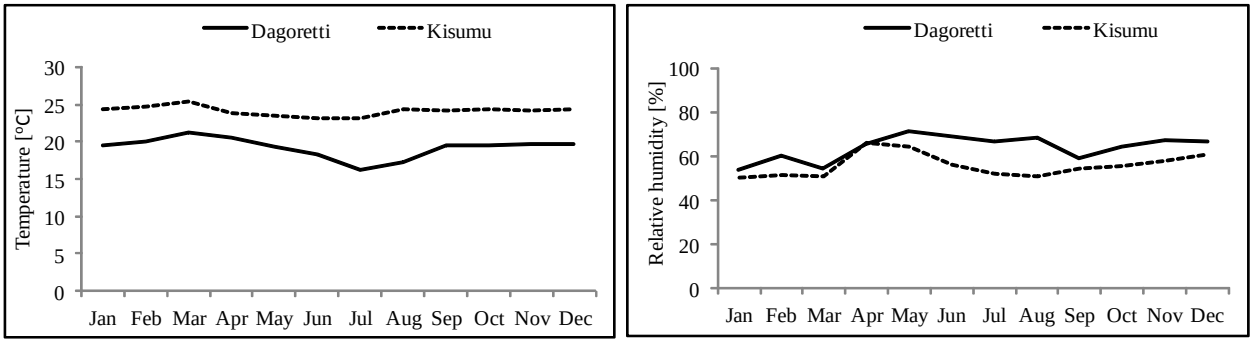

Fig. 1. Annual temperature [°C] and relative humidity [%] recorded for Dagoretti Corner and Kisumu Meteorological stations during 2009

Storage bags and peanut varieties

The storage containers used in the study were jute, polypropylene and polyethylene bags. Households and traders in Kenya commonly use polypropylene and polyethylene bags to store peanuts, while jute bags are recommended for storage (Mutegi et al. 2013). Visually clean peanut seeds of two local varieties (Homabay Local and Valencia Red) and two improved varieties (ICGV-SM 12991 and ICGV-SM 99568) were purchased from traders in western Kenya, the leading peanut producing region in the country. One and a half kilogram sample of each peanut variety was packed into each storage bag and replicated twice. The containers were incubated at three temperature and R.H. levels (19°C and 64% R.H.; 24°C and 56% R.H.; and ambient temperature – 22 ± 3°C, and R.H. – 55 ± 5%). The experiment was run for a period of six months from April to September, 2011.

Sampling

Sampling entailed thoroughly mixing the 1.5kg sample and drawing a 100g sub-sample. The sub-sample was first assessed for physical damage, and then sub divided into two equal portions of 50g. One portion

was analyzed for M.C. and rancidity whereas the other was analyzed for fungal infection (data not shown) and total aflatoxin level. Sampling was done for six months - with an initial sampling before storage of the peanuts - without replacement of the sub-samples in the storage containers.

Determination of physical damage and moisture content

Assessment of physical damage was based on guidelines for shelled peanut kernels adopted from the Kenya Bureau of Standards (KEBS 2007). Peanut kernels were considered physically damaged when they were insect damaged, discolored, diseased, mouldy, shriveled, heat damaged, split or broken. Kernels in these categories were counted and the proportion of physically defective nuts for each sample was calculated as the number of defective nuts divided by the total number of kernels, and multiplied by 100. Based on the Kenya Bureau of Standards regulations (KEBS 2007), the proportion of physically defective nuts in shelled peanuts should not exceed 2%.

Moisture content of peanut kernels was determined using the oven drying method. The kernels were ground in a kitchen coffee grinder (Coffee Grinding Mill, Armco Kenya Ltd, Nairobi, Kenya). Two grams of the ground sample were placed on an aluminium dish, which was placed in a dry air oven (Memmert ULM 500, Büchenbach, Germany). The samples were dried at 105°C for 3 hours and the net weight of the dried sample determined. Each sample was replicated twice and the M.C. calculated as follows:

$$\text{Moisture content (\% weight basis)} = \frac{M_0 - M_1}{M_0} \text{ X } 100$$

Where: M_0 – initial weight, in grams of test portion; M_1 - final weight, in grams of dried test portion.

Determination of oleic acid

The titration method of Joslyn (1970) for peanut oil was adopted. Peanut oil was extracted from a 30g ground sample for 8 hours using a Soxhlet apparatus. Twenty five mililiters of diethyl ether was mixed with 25 mL ethanol and 1 mL of phenolphthalein solution (1%) and carefully neutralized with 0.1 M sodium hydroxide. Ten grams of the oil was dissolved in the mixed neutral solvent and titrated with aqueous 0.1 M sodium hydroxide shaking constantly until a pink colour persisted for 15 seconds. Free fatty acid was calculated as oleic acid.

Analysis of peanut samples for aflatoxin levels

A 20g sub-sample was drawn from the 50g sample from each storage bag. The powder was triturated in a blender in 100 mL of 70% methanol (70 mL absolute methanol in 30 mL distilled water, v/v) containing 0.5% potassium chloride (w/v) until thoroughly mixed. The extract was transferred to a conical flask and shaken for 30 min at 250 rpm. The extract was then filtered through Whatman No. 1 filter paper and diluted 1:10 in phosphate buffered saline containing 500 µL/L Tween-20 (PBS-Tween) and analyzed for aflatoxin contamination with an indirect Competitive Enzyme-Linked Immunosorbent Assay (ELISA) as described by Waliyar et al. (2005). This method has a detection limit of 0.5 µg/kg.

Data analyses

Data were subjected to analysis of variance (ANOVA) using PROC ANOVA procedure of Genstat Discovery 2 statistical software (Version 13, Lawes Agricultural Trust, Rothamsted Experimental Station, 2006) and means compared using Fisher's protected LSD test at 5% significance level. Percentage data that were skewed were transformed using arcsine $\sqrt{p/100}$ while

other skewed data were transformed to $\log_{10}$ for data analysis and separation of means. Pearson correlation coefficient (SPSS version 16) was used to establish the correlations between different parameters.

RESULTS

Moisture content, physical damage and rancidity of peanut kernels

There were significant ($p \leq 0.05$) differences in M.C., physical damage and rancidity of peanut samples stored under different temperature and R.H. conditions and storage bags (Table 1). Moisture content of the samples varied from 3.3 to 6.9% and significantly ($p \leq 0.05$) decreased gradually from 5.6% before storage to 4.9% after four months of storage after which there were no significant changes recorded thereafter. Overall ranking of M.C. in peanuts in different containers was as follows, in increasing levels: polypropylene (5.1%), polyethylene (5.2%) and jute bag (5.3%). The mean M.C. of peanuts stored under different temperature and R.H. conditions was as follows: 24°C and 56% R.H. (5.0%), 22 ± 3°C and 55 ± 5% R.H. (5.2%), and 19°C and 64% R.H. (5.4%). The M.C. of the four varieties varied significantly ($p \leq 0.05$) and was in increasing order: ICGV-SM 12991 (5.1%), Homabay Local (5.2%), ICGV-SM 99568 (5.2%), and Valentia Red (5.3%), respectively.

Physical damage of the peanut samples ranged from 0.1 to 9.8%. The mean physical damage increased from 2.4% before storage and peaked at 3.6% after one month of storage (Fig. 2). Physical damage of peanut samples was significantly ($p \leq 0.05$) influenced by the type of storage bag in the following increasing order: polyethylene (1.8%), polypropylene (1.9%) and jute bag (2.0%). The lowest physical damage was recorded for peanuts stored at 24°C and 56% R.H. (mean = 1.7%), followed by peanuts stored at room temperature and R.H. (mean = 1.8%), while those stored at 19°C and 64% R.H. had the highest damage (2.2%). Local varieties - Valencia Red and Homabay Local - had the highest mean physical damage (2.4 and 1.8%, respectively) with lower corresponding values of 1.7 and 1.6% for improved varieties, ICGV-SM 12991 and ICGV-SM 99568, respectively.

Rancidity - which varied from 0.8 to 5.3 – significantly ($p \leq 0.05$) increased consistently with storage duration from 1.5 before storage to a peak of 2.5 after 5 months. The type of storage bag did not significantly ($p \geq 0.05$) influence rancidity of peanut samples. Peanuts of the variety ICGV-SM 12991 had significantly lower rancidity (1.5), followed by Valencia Red (1.6) and ICGV-SM 99568 (1.7), while Homabay Local recorded the highest rancidity levels (2.1). The overall effect of temperature and R.H. on rancidity was significantly different with the following means: 24°C and 56% R.H. (1.6), 19°C and 64% R.H. (1.7), room temperature and R.H. (1.9).

Aflatoxin levels in peanut samples

There was a significant ($p \leq 0.05$) variation in the total aflatoxin levels – which ranged from 0 – 47.8 µg/kg - among peanut kernels of the four varieties stored in different bag types (Table 2; Fig. 3). Overall, kernels of Homabay Local stored in polyethylene bags at 19 ^{o}C and 64% R.H. were the most contaminated (mean = 5.5 µg/kg) while those of Valencia Red stored at room temperature and R.H. were the least contaminated (mean = 0.3 µg/kg). Irrespective of the storage conditions and bags, the local varieties were more contaminated with aflatoxin (Homabay Local = 2.5, Valencia Red = 1.7 µg/kg), than the improved varieties (ICGV-SM 12991 = 1.7, ICGV-SM99568 = 1.3 µg/kg). However, there was no significant ($p \geq 0.05$)

difference in aflatoxin contamination level between Valencia Red and ICGV-SM12991.

Table 1. Physical damage [%] and rancidity of kernels of different peanut varieties with varying moisture content [%]

Temp. [°C]	R.H.[a] [%]	Bag type	Variety	Moisture content [%]	Physical damage [%]	Rancidity
19	64	Jute	Homabay Local	5.7±0.1[d]	2.2±0.3	1.9±0.1
			Valencia Red	5.9±0.0	3.0±0.4	1.6±0.1
			ICGV-SM12991	5.6±0.0	2.9±0.9	1.5±0.0
			ICGV-SM 99568	5.7±0.0	2.0±0.4	1.6±0.1
		Polypropylene	Homabay Local	5.3±0.1	2.4±0.5	2.2±0.2
			Valencia Red	5.5±0.1	2.7±0.5	1.6±0.1
			ICGV-SM12991	5.1±0.0	2.3±0.5	1.5±0.1
			ICGV-SM 99568	5.1±0.1	1.7±0.4	1.6±0.0
		Polyethylene	Homabay Local	5.2±0.1	1.9±0.4	2.1±0.1
			Valencia Red	5.4±0.1	2.6±0.4	1.5±0.1
			ICGV-SM12991	5.2±0.1	1.7±0.5	1.7±0.1
			ICGV-SM 99568	5.4±0.1	1.5±0.2	1.8±0.1
24	56	Jute	Homabay Local	5.1±0.1	1.6±0.2	1.8±0.1
			Valencia Red	5.2±0.1	2.4±0.3	1.5±0.0
			ICGV-SM12991	4.9±0.1	1.0±0.2	1.4±0.1
			ICGV-SM 99568	5.0±0.1	1.7±0.2	1.5±0.1
		Polypropylene	Homabay Local	4.9±0.1	2.0±0.2	2.0±0.1
			Valencia Red	4.9±0.1	2.1±0.1	1.4±0.0
			ICGV-SM12991	5.0±0.2	1.8±0.4	1.4±0.1
			ICGV-SM 99568	5.1±0.2	1.3±0.1	1.5±0.0
		Polyethylene	Homabay Local	5.1±0.1	1.2±0.1	1.9±0.1
			Valencia Red	5.0±0.1	2.3±0.2	1.3±0.1
			ICGV-SM12991	4.9±0.1	1.1±0.1	1.4±0.1
			ICGV-SM 99568	5.1±0.1	1.5±0.2	1.5±0.0
RT[b]	AR.H.[c]	Jute	Homabay Local	5.3±0.1	1.4±0.4	2.4±0.2
			Valencia Red	5.2±0.1	2.6±0.4	1.8±0.2
			ICGV-SM12991	5.1±0.0	1.7±0.5	1.6±0.1
			ICGV-SM 99568	5.4±0.1	1.7±0.3	1.7±0.1
		Polypropylene	Homabay Local	5.2±0.1	1.7±0.2	2.3±0.2
			Valencia Red	5.2±0.1	1.8±0.3	2.0±0.3
			ICGV-SM12991	4.9±0.1	1.4±0.4	1.5±0.1
			ICGV-SM 99568	5.1±0.1	1.4±0.3	1.8±0.1
		Polyethylene	Homabay Local	5.4±0.1	1.8±0.3	2.3±0.3
			Valencia Red	5.5±0.1	2.1±0.4	1.8±0.2
			ICGV-SM 12991	5.2±0.0	1.7±0.4	1.8±0.2
			ICGV-SM 99568	5.3±0.0	1.8±0.4	2.0±0.2
			Mean	5.2	1.9	1.8
			LSD ($p \leq 0.05$)	0.247	1.415	0.401

[a] – Relative humidity; [b] – Room temperature (22 ± 3°C), [c] – Ambient R.H. (55 ± 5%).
[d] Means accompanied by standard error of the mean.
LSD – least significant difference (Fisher's protected LSD test, $p \leq 0.05$).

The type of storage bag significantly ($p \leq 0.05$) affected aflatoxin levels, while the storage temperature and R.H. had no significant ($p \geq 0.05$) influence during the six months storage period (Table 2; Fig. 3). Aflatoxin contamination significantly increased with increase in storage period in 25% of the samples with polypropylene bags

accounting for 13.9%, polyethylene bags (8.3%) while jute bags had the least contamination (2.8%). Peanuts stored in polyethylene bags were 7.3% and 13.4% more contaminated than samples stored in polypropylene and jute bags, respectively.

Table 2. Aflatoxin contamination level [µg/kg] of different peanut varieties stored at three temperature and relative humidity conditions in different bag types for six months

Temp. [°C]	R.H.[a] [%]	Bag type	Variety	Time [months]							Sig.
				0 [d]	1	2	3	4	5	6	
19	64	Jute	Homabay Local	0.0	2.6	1.5	0.0	1.8	3.1	1.4	ns
			Valencia Red	4.2	2.2	1.0	0.0	1.5	4.9	0.0	ns
			ICGV-SM12991	1.2	2.1	0.0	2.6	5.6	2.4	0.0	ns
			ICGV-SM 99568	0.9	1.4	3.5	3.5	2.9	2.3	0.0	ns
		Polypro-pyrene	Homabay Local	0.0	6.0	1.6	2.2	3.1	2.2	0.0	**
			Valencia Red	0.0	5.7	1.4	1.1	1.3	19.8	0.0	**
			ICGV-SM12991	0.0	3.9	2.1	2.1	1.7	0.6	0.0	ns
			ICGV-SM 99568	0.0	5.0	0.0	1.2	3.3	1.6	2.1	ns
		Poly-ethylene	Homabay Local	23.9	6.1	4.6	0.6	3.3	0.0	0.0	**
			Valencia Red	0.0	1.9	4.8	3.9	0.9	0.0	0.0	ns
			ICGV-SM12991	0.0	2.2	4.1	0.5	1.3	1.1	0.0	ns
			ICGV-SM 99568	1.6	2.0	5.1	0.9	0.0	0.9	0.0	ns
24	56	Jute	Homabay Local	1.6	1.2	1.3	1.9	2.3	0.6	0.0	ns
			Valencia Red	0.0	1.1	2.1	5.7	4.0	0.8	0.0	ns
			ICGV-SM12991	0.0	2.0	2.6	1.3	3.6	0.0	0.0	ns
			ICGV-SM 99568	0.0	1.6	1.8	2.0	1.4	0.0	0.0	ns
		Polypro-pyrene	Homabay Local	0.9	3.1	0.6	0.0	3.0	6.0	0.0	**
			Valencia Red	0.0	2.3	0.0	0.0	2.6	1.9	0.6	ns
			ICGV-SM12991	0.0	0.7	0.0	0.0	2.8	7.5	1.1	**
			ICGV-SM 99568	4.0	0.0	3.0	0.0	0.0	0.0	0.0	ns
		Poly-ethylene	Homabay Local	3.7	0.9	4.6	0.0	0.9	4.2	0.0	ns
			Valencia Red	3.7	0.6	3.5	0.0	0.0	1.0	0.9	ns
			ICGV-SM12991	6.9	0.0	0.0	0.0	0.0	3.0	0.0	**
			ICGV-SM 99568	4.2	0.0	0.0	2.0	0.0	1.0	0.0	ns
RT[b]	AR.H.[c]	Jute	Homabay Local	1.1	0.8	14	2.5	1.0	0.0	1.0	ns
			Valencia Red	1.9	0.0	1.2	3.2	3.6	0.0	1.3	ns
			ICGV-SM12991	2.0	0.6	0.0	0.0	6.9	0.0	3.3	**
			ICGV-SM 99568	1.7	0.8	0.0	0.0	0.0	3.8	1.3	ns
		Polypro-pyrene	Homabay Local	10.2	0.0	4.1	0.0	7.0	1.9	0.0	**
			Valencia Red	0.9	0.0	0.8	0.0	0.6	0.0	0.0	ns
			ICGV-SM12991	3.2	0.0	1.1	1.1	0.0	0.6	4.5	ns
			ICGV-SM 99568	4.3	0.0	1.3	0.0	0.0	1.3	0.0	ns
		Poly-ethylene	Homabay Local	4.4	0.0	0.5	3.3	2.1	2.9	0.0	ns
			Valencia Red	1.2	0.0	0.0	3.5	0.7	3.4	1.3	ns
			ICGV-SM12991	1.1	5.2	7.9	3.5	0.0	0.9	1.1	**
			ICGV-SM 99568	1.0	5.1	0.0	0.9	0.0	0.0	1.2	ns
			Mean	2.5	1.8	2.2	1.4	1.9	2.2	0.6	

[a] – Relative humidity; [b] – Room temperature (22 ± 3°C), [c] – Ambient R.H. (55 ± 5%), [d] – Before storage.
** - Significant ($p \leq 0.05$), ns – not significant ($p \geq 0.05$).

Correlations among parameters associated with aflatoxin contamination

Different parameters were correlated to each other with different coefficients (Table 3). Whereas physical damage was weakly positively correlated to M.C., it was weakly negatively correlated to rancidity. Moisture content and rancidity were strongly

positively correlated (r = 0.76), and similarly M.C. and physical damage were significantly ($p \leq 0.05$) positively correlated to aflatoxin contamination level of the peanut samples. However, the correlation between rancidity and aflatoxin level was negative (r = -0.024).

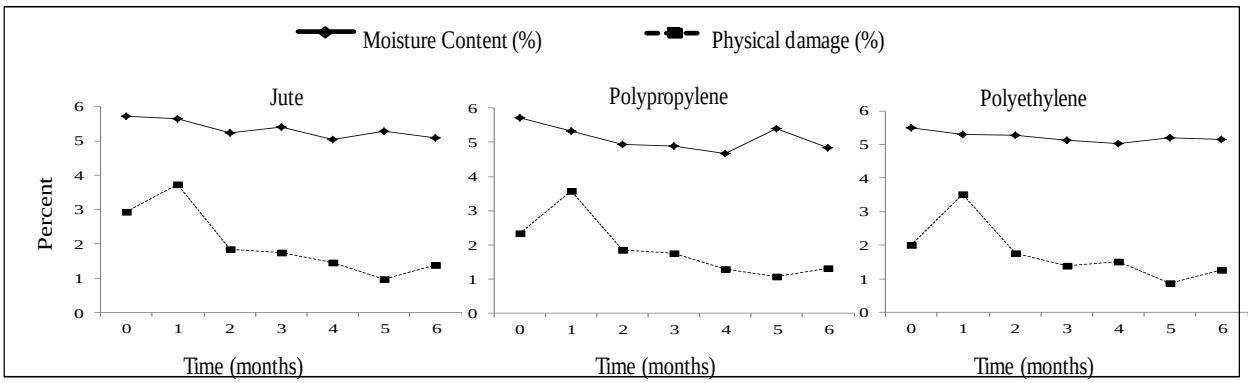

Fig. 2. Moisture content [%] and physical damage [%] of peanuts stored in different bag types for six months

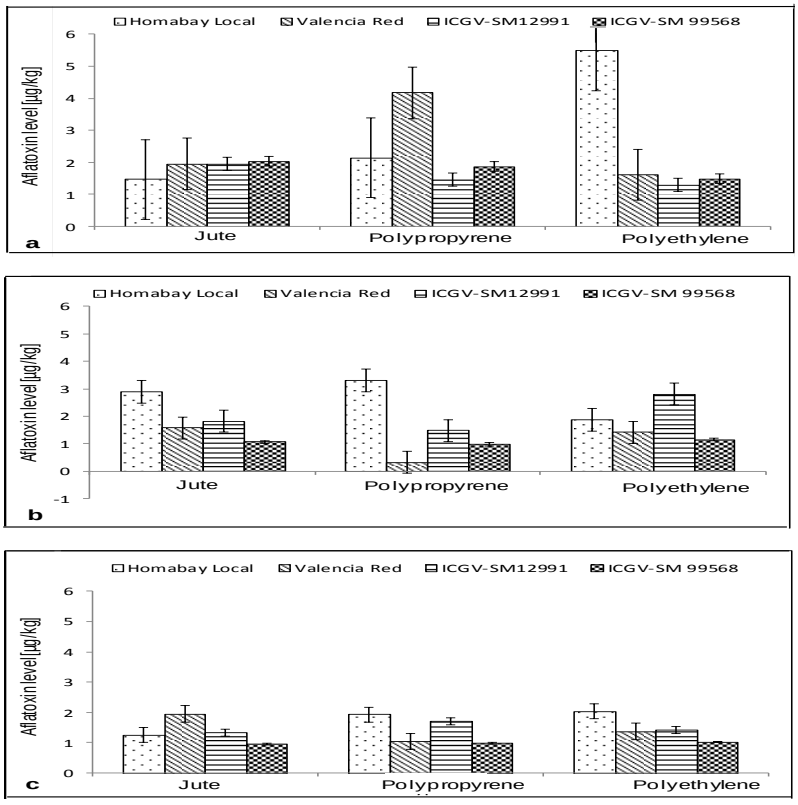

Fig. 3. Mean aflatoxin level [µg/kg] of peanut varieties stored in different bag types at varying temperature and relative humidity conditions for six months. Peanuts stored at: (A) 19 °C, 64% R.H.; (B) room temperature (22 ± 3°C) and ambient R.H. (55 ± 5%); (C) 24 °C, 56% R.H.
Error bars indicate standard error of the mean

DISCUSSION

Aflatoxin production in foods has been linked to environmental conditions, poor processing and lack of proper storage facilities in developing countries (Farombi 2006). Storage conditions of peanuts play a vital role in their quality, owing to their high oil content, that deteriorates depending on conditions under which the nuts are stored. After harvest, it is recommended that peanut kernels should be dried to safe moisture levels ≤ 10% (Rahmianna and Yusnawan 2007, WHO/FAO 2012). However, efforts to dry nuts to acceptable moisture levels are constrained in many tropical countries that are characterized by naturally occurring high humidity conditions, making drying ineffective before loading grains in stores (Mestres et al. 2004), thus increasing the risk of aflatoxin contamination.

Table 3. Correlation matrix of different parameters associated with aflatoxin contamination of peanuts

	Moisture content	Physical damage	Rancidity	Aflatoxin level
Moisture content				
Physical damage	0.20***			
Rancidity	0.76**	-0.26***		
Aflatoxin level	0.046**	0.040**	-0.024**	

, * - Significant at 5% and 1% levels, respectively.

Storage of kernels at relatively low temperature and high R.H. had the greatest effect on peanut quality. Peanuts stored at 19°C and 64% R.H. retained the highest M.C. and had the greatest proportion of physical damage while samples stored at 24°C and 56% R.H. had the lowest M.C., physical damage and rancidity. Overall, the mean proportion (1.9%) of physically damaged peanuts met the KEBS threshold of 2% for raw groundnuts (KEBS 2007). The significantly higher physical damage for the two local varieties compared to improved varieties, implied that breeding for various traits, besides resistance or tolerance to aflatoxin, can be an effective tool in managing aflatoxin contamination in peanuts. The length of storage of peanuts has also been reported to have a significant effect on physical damage with damaged and shriveled seeds increasing with increase in storage time (Rahmianna and Yusnawan 2007).

The significantly higher M.C. of kernels stored in jute bags compared to polypropylene and polyethylene bags could be attributed to absorption of moisture from the environment. The problem escalates when peanuts are stored in a facility where there is poor air circulation in the immediate environment (Mutegi et al. 2013). On the other hand, high M.C in polypropylene and polyethylene bags could result from lack of aeration within the bags. Similar to the findings in the current study, Bulaong and Dharmaputra (2002) reported that M.C. was significantly higher in peanuts stored in jute than in polypropylene bags and in jute bag lined with polyethylene. It is therefore necessary to ensure that peanuts stored in the recommended jute bags be kept in storage facilities where moisture and R.H. is adequately regulated.

Drying prevents growth of moulds, production of aflatoxin and formation of off-flavors from fungal lipase action and oxidative rancidity by decreasing water

content of seeds (Sanders et al. 1982). Because of the high amount of oil contained in peanut kernels, their quality can deteriorate quickly due to lipid oxidation depending on the presence of oxygen, light, moisture, and high temperatures (Reed et al. 2002). Rancidity, which was affected by storage temperature and R.H. but not the type of storage bag, increased gradually up to the fifth month of storage implying deterioration of peanuts during storage. The onset of oxidative rancidity is generally induced by exposure to heat and oxygen (Mercer et al. 1990). Storage fungi can change fat quality of peanuts by hydrolytic enzymes producing free fatty acids and glycerol (Pomeranz 1992), which lead to lower quality or rejection of foodstuffs (Bulaong and Dharmaputra 2002). Similar to the current findings, Bulaong and Dharmaputra (2002) reported that the level of free fatty acids significantly increased with the duration of storage of peanuts.

The popularity of polypropylene and polyethylene bags among farmers and traders in Kenya could be attributed to the lower cost and relative availability of plastic materials compared to the recommended jute bags. However, unlike jute bags which easily absorb moisture but allow good airflow, polypropylene and polyethylene bags are poorly aerated and non-absorptive but tend to trap heat inside (Kennedy and Devereau 1994), therefore encouraging growth of fungi and aflatoxin contamination (Hell et al. 2000, Udoh et al. 2000) especially if the kernels are not properly dried before storage. Therefore, whereas jute bags are recommended, the storage room should be maintained dry to avoid absorption of moisture from the environment which consequently promotes aflatoxin contamination and increase in free fatty acid content of peanut kernels. To maintain quality, besides storage of peanuts in appropriate bags, preferably sisal bags (Turner et. al. 2005), it is also necessary to facilitate aeration in transit (Hell and Mutegi 2011).

Peanuts stored in polypropylene and polyethylene bags were 5.6% and 13.4% more contaminated with total aflatoxin than samples stored in jute bag, respectively. This could be attributed to retention of heat and moisture in the two bag types – which promoted fungal growth (data not shown) and aflatoxin contamination - compared to jute bags. The duration of storage of peanuts also significantly affected aflatoxin contamination in 25% of the sampling regimes. Aflatoxin levels in maize have been shown to increase with increase in storage time (Hell et al. 2000). However, it should be noted that aflatoxin contamination of peanuts is complex and influenced by many factors. The lower aflatoxin contamination of improved cultivars compared to local peanut cultivars implies that farmers should be encouraged to grow improved peanut cultivars which in the current study were 41% less contaminated than the local ones.

Improving food quality can also result in improved market outcomes (Wu and Khlangwiset 2010), as lucrative markets have more stringent quality expectations. Peanuts should be adequately dried to safe moisture level and immediately packaged in a container – preferably sisal bags – which will delay critical increases in M.C. and free fatty acid formation (Bulaong and Dharmaputra 2002). Additionally, efforts should be made to prevent moisture migration into stored grains through leaking roofs and condensation resulting from inadequate ventilation (Bankole and Adebanjo 2003, Hell and Mutegi 2011). If the dried peanuts are to be stored in polypropylene bags, it is recommended that the bags should be air-tight and placed in an airy, dry and clean room (Rahmianna and Yusnawan 2007). Although Kenya has

established maximum allowable aflatoxin standards in food, strengthening of policy and adherence to proper packaging should be enforced.

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