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Assessment of Post-HARVEST Handling Effects on Quality of Cashew Nuts and Kernels in Ghana

Esther Gyedu-Akoto[1*], Samuel T. Lowor[1], Mike Assuah[1], Winifred Kumi[1] and Emmanuel A. Dwomoh[1]

[1]Cocoa Research Institute of Ghana, P.O. Box 8, Akim-Tafo, Ghana.

Authors' contributions

This work was carried out in collaboration between all authors. Author EGA designed the study, wrote the protocol, conducted the survey, determined the processing quality and aflatoxin levels in cashew nuts and wrote the first draft of the manuscript. Author STL performed the nutritional quality analysis of the kernels, authors MA and WK identified the disease pathogens and author EAD identified the storage insects of cashew nuts. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Purpose: A large quantity of cashew nuts is lost between harvesting and consumption. Nut quality which determine price in the world market cannot be compromised and this harvesting period is detrimental, therefore the need to evaluate the effects of post-harvest handling practices on quality.
Methodology: A survey was conducted in ten cashew growing districts in five regions of Ghana in 2009 and 2010. A total of 247 farmers, 3 buyers and 3 processors were sampled and interviewed using a questionnaire. Samples of raw nuts and kernels were collected from the cashew farmers, buyers, processors and mother trees and assessed for their processing and nutritional qualities. Data were analyzed using ANOVA and Correlation.
Findings: Results from the survey showed that 45.3% of farmers picked their nuts daily from the fields, 53.8% dried the nuts between 3-4 days and 76.1% had no storage facilities and these affected the quality of the nuts. Quality assessment using kernel analysis indicated that 41.2% of samples collected were within the standard grade with

**Corresponding author: E-mail: akua_akoto2004@yahoo.co.uk;*

the average nut weight ranging from 5.1 to 7.0 g. However, assessment of nuts collected from trees selected for germplasm establishment on farmers' farms nationwide showed that 73.9% of the nuts were of excellent grade.
Conclusion: Improper harvesting and post harvest practices may result in poor nutritional and processing quality of cashew nuts.

Keywords: Cashew nuts; post harvest; quality; drying; moisture content; outturn.

1. INTRODUCTION

One of the major sources of food insecurity in Africa is post harvest food loss. Pre- and post harvest food losses in Africa are higher than the global average and impact more severely on already endangered livelihoods [1]. It has been estimated that at least 10% of the continent's crop productivity is lost on and off farm [1]. This is because most farmers do not have access to appropriate production technologies, inadequate availability of food processing technologies and erratic climatic conditions such as heavy rains, droughts and other related factors. These food losses go beyond the threat of food security. They adversely affect farmers and consumers in the lowest income groups. They are a waste of valuable farming inputs such as water, energy, land, labour and capital and consequently affect economic growth [2]. Post-harvest food loss is a perennial problem facing the Ghanaian food economy. Ghana loses between 20-25% of its food production an equivalent of Ghc 700, 000 ($350, 000) annually due to poor post harvest management practices [3]. Thus, the need to assess post-harvest handling practices of agricultural products in Ghana cannot be over-emphasized.

The world annual production of all tree nuts in their raw state is 6.74 million tonnes [4]. Among them, cashew ranks first accounting for about 32.0% followed by almond (26.2%), hazelnut (14.3%), walnut (13.5%), pistachio (8.6%) and pecans (3.7%) making cashew production the subject of interest for development agencies, producer governments and advocates of sustainable economic and environmental development [5]. About 48% of the world's production comes from Africa and out of this only 10% is processed in Africa. As a resilient and drought resistant tree, cashew is adaptable to poor soil conditions and offers environmental benefits in the prevention of deforestation and soil erosion, especially in sub-Saharan Africa [6]. The tree and its by-products also give medicinal benefits from traditional malaria treatment to a rich source of nutrition [7]. This makes its cultivation economically promising for both rural farmers and urban industrial settlers in terms of employment generation and value addition to emerging economies. There are currently over 70,000 smallholder farmers involved in cashew cultivation in Ghana, who in turn create about 200,000 permanent and seasonal jobs, particularly for farm labourers and intermediaries such as agro-chemical input suppliers, haulers, processors and field agents [8]. There is therefore the need to ensure high and sustainable production of cashew in these economies.

Cashew was introduced into Ghanaian agriculture in the early 1980s. Originally, nuts were sold to buyers from Cote D'ivoire, at low prices and later in the early 1990s Ghanaian companies began purchasing nuts for export. The first raw cashew nuts of 15 tonnes were exported in 1991 [9]. Since then the production levels of cashew in Ghana have increased steadily Fig. 1 and it is expected to increase to over 100,000 tonnes within the next ten years. Local processing and marketing of cashew nuts have begun to take centre stage in the economic development of Ghana. Local processing of raw nuts has also increased

significantly. However, only 5% of the total annual production is processed and this is also expected to increase to 30% in the next ten years. The Government of Ghana together with its Development Partners, Non-Governmental Organizations and the private sector has contributed immensely to the growth of the cashew industry. The Government's major intervention is the implementation of the Ghana Cashew Development Project with the aim of increasing production and processing of cashew.

Cashew nut quality is of utmost importance as the kernel, which is the edible part of the nut, directly enters the retail market. High quality is of primary concern to importers, and one of the major criteria for success in the world market. Discoloured, pitted, shriveled nuts are not to be mixed with good nuts. Pests and diseases play an important role in determining nut quality since they can cause premature nut fall, incomplete nut filling and damage to the nut and consequently reducing its nutritional value. With the liberalization of cashew marketing, buyers are selective about what they purchase and are ready to pay higher price for clean nuts and those with higher percentage out-turn and lower moisture content [10]. Cashew nuts from some parts of Africa are valued more on the world market than others due to differences in quality characteristics. There is also no available information on natural occurrence of microbes on raw cashew nuts in Ghana. This study seeks to conduct a baseline research on the harvesting and post-harvest handling practices used by cashew farmers, buyers and processors and how they affect the processing and nutritional quality of raw nuts and kernels in Ghana. It is also to identify microbial contaminants in raw cashew nuts since some can grow and produce mycotoxins, infections and allergies.

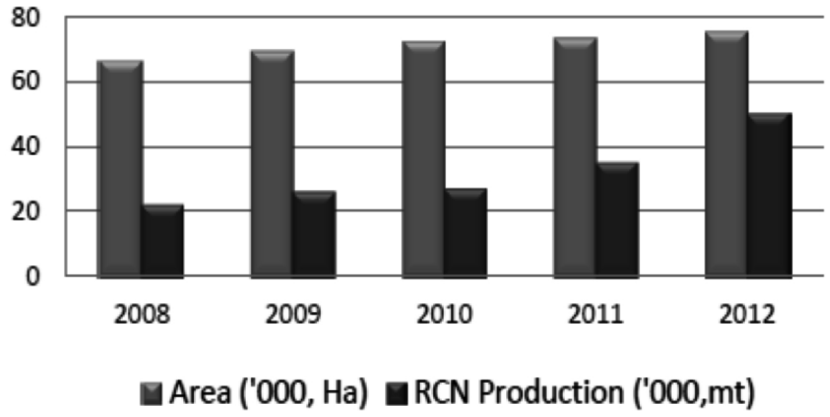

Fig. 1. Production of cashew nuts in Ghana from 2008 to 2012 (Source: MOFA, 2013)
(*rcn - raw cashew nuts)*

2. MATERIALS AND METHODS

2.1 Survey

A survey was conducted on cashew farmers in ten cashew growing districts located in five regions in Ghana using multistage sampling technique. The first stage involved the selection of regions using purposive sampling techniques where the regions were grouped into forest, forest-savanna (transitional belt) and savanna zones. The Volta and Eastern regions were selected from the forest zone, Brong Ahafo from the transitional belt and the northern and

upper west regions from the savanna zone. The second stage involved selection of the districts visited using purposive and simple random sampling. The districts were Jaman North, Wenchi and Kintampo in the Brong Ahafo Region where the bulk of Ghana's cashew production is obtained, Yendi, Gonja West and Bole in the Northern Region, Jirapa and Nadowli in the Upper West Region, Ho and the Afram Plains in the Volta and Eastern Regions respectively. Since cashew thrives well in both the transitional belt and savanna zone, the study was concentrated in these areas. The third and final stage was the selection of farmers that were interviewed. This was achieved with the help of the districts' ministry of food and agriculture (MOFA) directorates which selected the farmers randomly based on extension contacts and data with regards to their harvesting and post-harvest handling practices. A total of 247 farmers were selected and interviewed.

Three local buyers and three raw nut processors were selected at random and interviewed on the handling of their raw nuts prior to shipping and processing. Only three of each group was selected because there are only twelve processing units and a few local buying agents in Ghana who are mostly located in the Brong Ahafo region. Temperature and humidity of the storage environments were measured using a thermo-hydrometer. Samples of 2 kg of raw nuts were obtained from each farmer and buyer and assessed for their processing quality. Nuts from 199 selected trees for germplasm establishment by the cocoa research institute of Ghana were also assessed in terms of processing quality and the results compared to that obtained from the survey. The selection of the trees was done based on characteristics such as yield per tree, nut weight, tolerance to diseases and insect pests. Samples of kernels were also collected from the processors for nutritional quality assessment. The survey was conducted during the harvesting season (March-May, 2009/10), when farmers were doing their harvest, drying and storage of raw nuts prior to marketing.

2.2 Assessment of Processing and Nutritional Quality of Raw Nuts

Processing quality was assessed by determining the outturn, nut count, nut weight/size and moisture content of the raw nuts, where

Outturn (sellable) is the quantity of good kernels in 1 kg raw nuts.
Nut count is the number of individual nuts in 1 kg raw nuts
Nut weight/size is 1 kg/nut count

The outturn was determined by weighing 1 kg from each raw nut sample obtained and cutting each nut through the line of intersection of the shells and kernels. The kernels were then removed from the shells and separated into good, void, diseased and immature kernels. The various grades were then weighed separately and the outturn calculated as follows:

$$\boldsymbol{OT} = \boldsymbol{x} + \frac{\boldsymbol{a+b+c}}{\boldsymbol{2}} \qquad \text{.....(1)}$$

X is weight of good kernels
A is weight of void kernels
B is weight of diseased kernels
C is weight of immature kernels.

$$\%\boldsymbol{OT} = \frac{\boldsymbol{OT}}{\boldsymbol{1\,kg\,RCN}} \times \boldsymbol{100} \qquad \text{.....(2)}$$

RCN is raw cashew nut

The moisture content of the raw nuts was determined using the moisture meter.

Nutritional quality assessment was done by determining the fat and protein contents using Soxhlet extraction and Kjedahl's methods respectively. Moisture and ash contents were also determined using [11] methods. The quality of the fat obtained from the kernels was analyzed for refractive index, iodine and peroxide values and free fatty acid content.

2.3 Identification of Disease Pathogens and Storage Insects

Samples of diseased nut and kernels were cultured on water agar (WA) after surface sterilizing with 70% ethanol and rinsed in sterile distilled water. The plates were incubated at 25^{o} c and the mycelia that grew from the samples transferred onto potato dextrose agar (PDA) and malt extract agar (MEA) for growth and sporulation. The culture morphology and spore characteristics of the isolated organisms were used to identify the pathogens by physical observation and microscopic examination [12]. Insects which emerged from infested nuts and kernels during storage were also collected and sent to the natural resources institute (University of Greenwich, UK) for identification.

2.4 Aflatoxin Determination

This was carried out on diseased, oil-stained and good kernels (both raw and roasted) using methods described by [13]. Aflatoxin standards used were B1, B2, G1 and G2. Chemicals and reagents used included HPLC grade chemicals such as acetonitrile and methanol which were obtained from sigma aldrich.

2.4.1 Preparation of standard solutions

Serials of working standards of the four standards were prepared by diluting each stock standard solution with methanol and stored in the dark at 4°c when not in use.

2.4.2 Sample extraction

Twenty-five grams (25 g) of each ground sample was mixed with salt (NaCl) and 125 ml of methanol:water (70:30). The mixture was blended at high speed for 2 minutes and filtered through a fluted filter paper. Fifteen millilitres (15 ml) of each extract was then transferred into a test tube, diluted with 30 ml purified water and mixed well. The mixture was filtered through a glass microfiber filter and 15 ml of the extract was passed through Afla test® affinity column for purification.

2.4.3 Chromatograph analysis

The purified extracts were analyzed by reversed-phase isocratic high performance liquid chromatography (hplc) from shimadzu lc 10a using a supelcosil lc-18 hplc column (30cm×4.0 mm id, 5 µm) maintained at ambient temperature. A fluorescence detector from Shidmazu rf-10axl was set at 365 nm (excitation) and 435 nm (emission). The mobile phase applied was deionized water/acetonitrile/methanol (60:20:20) with flow rate of 1.0 ml/min and injection volume of 20 µl.

2.5 Data Analysis

Data obtained were analyzed using analysis of variance (ANOVA) and correlation.

3. RESULTS AND DISCUSSION

3.1 Survey

Mature agricultural products in the field go through a lot of production and processing techniques to convert them into suitable or acceptable forms for human consumption. There are many opportunities for food to be lost between harvest and consumption. It is a waste of effort to increase food production if the food does not reach the consumer for the utilization of its nutritional value and the inducement of satiety [14]. Food must not only be produced to achieve food security, it must also be fit and safe to eat. A lot of food is lost through harvesting and post harvest handling in Ghana mainly because most of the farming communities do not have access to the appropriate technologies.

Cashew nuts have similar characteristics to other oil-bearing nuts or fruits and must have similar requirements as other nuts with regards to care during harvesting and post-harvest handling. Cashew has a short harvesting season of about 60 days beginning from February to April depending on the area of growth. About 45.3% of the farmers interviewed harvested their raw nuts daily and this was done by picking mature and ripe fruits from the ground and manually detaching the nuts from the apples (Table 1). This was to ensure that only mature nuts were collected and prevented from rodents and thieves. The remaining 54.7% did their harvesting less frequently. They harvested their nuts in more than two days or sometimes weekly and this was because farmers did the picking themselves with their family members and therefore apportioned their time among other activities. This may therefore lead to loss of nuts since nuts left in the field for a long time may undergo deterioration due to exposure to extreme weather conditions as reported by [15]. In humid areas such as the Brong Ahafo, Eastern and the Volta regions where there are high rainfall patterns, most of the nuts that were not picked early enough had blemishes and black spots on them whilst in drier areas like the northern and upper west regions, the high temperatures led to discoloration or scorching of the nuts and seeping of cashew nut shell liquid (CNSL) into the kernels. This reduces the quality of raw nuts appreciably and this runs contrary to earlier reports [16] that in very dry climates where the topsoil is always dry, nuts can be left under the trees for several weeks without their quality being affected.

Cashew is one of the few commodities that travel a long distance between the time it is harvested and when it is consumed [4]. Nut spoilage is likely to occur during this period making drying a very important step in the post-harvest chain. Drying was normally done in farmers' homes. Therefore, farmers carried their nuts from the farms to their homes for drying. Out of the 247 farmers interviewed, 53.8% dried their nuts for 3-4 days with 64.8% drying under some form of shade (Table 1). Drying under shade was done mostly by farmers in the northern and upper west regions where the temperatures are very high with low humidity (Table 2). In the Brong Ahafo region where the bulk of cashew nuts in Ghana are produced, about 44.4% of farmers dried their nuts for 3-4 days. The remaining 65.6% either did their drying for less than two days or sometimes did not dry at all. This was due to competition among the local buying agents who buy the nuts early in the production season and stock for exporters for higher prices. Some of the farmers also thought that drying reduced the weight of nuts and thereby reduced the prices. Generally, prices of cashew nuts

at the beginning of the season are very low but wind up higher by the end of the season and farmers who are short of cash early in the season are forced to sell their produce without drying.

Moisture content determination showed that 23.1% of raw nut samples collected had moisture contents ranging from 6.1-8.0% (Fig. 2) and these were mainly from the northern and upper west region where temperatures were high and humidity low (Table 2). The nuts in these areas were found to be already dry in the field before picking and most of them scorched. A total of 59.3% of samples had moisture content of 12.0% or below with the remaining 39.7% having moisture content above 12.0%. Low moisture levels limit mould growth during storage. Most of the nuts with moisture contents above the acceptable level (10-12%) came from the brong ahafo region and this may be due to the high humidity levels (Table 2) in the area and the fact that farmers there dried their nuts mostly for less than 3 days. Correlation (r) between moisture content and storage humidity was significant but low (p = 0.05).

The three buyers interviewed during the survey also dried their nuts directly in the sun for just a day or two with the notion that farmers had already dried them before selling to buyers. However, the processors dried their raw nuts for longer periods and stored them in warehouses for processing throughout the year. Drying was mostly done on hard ground concrete floors in farmers' homes. About 64.4% of the farmers dried their nuts on the bare concrete floor without drying mats. Drying preserves the nuts through storage, transportation and processing. Therefore, drying nuts to the acceptable moisture range of 10-12% is a very critical operation in the production chain.

Table 1. Cashew postharvest handling practices carried out by farmers in the growing regions of Ghana

Description	Region					Total	%
	U/W	Eastern	B/A	Northern	Volta		
Total no. of farmers	34	43	81	53	36	247	100
Daily picking	17	22	31	25	17	112	45.3
Barefloor drying	27	29	40	42	21	159	64.4
Shade drying	28	21	41	49	21	160	64.8
3-4 days drying	20	22	36	34	21	133	53.8
Barefloor storage	32	20	39	33	25	149	60.3
No warehouse	29	32	56	45	26	188	76.1

In terms of storage, about 76.1% of the farmers did not have any storage facility at all and stored their nuts mostly in their kitchen. Those with storage facilities kept their nuts in small, dark rooms set aside in the house for storing cashew nuts. These rooms usually lacked proper ventilation. The nuts were stored mostly in pans, baskets, woven high density polyethylene (HDPE) bags and some heaped on the bare floor. However, both processors and buyers had bigger storage rooms which also lacked proper ventilation. They stored the nuts in jute sacks and placed them on wooden pallets. Late harvesting, improper drying and poor storage facilities contributed to losses incurred during storage. Storing raw nuts under such conditions may create warm humid conditions in the storage rooms which may also lead to spoilage by fungal infection. They also expose the nuts to insect pests, termites, rodents and theft.

Table 2. Storage conditions and moisture contents of raw nuts

Region	Storage temp (ºC)		Humidity (%)		Moisture content (%)			R
	Min	Max	Min	Max	Min	Max	Av	
Upper west	21.1	38.9	25.3	65.0	6.2	17.7	9.6	0.41
Eastern	24.4	36.1	49.0	73.0	6.3	16.3	11.4	0.30
B/a region	21.1	38.7	37.0	81.0	7.1	25.5	15.7	0.52
Northern	22.8	36.1	24.3	83.0	6.1	19.6	11.5	0.46
Volta	21.1	35.0	30.0	80.0	6.5	20.7	10.1	0.24

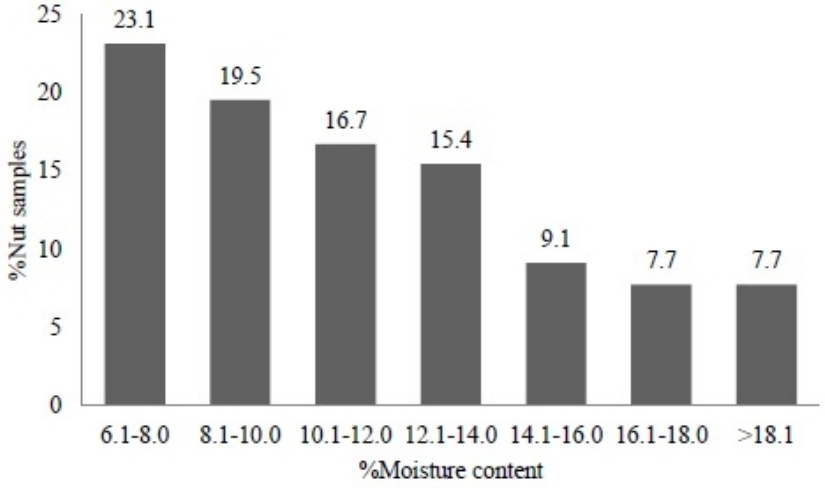

Fig. 2. Moisture distribution in raw nuts sampled from five regions

3.2 Processing and Nutritional Quality of Raw Nuts

The value of raw cashew nuts mostly depends on the surface appearance, size or weight of the nut, moisture content, outturn and defective nut. There are no general standards for raw cashew nuts in west africa. However, nuts with a good kernel yield have outturn ranging from 24-28% (standard grade) and an excellent one from 28-32% (excellent grade). Nuts of these grades are mature, dry and show no defect. Low or under grade nuts have outturn less than 24% and these are also mature, dry nuts and may have blemishes, spots and tolerable discolouration. Quality assessment of the raw nuts through cutting test showed that 41.2% of raw nut samples collected from the survey fell within the standard grade (Fig. 3) while 37.0% were within the low grade. However, 73.9% of nut samples from the selected trees for germplasm establishment had excellent grade with only 3.4% in the low grade (Fig. 3) indicating that nuts from the selected trees were of better quality than those collected from the respondents. For weight distribution, most nuts from both survey and selected trees weighed between 5.1-7.0 g (Fig. 4) confirming reports by exporters that nuts from West Africa are small in size weighing between 4.1 and 6.0 g since larger nuts attract a premium. Thus, the quality of raw nuts in terms of processing may be genetic and it is therefore suggested that the processing quality must be considered as one of the most important factors in future breeding and selection programmes for cashew in Ghana.

The primary product of cashew nut is the kernel, which is the edible portion of the nut. It is consumed either directly by the consumer as roasted nuts or in confectionery and bakery products or as paste to spread on bread. Kernels obtained from the three processing centres had protein contents ranging from 26.67 to 28.89% and fat content between 44.80 and 49.96% (Table 3). The protein and fat contents found in the survey shows that the kernels obtained in Ghana were relatively the same to the findings by [17]. However, there was no significant difference between the samples in terms of protein and fat contents.

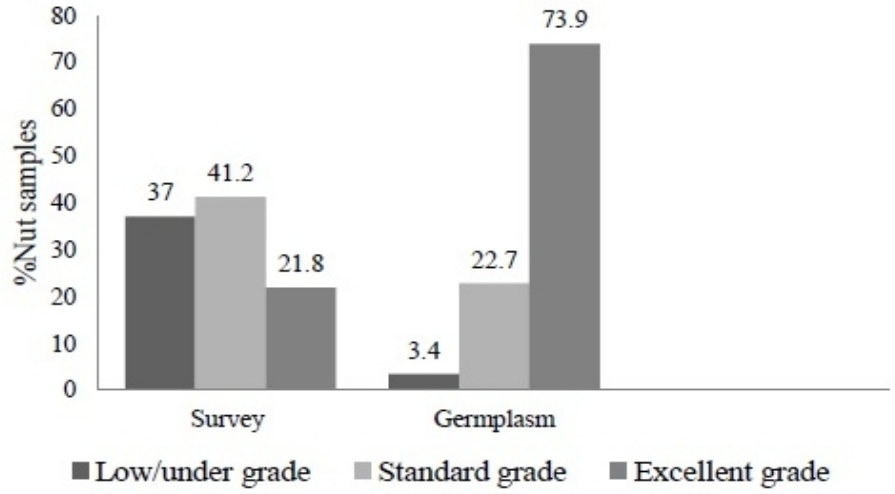

Fig. 3. Quality of raw nuts from both survey and germplasm collections

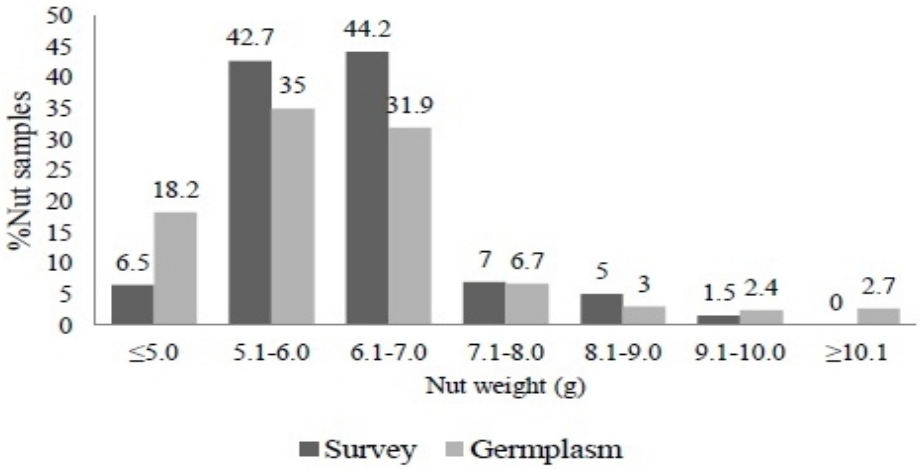

Fig. 4. Weight distribution of raw nuts from both survey and germplasm collections

The fat content of the kernel contributes substantially to its energy level [18]. Results of the fat analysis shown in Table 3 describe the quality characteristics of the fat in the kernel. Iodine values, which indicate the degree of saturation of fats, ranged from 75.41 to 90.48%. These fell within the limits of the literature data for vegetable oils, 77-95% [19], indicating that the kernel fat is non-drying, highly unsaturated and may contain high levels of oleic and

linoleic acids [20]. Peroxide value (pv) is the measure of the degree of oxidation in fats or storage stability of fats and oils. Peroxide values of the kernels ranged from 14.19 and 17.88 meq/kg. These values were higher than the acceptable level of 5.0 meq/kg. This may be due to the fact that cashew nuts are harvested during the dry season confirming reports that dry weather conditions may cause pv to be higher than the acceptable level [21]. The free fatty acid content is an indication of chemical degradation of fat and these were between 0.28 to 0.71%. Refractive index of the kernel fat ranged from 1.463 to 1.466 and these were very close to 1.4674-1.4736 as reported by [19]. However, kernels from Ghana had moisture contents below the acceptable level of 5%. All these showed that the kernel fat was of high quality and was quite stable in terms of storage. This therefore implies well managed from harvesting to processing are likely to produce kernels of high nutritional quality. There was however no significant difference between kernels from the three processing units in terms of their nutritional quality.

Table 3. Proximate analysis of cashew kernels

Parameter	Bole	Kabile	Nsawkaw
Moisture (%)	4.17 ± 0.12	3.83 ± 0.40	4.27 ± 0.59
Ash (%)	2.60 ± 0.10	2.53 ± 0.06	2.63 ± 0.06
Protein (%)	27.26 ± 2.87	26.67 ± 2.63	28.89 ± 0.99
Fat (%)	49.96 ± 1.72	44.80 ± 1.25	48.37 ± 0.51
Fat analysis			
Refractive index	1.466	1.463	1.463
Iodine value (%)	75.41 ± 0.08	90.48 ± 0.74	80.88 ± 1.32
Peroxide value (meq/kg)	14.19 ± 0.09	17.88 ± 1.25	17.79 ± 0.00
Free fatty acids (%)	0.28 ± 0.07	0.40 ± 0.00	0.28 ± 0.00

3.3 Disease Pathogens and Storage Insects

Pathogens on diseased kernels and shells were identified to be mainly fungal infections caused by *Aspergillus sp*, which are well known for the production of aflatoxins and other mycotoxins. The species identified were *A. carbonarius, A. tamari, A. niger, A. flavus,* and *A. terreus*. Other fungal isolates identified were *Lasiodiplodia theobromae*, *Paecilomyces sp*, and *Eurotium sp*. A few bacteria isolates were also found in the cultures of the diseased nuts. *L. theobromae* causes rotting and dieback in most plants they infect, *Paecilomyces sp* kills harmful nematodes in the soil and *Eurotium sp* are the sexual state of *Aspergillus sp* and *Penicillium sp*, which grow on seeds and stored foods. It was observed that these infections had their origin in the field rather than in storage confirming reports by that fungal infections normally occur when the hosts are in the field, but often show no symptom until post-harvest storage or transport [22]. All these infections depend on a number of factors including temperature, moisture and storage time [23]. Therefore, poor post-harvest management can also lead to the initiation of these fungal activities thereby causing losses of both commercial and nutritional values in the nuts.

Storage insects of the raw nut samples were identified as *Ephestia sp,* which is a moth and *Araecerus fasciculatus* or the coffee bean weevil. Nuts from previous year's harvest have also been observed to have a particular tendency to beetle infestation. It has been estimated that about a quarter of the world's grain production is lost during storage annually and that which is not lost is severely reduced in quality. Much of this is due to insect attack. These insects eat the kernels, thereby reducing their nutritional value.

3.4 Aflatoxin Determination

Fungal activity can result in the contamination with mycotoxins [22]. Among the various mycotoxins, aflatoxins are considered to be important due to their deleterious effects on human beings and animals (reddy and waliyar, 2000). Aflatoxins are produced by *Aspergillus* mould, particularly *A*. *Flavus* and *A*. *Parasiticus*. Out of the eighteen different types of aflatoxins identified, the major ones are aflatoxins B1, B2, G1 and G2. Aflatoxin B1 is the predominant one in food products and it is known to be carcinogenic in both human and animals. Aflatoxins have been reported to display potency of toxicity, carcinogenicity, mutagenicity in the increasing order of B1 > G1 > B2 > G2 [24]. Aflatoxin determination showed that both good and diseased kernels contained some levels of all the four types of aflatoxins (Table 4). They were all far below 20 ppb, which is the who and Ghana standards authority (GSA) regulatory limit. Low levels of exposure to aflatoxin are normally permitted, believing that limited exposures over a lifetime are not dangerous. However, it has been reported that low levels may have long term effects on livestock, poultry and animal products [25]. Raw good kernels had lower levels of aflatoxins (0.001-0.008 ppb) than raw diseased kernels (0.005-0.090 ppb). Roasted kernels also showed some levels of aflatoxins and this is because aflatoxins in the dry state are very stable to heat up to their melting points. However, in the presence of moisture and at high temperatures there is destruction of aflatoxin over a period of time. Kernels stained with cashew nut shell liquid (CNSL) had the least amounts of aflatoxins and this may be due to the acidic nature of CNSL.

Table 4. Levels of aflatoxins in cashew kernels

Sample	Type of aflatoxin and concentration (ppb)				Total conc
	G2	G1	B2	B1	
Raw good kernels	0.001	0.000	0.006	0.001	0.008
Raw diseased kernels	0.036	0.041	0.005	0.008	0.090
Oil stained	0.002	0.001	0.001	0.001	0.004
Roasted good kernels	0.091	0.011	0.071	0.012	0.185
Roasted diseased kernels	0.017	0.009	0.017	0.014	0.057

4. CONCLUSION AND RECOMMENDATIONS

In conclusion, poor management of harvesting and post-harvest practices may result in losses in cashew nut production and poor nutritional quality of cashew kernels. Processing quality in terms of outturn and nut size may also be genetic. It is therefore suggested that breeding and selection programmes must consider nut size, outturn as well as tolerance or resistance to insects and microbial infection. The following guidelines are recommended for the reduction of post-harvest losses of cashew nuts:

4.1 Proper Harvesting Techniques

Only mature nuts from fully grown apple must be picked and this must be done daily to prevent spoilage on the farm.

4.2 Proper Drying Methods

Nuts must be sun dried immediately after harvesting for 3-4 days to a moisture level of 10-12% or until the kernels rattle in the shell. Drying should be on hard ground, preferably,

concrete floors covered with mats to avoid contamination with foreign matter. Nuts should be spread thinly on the ground or should not exceed 20 kg/m^2 or a finger depth. Nuts must be turned constantly about 2 to 3 times daily for uniform drying. In northern and upper west regions where temperatures are very high, drying must be done under shade (open-air drying) to avoid scorching of nuts and oil-stained kernels.

4.3 Proper Storing Methods

Dried nuts should be stored in jute bags and not heaped on floors of storage rooms to avoid creating humid conditions in the rooms and absorption of moisture from the ground. Storing in woven hdpe bags are not recommended for storage of raw nuts since they create humid conditions in the bags. Bags of nuts must be placed on wooden pallets to avoid direct contact with the floor. Cheaper pallets can be made from bamboo sticks. Store rooms must be well-ventilated, insect-free and must have low humidity with leakage-free roofs. It is important not to store freshly harvested and dried nuts with old nuts since these may act as a source of insect infestation. The use of clean or new sacks is also recommended for cashew storage and the storage room must be cleaned occasionally.

Implementing these guidelines as a package or set of procedures will be more effective in the production of superior quality nuts and kernels than traditional post-harvest procedures. Any one of these methods has been demonstrated to have an impact on nut quality, however when used as a package these measures will reduce post-harvest losses in the food chain by more than half.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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