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Effects of Variety and Different Storage Structures on the Quality of *Cola acuminata* and *Cola nitida* in Storage

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Abstract: *Two kolanut varieties,* Cola acuminata *and* Cola nitida*, were stored in four (4) different structures over a period of 16 weeks, and their quality was evaluated. Palm frond-woven basket, paper carton, clay pot, and semi-evaporative pot were used as storage structures. To reduce moisture loss during storage, three materials were used to line each of the storage structures: transparent polyethylene sheet, newspaper, and leaves of Onchocalamas sp. (locally,* ugba*). Storage was carried out at the Department of Agricultural and Environmental Engineering, University of Agriculture, Makurdi, Nigeria. Dry bulb temperature and relative humidity during storage varied from 27–32^oC and 72–91%, respectively. Parameters used to evaluate quality during storage were sprouting, colour changes, rot, weight loss, mould formation, rusty-brown spots, and weevil damage. At the 95% significance level, rot and weight loss were found to be significantly greater in* Cola nitida *than in* Cola acuminata*, while sprouting was significantly greater in* Cola acuminata*. For both kolanut varieties, quality during storage varied significantly with storage structure, with variety having greater effect on quality in the paper carton and semi-evaporative pot than in other structures. For both kolanut varieties, paper carton recorded the highest reduction in quality based on the quality parameters measured.*
Keywords: acuminata*, kolanut,* nitida*, shelf life, storage*

I. Introduction

Kolanut (or cola) is a genus of tree native to the tropical rainforests of Africa, scientifically classified in the family *Malvaceae*, subfamily *Sterculioideae*. The term "kolanut" is used to refer to the cotyledons of some species of cola. Cola comprises of about twenty-five species, with a good number of them non-edible [1]. The most commonly used cola species are *C. verticillata* (Thonn.); Stapf, *C. acuminata* (Pal. de Beauv.) Schott and Endl., and *C. nitida* (Vent.) Schott and Endl., with the latter two having the greatest economic importance [2]. The nuts of a small number of kolanut species, including *C. nitida* and *C. acuminata* are edible; most species produce seed that is hard and inedible. Some kola species are poly-cotyledons, such as *C. acuminata*. The seeds of edible species are ovoid or ellipsoid in shape, getting up to 5cm in length and 3cm in width. Most of the seed consists of cotyledons to which the minute embryo is attached. In *C. nitida* there are two cotyledons and the seeds readily split into half whilst in *C. acuminata*, there are three or four cotyledons (sometimes as many as six), with the seed splitting into a corresponding number of pieces.

C. nitida was originally distributed along the West Coast of Africa, including Sierra Leone and the Republic of Benin, with Ghana and Cote D'Ivoire having the highest distribution [3]. Cultivation of *C. nitida* was carried eastwards through Nigeria towards Cameroon and the Congo around 1900, and spread westwards as far as Senegal [3]. Today, *C. nitida* is planted in most West African countries, including Nigeria.

The kolanut has been in use for a long time. It has a bitter taste and contains the chemicals caffeine, theobromine and kolanin, which are all stimulants. Its chewing is a part of many West African cultures, primarily to restore vitality (due to its stimulant content) and to ease pangs of hunger [4]. Kolanuts are an important part of the traditional spiritual practice of many ethnic groups in West Africa, Nigeria inclusive. Kolanuts are used as religious objects and as an important offering during prayers and significant life events such as naming ceremonies, weddings and funerals [5].

The cultivation, processing and storage of the nuts takes place in the warm, humid rainforest zone where there is high risk of mould infection. However, the nuts are so important that fairly mouldy samples are commonly ingested. This is in spite of the numerous toxic metabolies [6] frequently associated with mould-contaminated foods and the consequent risk posed to their consumers.

The problems posed by pests of kolanuts in storage, most especially the cola weevils (*Balanogastris kolae* and *Sophohinus sp.*) are detrimental to the little production often achieved by cola farmers. Generally, it is the most serious post-harvest problem of kolanuts, which farmers and kolanut traders seek to solve. Cola weevils, identified as pests of cola from the field to the store, are capable of causing 30–70% damage to the stored nuts, while greater damage has been recorded in cases of late harvest and in storage [7].

Unfortunately, the kolanut is one of the few indigenous African cash crops that have not attracted sufficient international support. Most countries outside Africa and even Africans to an extent shy away from its production and improvement. The weevils feed, oviposit and complete their life cycles entirely within the kola nuts thereby exposing the kola nuts to secondary invasion by microorganisms, especially fungi [8].

Apart from weevil damage, environmental factors such as high humidity and temperature can affect the rate at which the quality of kolanuts decline [9], usually discolouring the nuts and rendering them prone to fungal attack (especially from *Botryodiplodia theobromae*). Mechanical damage to the nuts especially during extraction of nuts with machetes also reduces quality significantly. Determinants of market value of kola nuts are flavour, colour, and size. Farmers mostly sell all produce immediately after gathering or harvesting due to lack of efficient storage facilities and transport problems. The quality of the nuts depends greatly on the methods used to extract the nuts from the pod, and in curing, cleaning and storage. Due to changes in physiology and composition, the appearance, taste or texture of the nuts are altered and make the nuts less desirable aesthetically to the end users. Discarded kolanuts, resulting from poor processing and storage, are an economic loss to the farmer.

Most cola species pickers, traders and industrial users depend on the traditional way of curing and preserving the nuts, which leads to substantial losses by way of insect infestation [10], in-situ germination, shrinkage, and mouldiness. Such losses can be avoided with the use of proper storage containers, proper pre- and post-storage, insect control strategies and periodic turning of the nuts in storage. Appropriate storage methods ensure kola products are available throughout the year and do not deteriorate in storage. This will ensure that producers are able to store their crop, ensuring that they command better prices. It is therefore important to study the storage environments and structures in the storage of kolanuts in order to proffer solutions to the problems common to the storage of kolanuts.

The objective of this work is therefore to ascertain the effect of four (4) storage structures on the quality of *Cola acuminata* and *Cola nitida* seeds.

II. Materials And Methods

Two varieties of kola nut popular in Nigeria, *Cola acuminata* and *Cola nitida*, were used for the experiment. They were acquired three (3) days after harvesting. They were soaked in potable water at room temperature for seven (7) hours to ease removal of the white testa surrounding them. After skinning, the nuts were washed in potable water, and then spread in a thin layer on jute bags for four (4) days for equilibrium moisture content to be attained before the commencement of storage activities.

Four (4) storage structures were used: palm frond-woven (wicker) basket, paper carton, clay pot, and semi-evaporative pot. To reduce moisture loss during storage, three materials were used to line each of the storage structures: transparent polyethylene sheet, newspaper, and leaves of *Onchocalamas sp.* (locally called *ugba* leaves). The *ugba* leaves were in direct contact with the kolanuts, followed by the newspapers, before the transparent polyethylene bags. The storage structures were properly prepared by keeping them clean and dry (not containing moisture that could affect the kolanuts in storage). The semi-evaporative cooling method was achieved by the use of two clay pots, one inside another. The smaller clay pot contained the kola nuts, placed inside the bigger clay pot. The space between the pots was filled with sandy soil which was kept wet throughout the period of the experiment.

Kolanuts of each variety were weighed using an electronic weighing balance to know the initial weight of the nuts and were counted to know the initial number of nuts before loading into the different storage structures. Daily readings of the wet and dry bulb temperatures were recorded by the use of a wet and dry bulb (alcohol-in-glass) thermometer; knowing the wet and dry bulb temperature, the relative humidity was determined from a psychrometric chart. The readings were obtained daily at noon. The kola nuts were observed weekly for quality changes, with percent sprouting, colour changes, rot, weight loss, mould formation, rusty-brown spots, and weevil damage determined during each observation. Rotten nuts were removed from the storage structure to prevent them from affecting other nuts.

The weevil damage index was determined from the following expression [11]:

$$\text{Weevil Damage Index} = \frac{\text{Number of nuts damaged by weevils}}{\text{Total number of nuts}} \times 100 \qquad (1)$$

The expression for the determination of weevil damage index was adopted and used for physiological changes observed in the stored kola nuts for each variety and structure.

Percentage weight loss was determined from the expression below [11]:

$$\%\ \text{weight loss} = \frac{\text{Initial weight} - \text{observed weight}}{\text{Initial weight}} \times 100 \qquad (2)$$

The experiment was carried out for 16 weeks (4 Months) at the Food Processing Laboratory of the Department of Agricultural and Environmental Engineering, University of Agriculture, Makurdi, Benue State, Nigeria.

Data were subjected to two-factor analysis of variance (ANOVA) using the General Linear Model (GLM) procedure, with kolanut variety and storage structures as factors. SPSS version 20, 2011, was used for all data analysis. Significantly different means were separated using the Duncan's Multiple Range Test (DMRT) of the same statistical package.

III. Results And Discussion

During the storage of *Cola acuminata*, the average room temperature ranged from 29°C to 32°C dry bulb temperature and 27°C to 29°C wet bulb temperature, while the average relative humidity ranged from 78% to 85%. The average room temperature during the storage of *Cola nitida* ranged from 30°C to 32°C dry bulb temperature and 27°C to 29°C wet bulb temperature, and the relative humidity ranged from 80% to 85%. [9] reported that a dry bulb temperature of 20°C and relative humidity of 75% – 90% were the most favourable conditions for storage of kolanuts. However, high temperature facilitates increased rate of respiration, exerting high vapour pressure and enhancing significant loss in kolanut weight. This is because at high temperatures, there is a greater tendency for metabolic activity and transpiration to occur, using up the energy of the kola nuts and resulting in greater weight loss. High relative humidity can also be a favourable condition for weevil breeding.

Variations in mean quality parameters between the two kola nut varieties stored (*Cola acuminata* and *Cola nitida*) are presented in TABLE 1 below.

Table 1: Variations in mean (± SEM) quality parameters of *Cola acuminata* and *Cola nitida* in storage

	Varieties	
Quality parameters (%)	*C. acuminata*	*C. nitida*
Sprout	6.33 ± 0.58^{a}	1.13 ± 0.19^{b}
Colour changes	3.42 ± 0.36	3.23 ± 0.65
Rot	0.23 ± 0.09^{b}	1.96 ± 0.66^{a}
Weight loss	4.23 ± 0.64^{b}	16.09 ± 2.08^{a}
Mould invasion	8.96 ± 1.21	8.96 ± 0.61
Rusty-brown spots	8.73 ± 1.82	9.08 ± 0.72
Weevil damage	8.73 ± 1.82	9.59 ± 0.85

^{a,b}within each row, means with different superscripts differ significantly (P<0.05)

It was observed, as seen from TABLE 1, that weight loss in storage was significantly greater in *C. nitida* than in *C. acuminata*. This is in agreement with the results of [11], and could be attributed to the fact that *C. nitida* has a higher (equilibrium) moisture content than *C. acuminata* under the same conditions [12], and will therefore lose water (and so weight) faster. Having higher moisture content would also encourage more rot, as was observed. Probably as a result of reduced rot, sprout was significantly greater in *C. acuminata* than in *C. nitida*.

Variations in mean quality parameters between the four storage methods used are presented in TABLE 2.

Table 2: Effect of storage method on quality parameters of *Cola acuminata* and *Cola nitida* in storage

	Storage structures			
Quality parameters (%)	Wicker basket	Paper carton	Clay pot	Semi evap. pot
Sprout	2.40 ± 0.49^{c}	5.24 ± 1.02^{a}	4.21 ± 0.83^{ab}	3.06 ± 0.50^{bc}
Colour changes	1.26 ± 0.96^{b}	4.80 ± 0.67^{a}	3.07 ± 0.52^{ab}	4.17 ± 1.14^{a}
Rot	0.09 ± 0.05^{b}	1.06 ± 0.25^{b}	0.12 ± 0.08^{b}	3.13 ± 1.27^{a}
Weight loss	6.25 ± 0.87^{b}	11.54 ± 1.68^{ab}	6.83 ± 1.66^{b}	16.03 ± 3.93^{a}
Mould invasion	5.44 ± 0.49^{b}	15.89 ± 1.93^{a}	7.79 ± 0.67^{b}	6.70 ± 0.92^{b}
Rusty-brown spots	6.99 ± 0.80^{b}	18.84 ± 2.99^{a}	3.78 ± 0.32^{b}	6.00 ± 1.24^{b}
Weevil damage	6.02 ± 0.64^{b}	19.92 ± 3.01^{a}	5.31 ± 0.65^{b}	5.38 ± 1.27^{b}

^{a,b,c}within each row, means with different superscripts differ significantly (P<0.05)

Sprouting, colour change, mould formation, formation of rust-brown spots and weevil damage were seen to be highest (significant) in the paper carton for both kolanut varieties, an indication that it is unsuitable as a storage structure for both *C. nitida* and *C. acuminata*. Due to the high moisture content during storage, rot was observed to be highest (significantly) in the semi-evaporative pot, as was weight loss.

TABLE 3 shows the interactions between variety and storage structures as they affect the quality of kolanuts in storage.

Table 3: Effects of cola variety and storage method on quality parameters of *Cola acuminata* and *Cola nitida* in storage

Quality parameters (%)	Storage type/variety							
	Wicker basket		Paper carton		Clay pot		Semi evap. pot	
	C. acuminata	*C. nitida*	*C. acuminata*	*C. nitida*	*C. acuminata*	*C. nitida*	*C. acuminata*	*C. nitida*
Sprout	3.93 ± 0.81^{a}	0.88 ± 0.18^{b}	9.00 ± 1.49^{a}	1.49 ± 0.41^{b}	7.83 ± 1.04^{a}	0.59 ± 0.23^{b}	4.56 ± 0.65^{a}	1.49 ± 0.41^{b}
Colour changes	1.60 ± 0.11	0.92 ± 0.11	7.00 ± 0.92^{a}	2.60 ± 0.61^{b}	2.84 ± 0.27	3.30 ± 1.01	2.25 ± 025^{b}	6.09 ± 2.19^{a}
Rot	0.00 ± 0.00	0.18 ± 0.10	0.94 ± 0.31	1.19 ± 0.41	0.00 ± 0.00	0.24 ± 0.16	0.00 ± 0.00^{b}	6.25 ± 2.33^{a}
Weight loss	3.30 ± 0.58	9.21 ± 1.27	8.88 ± 1.98	14.21 ± 2.61	1.88 ± 0.55^{b}	11.77 ± 2.80^{a}	2.88 ± 0.63^{b}	29.18 ± 6.35^{a}
Mould invasion	3.58 ± 0.29	7.30 ± 0.65	20.63 ± 3.37^{a}	11.16 ± 1.03^{b}	6.50 ± 0.65	9.08 ± 1.09	5.13 ± 0.50	8.28 ± 1.72
Rusty-brown spots	5.27 ± 1.05	8.70 ± 1.07	25.19 ± 5.48^{a}	12.50 ± 1.27^{b}	3.08 ± 0.36	4.48 ± 0.48	1.38 ± 1.80^{b}	10.63 ± 1.86^{a}
Weevil damage	5.27 ± 1.05	6.78 ± 0.71	25.19 ± 5.48^{a}	14.66 ± 1.93^{b}	3.08 ± 0.36	7.54 ± 0.99	1.38 ± 1.80^{b}	9.38 ± 2.12^{a}

^{a,b}within each storage type, means in the same row with different superscripts differ significantly (P<0.05)

From TABLE 3, it can be seen that sprouting was greater in *C. acuminata* than in *C. nitida* across all storage structures. Sprouting was found to be significantly higher (P<0.05) in all storage structures for *C. acuminata* than for *C. nitida*, probably because reduced moisture content may favour sprouting in cola in storage. Colour change was significantly greater in *C. nitida* than in *C. acuminata* for paper carton and semi-evaporative pot. Rot was also significantly greater in *C. nitida* than in *C. acuminata* for the semi-evaporative pot.

Only for the pots (clay and semi-evaporative) was there significant weight loss, with *C. nitida* losing more weight than *C. acuminata*. Mould invasion was significantly greater in *C. acuminata* for the carton only. Rusty brown spots and weevil damage were significantly greater in *C. acuminata* than in *C. nitida* for the carton, and significantly less in *C. acuminata* than in *C. nitida* for the semi-evaporative pot.

IV. Conclusion

At the 5% significance level, weight loss and rot were found to be significantly greater in *C. nitida* than in *C. acuminata*, regardless of storage structure, due to higher initial moisture content of *C. nitida* than *C. acuminata*, while sprout was significantly greater in *C. acuminata* than in *C. nitida*. Paper carton was found to be unsuitable for storing both *C. acuminata* and *C. nitida* as sprouting, colour change, mould formation, formation of rust-brown spots and weevil damage were seen to be significantly highest in the paper carton for both kolanut varieties.

Lining was also found to have an effect on spoilage rate as most of the defects measured in the stored kolanuts reduced whenever the lining materials (transparent polyethylene sheet, newspaper, and leaves of *Onchocalamas sp.*) were replaced.

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