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Studies on kolanut and cashew kernels: moisture adsorption isotherm, proximate composition, and functional properties

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Abstract

Kolanut (*Cola nitida*) and cashew (*Anacardium occidentale*) kernels were analysed and their moisture adsorption isotherms, proximate composition, and functional properties were compared. The dried powdered sample of kolanut contained 69% carbohydrate, 18% crude fat and 3.1% ash by weight, while the cashew sample had 51% crude fat, 36% crude protein, 0.3% ash and 3.4% carbohydrate. These differences significantly affected their relative water and oil absorption capacities, least gelation concentration, bulk density, and emulsion properties. However, both samples would retain nutritional integrity when stored in atmospheres with water activities of up to 0.68 for kolanut and 0.85 for cashew kernels. The Brunauer–Emmett–Teller (BET) and Henderson mathematical models described both isotherms with less than 2% mean relative deviation.

1. Introduction

Kolanut (*Cola nitida*) and cashew (*Anacardium occidentale*) are fruit-bearing plants of tropical origin (Gill, Omoigui & Nyawaume, 1993). Cashew fruit is popular world-wide and is relished for its tasty pulp and the roasted form of the kernel. On the other hand, the *C. nitida* kernel has economic value across West African countries where large numbers, of individuals popularly chew this kernel in the raw state for its stimulant effect, reminiscent of the effect of coffee drinks. The purple variety of *C. nitida* used in this study, is useful as a natural source of colorant in carbonated drinks (Table 1).

In Nigeria, the extracted principles of *C. nitida* have been investigated as hop-substitutes in several indigenous alcoholic drinks (Hutchinson & Dalziel, 1975; Okoro, 1993). The uses of whole cashew kernels, the oil extracted from them and the residual cake, are well known. In contrast, little has been published about the functional properties and uses of kolanut kernels.

Arogba (1997) observed from studies on mango (*mangifera indica*) kernel, that the functionality of a food item is dependent on its chemical composition and processing methodology. Furthermore, Palou, Lopez-Malo and Argaiz (1997) reported that studies on moisture sorption isotherms of foods have useful applications in equipment design for drying, and in packaging and storage designs in order to achieve optimum shelf life and consumer acceptability of the products.

Therefore, the present study was undertaken, primarily, to evaluate and compare the functional properties, proximate compositions, and moisture adsorption isotherms of kolanut and cashew kernels. The Brunauer–Emmett–Teller (BET) and Henderson mathematical models were also employed to describe their relative goodness of fit of the isotherms. BET equation is applicable only in the water activity range of 0.11 to 0.45 (Fennema, 1985; Akanbi, 1993) when compared with 0.11 to 0.97 using the Henderson equation (Igbeka & Blaisdell, 1982).

2. Materials and methods

2.1. Material collection and handling

Fresh samples of *C. nitida* and *A. occidentale* kernels were purchased at local retailing outlets in Idah, Kogi State, Nigeria. The respective tests were scraped off manually, and the kernels chopped into tiny pieces of 0.4 cm unit dimension using a stainless steel knife. The two types of kernels were dried separately in an air-oven to constant weights at 105°C ± 2°C, and pulverised using a ceramic pestle and mortar. Each sample was packaged in high-density polythene films and refrigerated at 4°C until required for analysis.

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Table 1
Physical characteristics of *C. nitida* and *A. occidentale* kernels

Scientific name	Common name	Colour	Size	Number of lobes	Unit lobe[a]		
					Shape	Dimension[b] (cm)	Fresh weight (g)
C. nitida	Kolanut	Purple	Medium	Two	Recurvate	5.0±0.8×3.2±0.3	15.51±1.3
A. occidentale	Cashew	Pale yellow	Medium	Two	Crescent	2.5±0.3×0.9±0.2	2.93±0.2

[a] Mean of triplicate measurements.
[b] Length×breadth at mid-length.

Table 2
Proximate compositions of dried *C. nitida* and *A. occidentale* kernels[a]

Components (% dry wt. basis)	*C. nitida*	*A. occidentale*
Moisture	6.0±0.1	9.3±0.1
Ether extract	18.2±0.7	51.0±1.0
Crude protein (N×6.25)	3.5±0.1	36.0±1.5
Ash	3.1±0.1	0.3±0.03
Carbohydrate (by difference)	69.2±1.2	3.4±0.6

[a] Results are means of triplicate determinations.

2.2. Physical evaluation of the kernels

The fresh and medium-sized kernels of each type were assessed for colour visually, and fresh weight using a Mettler digital top-loading balance. The shapes of the kernel lobes were noted and their dimensions (length and breadth at mid-length) were measured using a vernier caliper. All measurements were done at least in triplicate.

2.3. Proximate analysis

The pulverised samples were used for triplicate determinations of the moisture content (14.062), ash (14.063), crude fat (14.066), and protein (14.067) by the AOAC (1984) standard procedures. Total carbohydrates were calculated by difference. Results were expressed on a dry matter basis.

2.4. Determination of functional properties

The particle size distribution of each pulverised kernel-type was determined using a set of standard sieves with 0.2, 0.4, 0.6, 0.8, and 1.0 mm apertures. For the purpose of this study the extent of pulverization achieved, that is, the milling efficiency, was expressed as a plot of percent granulation against sieve size (Fig. 1).

Duplicate determinations were conducted for bulk density (Giami & Bekebain, 1992), minimum gelation concentration (Onweluzo, Onuoha & Obanu, 1995), water and oil absorption capacities (Beuchat, 1997), foaming properties (Coffman & Garcia, 1977), and emulsion properties (Yasumatsu et al., 1972). Minimum gelation concentration was recorded when a sample

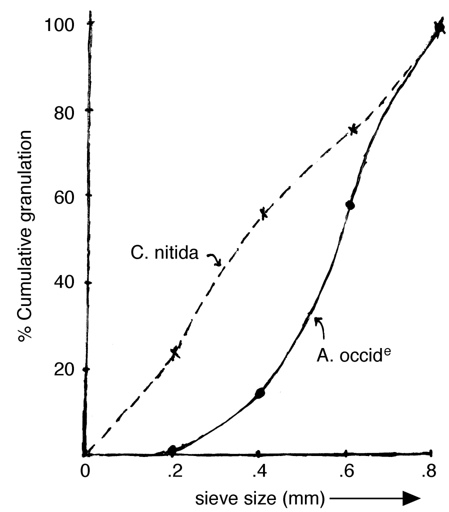

Fig. 1. Particle size of milled *C. nitida* and *A. Occidentale* kernels.

concentration just failed to slip down an inverted tube stored at 14°C for 2 h following a 1-h boiling period. Sample concentrations, as stated in Table 3, were taken for the determination of emulsion and foaming properties respectively, while stability measurements were recorded after an hour duration. Sedimentation was performed using a centrifuge (Hettich Universal II, Germany) at 5000 *g*. A refined vegetable oil (SG 0.9124) was purchased from a local supermarket for the oil absorption and emulsion experiments.

2.5. Adsorption isotherms

The moisture adsorption isotherms were determined gravimetrically by placing the pulverised samples in desiccators containing molal concentrations of sulphuric acid solutions corresponding to different water activity levels (Raganna, 1977). Triplicate samples of each kernel-type were placed inside the desiccators at an ambient temperature of 29°C±1°C. Equilibrium moisture contents were determined over a water activity (a_w) range of 0.11 to 0.97; the time required for the samples to reach equilibrium varied from 3 to 6 days. The sorption isotherms were obtained by plotting the moisture content of the samples, expressed as kg moisture/kg of dry matter (DM) versus a_w.

Table 3
Some functional properties of *C. nitida* and *A. occidentale* kernel flours[a]

Property	*C. nitida*	*A. occidentale*
Bulk density (g ml^{-1})		
Loose	0.48	0.30
Tapped	0.77	0.49
Medium gelation (%w/v)	14.0	11.5
Water absorption capacity (%w/v)	303.0	215.0
Oil[b] absorption capacity (%w/v)	145.0	175.0
Emulsion[b] activity (3.3 w/v sample; % unit)	41.7	Nil
Emulsion[b] stability (3.3 %w/v sample; % unit)	47.4	Nil
Foam capacity (6.7 %w/v sample; ml unit)	Nil	0.5
Foam stability (6.7 %w/v sample; ml unit)	Nil	0.5

[a] Results are means of duplicate determinations.
[b] Specific gravity of vegetable oil was 0.9124.

2.6. Isotherm models

The equilibrium moisture data were fitted using the BET equation in the linear form (Labuza, 1984):

$$\frac{a_w}{m(1-a_w)} = \frac{1}{M_o C} + \frac{(C-1)a_w}{M_o C}$$

where

a_w = water activity
C = constant related to heat of absorption
m = moisture/100 g of dry matter
M_o = monolayer moisture content expressed as on dry weight basis.

The M_o values were evaluated using the BET plot (Akanbi, 1993; Fennema, 1985) with a_w of up to 0.45 against $a_w/m\ (1-a_w)$ where

$$M_o = \frac{1}{\text{Slope} + (y\text{-intercept})}$$

while

$$C = \frac{1}{M_o(y\text{-intercept})}$$

Similarly, the isotherms were analysed using the Henderson equation in the linear form (Igbeka & Blaisdell, 1982):

$$\text{Log}[-\text{In}(1-a_w)] = n\,\text{Log}M + \text{Log}\,k$$

where

a_w = water activity
M = moisture content as percentage dry basis
n and k = constants depending on the material

Using a_w values of up to 0.97, the constants (n and k) were computed by the least squares method, while the critical moisture content (on dry weight basis) for predicting shelf-stability was derived from the Henderson plots.

The goodness of fit of the BET and Henderson models was evaluated with the mean relative deviation (%E) (Palou et al., 1997) between the experimental and predicted moisture contents in the modified formula:

$$\%E = \frac{100}{n}\Sigma\left|\frac{a_{w_e} - a_{w_p}}{a_{w_e}}\right|$$

where

n = number of observations, and a_{w_e},
a_{w_p} = experimental and predicted a_w respectively.

3. Results and discussion

3.1. Physical, chemical and functional properties

The physical characteristics of kolanut (*C. nitida*) and cashew (*A. occidentale*) kernels presented in Table 1 show differences in the colour, shape, dimension and fresh weights of both kernels. The kernels of both nuts are bi-lobed.

Further differences were observed from the results of proximate analysis (Table 2). The kolanut kernel had lower contents of crude fat and protein by 3- and 10-fold, respectively, compared to the cashew kernel. Therefore, the latter has a higher food value than the kolanut.

Pearson (1976) reported that cashew kernel contained, on average, 46% fat and that the protein content of most nuts could vary up to 30% on a dry weight basis. The results obtained on cashew kernel, in this respect, are in agreement with the literature.

It was observed that fresh kolanut kernel contained, on average, 51% moisture by weight, but the carbohydrate content (calculated by difference as 69% w/w) of the dried kernel better describes kolanut as a starchy food item. In contrast, the cashew kernel had remarkably low contents of total carbohydrate (3.4% w/w) and ash (0.3% w/w).

Differences between the functional properties of the two kernel types are shown in Table 3. The observations were ascribed to differences in chemical composition. For example, high lipid content in food affects texture (Darweesh, Toma, Lee & Weiss, 1991), and this was observed during the milling of the dried cashew kernel. Consequently, the plots of percent granulation per sieve size (Fig. 1), loose and tapped bulk densities (Table 3) were different for the two types of kernel, and could have affected their oil absorption capacities.

Differences in particle size, as were observed in this study (Fig. 1), have practically no effect on the water absorption properties of dried fruits (Lima & Cal-Vidal, 1983). However, because of the effects of starch and protein (NABIM, 1989), the higher carbohydrate content of the kolanut kernel could account for its higher water absorption capacity than that of the cashew kernel (Tables 2 and 3).

The presence of L-rhamnose in a polysaccharide molecule reduces the gelation capacity of a flour (Morris, 1973; Onweluzo et al., 1995) and could partly account for the relatively higher concentration of the kolanut flour needed to achieve minimum gelation. From our laboratory study of *Garcinia kola* kernel, containing a similar carbohydrate level but twice the concentration of protein as in the kolanut kernel, and the observed protein values of the kolanut and cashew kernels (Table 2), it was inferred that lower protein content also reduces the gelation capacity of kernel flours.

Although foaming ability is dependent on sample concentration (Abbey & Ibeth, 1987; Sathe & Salunkhe, 1981), and the globulin and albumin contents of a protein type (Desphande, Rangnekar, Sathe & Salunkhe, 1983), these kernels exhibited virtually no foaming properties. Arogba (1997) reported a similar observation on mango (*Mangifera indica*) kernel flour. The results of emulsion activity and stability studies further show that cashew kernel is deficient in emulsifying agents, and would be of poor functional application in food systems such as sausages, mayonnaise and salad dressing.

3.2. Moisture adsorption isotherms

The terms 'moisture adsorption isotherm', and 'water absorption capacity' used in the preceding discussion on functional properties, commonly describe measures of wetness of a sample but are technically distinguished by their methods of determination. The environment and state in which water is initially available for the sample to interact are different.

Fig. 2 shows the moisture isotherms of the powdered samples of dried *C. nitida* and *A. occidentale* kernels. Both curves are sigmoid in shape, which are described as type II isotherms (Labuza, 1984). Under the experimental conditions, the two types of kernel only differed significantly ($p < 0.05$) in equilibrium moisture contents at a_w 0.97. Consequently, analysis of the curves by the BET method (Fig. 3) gave similar monolayer moisture values of $6.0 \pm 0.27\%$ on a dry weight basis (Table 4) which are in agreement with the reported range of 3.2 to 16.0% for starchy foods (Mazza, 1984; Palou et al., 1997). The goodness of fit for both BET plots using the usual a_w range of up to 0.45 was computed as 1.85 and 0.91% mean relative deviations for *C. nitida* and *A. occidentale* kernels, respectively.

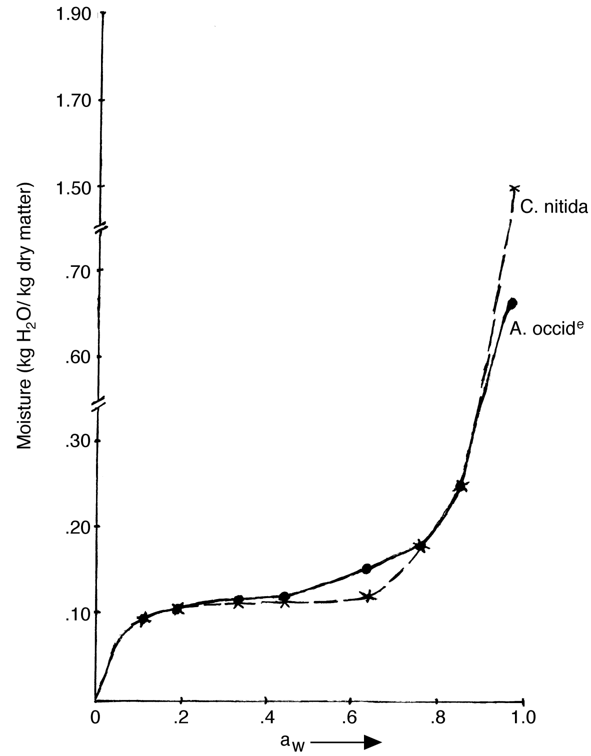

Fig. 2. Moisture adsorption isotherms of *C. nitida* and *A. occidentale* kernel flours at 29°C ± 1°C.

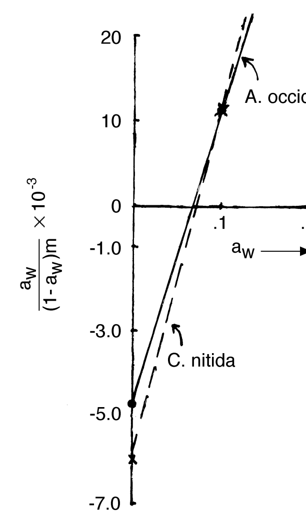

Fig. 3. The BET plots of the kernel isotherms.

Further adsorption characteristics of both kernels using the Henderson equation are presented in Table 4, and were derived from the plots shown in Fig. 4. More than one straight line could be fitted, as with similar studies reported on other food items (Igbeka & Blaisdell, 1982; Lima & Cal-Vidal, 1983). The breaks in the curves indicate changes in the type of water binding (Igbeka & Blaisdell). In each case, the two straight lines intersected at moisture contents of 13 and 25% (on dry weight basis) for *C. nitida* and *A. occidentale* kernels, respectively, Extrapolated from Fig. 2, the correspond-

Table 4
Parameter values for the BET and Henderson models to describe the isotherms

	BET[a]		Henderson							
				Moisture content of						
Kernel	C	$\%m_O$	$\%E^b$	Break	% dry basis	k_2	n_2	k_1	n_1	$\%E^b$
C. nitida	−28.03	5.88	1.85	1.12	13.2	0.0398	0.38	6.3×10^{-10}	8.68	1.73
A. occidentale	−34.01	6.30	0.91	1.40	25.1	0.0025	0.60	1.6×210^{-6}	5.20	0.85

[a] Up to a_w 0.45.
[b] $\%E$, mean relative deviation.

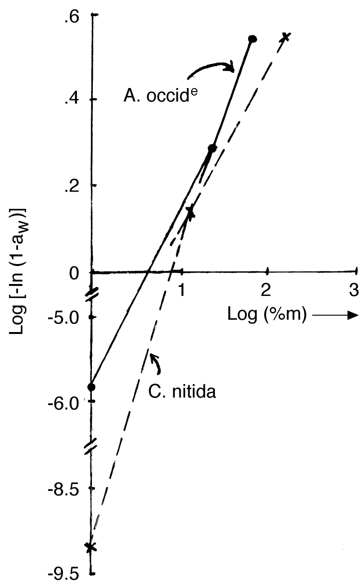

Fig. 4. The Henderson plots of the kernel isotherms.

ing water activities are 0.68 and 0.85. At higher values of a_w the kernels will deteriorate in quality. *Staphylococcus aureus* could thrive in the a_w range of $\geqslant 0.83$ (Igbeka & Blaisdell), and, in our study, mold growth was visible on samples stored in desiccators at a_w 0.97 by the sixth day.

The Henderson equation predicted the moisture isotherms of the kolanut and cashew kernels satisfactorily, with mean relative deviations (%E) of not more than 2% (Table 4). The GAB model (Palou et al., 1997), though not tested in this study, was reported to predict starchy food isotherms with, %E less than 5%.

4. Conclusion

The present study has shown that kolanut and cashew kernels are bi-lobed but differ markedly in appearance, size and chemical composition, The effects of chemical composition were apparent on functional properties such as bulk density, water and oil absorption capacities, least gelation concentration and emulsion properties. Consequently their potential food uses would vary.

However, the moisture adsorption studies reveal that both types of kernels would require similar storage conditions in the a_w range of 0.10 to 0.70. Above a_w 0.70, the kolanut kernel becomes more hygroscopic and would deteriorate faster than the cashew kernel.

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