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Note

Some physical properties of kola nuts – a response surface approach

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A b s t r a c t. This work studied the effect of drying temperature and duration on some physical and mechanical properties of two varieties of kola nuts using a response surface methodology approach. Physical properties determined were length, breadth, thickness, sphericity, aspect ratio, colour and moisture loss, while mechanical properties were force at break, yield, and peak, deformation at break and peak, energy to peak, energy to break, and yield, and Young modulus. At 5% level of significance, only mass, moisture loss, and sphericity were the physical properties affected. However, all measured mechanical properties were affected by drying temperature and duration ($p<0.05$).

K e y w o r d s: kola nut, drying kinetics, physical properties, mechanical properties

INTRODUCTION

Kola is a caffeine-containing nut, the two common species are *Cola nitida* and *Cola acuminata*. The nut has been receiving less attention in recent years and becoming uncommon among West African youths despite being native to this part of the world and having traditional values. Kola nut is chewed in many West African countries, as it is known to ease hunger pangs. It was reported to be used to treat whooping cough and asthma, and it contains caffeine, essential oils, and alkaloids (Asogwa *et al*., 2006). It is also a flavouring ingredient use in flavoured beverages. Demand for natural extracts for beverages increases the importance of kola nut fruit. In addition, research has shown some potential uses of kola nut such as that of kola wine and kola chocolate production as well as other non-alcoholic beverages (Jarvis, 2002). Understanding engineering properties of kola nut fruit would be important in designing appropriate processing equipment and preservation methods.

Engineering properties of foods including physical, mechanical, thermal, electrical, magnetic, and optical properties are important for proper design of food processing, handling, and storage systems (Akinoso and Raji, 2011). Food processing methods can alter those properties causing desirable or non-desirable changes in nutrient content, texture, colour, taste, aroma, and other quality attributes. Drying is a major unit operation in processing kola nut that aids handling and preservation. The process reduces moisture content to safe levels that inhibit deterioration by microbes and enzymes activities. Humidity, air velocity, and drying temperature and duration are variables determining efficiency of the drying process. Traditionally, kola nuts are packaged in either multiple layers of old cement paper bags lined internally with fresh banana leaves or in baskets: both of which make it possible for the nuts to lose moisture gradually and still remain fresh and in an acceptance condition for the customer (Daramola,1983). However, this process is space and time consuming. Literature is sparse on mechanical dehydration of kola nuts. Application of a convectional dryer for kola nut requires data on the effect of temperature, a major parameter in drying, on its quality. Therefore, effects of drying temperature and duration on selected physical and mechanical properties of two varieties of kola nuts (*Cola nitida* and *Cola acuminata*) were determined using response surface methodology. This methodology is both reliable and efficient because it provides accurate results with the minimum number of experimental level combinations (Mullen and Ennis, 1979; Montgomery, 2005).

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MATERIALS AND METHODS

Central composite rotatable design of response surface methodology was used (Montgomery, 2005). Response surface methodology is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes (Montgomery, 2005). Oluwole *et al.* (2013) reported successful use of response surface methodology to study physicochemical properties of white yam and bambara nut blend extrudates. The levels of variables were decided partly from a review of relevant literature (Odebunmi *et al*., 2009), but mainly from preliminary investigations. The five levels of independent variables were drying temperature (55.86, 60, 70, 80 and 84.14°C) and duration (3.59, 4, 5, 6 and 6.41 h). This gave thirteen experimental combinations (Table 1). The responses were such properties as length, breadth, thickness, mass, sphericity, aspect ratio and colour, force at yield, force at peak, force at break, energy to yield, energy at peak, energy to break, deformation at yield, deformation at peak, deformation at break, and Young modulus. Design-expert version 6.0.10 (Stat Ease Minneapolis, Minn) software was used for data analysis.

The physical properties of size, mass, shape and density of the samples were determined using standard methods. Length, breadth, and thickness were measured using a venier caliper with 0.01 mm accuracy (Cappera precision, China). Digital weighing balance (Scout™ Pro model SPU401) with ± 0.001 g accuracy was used for mass. The sphericity and aspect ratio were determined according to the reported method (Mohsenin, 1986). The ratio of mass to volume was recorded as density. Moisture content of the seeds was also determined using the standard method (ASABE, 2008). Colour was determined using a Hunter laboratory colourimeter (chr. 400/410 UK). Each sample was focused on colorimeter illumination while light transmissions through the samples were obtained.

Mechanical properties *viz*.: force at break, deformation at break, energy to break, force at peak, deformation at peak, energy to peak, force at yield, energy to yield, and Young modulus were determined using a Testometric AX Type DBBMTCL 2 500 kg (Rochdale, England). These tests were carried out using the reported method (Akinoso and Raji, 2011). A unit of kola nut from the samples was placed between the compressions plates of the testing equipment. Each seed was compressed at a constant deformation rate 10.00 mm min^{-1}, and readings were made using a data logger. The procedures were repeated in triplicates. Mean values were recorded as data. This was subjected to ANOVA and regression analysis at $p<0.05$.

RESULTS AND DISCUSSION

The effects of drying temperature and duration on mass, moisture loss, length, breadth, thickness, sphericity, aspect ratio, and colour of *Cola nitida* and *Cola acuminate* are shown in Table 1. Both drying temperature and duration had a significant effect ($p<0.05$) only on mass and moisture loss in *Cola nitida* (Table 2). Sphericity of *Cola acuminata* was influenced by drying temperature and duration while only drying temperature had a significant effect on mass and moisture loss ($p<0.05$). The other physical properties determined were not affected significantly. Sphericity ranged from 68.68 to 75.39 and 68.15 to 86.51% for *Cola nitida* and *Cola acuminate*, respectively. Roasting temperature (70°C) and duration (5 h) resulted in the highest moisture loss of 63.9 and 56.3% in *Cola nitida* and *Cola acuminate*, respectively. Mass of the two varieties of the kola nuts studied showed a similar trend with moisture loss. The lowest mass of 6.14 g and 5.15 g for *Cola nitida* and *Cola acuminate*, respectively, was produced by treatment that gave the highest moisture loss.

Drying temperature had a significant effect ($p<0.05$) on Young modulus of the two varieties of kola nut and force required to yield *Cola nitida* (Table 3). Deformation of *Cola nitida* depends on drying duration. However, a combined effect of drying temperature and duration significantly influenced deformation, force, and energy required to break *Cola acuminata*. Within the scope of the study, force and energy required to yield and deformation at break of *Cola nitida* ranged from 38.15 to 809.90 N, 0.0075 to 0.4125 N m, and 2.1590 to 4.3375 mm, respectively (Table 3). The Young modulus of *Cola nitida* ranged from 694.43 to 22657 N m^{-2}. Force and energy required for breaking, and deformation at peak of *Cola acuminata* ranged from 1.30-1459.7 N, 0.0702-2.1993 N m, and 0.3390-4.4690 mm, respectively (Table 3). The recorded Young modulus of *Cola acuminata* varied between 150.45 and 6412.1 N m^{-2}. It was observed that force and energy at peak and break were equal for the two varieties of kola nut.

Data on mass, shape, and moisture transfer is valuable in design of handling and drying process (Tavakoli, Mohtasebi and Jafari, 2009). The slight variation in the responses of the two varieties of kola nut may be associated with their chemical compositions. The chemical compositions of kola nut depend on the species (Odebunmi *et al*., 2009). The level of dehydration of kola nut is a major quality parameter that determines taste, storage, and economic value. Petu-Ibikunle *et al*. (2010) associated variation in caffeine content and levels of insect infestation of stored kola nuts to moisture content. Water is essential for food spoilage agents as without available moisture the spoilage agents would be inactive. Water activity is a measure of available water in foods suitable for microbial activities and dehydration is one of the controls. Drying influences physicochemical and quality characteristics of products, thus, evaluation of the drying characteristics as a function of drying conditions could help in predicting suitable drying conditions (Motevali *et al*., 2013; Raji and Ojediran, 2011). Drying temperature has the

T a b l e 1. Effect of sample treatments on physical properties of two varieties of kola nuts

Variables				Responses					
Temperature (°C)	Duration (h)	Mass (g)	Moisture loss (%)	Length (mm)	Breadth (mm)	Thickness (mm)	Sphericity (%)	Aspect ratio (%)	Colour (%)
Cola nitida									
70	5	7.57	54.1	34.56	25.55	16.39	70.35	73.68	32.05
70	5	7.56	50.6	33.21	25.20	15.11	70.08	76.02	34.72
55.86	5	15.85	12.5	38.91	28.67	19.22	70.99	73.82	35.04
60	6	9.92	56.4	36.54	28.54	19.65	74.86	78.12	28.95
70	5	8.81	49.6	34.32	22.36	16.96	69.12	66.13	39.06
60	4	8.68	46.6	33.06	22.78	18.89	73.06	69.05	31.80
80	4	10.40	38.8	31.42	22.55	18.77	75.39	71.89	43.21
84.14	5	10.85	35.0	34.08	25.29	17.14	71.92	74.22	45.04
70	3.59	7.16	56.1	31.65	22.09	16.06	70.75	70.13	34.43
80	6	10.75	37.8	35.59	22.97	17.92	68.68	64.65	38.48
70	6.41	8.89	43.4	31.42	25.04	14.14	71.06	79.91	45.45
70	5	6.41	63.6	33.98	25.67	19.44	71.04	77.69	30.98
70	5	6.14	63.9	38.72	27.27	20.35	71.62	70.58	32.12
Cola acuminata									
70	5	7.38	49.0	30.18	24.88	16.55	76.45	82.41	37.94
70	5	6.92	50.6	30.76	25.69	14.95	74.39	85.11	34.38
55.86	5	14.37	17.7	35.83	27.81	21.82	77.75	77.61	32.27
60	6	8.84	50.4	31.99	27.36	18.85	80.33	85.88	26.31
70	5	9.08	43.3	27.95	25.68	19.43	86.51	92.16	31.57
60	4	5.54	56.3	28.01	21.47	14.26	68.15	76.8	37.51
80	4	9.18	42.4	30.16	24.31	18.76	79.41	81.19	31.57
84.14	5	4.99	55.5	28.16	20.95	13.85	71.37	74.38	27.63
70	3.59	5.26	56.2	28.72	21.68	16.51	75.67	75.59	30.99
80	6	6.41	51.3	30.64	21.49	15.27	70.04	70.01	29.34
70	6.41	8.55	45.9	29.54	23.43	15.84	74.65	79.35	36.06
70	5	5.15	54.7	30.28	23.09	18.08	77.15	76.73	28.39
70	5	6.09	56.1	33.52	29.41	13.73	70.88	88.24	26.32

T a b l e 2. Summary of significant model terms at $p<0.05$

Parameters	Significant model terms	
	Cola acuminata	*Cola nitida*
Sphericity (%)	AB	ns
Moisture loss (%)	A, A2 ,A3	B,AB,B3
Mass (g)	A3	AB
Force at yield (N)	ns	A
Force at break (N)	AB	ns
Energy to break (Nm)	AB	ns
Energy to yield (Nm)	ns	A, A2
Deformation at peak (mm)	A, AB, A3	ns
Deformation at break (mm)	ns	B, B2, B3
Young modulus (N m^{-2})	A	A

A– drying temperature, B – drying duration, ns – not significant, $p<0.05$.

greatest effect on thin-layer drying, followed by initial moisture content, air velocity, and relative humidity. Since drying is an energy driven unit operation, its efficiency can be improved if the drying rate that determines the drying period is increased. Long drying periods may lead to poor quality of final products.

Mechanical properties provide a standard method for obtaining data for research and development, quality control, acceptance or rejection under specifications, and special purposes (Ogunsina *et al.*, 2008). The significant impact of drying temperature and duration on the investigated mechanical properties of the two varieties of kola nut may be traced by their chemical properties. Altuntas and Yildiz (2007) and Fathollahzadeh and Rajabipour (2008) reported similar observations on faba bean and barberry fruits, respectively. Equality in force to peak and break, and energy required to peak and break suggests that kola nut is brittle; therefore, a size reduction machine operating on the principle of impact force will be appropriate for dehydrated kola

T a b l e 3. Effect of drying temperature and duration on mechanical properties of two varieties of kola nuts

Variables				Responses				
Temperature (°C)	Duration (h)	Force at yield (N)	Force at break (N)	Energy to yield (N m)	Energy to break (N m)	Deformation at peak (mm)	Deformation at break (mm)	Young modulus (N m^{-2})
Cola nitida								
70	5	481.00	689.80	0.39	0.92	3.23	3.24	5 838.40
70	5	0.00	311.40	0.00	0.53	4.09	4.09	1 986.00
55.86	5	0.00	379.35	0.00	0.64	4.06	4.06	1 108.20
60	6	809.90	415.60	0.25	0.84	0.83	2.16	22 657.00
70	5	0	784.60	0	1.68	4.10	4.10	3 439.00
60	4	577.60	736.40	0.41	1.89	3.99	4.08	8 759.40
80	4	0	210.50	0	0.37	4.18	4.18	694.43
84.14	5	148.40	312.95	0.19	0.52	4.34	4.34	1 299.30
70	3.59	512.50	782.00	0.25	1.55	2.67	3.34	6 543.20
80	6	0	325.75	0	0.53	4.10	4.10	1 228.70
70	6.41	319.80	1 047.40	0.21	1.82	4.12	4.12	4 249.20
70	5	38.15	46.05	0.01	0.10	2.07	3.16	1 640.70
70	5	55.00	21.95	0.01	0.01	1.65	2.27	1 461.50
Cola acuminata								
70	5	361.05	562.95	0.50	1.29	4.02	4.18	2 737.30
70	5	159.10	459.95	0.09	0.89	4.16	4.16	1 956.40
55.86	5	124.90	248.10	0.16	0.53	4.15	4.15	942.29
60	6	109.95	25.00	0.01	0.18	0.34	4.13	6 412.20
70	5	52.80	411.25	0.04	0.90	4.19	4.19	1 678.70
60	4	147.10	1 459.70	0.05	2.20	4.16	4.16	5 801.20
80	4	50.70	57.55	0.09	0.12	4.47	4.47	157.63
84.14	5	12.35	39.60	0.01	0.07	4.17	4.17	150.45
70	3.59	257.00	252.55	0.48	0.47	4.13	4.13	1 606.00
80	6	287.30	287.30	0.59	0.59	4.18	4.18	1 296.90
70	6.41	0	449.70	0	1.02	4.20	4.20	1 070.70
70	5	46.95	1.30	0.01	0.09	3.17	4.57	1 664.60
70	5	57.05	63.85	0.02	0.15	3.50	4.17	1 212.90

nut. Maximum force (1 459.7 N) recorded in breaking the two varieties of kola nuts was lower than 2 060 N required to break dika nut reported by Ogunsina *et al*. (2008), breaking force for tenera palm kernel (2 791.3 N), and dura palm kernel (5 870.4 N) (Akinoso and Raji, 2011).

CONCLUSIONS

1. Size and colour of *Cola nitida* and *Cola acuminata* were not affected by drying temperature and duration.

2. Deformation, Young modulus, force, and energy required to break kola nuts depend on drying parameters.

3. Forces to peak and break were equal. Likewise, energy required to peak and break was equal.

4. Central composite rotatable design of the response surface methodology was successfully used to study dependence of physical and mechanical properties of kola nuts.

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