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Full Length Research paper

The effects of roasting temperatures on the rate of extraction and quality of locally-processed oil from two Nigerian peanut (*Arachis hypogea* L.) cultivars

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The effects of roasting conditions (time-temperature) on the rate of extraction and quality of oils from two peanut (*Arachis hypogea* L.) cultivars (namely, Kampala and ex-Dakar) were investigated. The oils were extracted at 50 ml hot-water/250 g peanut paste. High extraction rates were obtained by roasting the peanuts at 140°C for 20 min with Kampala yielding the highest oil. Above 140°C/20 min treatment, the rate of extraction decreased for both peanuts. Ex-dakar responds faster to heat treatment than did Kampala assessed by colour. Crude fat and total carbohydrates were found to be high in Kampala and protein high in ex-Dakar. Free fatty acids (FFA) contents of both oils were below 20% and peroxide values (PV) were below rancidity level of 10 Meq/kg for both oils at 0 week. At treatment 140°C/20 min for both oils, ex-Dakar oil deteriorate faster than Kampala assessed by FFA and PV levels after nine weeks storage under laboratory conditions. At this stage, ex-Dakar's oil developed rancidity while Kampala remained edible (PV<10 Meq/kg). Boiling points, smoke points, refractive indices and specific gravities decreased with the heat treatments. Kampala oil was more stable after nine weeks storage, and had high smoke point good for frying operations. It also had more extractable fat compared to ex-Dakar.

Key words: Nigerian peanut, processed oil, temperature,

INTRODUCTION

Fats and oils and their products when fully oxidized in the body yield about 9 kcal/g as compared to about 4 kcal/g furnished each by protein and carbohydrate (Pamplona-Roger, 2008). There is also an increased palatability conferred on foods by the addition of fats/oils and a delay in the digestion of food, thus preventing premature sensation of hunger after eating. Lack of adequate supply of calories in the diet predisposes a population to malnutrition, susceptibility to diseases and an impaired growth and developments. Hence, the need for a high-energy foods in the diets of Sub-Saharan Africa, the world's most food-insecure region, where fats and oils form less than 5% of the total per capita energy intake and average calorie intake in the region barely exceeds the daily requirement of 2100 kcal, the lowest in the world and income inequality exacerbates the problem (FAO, 2008). Peanut oil (arachis oil) is an organic material oil derived from peanuts, noted to have the aroma and taste of its parent legume. Peanut oil is most commonly used when frying foods, because of its high smoke point relative to many other cooking oils. Its major component fatty acids are oleic acid (56.6%) and linoleic acid (26.7%) along with small amounts of palmitic, arachidic, arachidonic acid, behenic acid and lignoceric acid (Peanut-oil, 2009; Carrín and Carelli, 2010).

Most vegetable oils such as peanut oil, sunflower oil,

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soybean oil and corn oil are rich in mono- and polyunsaturated fatty acids such as alpha-linolenic acid, an ω-3 fatty acid, and linoleic acid, an ω-6 fatty acid. Peanut seeds make an important contribution to the diet in many countries. They are a good source of proteins, lipids, and fatty acids for human nutrition. They are rich in oil, naturally containing from 47 to 50% (Grosso et al., 1997; Sanders, 2002). The chemical and physical properties of fats and oils are mainly determined by the fatty acids that they contain and their position within the triacylglycerol (TAG) molecule. Peanut oil is pale-yellow oil with distinctive nutty taste and odour obtained from the processing of peanut kernel. Its odour is almost removed with refining (Sanders, 2002). It has a high oleic content that is associated with its good oxidative and frying stabilities. It is a non-drying oil that solidifies from 0 to 3°C (O´Brien, 2004; Padley et al., 1994; Young, 1996). Nutritionists consider them to be a more desirable dietary ingredient than saturated animal fats because they helps improve blood vessel elasticity, keeps the heart rhythm beating normally, thin the blood, which makes it less sticky and less likely to clot, reduce inflammation and support the immune system and reduce blood pressure (Bucher et al., 2002; Mori et al., 1993).

Peanut oil is considered a premium cooking and frying oil due to its high smoke point and excellent oxidative stability relative to many other cooking oils (O´Brien, 2004). Moreover, it has been considered to be superior to soybean oil during frying, developing fewer flavour defects with long-term use (Young, 1996). Considerable importance has been ascribed to the role of the oleate/linoleate ratio (O/L) and iodine value (IV) in governing product shelf life. High O/L ratio and low IV have been associated with greatly enhanced shelf life and decreased rancidity of the product (Andersen and Gorbet, 2002). In Nigeria, the most popular vegetable oil plant materials include peanut, cottonseeds, melon seeds, sunflower, cashew nuts, sesame seed, coconut, oil palm, palm kernel, safflower and soybeans. Of these, peanut is the main source of vegetable oils used in most homes in Nigeria extracted locally using boiled water after pulverizing the kernels, and at one time an agricultural commodity with good foreign earnings to the country (World Bank, 1988).

The main varieties of peanuts grown in Nigeria include GB-3, MK-374, Samaru 38, RB-6, DS-5418, Spanish, Mubi local, ex-dakar and kampala. From them, DS-5418l, ex-Dakar and Kampala are the three varieties widely cultivated in the country Nigeria. However there is little available information on the optimum processing conditions as applied to the traditional method of extraction and subsequent storage. Optimization and standardization of the processing conditions will ensure maximum oil extraction with good keeping quality. The present study was carried out to determine the effect(s) of blanching peanuts on the rate and quality of the extracted oils from the two widely grown Nigerian peanuts varieties ex-dakar and kampala. Specifically, the study was meant to determine the effects of heat treatment on the rate of extraction of the peanuts' oil, determine the quality of the extracted oils and their storage stabilities, determine the optimum roasting conditions (time-temperature) and optimum extraction (ml hot water/g peanut slurry) of the two peanuts cultivars.

MATERIALS AND METHODS

The two peanuts varieties (Kampala and ex-Dakar), obtained from the local markets, were lines developed through conventional breeding by the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. The nuts were cleaned from decayed, mould-infested, shells and other parts before the investigation.

Method of analysis

The kernels were roasted in an air-oven at temperatures of 80, 100, 120, 140 and 160°C for 20 min each (Tsimiduo et al., 1995). At each roasting temperature, the kernels were turned after every 5 min to allow for even and uniform roasting. To ensure adequate control of the roasting conditions, the temperature of the oven was initially raised by about 4°C at each treatment to compensate for temperature drop when the nuts were first placed in the oven. Untreated raw peanuts were kept as control. After roasting, the kernels were cooled under a fast moving fan to stop further cooking and then blanched. The blanched kernels, both wholes and halves were ground to a smooth paste in a 3-stage milling operation.

Weight loss and roasting yield (%)

The weight loss due to roasting was determined by subtracting the weight of the roasted peanut from the weight of the raw peanut while roasting yield was determined by multiplying the ratio of the weight of the blanched (Z) peanut and the weight of the raw peanut (X) by 100.

Oil extraction

The blanched peanuts were ground into a smooth paste using a laboratory disc-attrition mill. Oils were then extracted from the paste by means of boiled water in a single stage batch extraction process. For each 500 g paste about 100 ml of freshly boiled water was added and the mixture stirred/kneaded continuously for about 20 minutes during which the oil separates from the semi-solid mass and were scooped off the viscous underflow. The recovered oils were then dried in an air-oven while the residual oil in the cake extracted with petroleum ether boiling point (b.p.) 40 to 60°C to get the total fat content. The extracted fat were immediately analyzed and then packaged in brown bottles for storage stability tests.

Proximate analysis

The chemical composition of both the raw and roasted peanuts was determined. The moisture contents were determined based on A.O.A.C. (1984). Mineral matter (total) was determined as described by Pearson (1981). Both the total protein (N×6.25) and fat were determined using the A.O.A.C. (1984) and total carbohydrate obtained by difference.

Table 1. Proximate composition of the two peanuts varieties.

Composition	Kampala (%)	Ex-Dakar (%)
Moisture	3.2 ± 3.1	3.1 ± 2.0
Carbohydrates	21.3 ± 4.1	17.6 ± 0.1
Protein (N × 6.25)	29.0 ± 1.3	37.1 ± 05
Fat	44.3 ± 3.0	40.0 ± 0.0
Ash	2.3 ± 1.3	2.3 ± 0.2

Chemical analysis of the fat

The extracted oils were analyzed immediately and subsequently for nine weeks. After the first analysis, the oils were stored under laboratory conditions and analyzed again at the third, sixth and ninth week storage.

Free fatty acid (FFA) and peroxide value (PV)

About 14.2 g of the oil was poured to Erlenmeyer flask, and 25 ml of hot neutralized alcohol plus 2 ml of indicator (1% phenolphthalein in 95% alc.) were added respectively. The resulting mixture was then titrated with 0.05 M sodium thiosulphate ($Na_2S_2O_3$) whilst shaking vigorously to the appearance of the first permanent pink colour, which persisted for 30 to 35 s (A.O.A.C., 1984).

The FFA was calculated as follows:

$$\% \text{ FFA (as oleic acid)} = \frac{\text{ml alkali} \times M \times 2.2}{\text{Weight of sample}}$$

ml = Titre value of alkali used.
M = Molarity of the alkali used.

The peroxide value was determined by Wij's method (A.O.A.C., 1984), and 5 g weight of oil was placed in a 250 ml stoppered conical flask and 30ml of acetic acid-chloroform (3:2) was added. The resulting mixture was then swirled vigorously. About 0.5 ml of saturated potassium iodide (KI) was added to the solution, allowed to stand with occasional shaking for about 1 min and 30 ml of distilled water added. Then, the resulting solution was then titrated slowly with 0.05 M sodium thiosulphate while shaking to the appearance of the yellow colour (AOAC, 1984).

The peroxide value (PV) was calculated as milli-equivalent peroxide per kilogram oil (Meq/kg). About 1ml starch solution (5.1%) was then added, and titration continued until the blue colour formed first disappear (a ml). Blank determination (b ml) was conducted omitting only the sample (AOAC, 1984).

$$\text{PV (Meq/kg)} = \frac{\text{(a and b) ml} \times M \times 100}{\text{Weight of sample}}$$

Where, M = Moles of $Na_2S_2O_3$ used for titration,
a = Titre value (ml) of the sample,
b = Titre value (ml) of the blank

Refractive index (RI), specific gravity, boiling point and smoke point

Determination of the RI was done based on A.O.A.C. (1984) using Abbe's refractometer. The instrument was first cleaned with moistened cotton wool and adjusted to read RI = 1.33 using distilled water. A few drops of the oil were placed on the upper prism and the cover tightly closed to ensure a thin film of the oil sample. The reading was taken when the angle of incident ray and the angle of refracted ray aligned at the interface between the two media. The specific gravity was found by method described by Nelkon and Parker (1995). A known volume of the oil was weighed in a beaker and the mass (g) noted. The mass was then divided by the volume of the oil (at 30°C) according to the formula:

$$\text{Density} = \frac{\text{Mass (g)}}{\text{Volume (ml)}}$$

The specific gravity (S.G.) was obtained by dividing the density of the oil by that of water:

$$\text{Specific gravity (S.G.)} = \frac{\text{Density of oil}}{\text{Density of water}}$$

About 20 ml of the oil sample was placed in a beaker (80 ml) and heated while a thermometer was held in the beaker with its sensitive bulb just above the bottom of the beaker. The temperature at which the oil just began to boil (showing bubbles) was noted as the boiling point (Young, 1996). To obtain the smoke point, boiling was continued until smoke was first noticed and that temperature was recorded as the smoke point.

RESULTS AND DISCUSSION

Proximate composition

The chemical composition of the two peanuts varieties studied showed that Kampala has the highest fat and carbohydrates content of about 44.3 and 21.3% respectively, compared to about 40 and 17% found in ex-Dakar. Protein content (crude) was however found higher in ex-dakar (Table 1). The ash and moisture contents did not vary much between the cultivars; Kampala and ex-Dakar had 3.2 and 3.1% moisture respectively, while they both followed the same pattern in their ash contents.

Blanching

Heat treatment of the peanuts at 80°C for 20 min did not ease the removal of the skin much, but this became progressively easier as the temperature is increased. At the 140°C very little or no skin remains on the kernels and at about 160°C the kernels were burnt. Moreover, roasting yield decreased, probably due to loss of the germs during blanching (Table 2). In all the treatments, the fat content and the protein increases depends on differences in the amounts of TAGs composition of oleic and linoleic acids (Yoshida et al., 2005), and partly due to thermal degradation of the cell wall matrix at temperature up to 140°C with consequent release of much oil (Pomeranz and Melon, 1978; Kramer and Twiggs, 1973). At 140°C treatment (Tables 3 and 4), the extraction

Table 2. Weight loss of the two peanuts due to roasting.

Treatment (℃/20 min)	Kampala			Ex-Dakar		
	Weight loss (%)	Skin (%)	Yield (%)	Weight loss (%)	Skin (%)	Yield (%)
80	1.48	4.57	95.43	4.76	5.76	95.34
100	3.50	6.14	93.85	6.32	6.50	93.68
120	4.50	6.19	93.84	6.50	7.37	93.50
140	5.60	8.35	91.65	7.10	8.50	92.90
160	7.60	9.93	90.07	8.60	9.62	91.38

Table 3. Rates of extraction of the peanut oils at different temperatures.

Treatment ℃ /20 min.	Kampala			Ex-Dakar		
	Volume of oil/ 250 g paste (ml)	Percent (%) oil	Total crude fat	Volume of oil/ 250 g paste (ml)	Percent (%) oil	Total crude fat
80	39.05	15.00	44.59	46.00	18.40	36.02
100	50.14	20.00	45.92	49.14	19.60	38.24
120	62.00	24.80	47.87	55.00	22.04	43.26
140	72.23	28.80	48.80	67.21	26.80	40.95
160	41.07	16.40	41.64	47.15	18.80	40.43
Untreated	35.17	14.00	42.26	59.00	20.40	40.04

Table 4. Physical properties of the oils at different time-temperature treatments.

Property	Treatment (℃/20 min)									
	Kampala					Ex-Dakar				
	80	100	120	140	160	80	100	130	140	160
Boiling point (℃)	146	143	143	142	138	130	130	126	125	115
Smoke point (℃)	166	160	156	156	149	155	149	139	137	130
Refractive index (at 30℃)	1.466	1.467	1.466	1.466	1.465	1.464	1.468	1.466	1.465	1.462
Specific gravity (30/30℃)	0.9213	0.9212	0.9272	0.9180	0.9162	0.9415	0.9317	0.9312	0.9302	0.9301

reached peak because of optimum degradation of the plant cell wall, with increased permeability of the oils to the surface (Rossell, 1988).

Physical analysis

Boiling point and smoke point

The boiling point and the smoke point of both peanut oils decreased with increase in temperature. The boiling point (b. p.) and the smoke point (s. p.) fall from 130℃ and 155℃ at 80℃/20 min treatment, to 125 and 137℃ at the 140℃/20 min treatment for the ex-Dakar oil, whereas for Kampala oil, the boiling point and smoke point decreased from 146 and 166℃ to 142 and 156℃, respectively at the 80℃/20 min. and 140℃/20 min. treatments, respectively. Further decline in smoke point occurred at 160℃ treatment (Table 4). These values however run contrary to report by Russell (1988) that peanut oil has a smoke point of about 200℃; a report that did not give ranges that could accommodate values for oil from different peanut varieties, neither does it specify the conditions at which the oil was extracted.

Refractive index and specific gravity

The refractive index of the oils did not change much with the heat treatment when measured at an average temperature of 30℃. The specific gravity increased initially at the 100, 120 and 140℃/20min. treatment (Table 4), but became low when the temperature treatment reached 160℃, due to slight decomposition of triacylglycerides during the roasting (Yoshida et al., 2005).

Table 5. Free fatty acids (FFA) of the two peanuts oils.

Treatment (℃/20 min)	Storage (week)									
	Kampala (% FFA)					Ex-Dakar(% FFA)				
	0	3	6	9	12	0	3	6	9	12
80	1.15	1.35	1.55	1.90	2.10	0.60	1.00	2.00	2.72	3.00
100	1.20	1.40	1.70	2.18	1.30	0.80	1.50	2.60	2.92	3.10
120	1.70	1.90	2.50	280	2.90	1.10	1.90	2.80	3.10	3.15
140	1.70	2.10	2.66	2.90	3.15	1.30	1.95	2.90	3.50	3.50
160	1.80	2.20	2.80	2.90	3.37	1.30	2.20	2.92	3.40	3.50
Untreated	0.45	0.90	0.10	0.80	0.76	0.30	0.40	0.40	0.90	0.95

Table 6. Peroxide values of the two peanuts oils extracted.

Treatment (℃/20 min)	Storage (week)									
	Kampala (Meq/Kg)					Ex-Dakar (Meq/Kg)				
	0	3	6	9	12	0	3	6	9	12
80	1.70	2.20	6.30	7.80	8.10	2.40	2.95	7.70	8.00	8.10
100	1.70	2.18	7.00	7.90	8.11	2.60	3.20	7.90	8.80	9.11
120	1.80	2.80	7.30	8.70	8.90	2.70	3.50	7.90	9.60	9.60
140	2.20	2.80	7.90	8.80	9.10	2.95	3.80	8.70	10.30	10.40
160	2.40	3.20	8.20	9.10	9.11	3.20	4.20	8.80	10.40	11.50
Untreated	1.50	2.78	6.65	8.34	9.55	2.00	2.50	5.80	7.70	9.10

Free fatty acid (FFA) and peroxide value (PV)

The free fatty acid (FFA) of both peanut oils increased with the temperature/time treatments, as shown in Table 5. The FFA increase in ex-Dakar and Kampala oil extracted at the 100, 120, 140 and 160℃/20min. Treatments during the first six weeks were uniform, but declined in the last 3 week of storage. The increased in the FFA of both oils may have resulted from decomposition of the glycerides in the oils affected by the heat treatment, or from increased activities of lipase enzyme at the lower temperature/time treatments (Kordylas, 1990; Young, 1996). The peroxide value (PV) of Kampala oil treated increased from 3 Meq/kg at o weeks to <10 Meq at the ninth week's storage. During the initial stage, oxidation was slow before it enters a second phase characterized by rapidly accelerating rate of oxidation greater than observed. This is expected with oxidation because the more radicals are formed the larger the quantity of decomposition products formed. The decline in the rate of peroxide formation in the last 3 weeks storage may be due to the decomposition and polymerization of the peroxide into a range of secondary products such as aldehydes and ketones more rapidly than they are formed (Swern, 1979).

The PV of ex-dakar also increased with the heat treatment (Table 6). On extraction, the PV of both oils at the 80, 100, and 120℃/20 min. Treatment was less than 3 Meq/kg. In general, the PV of both oils showed the same pattern of peroxidation throughout the period of storage.

Conclusion

Within the range of temperature-time treatments employed in the investigation, optimum colour (brownish-yellow as an index of the degree of roasting) was achieved at 140℃/20 min, the point at which extraction was maximal. Above 140℃ and approaching 160℃, peanut kernels of both cultivars became dirty-brown, less attractive and there is less oil recoverable from the kernels, and much of the fats may have decompose into their constituent fatty acids (Norman and Hotchkiss, 1995). Even though achieving a good extraction rate by heat treatment induces quality deterioration, the increase in the rate of extraction is greater than the corresponding decline in quality of the obtained oil. The cultivar Kampala yielded the highest oil in comparison to ex-Dakar, and was more stable. In situations where extraction is preceded by heat treatment of the raw material, the loss in quality of oil may not necessarily be associated with enzymes action, but chemical changes related to oxidation and hydrolysis induced by the heat process (Tsimidou, 1995). The quality of oils from all the treatments decreased with storage time. However, at the beginning of storage of the oils, the treated samples contain more FFA and PV than the control sample.

It is likely that the peanuts had appreciable amounts of FFA and PV before the investigation. This can be deduced from the gradual loss in quality of oils from both the treated and untreated peanuts stored under laboratory conditions. Controlled conditions such as this may not exist in our local settings (homes, villages etc) where peanuts oil processing prevailed. Presumably, therefore quality of oils obtained will deteriorate more rapidly. Hence, by the time maximum extractions have been achieved most of the naturally occurring antioxidant might have become inactivated or destroyed (Norman and Hotchkiss, 1995). However, roasting has been shown to increase antioxidants in peanut and defatted peanut kernels apparently due to production of Maillard reaction products (Hwang et al., 2001), and total phenolics and antioxidants in peanut hulls (Lee et al., 2006). disagreed with Rudolf and Resurreccion (2005) who found that antioxidant capacities of UV-treated sliced peanuts decreased ($P < 0.05$) after 24 and 36 h incubation, then increased after 48 h to levels not different ($P < 0.05$) from those at 0 h. Moreover, antioxidants found naturally in peanuts have limited shelf life beyond which they cease to function (Young, 1996).

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