Characterization of Peanut Pastes Sold on Selected Ghanaian Markets

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ABSTRACT

Peanuts are widely cultivated and consumed in Ghana, with peanut paste being the most popular product. The traditional processing of peanut paste is largely artisanal resulting in inconsistent product quality. This study evaluated the physico-chemical characteristics, oxidative stability and shelf life of peanut pastes sold in four selected markets in Accra, Ghana and a Reference sample prepared under laboratory conditions. Proximate compositions, colour, soluble protein, rheological characteristics, aflatoxins contamination levels and acid insoluble ash of the peanut pastes were determined. The proximate composition of the pastes was similar but, colour and soluble protein content differed significantly among the samples. Aflatoxins contamination levels were generally higher than the Codex limits although pastes were stable for 9 weeks at ambient temperature. Variations in peanut paste quality from different processors could be attributed to process variability due to lack of standardized units of operations. This could be ameliorated through appropriate equipment designs and training schedules for artisanal peanut paste processors.

Keywords: peanut paste, colour, aflatoxins, rheology, oxidative stability.

Introduction

Peanuts (*Arachis hypogea L*) are universally popular as food ingredients. They provide a wide range of nutrients including oil (47-50%) and proteins (25-30%) as well as vitamins and minerals (Woodroof, 1983). Peanut oil consists of 76-82% unsaturated fatty acid with more of oleic acid (47%) than linoleic acid (33%). It has been established that the fat and protein in peanuts contribute to high satiety value for consumers and consequently dieters on peanuts are able to shed off some weight (Lokko *et al.*, 2007; Mattes *et al.*, 2008; McKiernan *et al.*, 2010). Peanuts also have high amounts of the amino acid arginine, a precursor to nitric oxide, which helps to dilate blood vessels and improve blood flow, thus reducing the risk of cardiovascular diseases. Furthermore the presence of other bioactive components such as resveratrol, beta sitosterol, flavonoids, tocopherols and phytosterols (Isanga & Zhang, 2007) highlight the nutraceutical importance of peanuts in the diet.

Peanuts are widely consumed in Ghana, and almost all the crop produced is used locally in a wide variety of food products. Peanuts paste is among the most commercialized processed peanut product in Ghana. Its production involves sorting of raw peanuts, roasting to a desirable roast level, cooling and removal of the peanut skins. The deskinned seeds are ground into a smooth paste. It is locally used as the major ingredient in a wide array of products including peanut soup, *kulikuli, khebab* powder, or as a filling in pastries and confectioneries.

The production of peanut paste is largely done at the cottage level and it is dominated by women processors with little or no formal education. Even though most processors may be very experienced in the trade, there is frequently a great deal of product quality variability between processors, and also between batches of products. This is partly because as a cottage industry implementation of quality management practices is generally low, and there is little standardization of the

production processes (Anfu, 2016). Due to the minimal standardization in the process operations, changes in the quality characteristics of peanut paste between batches are usually as a result of variations in the critical unit operations of roasting and/or milling (i.e. particle size distribution of the paste) among many other causes. This study evaluated the variability of peanut paste quality sold in selected markets in Accra, Ghana, in terms of physico-chemical characteristics, safety and oxidative stability.

Methods

Materials

Samples of freshly prepared peanut paste were obtained from different processors at the mills in four selected food markets in Accra – Dome, Kaneshie, Makola and Mallam Atta. Approximately 1.5 kg of freshly milled peanut paste was obtained from each processor. A Reference sample of peanut paste was prepared by an independent experienced processor under supervision in the Food Processing Laboratory of the Department of Nutrition and Food Science, University of Ghana. About 3 kg of well sorted and cleaned peanut kernels were used to prepare the Reference sample. The peanut paste samples were stored in transparent plastic jars with well fitted lids at room temperature in a dark environment and were used for all the laboratory analyses.

Experimental design

Peanut paste processors were randomly selected from four different food markets (Kaneshie, Makola, Dome and Mallam Atta) in Accra. A fifth sample used as the Reference peanut paste sample was made by an experienced processor under supervision. All five samples were stored in well-sealed transparent plastic jars at room temperature in a dark environment. Samples were analysed for physical attributes and for storage stability over a time period of twelve weeks at room temperature.

Proximate analyses

The moisture, crude protein (N×6.25), crude fat, crude fibre and ash contents of the samples were determined using the Association of Official Analytical Chemists (AOAC) Approved methods; (AOAC, 1990). Carbohydrate content was determined by difference.

Colour determination of peanut paste

Colour measures of lightness, L, redness, a, and yellowness, b, were determined on each of the five samples of peanut paste using a Minolta CR -310 tristimulus colorimeter (Minolta Camera Co. Ltd, Osaka, Japan). The colorimeter was calibrated using a standard white porcelain tile (L = 97.64, a = -0.31, b = 4.63). Three measurements were taken for each sample while rotating the sample holder each time. The average of three measurements and standard deviations was recorded for L, a, b and total colour difference of samples was calculated as;

$$\Delta E = \sqrt{(L^2 + a^2 + b^2)}$$

Soluble protein at pH 8.0

The method described by Were *et al.*. (1997) was used for the determination of pH dependent solubility of peanuts protein. Approximately 1 g of the sample was dissolved in 50 ml of distilled water and the solution pH was adjusted to 8, using 0.1 N HCl and 0.1 N NaOH. The mixtures were stirred for 30 minutes at 24 °C, using a magnetic stirrer before centrifuging at 12,000 g for 20 minutes at 4 °C. The supernatant was filtered through a sintered glass Buchner funnel with suction to obtain a clear solution. Protein content in the supernatant was determined using the Kjeldahl method. The percentage soluble protein was calculated as follows:

$$Solubility\ (\%) = \left[\frac{Amount\ of\ Nitrogen\ in\ supernatant}{Amount\ of\ Nitrogen\ \ in\ the\ sample}\right] \times 1001.$$

Ash insoluble in dilute Hydrochloric acid

The standardised method of the International Standards Organisation (ISO) was used for the determination of ash insoluble content of the peanut paste in dilute HCl (ISO, 2003).

Aflatoxins extraction and analyses

The procedure for extraction and analyses of aflatoxins followed the CEN (European Committee for Standardization) method using high performance liquid chromatography (HPLC). Twenty five grams (25 g) of the sample together with 5 g NaCl were homogenized in a Waring blender (Waring Products Division, Torrington, USA) with 200 ml of methanol: water (80/20 v/v) and 100 ml hexane. The slurry was filtered using Whatman filter paper number 4. Ten ml (10 ml) of the filtrate was mixed with 60 ml phosphate buffer saline (PBS) and stirred. The mixture was passed through an Easi-Extract Afla column packed with monoclonal antibodies specific to Aflatoxin G_1, B_1, G_2 and B_2. The column was rinsed with 15 ml distilled water in 5 ml proportions. The column was rinsed with 15 ml distilled water in 5 ml portions. Aflatoxins were then eluted from the column with 2 ml HPLC grade methanol into HPLC vials and loaded onto the autosampler chamber for separation, detection and quantification.

Chromatographic (HPLC) analyses and quantification of aflatoxins

The separation of aflatoxins was done using Waters HPLC system consisting of Waters 1525 Binary HPLC pump, Waters 2707 Auto-sampler, and Waters 2475 Multi λ Fluorescence Detector (Waters Corp., Milford, MA) set at an excitation wavelength of 360 nm and an emission wavelength of 440 nm. It was equipped with a C_{18} column (sperisorb55 ODS-1) of dimensions 25 cm x 4.6 mm x 5 µm. The mobile phase consisted of water: methanol: acetonitrile (60:30:20) at a flow rate of 1 ml/min in an isocratic separation method and the injection volume was 10 µl. Aflatoxins were quantified by reference to calibration curves obtained from the peak areas of each of the components in a mixed aflatoxins standard (Sigma-Aldrich) ran under identical conditions of HPLC. The limits of detection were determined to be: G_1 and G_2 = 0.13 µg/kg; B_1 and B_2 = 0.15 µg/kg. Data acquisition and analyses were done using Breeze 2 software (Waters Corp., Milford, MA).

Textural characteristics of groundnuts paste

The textural and rheological characteristics of the samples were determined using the TA-XT2 Texture Analyser (Stable Micro Systems Ltd., Surrey, England) equipped with a back extrusion probe. Fifty grams (50 g) of the paste was weighed into a cylindrical glass container (50 mm internal diameter, 70 mm height) at room temperature (22°C). The test was performed at a pre-test speed of 1 mm/s, test speed of 1 mm/s, post-test speed of 10.0 mm/s, distance of 5.0 mm and trigger force of 5.0 g using a cylindrical probe with diameter of 40 mm. Based on the curves generated from the software, consistency was determined using the positive area of the curve (g.s), firmness was defined as maximum positive force (g), viscosity was determined using the negative area of the curve (g.s), and cohesiveness was defined as maximum negative force (g). A typical force-time graph obtained during back extrusion of samples is shown in Figure 1.

Shelf stability of peanuts paste

Samples of peanuts paste were obtained weekly from the bulk samples in storage and the fat extracted using a mixture of chloroform: methanol (2:1 v/v). Initial products of oxidation were monitored by determining the peroxide value using AOAC CD 8-53 and free fatty acids were assessed using the AOAC method 5a-40 (AOAC, 1997). Peroxides and free fatty acids were measured on all replications at weekly intervals for a total of 12 weeks, to evaluate the peroxide behaviour throughout the storage time (12 weeks).

Statistical Analysis

A single factor analysis of variance (ANOVA) and Duncan's multiple range-tests were used to compare the means. Principal component analysis (PCA) was used to determine the fundamentally different properties (or principal components) exhibited by the different peanut paste samples using Statistica software (Statsoft, version 6.0, 2001).

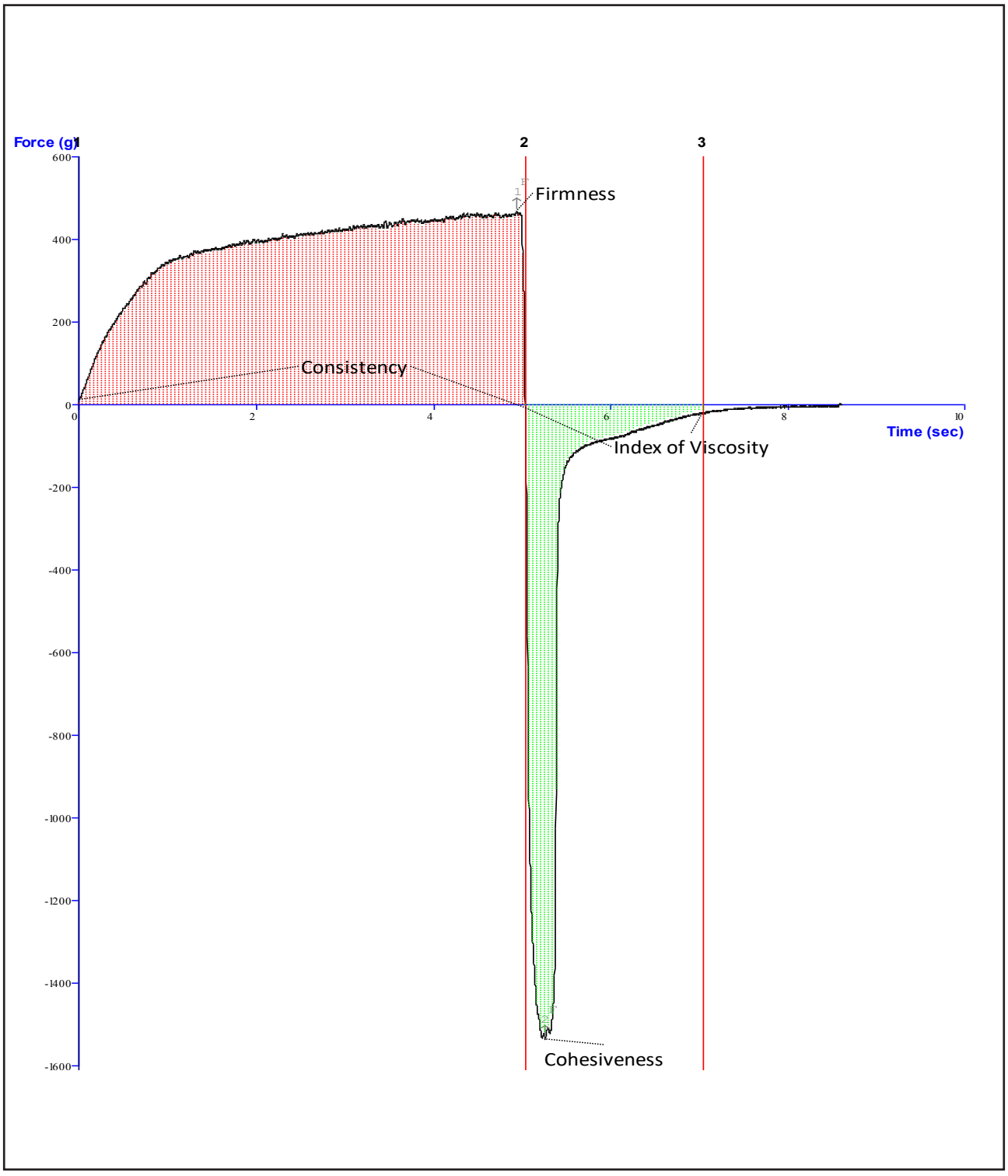

Fig. 1: Typical Back extrusion curves (force-time graphs) for peanut rheological parameters

Results and discussion

Proximate composition of peanut paste

The mean values of the proximate composition of freshly prepared peanut paste obtained from processors from the different food markets are given in Table 1. The moisture content varied between 1.12 % and 1.77 % across the samples. Peanut paste is a dry product with a very low water activity which helps to minimize hydrolytic rancidity.

Table 1 also shows the mean protein content of the samples which ranged from 21.52 - 27.54 %. The protein content of samples from Mallam Atta was significantly lower than the others whilst samples from Makola market contained the highest amount of protein. Since no other ingredient is added to roasted peanuts during paste production, the protein content of the paste is a direct reflection of the protein content of the peanuts used in production. Although there are many different cultivars of peanuts available in Ghana, most peanut paste processors tend to use the same variety of peanuts which is also the most popularly cultivated. In a preliminary survey of the traditional production processes of peanut products (results not shown) almost all the processors admitted to using the "*Chinese variety*" of groundnuts. This explains the marginal variability in the proximate composition of pastes from the different markets.

Table 1: Proximate analyses of peanut paste

Sample	Composition (g/100 g)					
	Total moisture	Crude protein*	Total Ash	Crude fat	Crude fiber	Carbohydrate**
Reference	1.64±0.2^{b}	25.32±0.6^{b}	1.69± 0.03^{a}	50.27±1.3^{a}	0.37±0.2^{b}	20.71±0.5^{b}
Dome	1.77±0.02^{c}	24.91±1.2^{b}	2.41±0.09^{c}	51.82±3.4^{a}	0.45±0.02^{c}	18.64±0.9^{a}
Kaneshie	1.28±0.03^{a}	26.25±0.9^{bc}	1.59±0.3^{a}	50.92±1.2^{a}	0.21±0.003^{a}	19.75±0.4^{b}
Makola	1.12±0.04^{a}	27.54±0.4^{c}	2.04±0.04^{b}	49.07±2.2^{a}	0.37±0.4^{b}	19.86±0.5^{b}
Mallam Atta	1.53±0.04^{b}	21.52±0.6^{a}	2.02 ± 0.1^{b}	48.75±1.8^{a}	0.25±0.007^{a}	25.93±0.3^{c}

*N ×5.46 ** Evaluated by difference

Values are mean and standard deviation of three replications. Values followed by the same letters in columns are not significantly different ($p < 0.05$) and vice versa.

Colour of peanut pastes

Instrumental colour measurements of the peanut paste samples are presented in Table 2. There were significant differences ($p<0.05$) in the lightness (L) values between the samples from the different processors. The mean lightness (L) values of the peanut paste samples ranged from 53.05 to 63.14 (i.e. medium to light roast colour). Peanut paste samples obtained from the Makola and Kaneshie Markets were generally not significantly different in lightness (i.e. L values) and were comparable to the Reference sample. On the other hand, samples obtained from the other markets (i.e. Dome and Mallam Atta) had similar roast colour, and they were significantly darker (i.e. lower L values) than the Reference sample. The differences in colour among the samples were probably due largely to varied roasting intensity by the processors, as observed in previous work reported by Shi *et al.*, (2018). In the traditional peanut paste processing, peanuts are invariably manually roasted in shallow

aluminium trays, over direct fire. Consequently, there is little control of the heating rate and intensity during peanut roasting.

The total colour differences (ΔE) for the market samples were calculated from the chromameter colour parameters for lightness (L), redness (a) and yellowness (b) against those for the reference sample. The colour of peanut paste obtained from the Dome and Mallam Atta Markets differed the most (ΔE = 5.89 and 12.16 respectively) from the Reference peanut sample (Table 2).

Table 2: L, a and b values of peanut paste samples

Sample	L	a	b	$\Delta E=\sqrt{(L^2+a^2+b^2)}$
Reference	62.88±1.9^{a}	+8.87±0.5^{c}	+39.35±1.2^{d}	
Dome	58.01±1.2^{b}	+10.97±0.5^{d}	+36.79±1.7^{c}	5.89^{a}
Kaneshie	63.14±2.3^{a}	+6.51±0.4^{a}	+32.92±1.5^{b}	6.85^{a}
Makola	60.96±2.1^{a}	+7.23±0.03^{b}	+30.36±1.0^{a}	7.61^{a}
Mallam Atta	53.05±1.0^{b}	+6.93±0.1^{ab}	+32.46±0.8^{ab}	12.16^{b}

Values are mean and standard deviation of three replications. Values with the same letter in a column are not significantly different ($p < 0.05$) and vice versa.

Soluble proteins of peanut paste

There were significant differences ($p < 0.05$) in soluble protein content at pH 8.0 between the samples obtained from the different processors (Table 3). The L values are influenced by the intensity of the peanuts, which in turn influences protein solubility (probably due to heat denaturation of the proteins). Samples with low L values received greater heat treatment and generally had lower protein solubility due to denaturation.

Table 3: Chemical and physical properties of peanut paste samples

Sample	Acid Insoluble ash (%)	Soluble Protein at pH 8 (%)	Acid value at week 1 (mg KOH/g oil)	Acid value at week 10 (mg KOH/g oil)
Reference	0.19±0.01^{a}	34.52±2.3^{c}	0.31±0.02^{b}	0.31±0.01^{a}
Dome	0.26±0.04^{c}	22.12 ±3.3^{a}	0.41±0.02^{c}	0.39±0.01^{b}
Kaneshie	0.24±0.01b^{c}	39.96 ±3.9^{d}	0.30±0.01^{b}	0.30±0.03^{a}
Makola	0.23±0.007ab^{c}	28.73±1.4^{b}	0.31±0.01^{b}	0.31±0.01a
Mallam Atta	0.21±0.02^{ab}	34.20 ±2.5^{c}	0.16±0.02^{a}	0.16±0.03^{c}

Values are means and standard deviations of three replications. Values with the same letter in a column are not significantly different ($p < 0.05$).

Acid insoluble Ash

The ash insoluble in dilute HCl gives an estimate of the level of siliceous impurities in the peanut paste. The ash insoluble in dilute Hydrochloric acid values of the peanut paste samples ranged from 0.19 - 0.26 %. The differences in ash insoluble in dilute HCl among the peanut paste samples were significant ($p < 0.05$) between the processors (Table 3). The Reference sample had the least (0.19 %) and the sample from Dome market had the highest (0.26 %) ash insoluble in dilute HCl values respectively. The values of ash insoluble in dilute HCl of the peanut samples even though significantly different among the samples, were generally low.

Aflatoxins in peanut paste

The aflatoxins have been implicated in the aetiology and pathogenesis of conditions such as primary liver carcinoma, malnutrition, immunosuppression, and growth retardation (Fung & Clark, 2004). Considering the health risks aflatoxins pose to consumers, the FAO and WHO set a maximum limit of 15 µg/kg (Codex Alimentarius Commission, 2018) in peanuts intended for further processing. The European Union (EU) however set a more stringent maximum acceptable level of 4 µg/kg for total aflatoxins in food products (Moss, 2002). Table 4 shows that total aflatoxin levels ranged from non-detectable in the Reference sample to 113 µg/kg in the Dome Market samples. Apart from the Reference and the Kaneshie Market samples which were within the acceptable Codex limits of 15 µg/kg, all the market samples contained much higher levels than the international regulatory limits for aflatoxins. Even the Kaneshie market sample with total aflatoxins of 12.45 µg/kg did not meet the EU standard of 4 mg/kg for maximum total aflatoxins. The prevalence of aflatoxins in peanuts and peanut products in Ghanaian markets has been known to be high. Awuah and Kpodo (1996) sampled peanuts from 21 selected markets in 10 regions of Ghana and reported total aflatoxins content ranging from 5.7 to 22,168 µg/kg in damaged kernels. The authors however noted that the mycotoxins were not detected in about 50 % of undamaged kernels, and even for those that tested positive, the aflatoxins ranged from 0.1 to 12.2 ppb. The peanuts used in the preparation of the Reference sample were thoroughly sorted before use and this could account for the non-detection of aflatoxins in the resulting product.

Table 4: Aflatoxins content in peanut paste samples

Sample	AFB_1 (µg/kg)	AFB_2 (µg /kg)	AFG_1 (µg /kg)	AFG_2 (µg/kg)	TOTAL (µg /kg)
Reference	ND	ND	ND	ND	ND
Dome	67.57 ± 2.34^a	25.52 ± 3.02^a	17.26 ± 1.09^a	2.66 ± 0.92	113.31^a
Kaneshie	8.24 ± 0.51^b	4.21 ± 0.03^b	ND	ND	12.45^b
Makola	6.23 ± 0.87^b	2.13 ± 0.42^b	11.94 ± 1.47^b	ND	20.30^c
Mallam Atta	36.76 ± 0.72^c	4.51 ± 0.91^b	1.20 ± 2.54^c	ND	42.47^d

Values are means and standard deviations of three replications. Values with the same letter in a column are not significantly different ($p < 0.05$) and vice versa.

The data for aflatoxins levels in peanut paste from the food markets (Table 4) suggest that some of the processors (Kaneshie market) were aware of the problem and thus sorted out damaged kernels during the processing operations reducing aflatoxin levels to within the Codex acceptable limits. However, the majority of them need training on how to minimize aflatoxins contamination during processing of peanut products.

Rheological and Textural characteristics of peanut paste

Apart from its application as an ingredient in many indigenous foods, peanut paste is also commonly used as a bread spread. In this application, its textural characteristics and spreadability are important to the consumer. The textural and rheological characteristics of the peanut paste samples are shown in Table 5.

Table 5: Rheological characteristics of groundnut pastes

Sample	Firmness (g)	Consistency (g)	Cohesiveness (gs)	Viscosity (gs)
Reference	740.77 ± 45.31^{b}	654.51 ± 51.0^{b}	1862.57 ± 331.55^{b}	788.56 ± 176.43^{b}
Dome	969.41 ± 25.41^{a}	877.68 ± 10.5^{a}	1829.16 ± 224.91^{b}	964.53 ± 94.16^{a}
Kaneshie	456.11 ± 6.93^{c}	608.44 ± 21.1^{c}	1922.39 ± 122.53^{a}	695.52 ± 68.44^{c}
Makola	642.83 ± 9.46^{b}	621.67 ± 15.5^{b}	1933.48 ± 576.38^{a}	741.71 ± 114.93^{b}
Mallam Atta	810.72 ± 9.88^{a}	855.54 ± 18.2^{a}	2038.71 ± 305.01^{c}	846.71 ± 67.24^{b}

Values are means and standard deviations of three replications. Values within a column with the same letter superscript are not significantly different ($p \leq 0.05$)

The Consistency of the peanut pastes ranged from 608 to 877 gs while the index of viscosity ranged from 741.71 to 964.53 gs. The samples differed significantly among the different market sources and also from the Reference sample. Peanut paste obtained from the Kaneshie market was the thinnest (i.e. had the least consistency of 608.44 gs and index of viscosity 695.52 gs). On the other hand samples from the Dome and Mallam Atta Markets were not significantly different in their firmness and consistency characteristics. They showed the hardest (i.e. high firmness) and most viscous (i.e. high consistency and index of viscosity) characteristics. Peanut paste samples from the two markets (i.e. Dome and Mallam Atta) were also not significantly different in their Lightness (L) values (Table 2), which is an indicator of the degree of roast. It therefore seems plausible that the rheological characteristics of peanut paste may be influenced by the roast intensity of the peanuts during processing.

Oxidative stability and shelf life of peanut paste

The acid values of samples stored for up to 10 weeks are shown in Table 3. The mean acid values (mg KOH/g Oil) of the samples ranged from 0.16 - 0.39. The acid values remained virtually constant for each sample throughout the storage period indicating no significant hydrolytic rancidity during storage at room temperature (27 ± 5 °C). Even though particle size distribution was not determined in this work, it has been established (Weiss, 1970) that milling influences stability of peanut paste. The amount of oil released during grinding of roasted peanuts depends on the particle size distribution, as coarsely ground peanuts have less free oil to separate and in this way provide some "partial stability" to the paste.

The trends in peroxide values of samples stored for 12 weeks after processing are presented in Figure 2. The plots indicate that for the first four weeks there were only minimal changes in the peroxide values. The peroxide values increased steadily after four weeks until the

eleventh week and then begun to drop (except for the reference sample) as they decomposed into secondary oxidation products (Labuza, 1975). High peroxide values (> 15 meq/kg oil) were observed in all the peanut paste samples after nine weeks to eleven weeks of storage. The differences in peroxides development among the samples could possibly be attributed to the severity of roasting during peanut paste production. Samples that were less intensely roasted (and had relatively high L-values) also showed relatively high peroxide values after 9 weeks of storage than those that were more intensely roasted (i.e. samples from Makola and Mallam Atta Markets). This trend might be because intense roasting of the peanuts broke down and reduced the levels of unsaturated fatty acids, with a consequent reduction in the capacity to form hydro-peroxides during initiation of auto-oxidation.

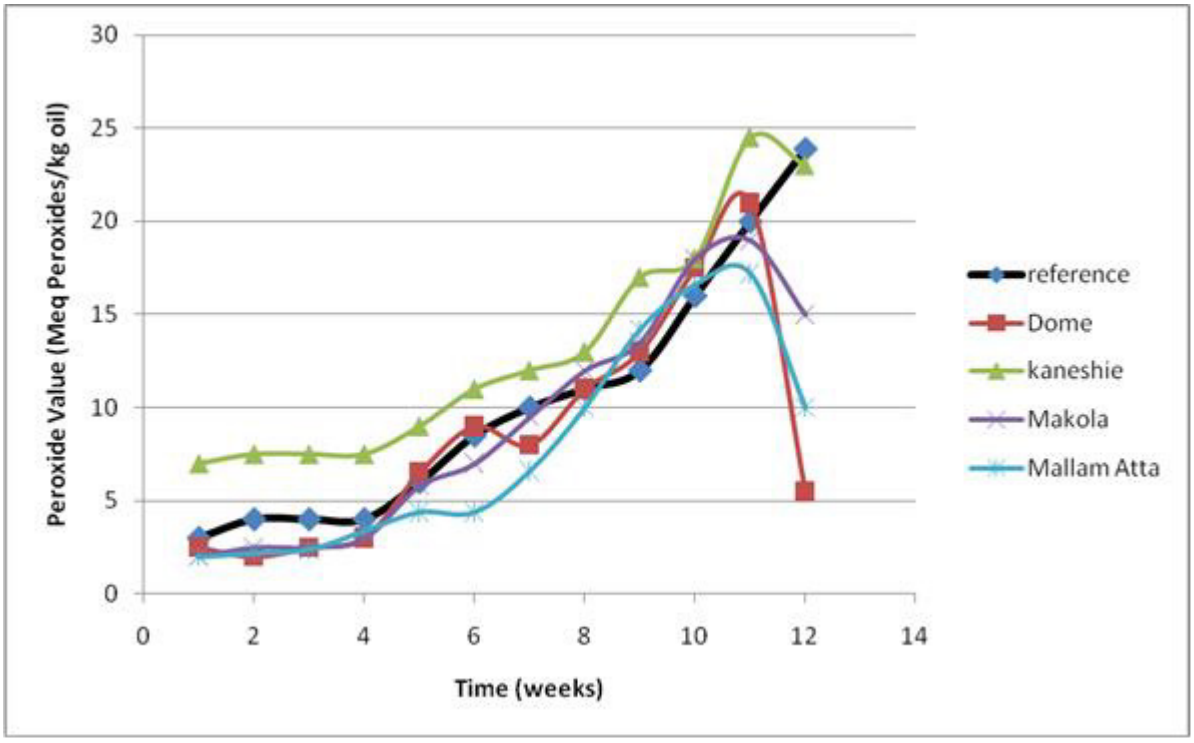

Fig. 2: Trends of peroxide values (Meq of peroxide/kg oil) during storage (weeks) of peanut paste samples.

Principal component analyses (PCA)

PCA was used to determine the alignments of the component variables of peanut paste samples from the different markets. The first two components accounted for 86.12 % of the total variance in the data set, and these two principal components (PC) were retained. The PC1 versus PC2 scores and loadings plots are presented in Figure 3A and B. The scores plot (Figure 3A) shows that the different peanut paste samples were associated based either on colour (L-values) or rheological properties. Samples obtained from the Kaneshie and Makola Markets were similar to the Reference sample and were loaded (or associated) together on the Lightness colour (L-values). The L values of peanut paste is an indication of the degree or intensity of roast. The intensity of roast of the peanuts from the Kaneshie and Makola samples were similar to the Reference samples, but differed markedly from the Dome and Mallam Atta samples.

The loadings plot (Figure 3B) shows that the textural and rheological properties of the peanut paste samples (consistency, firmness, index of viscosity, cohesiveness) were all clustered together at the negative side of PC1 and were more associated with the Dome and Mallam Atta samples. In particular the rheological characteristics of Mallam Atta samples, especially the cohesiveness may be related to its very high carbohydrate content, while the exceptionally high crude fibre content of the Dome samples may be the underlying influence on its rheological characteristics.

Conclusions

Artisanal peanut paste sold in the Ghanaian markets are generally clean and devoid of soils, but have unacceptable levels of aflatoxins contamination. They are quite stable to oxidative rancidity at ambient temperatures for about 9 weeks. While peanut paste did not differ much in the majority of physicochemical characteristics, observable differences in colour and shelf life are likely influenced by process variables such as the intensity of roasting of the peanuts, as manifested in key quality indices of colour (L-values), and textural and rheological properties. Such sources of product variability could be eliminated through appropriate equipment design, the application of quality management systems, as well as development of training schedules for artisanal peanut paste processors.

Funding

This work was supported by the USAID funded Peanut-CRSP Collaboration Project (#122) between the Department of Nutrition and Food Science, University of Ghana, and the University of Georgia, Griffin Campus.

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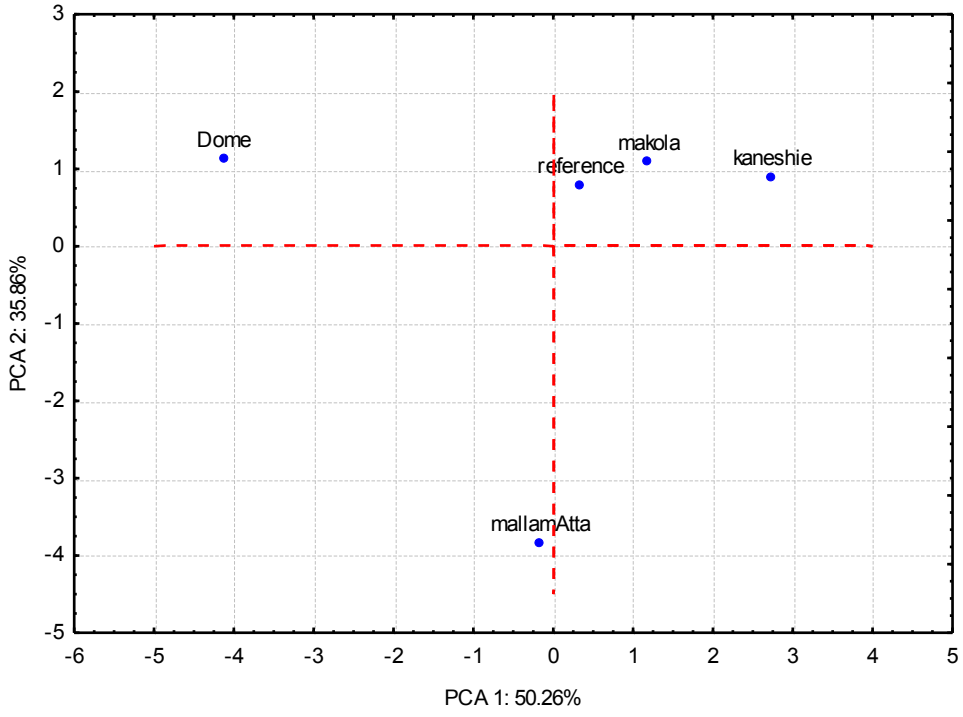

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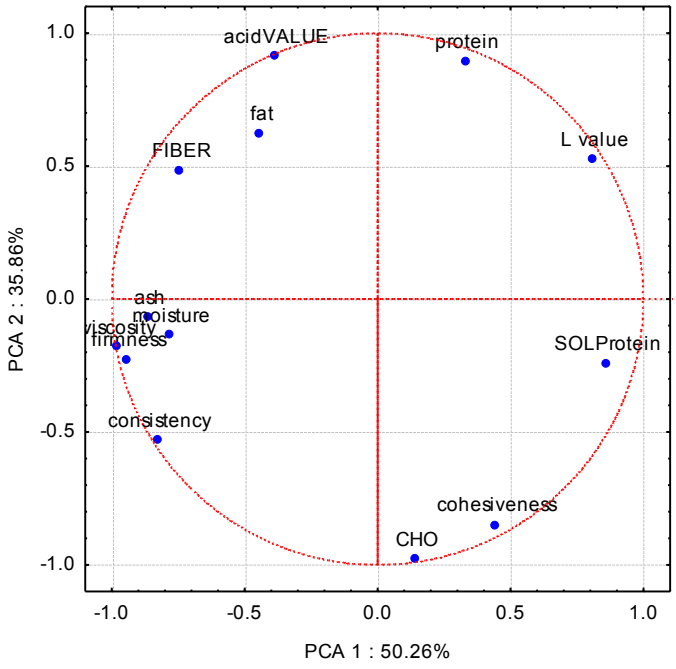

Fig. 3: Score and loading plot of PC1 vs. PC2 from peanuts paste samples (A) Samples labelled by market source (B) Loading plot based on physico-chemical variables of peanut paste samples.

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