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Package shrinking of commercially packed food products

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ABSTRACT

Since quality deterioration and package shrinking of commercially packed food product is a common problem, a study was carried out using 6 kg of clean finger millet (kurakkan seeds). The seed sample was divided into two equal portions and one portion was subjected to heat treatment at 90 °C for 5 minutes. The two portions were ground separately and divided into two equal portions again. Moisture content of each was brought to 10% and 14% by heating and re-hydration. Four samples, generated out of these treatments were replicated thrice and stored under normal environmental conditions for 3 months. Random samples were drawn from each treatment monthly, to determine starch content in terms of starch iodine blue value, development of FFA and package shrinking, measured by using Archimedes law.

Result revealed that development of FFA in raw millet powder at high moisture content (FFA - 85%) was more significant than the counter treatment (FFA - 35%). Starch iodine blue value of heat treated low moisture sample (0.169) was very closed to the initial value (0.174), even after 3 months of shelf life. High percentage of volume reduction (package shrinking) also occurred in raw millet powder at high moisture content 10.2% as against it's counter treatment, which is 5.5%. Hence the best treatment was the heat treatment (90 °C for 5 min)

Keywords: Package shrinking, Finger Millet (Kurakkan seeds), Starch Iodine Blue value, Archimedes law, Tripple laminate pouches, Organolaptic properties, Fat & Starch degradable enzymes Lipase, Amylose, Lipid peroxidation & Starch process oxidation

INTRODUCTION

Processed, semi-processed and unprocessed edible seeds, beans, fruits, nuts etc., are much popular food products throughout the world, as most of consumers prefer to have these items due to their relative cheapness, inherent flavour and nutritional value. (Hulse *et al.*, 1986) Therefore, these items are subjected to a series of production processes before converting into the edible form. The primary step associated with this process is removal of hazardous and harmful substances and thereafter segregation of inedible substances from the seed, if any (Kent Jones, 1983). The edible components derived from the process is either subjected for pounding, splitting, pulverizing or any other process, while carrying out necessary inspection and testing for high quality. Eventhough the producer produced the product in compliance with the laid down standards, a substantial amount of it cannot be sold in the market due to package shrinking, product hardening, offensive taste, offensive smell etc. (Oryetall, 1997). These changes may be caused by various invisible factors and become more significant, when products are manufactured out of raw seeds at high moisture levels. Hence in order to study the problems associated with these products,

an experiment was designed using millet seeds, while taking into account two factors; moisture content and enzymes in the seeds.

MATERIALS AND METHODS

The experiment was conducted by using two factor factorial design with two variables moisture content at two levels and heat treatment with and without. Six kg cleaned finger millet seeds (*Eleusine coracana*), locally known as Kurakkan, were taken and divided into two equal portions, one portion was subjected to the heat treatment at 90°C for 5 minutes (Jyothilakshmi and Prakash, 1997) to kill enzymes. The remaining portion was kept untreated. The two seed portions were ground with laboratory pin mill with number 6 mesh in order to get particle size less than 300μm. These two ground seed portions were divided into two equal parts again and moisture content of each was brought to 10% and 14% by heating and rehydration. During the heating process, samples were drawn frequently and analyzed until 10% moisture was achieved. In the case of rehydration process, amount of water required to achieve 14% moisture content was calculated after determining of initial moisture content of kurakkan seeds.

Amount of water required to maintain 14% moisture content was decided using the following equation.

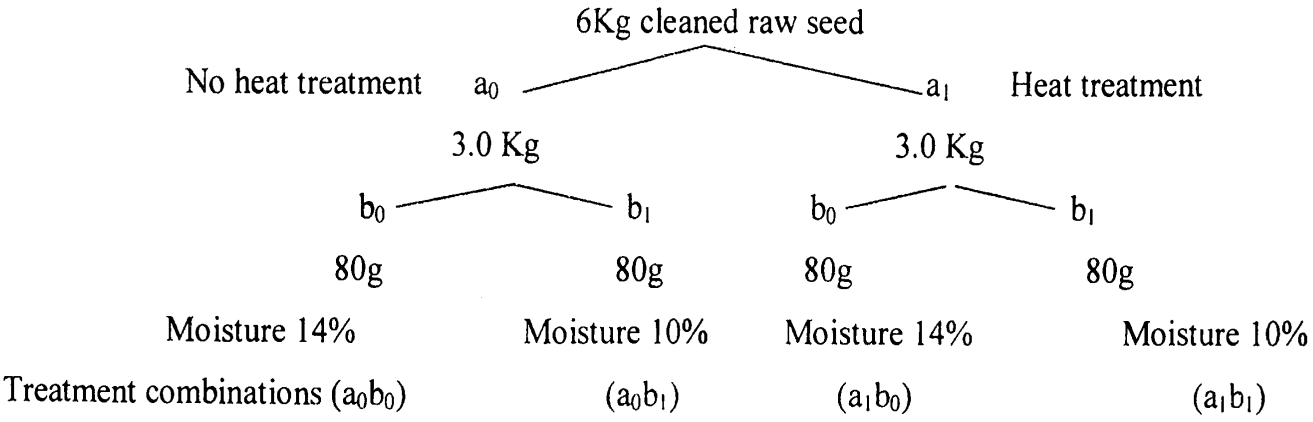
$$WR = \left(\frac{14 - MC_0}{100 - 14}\right)W$$

Where, WR - Amount of water required
Mc_0 - Initial moisture content
W - Weight of millet seeds (g)

All ground samples, were weighted into 80 g, packed in triple laminate (PET/MMETPET /LDPE) pouches of gauge 350, while maintaining same surface area of packing material for all samples.

All treatments were replicated 3 times, and stored under normal environmental conditions (28°-32 °C & RH 68-72%) for a period of 3 months and samples were drawn from each treatment every month for

Experimental Design



followings.

Since activities of enzymes of most of processed food products, will be ceased about 2-3 months after processing (unless they have been subjected to enzyme inactivation process), the experiment was scheduled to be carried out for 3 months period.

Determination of starch content in terms of starch iodine blue value

A sample of 1.0g finger millet powder was passed through a 0.5 mm screen and transferred into a 250 ml Erlenmeyer flask and added 100 ml of distilled water. Content in the flask was heated in a water bath for 45 minutes at 77 °C. The sample was allowed to stand at room temperature for 15 minutes and filtered through whatman number 12 filter paper. A 10 ml aliquot of filtrate was pipetted into a 100 ml volumetric flask, containing one milliliter of iodine solution, one milliliter of 30 percent hydrochloric acid and approx. 60 to 70 ml distilled water. The flask after being filled to the mark, was shaken and allowed to stand at room temperature for at least 30 min. The intensity of blue colour was determined in a photo electric colourimeter at 600 nm and recorded as the iodine blue value.

Determination of free fatty acids levels

According to Kent Jones (1967), some millet powder was taken into a beaker and added 80 ml of petroleum ether to extract the oil. Extracted oil was taken into a small flask of known weight and placed in an oven until constant weight was achieved. Fifty ml of isopropyle alcohol was taken into a beaker and kept on a water bath for several minutes. 2-3 drops of phenopthalein and few drops of 0.1 M KOH were added into the beaker to nutralize the media. The mixture was added to the oil and kept on the water bath until it boiled. It was titrated with 0.1 M KOH until the colour changed from colourless to pink. The volume of KOH was taken as the endpoint reading.

$$FFA = \frac{2.82V}{m}$$

Where, V = volume of KOH (ml)
M = weight of oil (g)

Measuring changes in volume of pouch

Four samples with three replicates for each treatment in 100 g were prepared and packed in triple laminate (PET/ MET PET/ LDPE) pouches. Filling orifice of all samples were double sealed in order to prevent air leakage, while maintaining air space above the content as minimum as possible.

Archimedes law was used to measure the volume reduction of package (Parker, 1983) during the period of storage. Initial volume of all samples were measured by dipping them in cold water at 27 °C and volume discharged by each was recorded. The same procedure was adopted for three replicates of each treatment and average volume decreased per 100 g of finger millet flour was calculated at 1, 2 and 3 months of shelf life.

Percentage of volume reduction was calculated using the following equation.

$$V_R = \frac{V_0 - V_s}{V_0} 100$$

Where, V_R - Percentage of volume reduction
V_0 - Initial volume of porch
V_s - Volume of porch during storage

Determination of organoleptic properties

Seven trained panelists analyzed finger millet

flour for aroma and taste, using five-point hedonic scale. Kurakkan flour from each treatment was used separately to prepare "kurakkan pittu" as pellets without incorporating any ingredients except pure water. The weight of each pellet was around 10g. Samples were presented in identical containers at the same temperature, coded with three digits. Sample order was randomized for each panelist and samples were presented to all penalists at once. Tap water at room temperature was served to rinse mouth. The data of sensory analysis were subjected to statistical analysis.

Result and Discussion

Development of free fatty acids (FFA) during storage

Development of free fatty acids in millet powder during the period of 3 months storage with respect to each treatment is shown in Figure 1.

The graph in Figure 1 clearly indicated that the development of FFA in the treatment "high moisture with no heat treatment (a_0b_0)" was more significant than the other treatments as fat degradable enzymes (Lipase) are still active (Galliard, 1983) which acted upon the fat fragments in the damage raw flour (Oryetal, 1997). Outcome of this process was formation of more free fatty acids as tri-glyceride of the oil subsequently oxidized by the lipase. The high moisture content of this treatment also contributed in accelerating fat degradation process (Karel, 1997) by hydrolization (Anonymous, 2003).

Heat treated flour at low moisture (a_1b_1) was the treatment having least development of FFA due to killing of lipase by heat treatment and low moisture. (Jyothilakshmi & Prakash, 1997).

Changes occurring in starch content

Changes occurring in starch content of millet powder were measured in terms of starch iodine blue value and results are shown in Figure 2.

Figure 2 indicates that the lowest amount of starch degradation occurred in "heat treated low moisture treatment (a_1b_1)" and the highest amount in "no heat treated raw flour at high moisture (a_0b_0)" as against initial value of 0.174. Since amylases and alpha amylases enzymes were still active in raw millet powder,

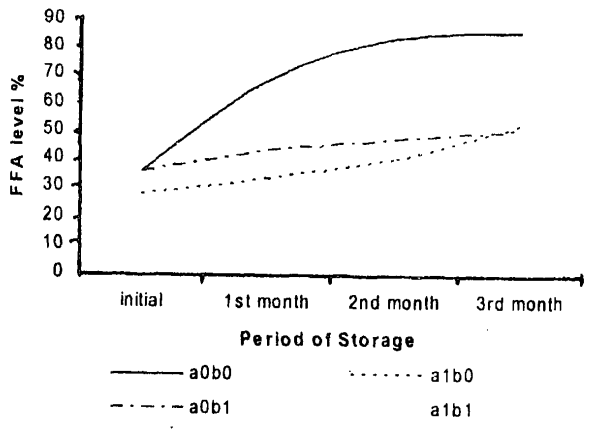


Figure 1.Relationship between FFA level and period of storage

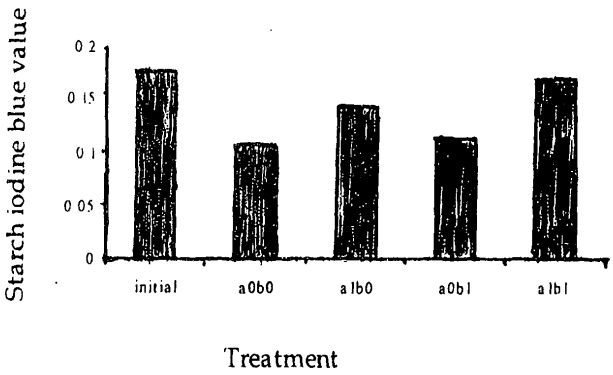


Figure 2: Starch iodine blue value of millet powder before storage (initial) and after 3 months of storage.

starch degradation process continued during the period of storage (Eskinetal, 1971). This process was accelerated by the high moisture content in raw seeds. "Heat treated low moisture treatment (a_1b_1)" showed counter results as moisture content was very low and activities of enzymes have also been ceased by the heat treatment.

Reduction of volume of the pack due to shrinkage

Reduction of volume of packets of each treatment during 3 months of storage was measured using Archimedes principles and results are shown in Figure 3.

The treatment "raw millet powder at high moisture content (a_0b_0)" shared a high degree of volume reduction as against all other treatments, of which "heat treated millet powder at low moisture content (a_1b_1)" was the least. Reason for this shrinking effect is activity of Amylase and lipase enzymes that have not been killed in raw millet powder. The amylase enzymes in the millet powder acted upon starch granules and convert them into sugars. (Robyt, 1984). These sugars are further combined with glucose oxidase under anaerobic condition and formed D-Gluconolactone. With the entry of e of O_2 to the anaerobic reaction (Rechardson & Finley, 1997) available oxygen in the packet itself gradually depleted, resulting in shrinking of the packet. Furthermore, the lipase enzymes also acted upon the fat fragments and contributed to accelerate hydrolytic or oxidative reactions or by a combination of both. According to Galliard (1983) oxygen was utilized by the lipid oxidation, lipid peroxidation and lipolitic enzymic degradation processes. As a result of utilization of oxygen by the fat degradation process, the packet tended to get contracted. This situation was further aggravated by the high moisture content (Richardson & Finley, 1997).

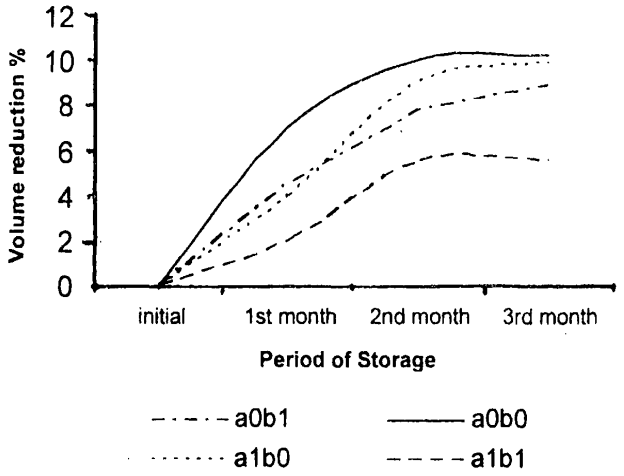


Figure 3. Relationship between percentage of volume reduction & period of storage of millet powder

Evaluation of effect of treatments in terms of organoleptic properties

Two sensory perceptions aroma and taste of millet powder after 3 months of storage were taken into account and evaluated by sensory means. The scores given by the panelists for aroma and taste are shown in Figures 4 and 5 respectively.

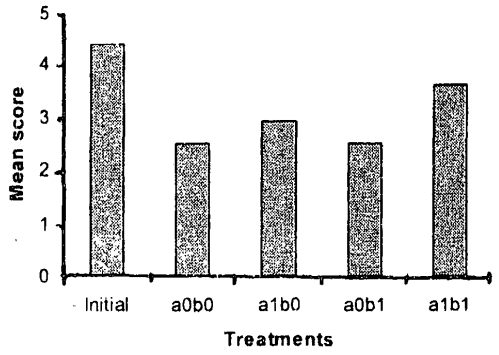
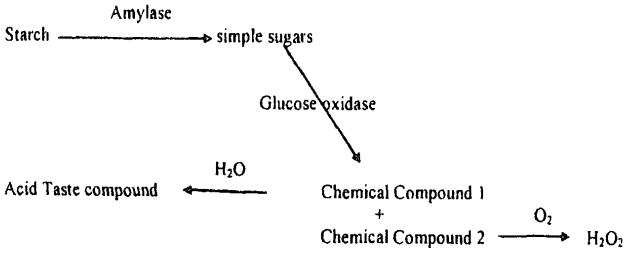


Figure 4. Effect of treatments on taste before storage (initial) and after 3 months of storage

The Figure 4 clearly showed that minimum changes occurred in "heat treated 10% moisture treatment (a_1b_1)" relative to the initial taste. The reason for least change in taste of a_1b_1 treatment was inhibition of activities of enzymes by heat treatment and lowering of moisture content in the flour. The worst treatments were "raw seeds at low moisture (a_0b_1)" and "raw seed at high moisture (a_0b_0)" as these treatments remained under the influence of enzymes and high moisture content. The reason for this phenomenon was oxidation of polysaccharides by enzymes into simple sugars (Richardson and Finley 1997). Simple sugars were further subjected to oxidation process by glucose oxidase enzymes and produced two unstable components. One of which was hydrolyzed with free water available in the product and produced an acidic compound which was stable and imparted an acid taste for the product. The other portion reacted with oxygen available in the pouch and produced H_2O_2 (Richardson and Finley 1997).



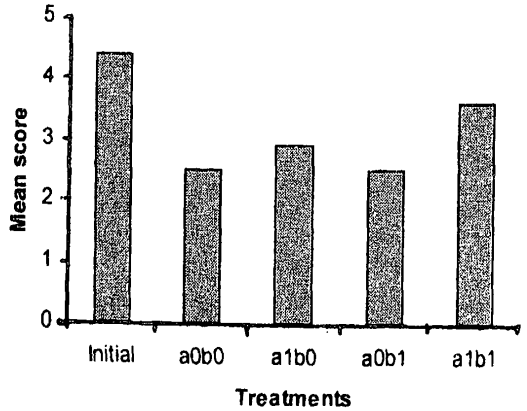


Figure 5. Effect of treatments on smell before storage (initial) and after 3 months of storage

Figure 5 clearly showed that least change in the smell occurred in "heat treated flour at low moisture (a_1b_1)" treatment than the other treatments relative to the initial value. A disturbing change occurred in a_0b_1 and a_0b_0 treatments due to the activity of lipase. High moisture content in the flour further aggravated the situation. The reason for the smell change was oxidation of fat by lipase enzyme and forming of free fatty acids (Galliard, 1983). Free fatty acids are further subjected to degradation process by utilizing oxygen available in the pouch itself. Outcome of this process was formation of highly volatile aldehides and ketones that contributed to emit a little unpleasant smell from the product as finger millet contained a little amount of fat (Gunstone and Norris, 1983).

CONCLUSION

Giving a heat treatment at 90 ^{0}C for 5 minutes and maintaining the moisture content less than 10% was the best treatment in preventing the quality deterioration of finger millet powder during the period of storage.

Heat treatment coupled with low moisture would control lipid and starch degradation processes to a great extent, which result in minimization of starch and lipid oxidation process and shrinking of packing material or volume reduction.

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Studies on the intrinsic physico-chemical properties of pigeon pea (*Cajanus cajan* L.) seed flour

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ABSTRACT

Intrinsic physico-chemical properties of pigeon pea (*Cajanus cajan* L cv. IITA 8860) seed flour were investigated. The results indicated that although pigeon pea seed weight, volume and density were in the range reported for some commonly consumed seed legumes, the seed exhibited lower hydration and swelling coefficients. The seed flour was a good gel-forming agent; more hydrophobic but less lipophilic in nature; and it had poor foaming qualities and poor emulsion stability. Furthermore, its protein showed least solubility at pH 4.0.

Keywords: Pigeon pea, physico-chemical properties, flour.

INTRODUCTION

In recent times, nutrition research has focused attention on bridging the gap between the population growth and protein supply in Nigeria. Research efforts have been on the introduction of cheaper and affordable vegetable protein sources in the diets of the less privileged and low-income group. In this regard, nutritional quality potential of the under-exploited seeds of *Cajanus cajan* L. has been reported (Oloyo, 2002; 2004). This therefore, adds to the list of food legumes such as *Vigna unguiculata* and *Glycine max* that have been earlier targeted in the campaign for increased consumption to prevent incidence of protein malnutrition among the populace. However, acceptability of *Cajanus cajan* seeds as ingredients in prepared foods requires a knowledge of its physical and functional properties. The present study reports on the intrinsic physico-chemical properties of *Cajanus cajan* seeds. The information will assist in predicting useful applications of the seed flour in prepared foods.

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MATERIALS AND METHODS

Clean and healthy seeds of pigeon pea, *Cajanus cajan* L. cv. IITA 8860 were collected from the International Institute of Tropical Agriculture, Ibadan, Nigeria.

Determination of physical properties

Physical properties of seeds were studied in accordance with the procedures of Attia *et al.*, (1994). Weight of randomly sampled 100 seeds was taken, and the volume was measured by absolute displacement using distilled water. Apparent density of the seeds was calculated by dividing weight of seeds by their volume. Percentage seed coat was calculated by manually decorticating 100 seeds. Hydration coefficient and swelling coefficient were determined by soaking 50 g of seeds in 150 ml

distilled water for 16 h, while noting the weight and the volume of soaked seeds at intervals of 4 h. Hydration coefficient was calculated as the percentage increase in weight of seeds, while swelling coefficient was calculated as the percentage increase in volume of seeds.

Determination of functional properties

A bulk of the seeds were oven-dried at 60°C for 24 h, milled in a Wiley mill to pass through a 40 mm mesh sieve, and then stored in air-tight container for subsequent chemical analyses.

a. Least gelation concentration

Least gelation concentration was determined following the procedure of Coffman and Garcia (1977). Suspensions of the milled seed samples, i.e., 2, 4, 6, 8, 10, 12, 14 and 16% (w/v) were prepared in 10 ml distilled water in test tubes. The test tubes containing these suspensions were heated in a boiling water bath for 60 min. after which they were rapidly cooled to 4oC under running cold tap water. Cooling at this temperature continued for another 2 h. The minimum concentration of the sample which did not drip or slip from inverted tubes determined the least gelation concentration.

b. Water and oil absorption properties

Water and oil absorption capacities were determined by the method of Sathe *et al.*,(1982). A 0.5 g milled seed sample was added to each of 5 ml distilled water and 5 ml oil (AVOP vegetable oil) in separate 10 ml graduated centrifuge tubes. The mixtures were stirred with glass rods to disperse the samples in both solvents. After standing for 30 min at room temperature (29-30°C), the mixtures were centrifuged (5000 x g, 30 min). Volumes of both supernatants were noted, and then excess water or oil absorbed was expressed as the percentage water or oil bound by 100 g sample. Densities of water and oil used were 1 g/ml and 0.88 g/ml, respectively.

c. Emulsion properties

Emulsions were prepared according to the method of Sathe and Salunkhe (1981). Milled seed sample (1 g) was blended in a KENWOOD blender with 50 ml distilled water for 30 s at high speed. Vegetable oil (AVOP) was added continuously from a burette at the rate of 5 ml/min while blending continued. Oil addition was stopped when the nature of emulsion changed, as marked by decreased homogeneity. The emulsion so prepared was then used to study emulsion capacity and stability. A portion of the emulsion was centrifuged (35000 x g) until the volume of oil separated from the emulsion was constant in order to determine emulsion capacity. Another portion of the emulsion was allowed to stand in a graduated cylinder for 0, 0.5, 1, 2, 3, 4, 5, 6 and 24 h at room temperature while noting the volume of water separated. Emulsion capacity and stability were calculated using the following equations.

$$\text{Emulsion capacity (\%)} = \frac{\text{Height of emulsified layer}}{\text{Height of whole layer}} \times 100$$

$$\text{Emulsion stability (\%)} = \frac{\text{Height of the remaining emulsified layer}}{\text{Height of whole emulsified layer}} \times 100$$

d. Foaming properties

Foaming capacity and stability were determined according to the method reported by Coffman and Garcia (1977). A sample of 2.0 g seed flour was whipped with 100 ml distilled water for 5 min in a KENWOOD Blender at speed setting "Max" and then

poured into a 250 ml graduated measuring cylinder. The total volume at time intervals of 0.0, 0.25, 0.5, 1.0, 1.5, 2.0, 3.0 and 4 h was noted. Percent volume increase was calculated according to the following equation.

$$\text{Volume increase (\%)} = \frac{\text{Volume after whipping (ml)} \times \text{Volume before whipping (ml)}}{\text{Volume before whipping (ml)}} \times 100$$

e.Protein solubility

Protein solubility profile was determined in the pH 2 to 12 for the sample at room temperature (29-30°C) by the method of Narayana and Narasinga Rao (1982). A 0.2 g of milled sample and 20 ml distilled water were shaken for 2 h at room temperature. The pH of resultant slurries was adjusted to values ranging from 2 to 12 using either 0.1 M HCl or 0.1 M NaOH. Insoluble materials were removed by centrifugation (3500 x g, 30 min) and the supernatant was digested for subsequent total nitrogen determination by the micro Kjeldahl procedure. Percentage nitrogen was converted to crude protein by multiplying %N by 6.25.All determinations were done in three replications, and all data obtained in the study were subjected to statistical analysis using the Statistical Package for Social Sciences (SPSS Inc. 1998) on a COMPAQ personal computer.

RESULTS AND DISCUSSION

The physical properties shown in Table 1 indicated that seed weight and volume of *Cajanus cajan* were similar to those reported for *Glycine max* and *Vigna unguiculata* (Kay, 1979), but less than those of *Cicer arietinum* and *Phaseolus lunatus* (Kay, 1979; Attia *et al.*, 1994) and higher than those of lentil (Kay, 1979). The seed coat (as percent of the whole seed) of *Cajanus cajan* was similar to that of *Phaseolus lunatus*, but lower than that of *Vigna unguiculata*, and was about twice that of *Cicer aeritinum* (Kay, 1979; Attia *et al.*,1994). The seeds of *Cajanus cajan* and *Cicer arietinum* had similar apparent densities. *Cicer arietinum* seeds had higher hydration and swelling coefficients than those of *Cajanus cajan* (Attia *et al.*,1994). Compared to *Cicer aeritinum*, lower values of hydration and swelling coefficients observed in *Cajanus cajan* might be due to its higher percent seed coat more so that seed coat acts as a barrier for water migration into seeds (Rolston, 1978). Results in Table 1 showed that rates of hydration and swelling of *Cajanus cajan* seeds were rapid within 8 h of soaking and approached zero after 12 h.

Table 2 shows the functional properties of *Cajanus cajan* seed flour. The least gelation concentration exhibited by *Cajanus cajan* seed flour was less than that shown by *Lupinus*

Table 1. Physical properties of pigeon pea seeds

Parameter	Mean	±SD
100 seed weight (g)	10.57	1.029
100 seed volume (cm^3)	9.01	1.006
Apparent seed density (g/cm^3)	1.17	0.003
Seed coat (%)	8.88	1.376
Hydration coefficient (%) at:		
4 h	39.83c*	2.289
8 h	70.83b	3.289
12 h	91.00a	4.068
16 h	91.00a	5.300
Swelling coefficient (%) at:		
4 h	68.74t*	3.215
8 h	81.27s	4.646
12 h	112.50r	6.872
16 h	112.50r	5.139

*Mean values denoted by different subscripts, r-t within the column for a parameter differ significantly at P(0.05).

* Mean values denoted by different subscripts, a-c within the column for a parameter differ significantly at P(0.05).

mutabilis seed and *Phaseolus vulgaris* seed flour (Sathe *et al.*, 1982). The result thus tended to suggest that *Cajanus cajan* seed flour is a better gel-forming agent and the gel produced from the flour is relatively firmer. Differences in the gelling properties of legume flour have been ascribed to the relative ratios of different constituents (i.e. proteins, carbohydrates and lipids) and that interactions between such components have a significant role in the functional properties (Sathe *et al.*, 1982). Indeed, *Cajanus cajan*, *Lupinus mutabilis* and *Phaseolus vulgaris* seed flour differ in their chemical composition (Kay, 1979; Sathe and Salunkhe, 1981; Sathe *et al.*, 1982; Oloyo, 2002) and this might have accounted for the differences in the least gelation concentrations.

Water absorption by the *Cajanus cajan* seed flour was higher than those reported for sunflower seed, *Glycine max*, *Lupinus mutabilis* seed and *Phaseolus vulgaris* seed flour (Sathe *et al.*, 1982), an indication that the *Cajanus cajan* seed flour is more hydrophobic in nature (Lin *et al.*, 1974). The higher water absorption for the *Cajanus cajan* seed flour might be due to its low fat content and the predominance of polar amino acids in its protein structure (Kay, 1979). While polar amino acids have shown to be the primary sites for water absorption, fat creates lipophilic environment that blocks the water binding sites on the proteins (Kuntz, 1971; Chou and Morr, 1979).

Data on oil absorption of *Cajanus cajan* seed flour (Table 2) showed that it absorbed less oil than water, thus suggesting the seed's protein is less lipophilic. While it absorbed more oil than soybean flour, sunflower seed flour, lupin seed flour, wheat flour and full-fat fluted pumpkin, it absorbed less than isolated protein concentrates from soybean, lupin seed, great northern seed, sunflower seeds (Lin *et al.*, 1974; Sathe *et al.*, 1982, Giami and Bekebain, 1992).

Emulsion capacity of *Cajanus cajan* seed flour shown in Table 2 was in the range reported for full-fat fluted pumpkin seed flour, wheat flour, soybean seed flour, and protein concentrates and isolates from soybean and sunflower seeds. On the other hand, the emulsion capacity for the pigeon pea flour was less than those of lupin seed flour and sunflower seed (Lin *et al.*, 1974; Sathe *et al.*, 1982; Fagbemi and Oshodi, 1991). Figure 1 depicts the emulsion stability of the pigeon pea flour. It revealed that the emulsion stabilized for only 2 h after which water separation began. The emulsion broke down rapidly within 6 to 24 h on standing at 29°C, and it was considered poor. However, the medium emulsion capacity of the pigeon pea flour may be useful for food applications especially serving as a replacement

Table 2. Functional properties of pigeon pea seed flour

Parameter	Mean	±SD
Least gelation concentration (%)	8.00	0.592
Water absorption capacity (%)	409.00	12.098
Oil absorption capacity (%)	251.00	9.162
Foaming capacity (%)	9.81	1.827
Emulsion capacity (%)	20.93	1.021
Emulsion stability (%)	42.50	2.010

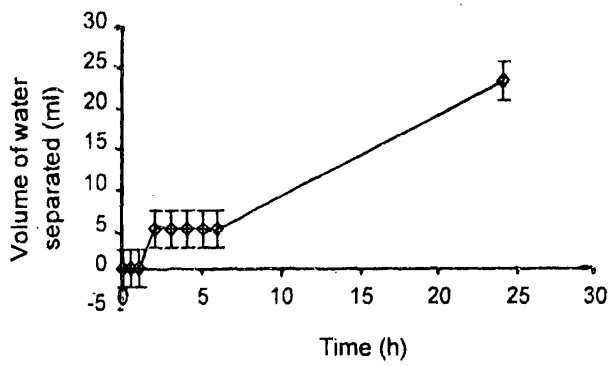

Figure 1. Effect of keeping time on emulsion stability of pigeon pea seed flour

for wheat and soybean flour as meat additive, meat extender, binder formulation and in stabilizing colloidal food system (Fagbemi and Oshodi, 1991).

Foaming capacity of pigeon pea seed flour (Table 2) compared with that reported for full-fat fluted pumpkin seed flour (Fagbemi and Oshodi, 1991) but it was lower than those of soybean seed flour, sunflower seed flour (Lin *et al.*, 1974) and lupin seed flour (Sathe *et al.*, 1982). The foaming stability of pigeon pea seed flour depicted in Figure 2 indicated that it was poor as it collapsed within 1 h of standing at 29°C. Foaming characteristics of flour and protein isolates or concentrates had been associated with the concentration of protein, fat and carbohydrate in the substrates. While protein causes an increase in foaming capacity and stability, the reverse was true for fat and carbohydrates (Richert, 1979; Sathe and Salunkhe, 1981; Sathe *et al.*, 1982). The poor foaming capacity and stability of the pigeon pea flour, therefore, may be attributed to the lower protein and higher carbohydrate contents of the seed flour, compared to those of soybean, sunflower and lupin seeds flour (Lin *et al.*, 1974; Kay, 1979; Sathe *et al.*, 1982; Oloyo, 2002).

Profile shown in Figure 3 indicated that solubility of the pigeon pea seed flour protein

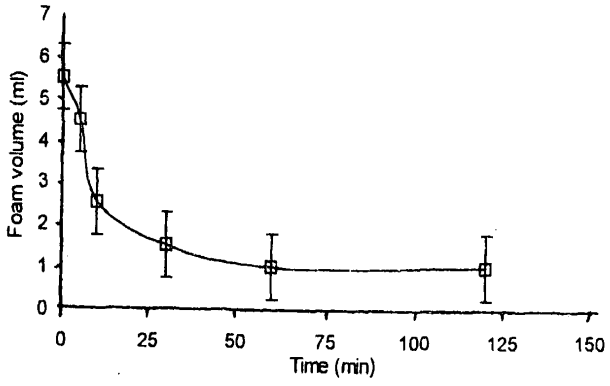

Figure 2. Foaming stability of pigeon pea seed flour

was pH dependent. Least solubility was at pH 4.0 and it increased with the increase of pH. The result is suggestive that the isoelectric pH of pigeon pea seed flour protein is about pH 4. The trend in protein solubility observed in the present study agreed with the solubility profiles

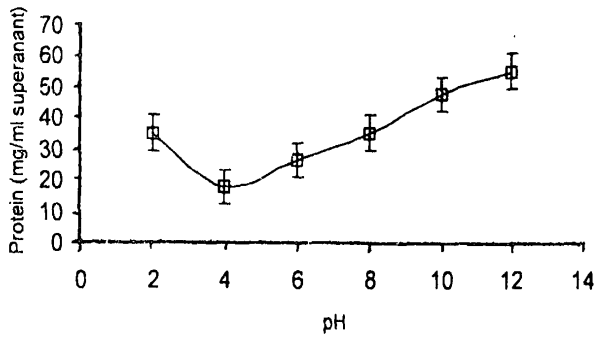

Figure 3. Effect of pH on pigeon pea seed protein solubility

of lupin seed flour (Sathe *et al.*, 1982), and full-fat fluted pumpkin seed flour (Fagbemi and Oshodi, 1991; Giami and Bekebain, 1992) where minimum solubility was recorded at pH 4.0. Also, Ruiz and Hove (1976) and Narayana and Narasinga Rao (1982) observed isoelectric pH of 4.5 for dehulled lupin seed proteins and winged bean flour, respectively.

CONCLUSION

From the foregoing, it may be concluded that although *Cajanus cajan* L cv. IITA 8860 seed weight, volume and density were within the range reported for some commonly consumed seed legumes, the seeds exhibited lower hydration and swelling coefficients. The seed flour was a good gel-forming agent; more hydrophobic but less lipophilic in nature and it had poor foaming qualities and poor emulsion stability. Furthermore, its protein showed least solubility at pH 4.0.

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