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Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

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The Effect of Steeping with Chemicals (Alum and Trona) on the Proximate and Functional Properties of Pigeon Pea (*Cajanus cajan*) Flour

J.N. Nwosu, N.C. Onuegbu, N.O. Kabuo and M.O. Okeke
Department of Food Science and Technology, Federal University of Technology, Owerri, Nigeria

Abstract: The effectiveness of steeping in different chemicals (Alum and Trona) on the proximate and functional properties of Pigeon pea seed was studied. The seeds were steeped in different chemicals (Alum and Trona) with different concentrations and time intervals of 24 h and 48 h. The above treated seeds were then dehulled, dried and milled. Properties of the resulting flours were determined using standard methods and the result obtained were analyzed statistically. Results obtained showed that steeping improved the ease of dehulling pigeon pea seed with optimum at 48 h without chemical. Increase in concentration of chemicals (Alum and Trona) increased fibre content being more effective with trona (3.89-4.92%). Increase in concentration decreased protein (22.1-19.76%), fat (1.48-1.23%) and moisture content (12.27-11.33%). This happened in all cases while it increased ash (3.16-4.12%), fibre (3.89-4.92%) and carbohydrates (61.86-63.03) in proximate analyses. Increase in chemical concentration increased wettability (198sec-411sec), water absorption (1.27-4.16 ml/g) and decreased oil absorption (2.55-1.28 ml/g) except water absorption for 48h (1.65-2.25 ml/g) which had a change in trend. Increase in Trona concentration decreased gelling point (83-66°C) as a result, this product could be used in food formulation such as ice-cream because of its appetizing aroma and foaming stability.

Key words: Pigeon pea seed, food formulation, flour

INTRODUCTION

The pigeon pea (*Cajanus cajan*) belongs to the family Fabacea. It is an important grain legume crop of rain forest agriculture in the semi-arid tropics; this means that it has nodules on its roots which contain bacteria. These bacteria take nitrogen from the air, which is known as nitrogen fixation (Wikipedia, 2005). Pigeon peas are both a food crop (dried peas, flour, or green vegetable peas) and a forage/cover crop. The dried peas may be sprouted briefly and then cooked, for a flavour different from the green or dried peas. Pigeon pea originated from India, Asia and was brought millennia ago to Africa where different strains developed and by means of the slave trade to the American continent. The places/countries pigeon peas are found in the world are India, Senegal, Ghana, Togo, Nigeria, Puerto Rico Dominican Republic Hawaii, in North Australia (Wikipedia, 2005), in East Africa and in the Caribbean areas, etc. The early scientist gave it different names. It was named *Cytisus cajan* by Crawford in 1852 and *Cajanus indicus* by Valder in 1895. But different regions which they are found have different names for it. It is known as "*Arthar*" (Bengali), "*Fio-fio*" (South-East Nigeria), "*Togari*" (Canada), "*Kandi*" (Telugu), and also known as "*Gandul*", "*Guandul*", "*Gunga*" pea, Congo pea, "*Gungo*" pea and "*No-eye*" pea in different countries.

Pigeon peas are nutritionally important, as they contain high levels of protein and the important amino acids, methionine, lysine and trypotophan. In combination with cereals, pigeon peas make a well-balanced human food (Wikipedia, 2005). Pigeon peas are popular food in developing tropical countries. Nutritious and wholesome, the green seeds (and pods) serve as vegetable. Ripe seeds are source of flour, used in soups or eaten with rice. Dhal contains as much as 22% protein, depending on the location. Tender leaves are rarely used as a potherb. Ripe seeds may be germinated and eaten as sprouts. Plants produce forage quickly and can be used as a perennial forage crop or used for green manure. They are also grown as a shade crop for tree crops or vanilla, a cover crop, or occasionally as a windbreak hedge. In Thailand and N. Bengal, pigeon peas serve as host for the scale insect which produces lac or sticklac. In Malagasy, the leaves are used as food for the silkworm. Dried stalks serve for fuel, thatch and basketry. They are also used as feed for poultry (Wikipedia, 2005). The problem associated with pigeon pea, is that it is hard-to-cook and storage may leave direct and indirect effects on the nutritive value of foods and diets. Poor storage conditions with high temperature and relative humidity will result in staple foods with high moisture levels and a decrease in quality because of the millard reaction. Such conditions will also result in the growth of fungi that produce toxic compounds that have adverse effects on animals consuming such foods. Poor storage conditions can also affect nutritive value by favouring insect infestation which also results in losses of dry matter. Finally, the improper use of chemicals to protect grains can also decrease the nutritive value of the staple food. Various

Corresponding Author: J.N. Nwosu, Department of Food Science and Technology, Federal University of Technology, Owerri, Nigeria

examples will be given for situations that are common in tropical developing countries (Wikipedia, 2005).

The aim of this study therefore is to investigate the effect of steeping with chemicals (Trona and Alum) on the proximate and functional properties of the flour made from pigeon pea (*Cajanus cajan*) seeds to see if it would retain some of its nutritional properties. It is hoped that the nutritional potential of pigeon pea will be exposed and its usage enhanced with this study to help in its utilization.

MATERIALS AND METHODS

Pigeon pea seed used was obtained from a local market in Enugu state. The chemicals equipment/ facilities were obtained from Ekeonunwa market in Owerri Imo State, processing laboratory of the Department of Food Science and Technology and the Department of Crop Science and Technology, Federal University of Technology, Owerri and they are high grade standard.

Production of flour: Dry seeds of pigeon pea (150 g) each were sorted, washed and steeped in required solution for 24 h and 48 h. After half of each sample was collected for further processing the steep solution being changed at 6 h intervals. The steep solutions were prepared using alum and trona powder on dry matter basis (dmb), with the solution variation based on concentration difference, ranged from 0.00%, 0.5%, 1.00% and so on. At the end of each steeping time, the samples were dehulled manually, oven dried (50-60°C) and milled separately into flour. After which they were stored in air tight containers at room temperature, ready for use in analysis.

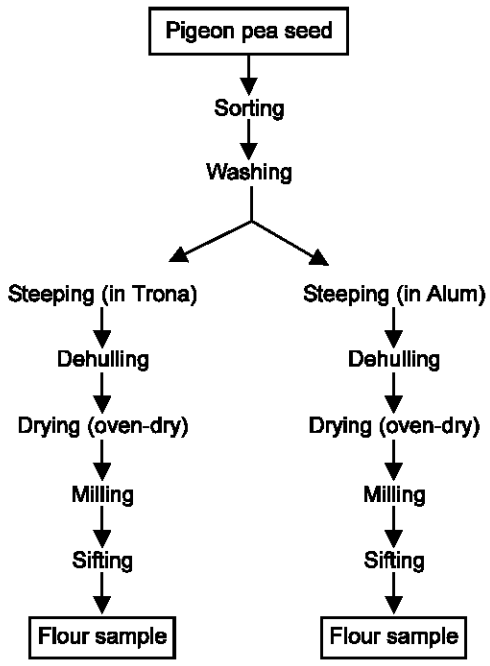

Fig. 1: Flow diagram for the production of pigeon pea flour

Analysis on flour sample: All samples were subjected to analysis to determine the proximate composition and functional properties as affected by processing conditions.

Proximate analysis: The standard AOAC (1990) methods were used to determine proximate composition of flour sample.

Analysis of the functional properties

Determination of bulk density: Method as described by Onwuka (2005) was adopted. A graduated cylinder 10 ml was weighed dry and gently filled with the flour sample. The bottom of the cylinder them gently tapped on a laboratory bench several times. This continues until no further diminution of the test flour in the cylinder after filling to mark, was observed. Weight of cylinder plus flour was measured and recorded.

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample (ml)}}$$

Determination of pH: About 10% (m/v, dmb) of flour suspension for each sample was prepared and allowed to settled at room temperature (30±2°C) for 15 min. The pH meter was switched on and allowed for 15min to stabilize. The electrodes were standardized chemically, using buffer solution of pH 7, 4 and 9 respectively, the electrode was then inserted into the test suspension and the pH value read and recorded as described by Onwuka (2005).

Determination of water absorption capacity: The method of Sosulski (1962) as described by Abbey and Ibeh (1988) was adopted. The test flour (1 g) of each treatment was weighed out into a dry, clean centrifugal tube and both weight noted. 10 ml of distilled water was poured into the tube and properly mixed with the flour to make a suspension. It was then centrifuged at speed of 3500 rpm for 15 min. after which, supernatant was discarded, then the tube and its content re-weighed and noted. The gain in weight is the water absorption capacity of the test sample.

Determination of oil absorption capacity: The method of Sosulski (1962) as described by Abbey and Ibeh (1988) was adopted. One gram (dmd) of each flour sample was weighed into a dry, clean centrifugal tube and both weight noted. 10 ml of Devon King's vegetable oil was poured into the tube and properly mixed with the flour. The suspension was centrifuged at 3500 rpm speed for 15 min then, the supernatant was discarded and the tube content re-weighed. The gain in mass is the oil absorption capacity of the sample.

Determination of swelling index: A portion (3 g) of each flour sample was weighed into a clean, dry, graduated (50 ml) cylinder. The flour sample gently leveled in the cylinder and the volume noted. 30 ml of distilled water was added to each sample. The swirled cylinder was allowed to stand for 60 min, while the change in volume recorded every 15 min. The swelling power index of each flour sample was calculated as multiple of the original volume as done by Ukpabi and Ndimele (1990).

Determination of wettability: This as described by Onwuka (2005) was adopted. One gram each flour sample was placed in a clean, dry measuring cylinder (10 ml). Placing a finger over the open end, the cylinder was inverted and clamped at a height of 10 cm from surface of a 600 ml beaker containing 500 ml of distilled water. The flour in the cylinder was gradually spread on the surface of the water on moderate speed. The time taken for the sample to be completely wet is noted as wettability.

Determination of gelling and boiling points: The method of Narayana and Rao (1982) was adopted. The flour sample (10 g) was dispersed in distilled water, in a 250 ml beaker and made up to 100 ml. A thermometer was clamped on a retort stand with its bulb submerged in the suspension. With a magnetic stirrer, the suspension was continuously stirred and heated. This continued until the suspension began to gel and the corresponding temperature recorded. The temperature as soon as boiling commenced was noted and recorded.

Determination of foam capacity: The method as described by Onwuka (2005) was adopted in the determination of foam capacity. Test flour 2 g each was mixed in 100 ml distilled water and its volume noted. The suspension was blended with a warming blender at 1600 rpm for 15 min. It was poured into a 250 ml measuring cylinder, its volume noted and recorded. Using Abbey and Ibeh (1988) formula, foam capacity expressed percentage increase in volume is as follows:

$$\text{Foam capacity} = \frac{\text{Volume of whipping - Volume before whipping}}{\text{Volume before whipping}} \times \frac{100}{1}$$

Determination of emulsion capacity: The procedure of Eke (2002) was adopted. Flour sample 2 g was mixed with 10ml of oil for 30 sec in a mixer and magnetically stirred. After complete dispersion deodorized vegetable oil (Devon Kings oil) was added continuously through a burette until emulsion breakpoint, separation into 2 layers was reached. The emulsion capacity as ml of oil emulsified per g of flour was recorded.

RESULTS AND DISCUSSION

Effect of chemical treatment, steeping time and steeping concentration on the proximate composition of pigeon pea flour: Table 1 showed the proximate composition of pigeon pea flour as affected by chemical treatment, steeping time and steeping concentration. From the results, the protein content of the bean flour decreased as the steeping time and concentration increased in all cases. This might have resulted from the breakdown of protein molecules causing it to be easily lost by leaching. Samples steeped for 24 h in

Table 1: Mean values on the proximate composition of pigeon pea flour as affected by chemical treatment, steeping time and steeping concentration

		Proximate composition (%)											
		Trona						Alum					
Steep. time (h)	Steep. Conc.	Protein	Fat	Ash	Fibre	M.C	CHO	Protein	Fat	Ash	Fibre	M.C	CHO
		(%)											
24	0.00	22.1^{a}	1.48^{ab}	3.16^{d}	3.89^{g}	12.96^{a}	61.86^{a}	22.1^{a}	1.46^{a}	3.16^{a}	3.86^{d}	12.27^{a}	61.86^{f}
	0.50	20.88^{b}	1.45^{ab}	3.94^{c}	4.67^{f}	12.52^{a}	62.02^{b}	22.02^{b}	1.38^{ab}	3.02^{b}	3.92^{cd}	12.20^{b}	61.97^{f}
	1.00	20.67^{b}	1.39^{b}	3.95^{bc}	4.73^{e}	12.35^{a}	62.18^{c}	21.95^{c}	1.32^{ab}	3.04^{b}	3.97^{c}	12.08^{c}	62.05^{e}
	1.50	20.23^{c}	1.34^{bc}	3.98^{bc}	4.78^{d}	12.04^{a}	62.37^{d}	21.57^{d}	1.27^{b}	3.07^{ab}	4.06^{b}	11.96^{d}	62.25^{d}
	2.00	20.11^{cd}	1.30^{c}	4.03^{b}	4.83^{c}	11.67^{a}	62.64^{e}	21.23^{e}	1.21^{b}	3.09^{ab}	4.14^{b}	11.72^{e}	62.5^{c}
	2.50	19.89^{d}	1.26^{c}	4.08^{ab}	4.87^{b}	11.43^{a}	62.89^{f}	21.09^{f}	1.16^{b}	3.12^{ab}	4.2^{ab}	11.64^{f}	62.8^{b}
	3.00	19.76^{d}	1.23^{c}	4.12^{a}	4.92^{a}	11.12^{a}	63.03^{g}	20.94^{g}	1.11^{b}	3.16^{a}	4.28^{a}	11.33^{g}	63.06^{a}
	LSD	0.234	0.071	0.077	0.032	ND	0.067	0.028	0.15	0.09	0.085	0.035	0.072
48	0.00	22.04^{a}	1.46^{a}	3.14^{d}	7.77^{a}	12.27^{a}	61.36^{a}	22.07^{a}	1.46^{a}	3.14^{c}	7.77^{f}	12.96^{a}	61.36^{e}
	0.50	21.74^{b}	1.38^{ab}	3.89^{c}	7.78^{a}	12.22^{ab}	61.53^{b}	21.96^{b}	1.43^{ab}	3.96^{b}	7.78^{f}	12.52^{b}	61.50^{e}
	1.00	21.58^{c}	1.33^{b}	3.95^{bc}	7.94^{b}	12.15^{b}	61.70^{c}	21.35^{c}	1.35^{b}	3.98^{b}	7.94^{e}	12.35^{c}	61.62^{d}
	1.50	21.36^{d}	1.27^{bc}	3.96^{b}	8.12^{c}	12.09^{b}	61.85^{d}	21.26^{d}	1.30^{bc}	4.00^{b}	8.12^{e}	12.04^{d}	61.75^{d}
	2.00	21.17^{e}	1.21^{c}	4.03^{ab}	8.22^{d}	11.93^{c}	62.12^{e}	21.19^{e}	1.24^{c}	4.01^{ab}	8.22^{c}	11.67^{e}	62.0^{c}
	2.50	20.98^{f}	1.16^{cd}	4.07^{a}	8.40^{e}	11.80^{d}	62.40^{f}	21.12^{f}	1.21^{c}	4.03^{ab}	8.40^{b}	11.43^{f}	62.26^{b}
	3.00	20.75^{g}	1.11^{d}	4.11^{a}	8.48^{f}	11.7^{e}	62.60^{g}	21.04^{g}	1.18^{c}	4.05^{a}	8.48^{a}	11.12^{g}	63.5^{a}
	LSD	0.04	0.09	0.08	0.07	0.09	0.089	0.063	0.08	0.04	0.07	0.089	0.179

Mean followed by same superscript are not significantly different at $p \leq 0.05$. CHO = Carbohydrate Content; LSD = Least Significant Difference; ND = Not Determined; MC = Moisture Content; Steep. = Steeping; Conc. = Concentration

trona showed a significant difference ($p \leq 0.05$) from 0.50-2.00%, while the sample steeped in alum both at 24 h and 48 h caused a significant decrease in the protein content of the flour. This decrease remained insignificant up to 3.00% concentration. Therefore, for economic reasons and better retention of protein value, it is best to steep in water for 24 h, as this had the highest protein value; since beans has become the major source of protein in the country for an average Nigerian.

With regards to the fat content, as the concentration increased, the fat content of the flour samples decreased in all cases. This is likely due to the breakdown of the molecules, thereby enhancing its leaching into the solution. Samples steeped in alum showed no significant difference ($p \leq 0.05$) from 1.00-3.00%, while trona from 24 h showed no significant difference ($p \leq 0.05$) from 2.00-3.00%, After 48 h, samples steeped in trona from 1.50-2.50% concentration showed no significant difference, while samples steeped in alum for 48 h, showed no significant difference from 1.50% and decrease in fat content was noticed. Therefore for a better keeping quality it is desirable to steep pigeon pea seed in 2.5% or 3.0% of trona solution for 48 h. This had the lowest fat content, hence reducing losses due to rancidity on storage. The ash content of the samples had a similar relationship with concentration in all cases. This owing to the possibility of attached mineral of aluminum and sodium bond over time (Michell and Robert, 1981).

In all cases, increase in concentration increased fibre content with significant difference ($p \leq 0.05$) in each of them and after 48 h steeping, there was no significant difference ($p \geq 0.05$) between the samples steeped in trona and alum. Also it was observed that samples not steeped in chemical rapidly increased the moisture content but increase in steeping concentration decreased the moisture content of the flour samples. This probably might have resulted from the replacement of water molecules by the solutes, causing loose water bonds to be lost easily during drying. For samples steeped for 24 h the decreases in moisture content for samples steeped in trona was small as not to cause significant difference among their mean. In alum for 24 h, variation occurred from 0.0-3.00% with a significant decrease in moisture content. After 48 h there was significant variation (for alum and trona as the concentration increased). This might have resulted from increased chemical reactions as time increased. Therefore for storage reasons, it is preferable to steep pigeon pea seed in 3.0% alum solution concentration for 24 h, as this had the lowest moisture content and could be time saving and possibly retard biological and chemical reactions that would take place in the bean flour on storage. The carbohydrate increased with concentration after 24 h for both alum and trona. At the end of 48 h, coherent increase or decrease was not obtained. This may have resulted from the increased chemical reaction, deterioration/leaching over time of the other proximate components which are not steady. Since carbohydrate value was dependent on them as it was determined by difference not chemically.

Effect of chemical treatment, steeping time and steeping concentration on the functional properties of pigeon pea flour: Table 2 and 3 showed the effect of chemical treatment, steeping time and steeping concentration on the functional properties of pigeon pea flour. The results obtained showed that there were significant differences ($p \leq 0.05$) among the samples steeped for 24 h and 48 h in trona and alum respectively. For the 24 h steeping samples steeped at 2.00% trona had the highest bulk density (0.73 g/ml) while the 48 h samples steeped at 2.50% had the highest bulk density (0.74 g/ml). However, with respect to alum treated samples, the highest bulk density (0.74 g/ml) was obtained with sample steeped for 48 h at 0.50% concentration. For the swelling index samples steeped for 24 h slightly decreased in 0.5% trona and as the concentration increased, the swelling index increases. Conversely, for the alum treated samples, the swelling index decreases as the concentration increased for samples steeped for 24 h and 48 h respectively. These results suggest that trona has the ability to convert starch to soluble form which will lead to increase in volume of flour whereas alum is an effective swelling inhibitor (Enwere, 1985).

However, steeping in water for 24 h is more economical to steeping in alum at different concentrations and should be utilized in foods like moin-moin or akara, where increased swelling ability is needed during processing. Table 2 also showed that samples steeped for 24 h in trona caused a decreasing effect in gelling point temperature as concentration of steep solution increased. Samples steeped in 0.50% of trona showed no significant difference ($p \geq 0.05$) from the control sample. This probably means that the quantity of trona in the solution was too small to cause a significant change; while other steeped samples in trona showed significant difference from each other, because of significant decrease in the gelling point temperature when compared to control. After 48 h of steeping in trona, increase in concentration decreased slightly the gelling point temperature, with significant difference ob served. This means that the steep solution concentration had little effect on the gelling point with increased times, as the values were closely related to those steeped for 24 h. But with alum (Table 3); the trend was different, in that, increase in concentration increased gelling point temperature. It was noticed that alum steeped for 24 h caused a significant difference ($p \leq 0.05$) in the gelling point temperature in almost all the

Table 2: Mean values on the functional properties of pigeon pea flour treated with trona

Steeping Time (h)	Steeping Conc. (%)	Bulk density (g/ml)	Swelling index (cm^3/cm^3)	Gelling point (°C)	Foam capacity (%)	Wett-ability (s)	Boiling point (°C)	pH	WAC	OAC	Emulsion capacity (ml/g)
24	0.00	0.71^{a}	1.41^{dc}	83^{a}	23.01^{d}	198^{a}	92^{a}	6.69^{e}	1.27^{d}	2.55^{a}	3.44^{a}
	0.50	0.68^{ab}	34^{f}	81^{ab}	21.19^{e}	360^{a}	88^{b}	6.74^{d}	2.38^{c}	2.22^{b}	3.51^{e}
	1.00	0.69^{a}	1.38^{e}	78^{b}	25.70^{c}	393^{a}	85^{b}	6.98^{d}	2.43^{c}	1.92^{c}	3.53^{e}
	1.50	0.71^{b}	1.43^{d}	75^{c}	26.52^{b}	399^{a}	80^{c}	7.15^{c}	3.83^{b}	1.70^{d}	3.69^{d}
	2.00	0.73^{b}	1.48^{c}	72^{d}	28.23^{a}	402^{a}	77^{c}	7.46^{b}	3.94^{b}	1.62^{e}	3.75^{c}
	2.50	0.70^{c}	1.53^{b}	69^{d}	29.94^{a}	405^{a}	72^{d}	7.77^{a}	4.05^{a}	1.48^{f}	3.81^{b}
	3.00	0.71^{a}	1.58^{a}	66^{e}	31.65^{d}	411^{a}	67^{e}	8.08^{f}	4.16^{a}	1.28^{g}	3.87^{a}
	LSD	0.03	0.031	2.86	0.21	ND	3.1	0.065	0.16	0.059	0.038
48	0.00	0.69^{ab}	1.39^{a}	82^{a}	24.61^{a}	140^{a}	93^{a}	6.63^{f}	1.50^{a}	1.65^{a}	3.42^{c}
	0.50	0.60^{a}	1.42^{a}	80^{b}	26.57^{f}	178^{b}	92^{ab}	6.81^{e}	2.98^{b}	1.49^{e}	3.51^{f}
	1.00	0.65^{ab}	1.47^{b}	77^{c}	28.53^{e}	304^{c}	89^{b}	7.12^{d}	3.34^{c}	1.57^{de}	3.59^{e}
	1.50	0.66^{b}	1.52^{c}	76^{cd}	30.49^{d}	364^{d}	88^{b}	7.19^{d}	3.46^{d}	1.62^{d}	3.74^{d}
	2.00	0.72^{b}	1.57^{d}	74^{d}	30.80^{c}	397^{e}	86^{c}	7.31^{c}	3.65^{e}	1.83^{c}	3.84^{c}
	2.50	0.74^{bc}	1.62^{e}	71^{e}	31.14^{b}	430^{f}	84^{c}	7.43^{b}	3.89^{f}	2.04^{b}	3.94^{b}
	3.00	0.72^{c}	1.67^{f}	70^{e}	31.37^{a}	463^{g}	81^{d}	7.55^{a}	4.03^{g}	2.25^{a}	4.04^{a}
	LSD	0.03	0.03	2.365	0.063	9.95	2.45	0.10	0.051	0.09	0.051

Mean followed by same superscript are not significantly different at $p \leq 0.05$. LSD = Least Significant Difference; ND = Not Determined; WAC = Water Absorption Capacity; OAC = Oil Absorption Capacity

Table 3: Mean values on the functional properties of pigeon pea flour treated with alum

Steeping Time (h)	Steeping Conc. (%)	Bulk density (g/ml)	Swelling index (cm^3/cm^3)	Gelling point (°C)	Foam capacity (%)	Wett-ability (s)a	Boiling point (°C)	pH	WAC	OAC	Emulsion capacity (ml/g)
24	0.00	0.71^{a}	1.41^{b}	83^{cd}	23.01^{b}	198^{a}	92^{b}	6.69^{a}	1.27^{d}	2.55^{a}	3.44^{a}
	0.50	0.68^{ab}	1.46^{a}	77^{e}	23.82^{a}	125^{f}	85^{d}	6.00^{b}	2.01^{c}	2.05^{b}	3.43^{a}
	1.00	0.67^{ab}	1.41^{b}	80^{e}	22.14^{c}	127^{f}	88^{c}	5.93^{c}	3.11^{b}	1.82^{c}	3.32^{a}
	1.50	0.65^{c}	1.35^{c}	81^{d}	19.99^{d}	173^{e}	92^{b}	5.64^{d}	3.19^{b}	1.67^{d}	2.91^{b}
	2.00	0.61^{cd}	1.32^{cd}	86^{c}	16.09^{e}	178^{d}	93^{ab}	5.57^{e}	3.22^{a}	1.41^{e}	3.75^{c}
	2.50	0.57^{d}	1.29^{d}	91^{b}	12.19^{f}	183^{c}	94^{a}	5.50^{f}	3.25^{a}	1.73^{d}	2.87^{b}
	3.00	0.71^{c}	1.27^{d}	96^{a}	14.90^{g}	188^{b}	95^{a}	5.43^{g}	3.28^{a}	1.99^{b}	2.85^{b}
	LSD	0.09	0.03	3.1	0.09	2.90	2.365	0.024	0.09	0.09	0.13
48	0.00	0.69^{b}	1.39^{a}	82^{a}	24.61^{a}	140^{e}	93^{ab}	6.63^{a}	1.50^{a}	1.65^{a}	3.42^{a}
	0.50	0.60^{d}	1.37^{a}	72^{b}	26.57^{f}	124^{f}	79^{e}	6.00^{b}	2.33^{b}	1.57^{b}	3.38^{a}
	1.00	0.72^{c}	1.31^{b}	76^{b}	28.53^{e}	127^{f}	82^{e}	5.42^{c}	2.42^{c}	1.53^{b}	3.01^{b}
	1.50	0.67^{bc}	1.20^{c}	80^{ab}	30.49^{d}	169^{d}	85^{d}	5.06^{d}	2.61^{d}	1.39^{c}	2.88^{c}
	2.00	0.64^{ab}	1.16^{cd}	81^{a}	30.80^{c}	193^{c}	90^{c}	4.80^{e}	2.70^{e}	1.31^{d}	2.82^{cd}
	2.50	0.6^{a}	1.12^{d}	82^{a}	31.14^{b}	197^{b}	95^{b}	4.54^{f}	2.79^{f}	1.22^{e}	2.76^{d}
	3.00	0.57^{ab}	1.08^{d}	83^{a}	31.37^{a}	201^{a}	100^{a}	4.24^{g}	2.88^{g}	1.14^{f}	2.70^{d}
	LSD	0.05	0.04	4.38	0.13	3.79	3.79	0.155	0.04	0.04	0.09

Mean followed by same superscript are not significantly different at $p \leq 0.05$. LSD = Least Significant Difference; ND = Not Determined; WAC = Water Absorption Capacity; OAC = Oil Absorption Capacity

samples when compared to the control sample. This was also similar for samples steeped for 48h in alum, though the figures were low generally (Hickson *et al*., 1982). Therefore for economic reasons, it is best to steep in 3.00% concentration of trona for 24 h, as this had the lowest gelling point temperature, hence saving time and energy cost, and should be utilized in foods where gelling property is required e.g. thickeners in soups and sauces.

It was also observed from Table 2 that, samples steeped in trona caused an increase in foam capacity as concentration increased. For 24 h samples, increase in concentration increased foam capacity until 2.50% concentration of the solution, which showed a significant decrease in foam capacity. After 48 h, increase in concentration increased foam capacity in all cases, because trona with its thickening ability enhances the trapping of air in the bean flour slurry during whipping. In contrast from Table 3, samples steeped in alum decreased in foaming capacity as concentration increased, but there was significant variation ($p \leq 0.05$) among the samples. This decrease could be desirable in food processes where excessive foaming is not required as it reduces loss due to foam spillage or the need for including an extra steep or antifoaming agent to check foaming. Therefore steeping in alum at 3.0% for 24 h is advisable.

Table 2, also showed that wettability increased with concentration in all cases, the samples steeped in trona for 24 h shows no significant difference ($p \geq 0.05$) on their mean. This probably means that time and concentration difference was too small to cause a significant

difference in wettability of pigeon pea flour. Samples steeped in alum appeared to have marked reduced difference in their wettability values when compared to those steeped in trona. This is because alum causes a reduction in density of the flour (Freeman, 2001). This is desirable as it reduces processing time and cost in food where wettability is of interest. Therefore, if wettability is a critical characteristic for choosing the sample then it should be steeped in 0.50% of alum solution for 48 h as this had the lowest value. The boiling point temperature of pigeon pea decreased as concentration increased for samples with trona and steeped for 24 h and 48 h respectively. This decrease generally might have resulted from the fact that trona being a tenderizing agent in food must have caused a softening effect on the molecular network of the flour. This made them easily attacked by heat and is desirable as it reduces energy cost and destruction of heat liable nutrients during processing.

From Table 3 increase in boiling point temperature was directly related to alum concentration, for both 24 h and 48 h samples. Concentrations as low as 0.50% caused a significant decrease in boiling point temperature compared to the control and others. Though samples steeped for 48 h generally had lower values with a step further in variation. Therefore it is techno-economically better to either steep in 0.50% solution of trona for 24 h or 0.50% of alum for 48 h as they had the lowest boiling point temperature (Fox and Cameron, 1980). It was observed that samples steeped in trona for 24 h had a slight increase in pH as concentration increased (Table 2) with significant difference ($p \leq 0.05$) among the samples. A similar result was obtained with steeping for 48 h. This general increase is because trona is slightly alkaline in nature.

However the pH of the samples steeped is alum (Table 3) were significantly different ($p \leq 0.05$) though the pH decreased as the concentration increased. Therefore steeping in water is best as it maintains the almost neutral pH of pigeon pea flour needed for the processing of certain foods (Prinyawiwatkul *et al*., 1992).

The water absorption capacity has a direct relationship with concentration in all cases (Table 2 and 3). This probably could have resulted from the loss of moisture during drying, therefore causing a high water affinity of the flour. Concentration of 0.50% caused a significant increase in the water absorption capacity of the flour when compared to control after 24 h of steeping. The increase was slight until at 1.50% of the trona solution, where a further significant increase was observed in the water absorption capacity compared to the control samples. However in all cases samples steeped at 3.00% concentration for both trona and alum had the highest water absorption capacities. Therefore it is better to steep pigeon pea in 3.00% of trona for 24 h as this had the highest water absorption capacity (4.16 cm^3/cm^3) and is desirable as this can cause an increase in volume e.g. bread (Narayana and Raon, 1982).

For oil absorption capacity, samples steeped in trona for 24 h decreased slightly as concentration increased with significant variations in their mean (Table 2). After 48 h a reverse trend was observed as slight decrease on 0.50% concentration. Where a further significant decrease was observed was sample steeped in alum as shown in Table 3, the decreasing trend was observed both in the 24 h and 48 h interval, with a little variation occurred between them. After 48 h the concentration decreased significantly from control until 3.00% concentration except for 0.50-1.00% where no further significant decrease was observed. This decrease in oil absorption capacity with respect to concentration over time, which assumed the same trend with fat was found to have resulted from increased breakdown in fat molecules, hence increasing their leaching effect (Gaman and Sherrigton, 1977). This low oil absorption capacity is desirable in frying of akara balls as less oil is absorbed by the balls, hence reducing losses due to rancidity in the akara ball on storage. It is therefore best to steep in 3.00% of alum for 48h as this had the lowest oil absorption capacity.

For the emulsion capacity as shown in Table 2 there was significant difference ($p \leq 0.05$) among the samples though as the concentration increased, the emulsion capacity increased too. This increase in emulsion capacity is desirable as it can be utilized in foods such as sausage. For samples steeped in alum as shown in Table 3, increase in concentration decreased emulsion capacity for samples steeped for 24 h and 48 h respectively. This decrease might have resulted from alum being a coagulant (cleanser) (Freeman, 2001) thereby resulting in the separation of oil and water.

Conclusion: At the end of the experiment the result obtained from this study have shown that steeping pigeon pea seed in alum and trona separately at different concentration (0.0%, 0.50%) for 24 h and 48 h caused significant variation in the proximate and functional properties of its flour. Based on this, pigeon pea can suit for various products due to its diverse utilization of combining any or all the above conditions. For better retention of nutrients, it should not be steeped for more than 24 h.

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