EFFECT OF PROCESSING METHODS ON THE PHYSICOCHEMICAL, ANTINUTRIENT AND PASTING PROPERTIES OF THREE COMMONLY CONSUMED SOUP THICKENERS

ABSTRACT

The effect of processing methods on the physicochemical, functional, anti-nutrient factors and pasting properties of *Mucuna sloanei* (ukpo), *Brachystegia eurycoma* (achi) and *Daterium microcarpum* (ofor) were assessed using standard methods. Flour from these seeds were produced after boiling and soaking at different time intervals. The moisture and ash contents of the three soup thickeners ranged between 5.58- 8.92% and 1.14-5.59% with sample B_1 (achi boiled for 15 min) and C_4 (ofor soaked for 48 h) having the lowest while sample B_2 (achi boiled for 30 min) and C_1 (ofor boiled for 15 min) having the highest. Crude Fat and fibre contents ranged from 2.90-10.95% and 1.30-14.39% with samples C_1 and A_1 (ukpo boiled for 15 min) as the highest respectively. Crude protein and carbohydrate contents of soup thickeners ranged between 9.19 -21.31% and 45.01-71.38% with samples A_3 (ukpo soaked for 24 h) and B_4 (achi soaked for 48 h) as the highest. Sugar and starch contents ranged from 2.61-5.04% and from 69.00-74.27% respectively with sample C_4 and A_4 (ukpo soaked for 48 h) as the lowest and sample A_3 and B_3 (Achi soaked for 24 h) as the highest. Amylose content increased with boiling and decreased with soaking which was the reverse amylopectin. Functional properties showed bulk density and dispersibility to range between 0.56-0.76g/ml and 32.50-48-00% with sample B_3 (achi soaked for 24 h) as highest in both cases. Solubility and swelling power ranged from 32.56-107.51% and from 4.61-8.72g/g with sample A_2 (ukpo boiled for 30 min) and A_1 having the highest respectively. Foam capacity ranged from 2.50-29.50% with sample C_2 (ofor soaked for 48 h) having the lowest and sample A_1 having the highest, while the least gelation concentration of the three soup thickeners recorded 2.00% for all the treatments. Water absorption capacity ranged between 0.67-10.46ml/g with B_1 having the lowest and sample C_2 having the highest. Antinutritional factors showed that phytate recorded 0.01g/kg for all the treatments, tannin ranged from 2.22-40.71mg/kg, oxalate between 3.40-7.90mg/100g and saponin between 2.60-9.18% with different treatments affecting the antinutrients. Free fatty acid, peroxide value, saponification and acid values increased with an increase in treatment time while iodine value decreased as processing time increased. Pasting result showed that treatment and time affected pasting properties with the highest values as peak viscosity 16429RVU, trough viscosity 9231RVU, breakdown 7858RVU, final viscosity 19977RVU and set back viscosity 13004RVU respectively. Peak time and pasting temperature ranged between 1.60-6.10 min and between 50.25-76.18^{0}C for the different treatments. This study shows the need for appropriate treatment and time combination for better nutrient availability and detoxification of these seeds as soup thickeners.

Keywords: Processing methods, soup thickeners, physicochemical, antinutient, pasting

INTRODUCTION

In West Africa, dietary pattern vary and is influenced by vegetation belt. In the Northern parts of Nigeria, cereals dominate, while in the South, legumes, nuts, seeds and starchy roots or tubers are the main food components (Ene-Obong and Carnovalue, 1982). However, processing of the cereals and starch roots into a form of paste and eaten with soups is the general practice. Among the legumes used in soups for emulsification and stabilization are *Mucuna sloanei* (ukpo), and *Brachystegia eurycoma* (achi) and *Detarium microcarpum* (ofor).

Each of the soup thickeners differs in species from the others and so have their individual characteristic flavor which they impart to soups. At present, most of the indigenous edible plants which could be used as food thickeners in Nigeria and other West African countries have been neglected and have remained relatively unknown and under-utilized. *Mucuna* *sloanei*, *Brachystegia eurycoma* and *Detarium microcarpum* are naturally found in tropical and sub-tropical areas respectively (Ayozie, 2010).

Soup is a primary liquid food general served warm that is made by combining ingredients such as meat and vegetables with stock, juice, water or another liquid, it is a tasty popular food that is nutritious, wholesome and stimulates the appetites. Thickening usually improves the taste, but most important is the nutritional value of foods. Thickeners are substances, which when added to a mixture, increase its viscosity without substantially modifying other properties such as taste and aroma (Okwu *et al.*, 2010).

Flours from these soup thickeners have been found to be used in most state in Nigeria with varying processing methods. They are used as thickeners in traditional soups (for eating of garri, pounded yam or cocoyam and fufu), equally used as emulsifiers and flavoring agents in traditional soups due to their ability to swell in water and influence the viscosity of liquid in addition to their low cost, which is an advantage to most customers as little quantity of this thickeners create great viscosity as against other thickeners like melon and ogbono (Ezeoke, 2010). Nutritionally, *ukpo, achi and ofor* are important and economic sources of protein and carbohydrates, these nutrients are essential to human nutrition but the composition of these nutrients in them differs.

Several issues are associated with available soup thickeners used in this region due to improper processing, as the soup thickeners are usually exposed to the environment, leading to moisture uptake, contamination by dust and black soot which affects their thickening ability. There is little or no information on improved methods that are suitable for processing of soup thickeners in order to increase their thickening ability as well as safety. The study is therefore aimed at determining the effect of boiling and soaking on the physicochemical, functional and pasting properties of three commonly consumed soup thickeners.

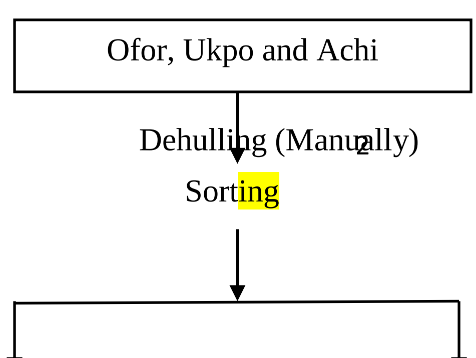
MATERIALS

Achi (*Brachystegia eurycoma*), *ofor* (*Detarium microcapum*) and *ukpo* seeds (*Mucuna sloanei*) were purchased from Mile 3 Market and chemicals used were of analytical grade and were obtained from the Department of Food Science and Technology Laboratory, Rivers State University, Port Harcourt.

Methods

Preparation of sample

The method described by Nwosu *et al.*(2011) was used for the processing of the seeds into flour. The seeds were sorted and each grouped into four. Boiled (15 min and 30 min) and soaked (24 h and 48 h). The boiled and soaked seeds were manually dehulled using kitchen knife, oven-dried for 12 h at 60^0C, milled (Corona Corn Mill, REF 121) and sieved with a 0.25 µm sieve to obtained flour as shown in Figure 1. The flour was stored in air tight plastic containers at room temperature for subsequent analysis.



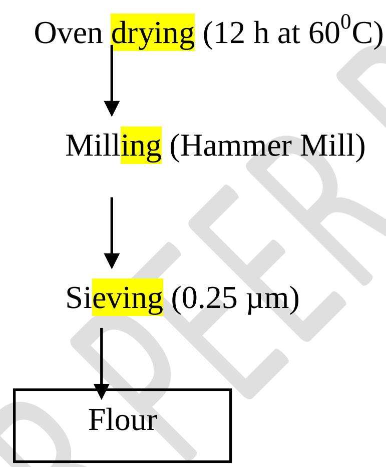


Figure 1: Production of *Mucuna sloanei, Detarium microcarpum and Brachystegia eurycoma* flour based on Nwosu *et al*., (2011)

Physicochemical Analysis

The proximate compositions of the flour samples (moisture, ash, crude fat, crude fiber, crude protein and carbohydrate calculated by difference) were determined using the (AOAC, 2012). The amylose content of starch extracted from the samples were determined using the iodine calorimetric method reported by Zakpaa *et al*., (2010), while amylopectin was calculated by difference. Starch and sugar were determined by the method of Eke (2006).

Functional Properties

Least gelation concentration was determined by the method of Onwuka (2005), dispersibility by the method described by Kulkarni *et al*., (1991), bulk density was by the method described by Okaka and Potter (1979). Foam capacity was determined according to the method described by Narayana and Narasinga, (1982). Solubility and swelling power were determined according to the method described by Takashi and Sieb (1988), while the method of Abbey and Ibeh (1998) was adopted for determination of water absorption capacity.

Determination of Anti-nutrient Composition The phytate content of the samples were determined by the method of Reddy *et al*., (1982), tannin content by the Folin-Denis spectrophotometric method as described by Price *et al.*, (1978), oxalate content by the method described by Munro (2000) and total saponins by the method of Hudson and El-Difrawi (1979).

Pasting Properties

Pasting properties of the flour was carried out using a rapid visco-analyser (RVA Model 3c, New Port Scientific, Sydney) as described by Sanni *et al*., (2006).

Determination of storage Properties

Determination of chemical properties such as saponification value (SV), iodine value (IV), peroxide value (PV), free fatty acid (FFA) and acid value (AV) were carried out by the procedure and method of (A.O.C.S, 1986).

Statistical Analysis

Results were expressed as mean values and standard deviation of two determinations. The obtained data were analyzed using a one way of variance (ANOVA) using statistical packaging for social science (SPSS) version 20.0 software 2011 to test the level of significance ($P < 0.05$). Duncan multiple range test (DMRT) was used to separate the mean where significant differences existed (Wahua, 1999).

RESULTS AND DISCUSSION

Physicochemical Composition of Three Commonly Consumed Soup Thickeners

The result of physicochemical composition of ukpo, achi and ofor is shown in Table 1. Moisture content of the three soup thickeners ranged between 5.58- 8.92% with sample B_1 (achi boiled for 15 min) having the lowest while sample B_2 (achi boiled for 30 min) having the highest. Moisture content of samples showed that there was an increase in moisture content as treatment time increased. Sample B_1 (achi boiled for 15 min) had the lowest and sample A_4 (ukpo soaked for 48 h) had the highest moisture content. This study is in line with Udensi *et al*. (2010) who reported an increase in the moisture content of *Mucana flagellipes* as soaking and boiling time increase. Boiling and soaking in water softened the cell tissues of the seeds, increasing the water absorbing and retention capacities of the seeds due to increased permeability of the cell membrane to water (Talabi *et al*. 2016). There was a significant difference ($p<0.05$) in the soaked and boiled ukpo and achi. However all samples showed low moisture content which was less than 10% meaning that products would have a better storability and shelf life.

Ash content of three soup thickeners ranged from 1.14-5.59% with sample C_4 (ofor soaked for 48 h) having the lowest and sample C_1 (ofor boiled for 15 min) having the highest. Ash content in the present study showed that there was a decrease in the ash content as treatment time increased. Sample C_4 (ofor soaked for 48 h) had the lowest while sample C_1 (ofor boiled for 15 min) had the highest ash content. Several researchers also reported that as the boiling and soaking time increases, there is loss of minerals as the seed utilizes them for emergence of rootlet and hence the ash content is reduced (Wang *et al*. 1997). The decrease in the ash content of the seeds as boiling and soaking time increased agreed with the findings of Ozung *et al.* (2011) who reported a decrease in ash content of soaked and boiled castor oil seeds 5.54-4.61% and 5.25-4.73% respectively after boiling for 30 min and soaking for 96 h. Similarly, Amaefule *et al*, (2006) recorded a decrease in ash content of pigeon pea seeds from 5.50% (raw seeds) to 4.00% after 30 min boiling. The ash content of soaked ukpo seeds for 48 h and boiled ofor seeds for 15 min were significantly different (p<0.05) from all other treatment. Soaking showed to reduce ash content which may be due to leaching of minerals into the soaking water.

Fat content of thickeners ranged from 2.90-10.95% with sample C_2 (ofor boiled for 30 min) as the lowest and sample C_1 (ofor boiled for 15 min) as the highest. Fat content of samples showed that there was a decrease in the fat contents with increase in boiling and soaking time. Sample C_2 had the lowest and sample C_1 had the highest. Ozung *et al.* (2011) reported a decrease in fat content of castor oil seed after boiling and soaking (20.72-18.44%) and 19.92-18.92% respectively). Similarly, the decrease in fat agrees with the findings of Okigbo (1975) on soyabean and Alberecht *et al*. (1996) on beans. Fat content showed a significant difference (p<0.05) for all samples but showed no significance difference (p>0.05) on the soaked ofor seeds. Boiling of all the samples for a period of 15 min seemed to retained more fat than boiling for 30 min. However, the decrease in fat content can be attributed to the loss of soluble materials on boiling and soaking which increased as the treatment time increased.

Crude fibre of three soup thickeners ranged from 1.30-14.39% with sample C_4 (ofor soaked for 48 h) having the lowest and A_1 (ukpo boiled for 15 min) having the highest. Crude fibre showed that there was a decrease in the crude fibre of soup thickeners. Samples C_4 (ofor soaked for 48 h) having the lowest and sample A_1 (ukpo boiled for 15 min) having the highest crude fiber. The decrease in boiling and soaking time correlates with the findings of Okunda and Ojinnaka (2017) who reported a decrease in crude fibre content of bambara groundnut (4.8-4.1%) after soaking for 72 h. Talabi *et al*. (2016) also reported a decrease in crude fibre content of *P.americana* seeds (3.97-1.58%) after boiling for 25 min. There was no significant effects (P>0.05) of increased boiling time of achi seeds while increase soaking and boiling was observed to significantly decrease (P<0.05) the crude fibre content. The reduction in crude fibre levels as duration of boiling and soaking increased could be due to softening and subsequent loss of hard coat of the seeds in course of boiling and soaking.

Crude protein of soup thickeners ranged from 9.198-21.31% with sample B_4 (achi soaked for 48 h) having the lowest and sample A_3 (ukpo soaked for 24 h) having the highest. Crude protein result showed a decrease as the treatment time increased. Sample C_4 (soaked ofor for 48 h) had the lowest while C_3 soaked ukpo for 24 h had the highest. The decrease in protein as boiling time increased was reported by Ukachukwu and Obioha, (2010) who attributed it to progressive solubilization and leaching of nitrogenous substances during boiling of the seeds. Nsa *et al*. (2013) reported a decrease in protein content of castor oil seed from 30.8 to 24.76% after boiling for 30 min. Okundu and Ojinnaka, (2017) also reported a decrease in protein (22.4-20.20%) for Bambara groundnut. Treatment had a significant effect ($p<0.005$) on the boiled achi and soaked ofor as increase in boiling and soaking was observed to significantly decrease ($P<0.05$) the crude protein of other samples. The reduction in crude protein content in boiled seeds with increase in boiling time could be attributed to the denaturation of protein by heat (Potter and Hotchkiss, 2006), or leaching of the protein into the soaking or boiling water.

Carbohydrate content ranged from 45.01-71.38% with sample A_1 (ukpo boiled for 15 min) as the lowest and sample B_4 (achi soaked for 48 h) as the highest. Result of these soup thickeners showed an increased as the treatment time increased. ukpo seed boiled for 15 min had the lowest while soaked achi seeds for 48 h had the highest. The findings of this study agrees with that of Okundu and Ojinnaka (2017) who reported an increase in carbohydrates content (51.0-55.0%) of Bambara groundnut after soaking for 72 h. Kajihausa *et al*. (2014) also reported that boiling of sprouted sesame seeds after 20 min significantly increased ($p<0.05$) the carbohydrates content (1.62-5.06%). Carbohydrate content of the seeds increased significantly($p<0.05$) as the boiling and soaking time increased except for soaked ofor seeds which did not show any significant difference($p>0.05$).

Sugar content ranged from 2.61-5.04% with sample C_4 (ofor soaked for 48 h) as the lowest and sample A_3 (ukpo soaked for 24 h) as the highest. Sugar content of samples showed that there was a decrease in the treatment time. ofor seeds soaked for 48 h had the lowest and ukpo seeds soaked for 24 h had the highest. This is in agreement with earlier studies of Numfor, (1999). There was a significant difference ($p<0.05$) for all the samples but boiled ofor showed no significant difference ($p>0.05$). However, the decrease in the sugar content of the flour indicates that, the longer the boiling and soaking time the higher the consumption of soluble sugars.

Starch content ranged from 69.00-74.27% with sample A_4 (ukpo soaked for 48 h) having the lowest and sample B_3 (achi soaked for 24 h) having the highest. Starch content samples showed that there was an increased in the boiling time but soaking decreased as the treatment time increased. Boiled ukpo seed for 48 h had the lowest and soaked achi seeds for 24 h had the highest starch content obtained in this study was close to the range (81.1-87.7%) reported by Lu *et al*, (2005) for cocoyam (*Xanthosoma sagittifolium*) starches. There was no significant differences ($p>0.05$) in ofor and boiled achi samples but increase in boiling and soaking significantly (p.0.05) affect ukpo and soaked achi samples. Decrease in starch content after soaking might be due to leaching of amylose during soaking in water (Sing *et al*, 2010).

Amylose content ranged from 25.20-29.68% with sample C_3 (ofor soaked for 24 h) as the lowest and sample A_2 (ukpo boiled for 30 min) as the highest. Amylose content of samples showed that there was an increase in the boiled samples as the treatment time increased. ofor seeds soaked for 24 h had the lowest while ukpo seeds boiled for 30 min had the highest. The amylose content by the boiled seeds were higher than the soaked seeds The amylose content in this study were higher than the amylose content of fermented cassava starches (18.23-2035%) reported by Numfor (1999). There was a significant difference ($p<0.05$) for all the treatment. The higher the concentration of amylose in a starch/flour, the higher its tendency towards retrogradation (Zubai and Osundahansi, 2016).

Amylopectin ranged from 70.33-74.80% with sample A_2 (ukpo boiled for 30 min) having the lowest and sample B_4 (achi soaked for 48 h) having the highest. Result showed that there was a decrease in the boiled seeds due to increase in boiling time. Boiled ukpo seeds for 30 min had the lowest and soaked achi seeds for 48 h had the highest. The percentage of amylopectin of flour in this study were higher than the range reported by Lu *et al*. (2005) for cocoyam (*Xanthosoma sagittfolium)* starches (2.47-2.89%).

Table 1: Physicochemical composition (%) of three commonly used soup thickeners as affected by boiling and soaking time

Samples		Moisture	Ash	Fat	Crude Fibre	Crude Protein	CHO	Sugar	Starch	Amylose	Amylopec-tin
Ukpo	A1	7.93^{a}	3.10^{a}	8.48^{a}	14.39^{a}	21.09^{a}	45.01^{c}	4.30^{b}	69.21^{c}	27.72^{b}	72.28^{c}
	A2	7.94^{a}	2.90^{a}	5.18^{bc}	7.55^{c}	20.65^{b}	55.78^{b}	3.70^{c}	71.72^{a}	29.68^{a}	70.33^{d}
	A3	6.66^{b}	3.09^{a}	6.37^{b}	9.65^{b}	21.31^{a}	52.92^{b}	5.04^{a}	70.47^{b}	26.02^{c}	73.99^{b}
	A4	8.87^{a}	1.70^{b}	5.67^{c}	6.95^{c}	20.44^{b}	56.37^{a}	3.21^{d}	69.00^{c}	25.69^{d}	74.31^{a}
Achi	B1	5.58^{a}	3.04^{a}	7.98^{a}	3.50^{c}	10.92^{a}	68.98^{c}	3.71a	69.98b	26.10c	73.90^{b}
	B2	8.92^{b}	2.80^{a}	3.66^{c}	3.38^{c}	10.92^{a}	70.32^{a}	3.21b	70.12b	26.75a	73.25^{c}
	B3	7.64^{ab}	2.70^{ab}	4.70^{b}	7.49^{a}	10.06^{b}	67.41^{c}	2.84c	74.27a	26.50a	73.50^{c}
	B4	7.87^{a}	2.25^{b}	3.58^{c}	5.74^{b}	9.18^{c}	71.38^{b}	2.93c	70.05b	25.20b	74.80^{a}
Ofor	C1	6.35^{a}	5.59^{a}	10.95^{a}	5.39^{a}	14.38^{a}	57.34^{b}	3.79^{a}	71.66^{a}	26.02^{c}	73.99^{b}
	C2	7.82^{a}	2.80^{b}	2.90^{c}	4.56^{b}	12.63^{b}	69.29^{a}	3.62^{a}	70.26^{a}	27.00^{a}	73.01^{d}
	C3	6.92^{a}	1.64^{b}	10.54^{ab}	2.29^{c}	10.92^{c}	67.69^{a}	3.67^{a}	71.10^{a}	25.20^{d}	74.80^{a}
	C4	7.67^{a}	1.14^{b}	10.08^{b}	1.30^{d}	10.92^{c}	68.89^{a}	2.61^{b}	70.77^{a}	26.51^{b}	73.50^{c}

Values are expressed as mean ± standard deviation of duplicate determination.
Means with the same letters along the same column are not significantly different ($p>0.05$).

KEYS:

Ukpo A1 = Boiled for 15 min, A2 = Boiled for 30 min, A3 = Soaked for 24 h, A4 = Soaked for 48 h
Achi B1 = Boiled for 15min, B2 = Boiled for 30 min, B3 = Soaked for 24 h, B4 = Soaked for 48 h
Ofor C1 = Boiled for 15 min, C2 = Boiled for 30 min, C3 = Soaked for 24 h, C4 = Soaked for 48 h

Functional Properties of Three Commonly Consumed soup Thickeners

The result of functional properties of ukpo, achi, and ofor is shown in Table 2. Bulk density ranged from 0.56-0.76g/ml with sample A_2 (ukpo boiled for 30 min) having the lowest and sample B_3 (achi soaked for 24 h) having the lowest. Bulk density result showed that there was a decrease with increase in treatment time. Bulk density gives an indication of the relative volume of packaging materials required. Kajihausa *et al.* (2014) reported that bulk density of sprouted sesame seed flour increased during boiling but this increase was not significantly different (p.> 0.05). Studies by Onuegbu *et al*. (2013) showed are increase in the bulk density of boiled ukpo seed (*Mucuna flagelipes*) from 0.68 – 1.17 g/ml after boiling for 60 min. There was no significant difference (P > 0.05) between the treatments except for boiled ofor which differed significantly (P<0.05). However, low bulk density of flours is a good physical attributes when determining transportation and distributed to required locations (Agunbiade and Sanni, 2003).

Dispersibility of thickeners ranged from 32.50-48-00% with sample A_3 (ukpo soaked for 24 h) having the lowest and sample B_3 (achi soaked for 24 h) having the highest. Result showed an increase in dispersibility as the boiling time increased. This is in agreement with the findings of Achy *et al.* (2017) who reported that boiling increased the dispersibility of bulbils flours after 30 min, with values ranging from 25 % - 36 %. There was a significant difference (p <0.05) in the samples expect for boiled ukpo and soaked ofor which showed no significant difference. Adebowale *et al*. (2008) stated that the higher the dispersion, the better the flour reconstitutes in water, while (Kulkarni *et al*. 1991), stated that higher dispersion ability enhances the emulsifying and foaming capacities of proteins.

Solubility ranged from 32.56-107.51% with sample A_3 (ukpo soaked for 24 h) having the lowest and sample A_2 (ukpo boiled for 30 min) having the highest. Solubility of samples ranging from 12.63 – 107.51% showed that there was an increase in solubility as the boiling and soaking time increased. Boiled ofor seeds for 15 min had the lowest and boiled ukpo seeds for 30 min had the highest. Kajihausa *et al*. (2014) also reported that boiling have a significant effect (P <0.05) on the solubility index of the sesame seed flour. They reported that boiling of the sesame seeds increased the solubility index of the samples soaked for 8 – 14 h. There was a significant difference (P< 0.05) for all the samples.

Swelling power ranged from 4.61-8.72g/g with sample B_3 (achi soaked for 24 h) having the lowest and sample A_1 (ukpo boiled for 15 min) having the highest. Result showed that there was a decrease in swelling power as the boiling and soaking time increased. Kajihausa *et al*. (2014) reported that swelling power increased at a soaked time of 8 h from an initial value of 9.52 to a value of 9.66%. Increase in boiling and soaking of ukpo seeds differed significantly (P< 0.05). Moorthy and Ramanujam (1986) reported that the swelling power of flour samples is an indication of the extent of associative forces within the granule. Swelling power is also related to the water absorption index of the starch- based flour during heating (Loos *et al*.1981).

Foam capacity ranged from 2.50-29.50% with sample C_2 (ofor soaked for 48 h) having the lowest and sample A_1 (ukpo boiled for 15 min) having the highest. Foam capacity ranging from 2.50 – 290% showed that there was a decrease in foam capacity as treatment time increased. Soaked ofor seeds for 48 h had the lowest and boiled ukpo seeds for 15 min had the highest. Studies by Achy *et al.* (2007) reported that foam capacity of *Dioscorea bulbifera* CV Dugu-won bulbils flours varied from 26.67% in raw to 13.00% for bulbils boiled during 30 min. Ofor flour showed a significant difference (P<0.05) but soaked ukpo and boiled achi showed no significant difference (P> 0.05). the decreased in foam capacity of these soup thickeners with increase in soaking and boiling time is due to decreased in protein content during boiling and soaking protein in the dispersion may cause a lowering of the surface tension at the water an interface, thus always been due to protein which forms a continuous cohesive film around the air bubbles in the foam Kaushat *et al.* (2012). Foams are used to improve textures, consistency and appearance of foods (Akubor, 2007).

The least gelation concentration of the three soup thickeners recorded 2.00% for all the treatments, showing that increase in boiling and soaking time had no significant effect (P> 0.05) on the least gelation concentration of the flours. The ability of protein to form gels and provide structural matrix for holding water flavor, sugars and food ingredients is useful in food application in new product development (Aremu *et al.* 2006). Udensi *et al*. (2010) indicated that gelation is a quality indicator influencing the texture of good such as soup. Flour with least gelation concentration are not suitable for infant formulations since they require move dilution and would result in reduced energy density in relations to volume (Onwulezo and Nwabuyu 2009).

Water absorption capacity (WAC) ranged from 0.67-10.46ml/g with B_1 (achi boiled for 15 min) having the lowest and sample C_2 (ofor boiled for 30 min) having the highest, showing an increase as the treatment time increased. Soaked achi seeds after 24 h had the lowest and boiled ofor seeds for 30 min had the highest values. Onuegbu *et al*. (2013) reported an increase in WAC of boiled ukpo seeds (1.60 – 3.20%) after boiling for 60 min and suggested that an increase in cellular water uptake with increased boiling time. Similarly Kajihausa *et al*. (2014) also reported an increase in WAC of sprouted sesame seed flour (1.37 – 1.64ml/g) as soaking time increased form 8- 16 h. They attributed the varied WAC of the samples to the change in protein structure with increase in soaking time. There was a significant difference (P<0.05) in boiled and soaked ukpo and ofor samples. However, WAC is useful in determining the suitability of the materials in baked flours (Natt and Narasinga 1981). It is a desirable trait in foods such as custards, Sausages and dough because these are supported to imbibe water without dissolution of protein (Seena and Sridhar 2005).

Table 2: Functional Properties of three commonly used soup thickeners as affected by boiling and Soaking time

Samples		Bulk density (g/ml)	Dispersibility (%)	Solubility (%)	Swelling power (g/g)	Foam capacity (%)	Least gelation (%)	Water absorption (ml/g)
Ukpo	A1	0.59^{a}±0.02	33.00^{b}±1.91	55.56^{c}±0.46	8.72^{a}±0.11	29.50^{a}±0.71	2.00^{a}±0.00	0.91^{c} ±0.54
	A2	0.56^{a}±0.05	34.00^{ab}±0.71	107.51^{a}±0.05	4.69^{b}±0.44	13.50^{b}±0.71	2.00^{a}±0.00	1.00^{c}±0.00
	A3	0.59^{a}±0.02	32.50^{b}±0.71	32.56^{d}±0.21	5.78^{b}±0.41	10.50^{c}±0.71	2.00^{a}±0.00	8.67^{b}±0.59
	A4	0.58^{a}±0.04	36.50^{a}±0.71	84.28^{b}±0.89	8.00^{a}±0.82	9.50^{c}±0.71	2.00^{a}±0.00	10.42^{a} ±0.47
Achi	B1	0.70^{a}±0.14	41.00^{d}±0.00	100.94^{b}±0.01	5.05^{b}±0.03	9.50^{a}±0.71	2.00^{a}±0.00	0.67^{a} ±0.00
	B2	0.68^{a}±0.01	42.00^{c}±0.00	105.85^{a}±0.04	4.77^{b}±0.81	7.50^{a}±0.71	2.00^{a}±0.00	0.82^{a} ±0.26
	B3	0.76^{a}±0.05	48.00^{a}±0.00	34.66^{d}±0.49	4.61^{b}±0.49	9.50^{a}±0.71	2.00^{a}±0.00	0.67^{a} ±0.00
	B4	0.74^{a}±0.10	47.00^{b}±0.00	55.68^{c}±3.24	7.23^{a}±0.83	4.50^{b}±0.71	2.00^{a}±0.00	1.08^{a} ±0.24
Ofor	C1	0.66^{b}±0.05	37.00^{b}±1.41	12.63^{d}±0.52	6.88^{a}±0.26	6.50^{a}±0.71	2.00^{a}±0.00	7.03^{c} ±0.16
	C2	0.72^{a}±0.04	46.00^{a}±1.41	49.26^{c}±0.34	5.37^{b}±0.39	3.50^{b}±0.71	2.00^{a}±0.00	10.46^{a} ±0.64
	C3	0.67^{ab}±0.03	35.00^{b}±1.41	53.43^{b}±0.05	5.37^{b}±0.59	5.50^{a}±0.71	2.00^{a}±0.00	2.41^{d} ±0.13
	C4	0.63^{ab}±0.04	34.00^{b}±0.71	59.70^{a}±0.42	5.92^{ab}±0.24	2.50^{b}±0.71	2.00^{a}±0.00	8.67^{b}±0.47

Values are expressed as mean ± standard deviation of duplicate determination.
Means with the same letters along the same column are not significantly different (p>0.05).

KEYS:

Ukpo A1 = Boiled for 15 min, A2 = Boiled for 30 min, A3 = Soaked for 24 h, A4 = Soaked for 48 h
Achi B1 = Boiled for 15 min, B2 =Boiled for 30 min, B3 = Soaked for 24 h, B4 = Soaked for 48 h
Ofor C1 = Boiled for 15 min, C2 =Boiled for 30 min, C3 = Soaked for 24 h, C4 = Soaked for 48 h

Antinutritional Factors of Three Commonly Consumed Soup Thickeners

Table 3 shows the selected anti-nutrient of three soup thickeners. Phytate recorded 0.01g/kg for all the treatments. Bawa *et al*., (2003) reported no significant reduction in phytate when lablab seeds were cooked for 30 min. Similarly, Lorgyer *et al*., (2009) reported a significant reduction in phytate content of boiled pigeon pea seeds (1.25- 1.20g/kg) after boiling for 30 min. There was no significant difference (P>0.05) in the phytate content of the boiled and phytate is heat stable, which may be due to covalent linkage between atoms and the phosphate structure (Deboland *et al*., 1975).

Tannin content ranged from 2.22- 40.71mg/kg with sample C_4 (ofor soaked for 48 h) having the lowest and sample A_4 (ukpo soaked for 48 h) having the highest. Results showed that tannin content decreased with increase in boiling and soaking time. This result is in correlation with the findings of Okundu and

Ojinnaka, (2017) who reported a decrease in tannin contents of Bambara groundnut (0.45 – 0.16mg/kg) after soaking for 48 h. Similarly, Iorgyer *et al* (2009) reported significant reduction ($P<0.05$) in the tannin content of pigeon Pea seeds after boiling for 60 min (0.085 – 0.040 mg/kg). Tannin content significantly reduced (P<0. 05) for all the samples as boiling and soaking time increased. The reduction in the tannin content of the soup thickeners with increase in soaking and boiling time may be due to solubility and leaching into the liquid media (Reddy and Pierson, 1994), as well as differences in plant origin

Oxalate content of seed flour samples ranged from 3.40-7.90mg/100g with sample B_4 (Achi soaked for 48 h) having the lowest and sample A_4 (ukpo soaked 48 h) having the highest. Analysis result showed that there was a decrease in oxalate content of the soup thickeners as the treatment time increased. Soaked achi seeds for 48 h had the lowest and soaked ukpo seeds for 24 h had the highest. Talabi *et al.*, (2016) reported a decrease in oxalate content of *Persia americana* (4.07 – 2.77%) after boiling for 25 min. Similarly, 1orgyer *et al*., (2009) recorded a decrease in oxalate content of pigeon pea seeds form 0.83 – 0.66% after 60 min of boiling. Okundu and Ojinnaka, (2017) also reported a decrease in oxalate content of Bambara groundnut seeds (1.06 – 0.29%) after soaking for 72 h. Soaking had a significant effect ($P<0.05$) for all the samples, however, there was no significant difference ($p<0.05$) in boiled achi and ofor.

Saponin content ranged from 2.60-9.18% with sample B_4 (achi soaked for 48 h) having the lowest and sample A_1 (ukpo boiled for 15 min) having the highest. This parameter showed a decrease in the saponin content the treatment time increased. Soaked achi seeds for 48 h had the lowest and boiled ukpo seeds for 15 min had the highest. This result correlates with the findings of Iorgyer *et al*., (2009) that saponin content of pigeon pea seeds decreased form 0.89 – 0.73% after boiling for 60 min. Okundu and Ojinnaka (2017) also reported a decrease in saponin content of Bambara groundnut seeds (0.82 – 0.12%) after soaking for 72 h. There was a significant difference ($P<0.05$) in ukpo seeds and boiled achi seeds, but boiling and soaking of ofor seeds show no significant difference (p.>0.05).

Table 3: Anti-nutritional Factors of Ukpo, Achi and Ofor as affected by boiling and soaking time

Samples		Phytate (g/kg)	Tannin (mg/kg)	Oxalate (mg/100g)	Saponin (%)
Ukpo	A1	$0.01^{a}\pm0.00$	$40.00^{b}\pm0.00$	$9.30^{b}\pm0.25$	$9.18^{a}\pm1.13$
	A2	$0.01^{a}\pm0.00$	$32.73^{c}\pm0.09$	$4.90^{c}\pm0.47$	$5.29^{b}\pm0.15$
	A3	$0.01^{a}\pm0.00$	$39.65^{b}\pm0.28$	$9.60^{a}\pm0.36$	$7.85^{a}\pm0.26$
	A4	$0.01^{a}\pm0.00$	$40.71^{a}\pm0.00$	$7.90^{b}\pm0.53$	$3.15^{c}\pm0.78$
Achi	B1	$0.01^{a}\pm0.00$	$12.27^{b}\pm0.00$	$5.07^{a}\pm0.19$	$6.18^{a}\pm0.70$
	B2	$0.01^{a}\pm0.00$	$8.80^{c}\pm0.00$	$4.65^{a}\pm0.11$	$4.18^{b}\pm0.54$
	B3	$0.01^{a}\pm0.00$	$14.44^{d}\pm0.00$	$3.93^{b}\pm0.08$	$2.69^{b}\pm0.71$
	B4	$0.01^{a}\pm0.00$	$8.03^{a}\pm0.00$	$3.40^{c}\pm0.19$	$2.60^{b}\pm0.00$
Ofor	C1	$0.01^{a}\pm0.00$	$4.46^{b}\pm0.00$	$5.54^{a}\pm0.37$	$3.28^{b}\pm0.71$
	C2	$0.01^{a}\pm0.00$	$3.95^{c}\pm0.22$	$5.07^{ab}\pm0.43$	$2.68^{b}\pm0.14$
	C3	$0.00^{a}\pm0.00$	$5.09^{a}\pm0.00$	$4.50^{c}\pm0.30$	$6.46^{a}\pm0.68$
	C4	$0.00^{a}\pm0.00$	$2.22^{d}\pm0.00$	$3.64^{b}\pm0.87$	$5.20^{a}\pm0.57$

Values are expressed as mean ± standard deviation of duplicate determination.
Means with the same letters along the same column are not significantly different ($p>0.05$).

KEYS:

Ukpo A1 = Boiled for 15 min, A2 = Boiled for 30 min, A3 = Soaked for 24 h, A4 = Soaked for 48 h
Achi B1 = Boiled for 15 min, B2 =Boiled for 30 min, B3 = Soaked for 24 h, B4 = Soaked for 48 h
Ofor C1 = Boiled for 15 min, C2 =Boiled for 30 min, C3 = Soaked for 24 h, C4 = Soaked for 48 h

Table 4: Storage Properties of three commonly consumed soup thickeners

The storage properties of ukpo, achi and ofor is shown in Table 4. Free fatty acid content ranged from 0.25-0.87% with sample C_1 (ofor boiled for 15 min) having the lowest and sample C_2 (ofor boiled for 30 min) having the highest. This result shows that there was an increase in free fatty acid content as the treatment time increased. Adejumo *et al*. (2018) reported that sour-sop seeds of moisture content 20% had higher free fatty acid value (5.29%) than seeds with 6 – 12% moisture (3.11 – 3.33%). There was a significant difference (P<0.05) in the free fatty acid with an increase in boiling and soaking time. But soaked ukpo showed no significant difference (p>0.05)) free fatty acid value, which is an indicator of the hydrolytic rancidity of oil that causes an undesirable flavor and aroma in the oil and it is mainly due to the action of lipase or moisture (Hoover *et al*. 1973). The formation of free fatty acid which increased with increase in boiling and soaking time can be related to the presence of moisture. This chemical reaction has been found to be due to the reaction of seed oil with moisture in the presence of enzymes acting as catalysts. The level of free fatty acid depends on time, temperature and moisture content (Mahesa *et al*. 2014).

Peroxide value (PV) ranged between 0.00-6.60meq/kg with sample A_3 (ukpo soaked for 24 h) having the lowest and sample B_2 (achi boiled for 30 min) having highest. Result showed that there was an increase in PVof the samples as the treatment time increased. Soaked ukpo seeds for 24 h had the lowest and boiled achi seed for 30 min had the highest. Udoh *et al*. (2017) reported that moisture content of soursop seeds with 7-21% had higher PV (0.11-0.17 meq/kg) than seeds with moisture content of 6-12% (0.08-0.11 meq/kg). (PV) is commonly used to determine the magnitude of primary oxidation products (mainly peroxides) in oils (Shaidi and Wanasundara, 2008). There was a significant difference (p<0.05) in the boiling and soaking of these seeds. The increase in PV as soaking and boiling time increased can be attributed to the accumulation of hydrogen peroxides as a result of free radicals attacking the unsaturated fatty acids of oil (Nyam *et al.* 2013). It is known that factors such as temperatures and moisture affect the rate of oxidation.

Iodine value (IV) ranged from 21.45-235.67g/100g with sample A_4 (ukpo soaked for 48 h) having the lowest and sample B_3 (achi soaked for 24 h) having the highest. IV value was significantly (p< 0.05) decreased as the treatment time increased. Increase in soaking and boiling time significantly decrease (p>0.05) the IV of the samples. Iodine value is an index of the unsaturation which is the most important analytical characteristic of oil (Gulla and Waghray, 2011). A decrease in this parameter is generally attributed to the destruction of the double bonds of polyunsaturated fatty acids by free radicals (Tynek *et al*, 2001).

Saponification value (SV) ranged between 189.06-356.34 mgKOH/g with sample A_1 (ukpo boiled for 15 min) having the lowest and sample C_4 (ofor soaked for 48 h) having the highest. SV showed that there was an increase in SV with increase in treatment time. Boiled ukpo seeds for 15 min had the lowest and soaked ofor seeds for 48 h had the highest. Saponification value (SV) measures the average molecular weight of fatty acids present in the oil (Prasauth *et al*, 2015). An increase in SV as boiling and soaking time increased is also a function of the moisture content and the time. Adejumo and Salihu, (2018) reported an increase in the SV of tigernut oil (143.066-294.52mgKOH/g) due to increased moisture content (9.5-40%) in the nuts. There was a significant difference (p<0.05) in the samples which may be due to differences in plant origin and treatments. Soaking and boiling treatment led to increase in moisture content of seeds as a result of moisture absorption. This indicated that the oil extracted from the samples as a result of increasing boiling and soaking time would be suitable for soap making since its saponification values is high.

Acid value ranged between 0.51-1.74mgKOH/g with sample C_1 (ofor boiled for 15 min) having the lowest and sample C_2 (ofor boiled for 30 min) having the highest. Result of the present study showed that there was an increase in the acid value with increase in treatment time. Boiled ofor seeds for 15 min had the lowest and boiled ofor seeds for 30 min had the highest. Acid value determines the amount of free fatty acids in a sample. Adejumo *et al*. (2015) reported an increase in acid value of water melon seed (5.61-10.10 MgKOH/g) as moisture content increased from 4-30%. Increase in boiling and soaking time resulted to a significant increase ($P<0.05$) in the acid values of achi and ofor seeds. The codex maximum level of 4 MgKOH/g oil does not produce off-flavors and are also desirable for consumption. Acid values are dependent on FFA, acid phosphate and amino acids (Nielsen, 1994). Therefore, the higher the FFA content, the higher the acid value, with higher acid values undesirable in finished oil based product. The increase in acid value of the seeds is a function of an increase in free fatty acid content as well as moisture content. The increased acid values observed as soaking and boiling time increased is in relation to the presence of water during these treatments and the increased time that caused hydrolysis and aided the degradation of the seeds. Hydrolysis processes occurring in the seeds reduced the acid value which led to the increase in the acid value (Nielson, 1994).

Table 4: Storage Properties of Ukpo, Achi and Ofor as affected by boiling and soaking time

Samples		FFA (%)	PV (Meg/kg)	IV (g/100g)	SV (MgKOH/g)	AV (Mgkoh/g)
Ukpo	A1	$0.31^{c}\pm0.04$	$0.10^{b}\pm0.10$	$175.84^{a}\pm12.82$	$189.06^{c}\pm3.97$	$0.62^{b}\pm0.08$
	A2	$0.40^{b}\pm0.00$	$0.20^{b}\pm0.00$	$164.97^{a}\pm2.56$	$236.23^{b}\pm2.45$	$0.79^{c}\pm0.00$
	A3	$0.68^{a}\pm0.00$	$0.00^{b}\pm0.00$	$25.38^{b}\pm3.64$	$266.31^{a}\pm10.23$	$1.34^{a}\pm0.00$
	A4	$0.70^{a}\pm0.04$	$0.40^{a}\pm0.00$	$21.45^{b}\pm0.43$	$283.70^{a}\pm15.94$	$1.40^{a}\pm0.08$
Achi	B1	$0.35^{d}\pm0.02$	$1.40^{c}\pm0.28$	$163.16^{b}\pm5.13$	$265.91^{c}\pm7.93$	$0.70^{d}\pm0.04$
	B2	$0.45^{b}\pm0.00$	$6.60^{a}\pm0.85$	$137.78^{c}\pm10.26$	$329.87^{b}\pm4.76$	$0.90^{b}\pm0.00$
	B3	$0.40^{c}\pm0.00$	$1.80^{c}\pm0.29$	$235.67^{a}\pm5.13$	$349.92^{a}\pm1.39$	$0.79^{c}\pm0.00$
	B4	$0.51^{a}\pm0.00$	$3.99^{b}\pm0.02$	$231.61^{a}\pm0.62$	$350.06^{a}\pm0.00$	$1.01^{a}\pm0.00$
Ofor	C1	$0.25^{c}\pm0.04$	$0.10^{d}\pm0.14$	$77.05^{b}\pm1.28$	$253.63^{d}\pm0.08$	$0.51^{c}\pm0.08$
	C2	$0.87^{a}\pm0.04$	$2.40^{a}\pm0.57$	$30.88^{c}\pm0.00$	$271.63^{c}\pm0.05$	$1.74^{a}\pm0.08$
	C3	$0.28^{c}\pm0.00$	$0.49^{cd}\pm0.42$	$121.61^{a}\pm7.48$	$299.45^{b}\pm1.42$	$0.56^{c}\pm0.00$
	C4	$0.48^{b}\pm0.04$	$1.49^{ab}\pm0.42$	$112.30^{a}\pm0.00$	$356.34^{a}\pm1.36$	$0.95^{b}\pm0.07$

Values are expressed as mean ± standard deviation of duplicate determination.
Means with the same letters along the same column are not significantly different ($p>0.05$).

KEYS:
Ukpo A1 = Boiled for 15 min, A2 = Boiled for 30 min, A3 = Soaked for 24 h, A4 = Soaked for 48 h
Achi B1 = Boiled for 15 min, B2 =Boiled for 30 min, B3 = Soaked for 24 h, B4 = Soaked for 48 h
Ofor C1 = Boiled for 15 min, C2 =Boiled for 30 min, C3 = Soaked for 24 h, C4 = Soaked for 48 h
FFA= Free Fatty Acid, PV=Peroxide Value, IV=Iodine Value, SV =Saponification Value AV= Acid Value

Pasting Properties (RVU) of Three Commonly Consumed Soup Thickeners

The pasting properties of three commonly consumed soup thickeners are shown in Table 5. Pasting property of a food material is important in predicting the behavior of the food material in industrial applications (Adebowale *et al.,* 2008). Peak viscosity ranged from 6704-16429RVU with sample A_2 (ukpo boiled for 30 min) having the lowest and sample B_4 (achi soaked for 48 h) having the highest. Peak viscosity is the ability of starch to swell freely before their breakdown. Peak viscosity ranging from 6721 – 16429RVU showed that there was a decrease in peak viscosity as the soaking time increased. Boiled ukpo seeds for 15 min had the highest and soaked achi seeds for 48 h had the highest. The values are higher compared to the values obtained from dried fufu and tapioca

(Adebowale *et al*., 2005; Adebowale *et al*., 2008). Increase in boiling and soaking had no significant effect (P<0.05) for all the samples. The relative high peak viscosity of the samples is an indication of high starch content (Osungbaro, 2009). Peak viscosity usually indicates the water binding capacity of a mixture in a product and it is also an indication of viscous load likely to be encountered by a mixing cooker (Ingbian and Adegoke, 2007).

Trough viscosity ranged from 3846-9231RVU with sample A_3 (ukpo soaked for 24 h) having the lowest and sample C_1 (ofor boiled for 15 min) having the highest. This parameter measures the ability of the paste to withstand breakdown during cooling (Newport Scientific, 1998). Trough viscosity result in the present study showed that boiling increased the trough viscosity as treatment time increased in ukpo and achi samples. There was no significant difference (P>0.05) among the treatments.

Breakdown viscosity ranged between 1933-7858RVU with sample C_4 (ofor soaked for 48 h) having the lowest and sample B_4 (achi soaked for 48 h) having the highest. Breakdown viscosity value therefore is an index of the stability of starch. The breakdown viscosity ranging from 1933 – 7858RVU showed that soaking had the highest breakdown value with increase in soaking time. Soaked ofor seeds for 48 h had the lowest and soaked achi seeds for 48 h had the highest. The values were lower than results of Uzomah and Odusanya, (2011) for defatted and undefatted *Detarium microcarpum* flours. There was no significant difference (P>0.05) for all the treatments. Breakdown viscosity is the difference between the peak and trough viscosity and is an indication of the rate of gelling stability, which is dependent on the nature of the product (Newport scientific 1998). Breakdown: Peak viscosity minus trough and is a period when test sample was subjected to constant temperature which is a measure of the ability of paste to withstand breakdown during cooling.

Final viscosity ranged from 11716-19977RVU with sample A_4 (ukpo soaked for 48 h) having the lowest and sample C_1 (ofor boiled for 15 min) having the highest. The final viscosity is the ability of starch to form a viscous paste and gel during cooking and after cooling, respectively (Maziya – Dixon, *et al.*, 2007). The final viscosity ranging from 11716-19977RVU showed that a decrease in the final viscosity of soaked ukpo and boiled ofor with increase in boiling and soaking. Soaked ukpo seeds for 48 h had the lowest and boiled ofor seeds for 15 min had the highest. There was no significant difference (P>0.05) among the samples except for boiled achi which differed significantly (P<0.05). The final viscosities are very high for all samples and this indicated that retrogradation or precipitation of the linear molecule of these seeds were very high. Final viscosity: Viscosity at the end of the test set back viscosity. Final viscosity minus peak viscosity.

Set back viscosity ranged from 6763-13004RVU with sample B_1 (Achi boiled for 15 min) having the lowest and sample A_3 (Ukpo soaked for 24 h) having the highest. Set back viscosity is an index of the tendency of the cooked flour to harden on cooling due to amylose retrogradation. The set back viscosity ranging from 6763 – 13004RVU showed that increased in boiling and soaking increase the set back viscosity of achi and ofor but decrease the ukpo sample. Boiled achi seeds for 15 min had the lowest and soaked ukpo seeds for 24 h had the highest values. Increase in soaking time of ukpo seeds differed significantly (P<0.05) from others. The values were much higher than set back viscosities

(31.66 and 32.91RVU) for defatted and undefatted *D. microcarpum* seeds as reported by Uzomah and Odusanya (2011). Sanni *et al*., (2004) reported that lower set back viscosity during cooking of a paste indicates greater resistance to retrogradation.

Peak time ranged from 1.60-6.10 min with sample C_3 (Ofor soaked for 24 h) having the lowest and sample B_4 (Achi soaked fro 48 h) having the highest. Peak time is the time at which peak viscosity occurs and a measure of the cooking time, had values ranging from 1.60 – 6.10 min showed that increased in boiling and soaking increase the peak time. Soaked ofor seeds for 24 h had the lowest and soaked achi seeds for 48 h had the highest. Peak time is a measure of the cooking time. There was a significant difference (P<0.05) in the boiling and soaking had no significant different (P>0.05) on ukpo seeds. The boiled sample had the lowest peak time (50. 25 min) which could be as a result of cooking in water during processing.

Pasting temperature ranged 50.25-76.18^{0}C with sample A_1 (Ukpo boiled for 15 min) having the lowest and sample B_4 (Achi soaked for 48 h) having the highest. Peak temperature: Temperature at which peak viscosity occurs. Pasting temperature is a measure of the minimum temperature required to cook a given sample. The temperature at the onset of the rise in viscosity is the pasting temperature (Adebowale *et al*., 2008). The pasting temperature ranging from 50.25 – 76.18^{o}C showed there was an increase in soaked achi and ofor seeds with increased in treatment time. Boiled ukpo seeds for 15 min had the lowest and soaked achi for 48 h had the highest. There was no significant difference (P>0.05) among ukpo and ofor seeds but boiled and soaked achi seeds differed significantly (P<0.05).

Table 5: Pasting Properties (RVU) of three commonly consumed soup thickeners

Values are expressed as mean ± standard deviation of duplicate determination.

Sample		Peak Viscosity (RVU)	Trough viscosity (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Set back (RVU)	Peak time (min)	Pasting temperature (^{o}C)
Ukpo	A1	7263±2677.0^{a}	4249±577.0^{a}	3014±2100^{a}	16980±2023^{a}	127301±2600^{a}	5.20±0.47^{a}	50.25±0.07^{a}
	A2	6704±660.0^{a}	4565±152.0^{a}	2139±507.0^{a}	14247±138^{ab}	9683±290.6^{ab}	4.27±0.57^{a}	50.30±0.07^{a}
	A3	7581±1298.0^{a}	3846±18.4^{a}	3735±1280^{a}	16850±1535^{a}	13004±1517.0^{a}	5.20±0.10^{a}	50.35±0.00^{a}
	A4	6721±2814.0^{a}	4000±583.0^{a}	2721±2232^{a}	11716±157^{a}	7716±739.6^{b}	5.67±1.32^{a}	50.28±0.04^{a}
Achi	B1	6721±2814^{b}	7950±3743^{a}	2118±1271^{b}	14713±390^{b}	6763±3354^{a}	6.04±0.33^{a}	50.30±0.00^{b}
	B2	10068±5015^{ab}	9034±897.0^{a}	5523±112^{ab}	19946±1731^{a}	10913±2628^{a}	4.37±0.52^{b}	50.35±0.00^{b}
	B3	14556±785^{ab}	9178±742.0^{a}	7251±3103^{ab}	16604±2457^{ab}	7426±3200^{a}	5.97±0.23^{a}	74.65±1.77^{a}
	B4	16429±2361^{a}	9062±510.0^{a}	7858±2065^{a}	19368±1938^{ab}	10306±1428^{a}	6.10±0.33^{a}	76.18±0.61^{a}
Ofor	C1	15766±4633^{a}	9231±1435^{a}	6535±3198^{a}	19977±5812^{a}	10746±4376^{a}	2.03±0.14^{b}	50.35±0.07^{a}
	C2	11485±3143^{a}	8924±2089^{a}	2561±1054^{a}	19768±2832^{a}	10844±4921^{a}	6.00±0.85^{a}	50.33±0.04^{a}
	C3	15241±4501^{a}	8991±2625^{a}	6251±1876^{a}	16152±1976^{a}	7161±649^{a}	1.60±0.10^{b}	50.28±0.04^{a}
	C4	9894±3506^{a}	7962±1996^{a}	1933±1510^{a}	18648±347^{a}	10686±2345^{a}	5.57±0.05^{a}	50.30±0.07^{a}

Means with the same letters along the same column are not significantly different ($p>0.05$).

KEYS:

Ukpo A1=Boiled for 15 min, A2 = Boiled for 30 min, A3 =Soaked for 24 h, A4 = Soaked for 48 h

Achi B1 = Boiled for 15 min, B2 =Boiled for 30 min, B3 = Soaked for 24 h, B4 = Soaked for 48 h

Ofor C1 = Boiled for 15 min, C2 =Boiled for 30 min, C3 = Soaked for 24 h, C4 = Soaked for 48 h

FFA= Free Fatty Acid, PV=Peroxide Value, IV=Iodine Value, SV =Saponification Value AV= Acid Value

Conclusion

The study showed that ukpo, achi and ofor flour contains appreciable quantities of nutrients like carbohydrate and protein. The high water absorption capacity of the flour justifies its use as a soup thickener. The anti-nutritional factors were reduced by processing methods adopted especially boiling for an extended time of 30 min. However, the functional and physicochemical parameters of ukpo, achi and ofor seed flour compared effectively well with other legumes, roots, cereals and tubers. Therefore, this processing method should be used to improved safety of the seed for consumption.

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