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Full Length Research

Variation in the functional properties of blends of heat-treated local thickening seeds and cocoyam flour

Mbanali, U. G.[1], Chukwu, M. N.[2*] and Iwuagwu, M. O.[3]

[1]Department of Nutrition and Dietetics, Imo State College of Health and Management Sciences, Amaigbo, Imo State, Nigeria.
[2]Department of Food Technology, Abia State Polytechnic, Aba, Abia State, Nigeria.
[3]Department of Plant Science and Biotechnology, Abia State University, Uturu, Abia State, Nigeria.

Corresponding author. Email: mchukwu61@gmail.com. Tel: +234 8184516106, +234 8051862340.

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ABSTRACT: The effects of pre-milling heat treatment types on the functional properties of the resultant flour blends of some indigenous thickening seeds and cocoyam (*ede-ocha*) at various percentages were examined. Flours of indigenous thickening seeds of *achi*, *ofo* and *ukpo*, and that of cocoyam were used in this work. Functional analyses showed that the blend type of *ofo*-cocoyam flour had better swelling index (SI) (3.28±0.28) and water absorption capacity (WAC) (5.10±1.77ml/g) than that of *ukpo*-cocoyam; *ukpo*-cocoyam blend exhibited better oil absorption capacity (OAC) (1.41±0.21ml/g), though not significantly higher than *ofo*-cocoyam and *achi*-cocoyam ($p \leq 0.05$). Among treatment types, flour of boiled sample had better SI (3.35±0.60) and WAC (4.56±1.58ml/g) than that of the roasted sample which gave better OAC (1.45±0.33ml/g) that was statistically equal to boiled blend (1.39±0.23ml/g), steamed blend (1.26±0.27ml/g) and raw blend (1.44±0.29ml/g). Among blending ratios, 25% cocoyam (CY) flour blend had significantly higher WAC (5.07±0.62ml/g) than the control and other blends, with SI of 3.06±0.59 which statistically equal to the 75% cocoyam flour blend (3.12±0.53). The boiled sample exhibited better functional properties than others; such that *ofo*-CY exhibited better functional properties than other blends types as the 25% CY flour sample exhibited better functional properties than other blend ratio samples. Further work should be directed to investigate this experiment with another species of cocoyam to check whether remarkable improvements can be obtained in the characteristics of the resultant flour blend with *achi*, *ofo*, *ukpo*.

Key words: *Achi*, blend, cocoyam, functional properties, *ofo*, thickening seeds, *ukpo*.

INTRODUCTION

Thickening agent is the term applied to substances which increase the viscosity of a solution or liquid/solid mixture without substantially modifying its other properties. It can be any ingredient or agent that is added to other food ingredients in order to create a stiffer or denser food mixture (Food Additive, 2011). Several food materials have been implicated over the years to have thickening potentials, and the legumes in particular are quite obvious here.

Legumes refer to the edible seeds of leguminous plants belonging to the *Leguminosae* family (Chukwu et al., 2017; 2018a). They are usually referred to as pulses and include all forms of beans and peas from the *Fabaceae* botanical family. They are grown primarily for their food grain seed (e.g., beans and lentils or generally pulse). They are major sources of dietary proteins. Legumes seeds are also rich in other nutrients such as starch, dietary fibre, protective phytochemicals, oil, vitamins and minerals such as phosphorus and iron (Shimelis et al., 2006).

However, research efforts are being directed towards identifying and evaluating unexploited areas regarding the optimal utilization of the legume seeds. Some legumes such as the *Brachystegia eurycoma*, *Detarium microcarpum* and *Mucuna solanei* amongst others have been found to be most efficient as emulsifiers and thickeners in food formulation, especially in traditional soups.

Brcachystegia eurycoma is one of the lesser known legumes which have not been fully utilized to alleviate protein-energy malnutrition common in developing counties such as Nigeria (Uhegbu et al., 2009; Ikegwu et al, 2010). Nutritionally, *Brachystegia ecryeoma* (*achi*) contains 10.47% protein, total carbohydrate content 71.94% (Olayemi and Jacob, 2011). It contains bioactive compounds comprising favonoids, alkaloids, phenolic compounds, saponins and tannins, protein, carbohydrates, lipids and fibre. Uhegbu et al. (2009) reported that it is a good source of water soluble vitamins (ascorbic acid, thiamine, riboflavin and niacin) and minerals such as calcium, phosphorus, potassium, magnesium, sodium, zinc, iron and copper; thereby playing a major role in the nutritional status of consumers. Ajayi et al. (2006) also reported that *Brachystegia eurycoma* is rich in carbohydrate, protein and crude fiber with high amount of essential unsaturated fatty acids.

Detarium microcarpum is an unexploited legume indigenous to drier regions of West and Central Africa (Contu, 2012). It is variously called sweet *dattock* or tallow tree (English), *Dankh* or *Petitdetar* (French), *Ofo* (Igbo), *Taura* (Hausa) and *Ogbogho* (Yoruba) (Ayozie, 2010). It is rich in vitamin C (3.2 mg) with 4.8 g protein and 64.5 g of sugar per 100 g. The fruit pulp has been found to have high proportions of carbohydrate (40 to 42%) and protein (29.1 to 30.9%) (Abdalbasit et al., 2009). The seeds yield 7.5% oil with the predominant linoleic acid. The hulled seed flour contains per 100 g: 3.5 to 6.5 g water, 3 g crude fiber, 13 to 15 g crude fat, 13.5 to 27 g crude protein, 39 g carbohydrate, Ca 500 mg, Mg 500 mg, Fe 100 mg (Kouyate and Van Damme, 2006). Akpata and Miachi (2001) reported that the seeds of *D. microcarpum* possess high proportions of protein (37.1% dehulled) and a high amount of carbohydrates (54.03%) and crude fiber (10%) in the seed coat. It has good nutritional quality and acceptable functional properties, thus confirming their suitability for use in various food preparations and formulations (Bhat and Karim, 2009).

The enormous legume family contains species of tropical vines, but some of the most interesting belong to the genus *Mucuna* (Armstrong, 2010). *Mucuna sloanei (ukpo)* as a food thickener is known to originate from Asia and was later introduced into the western hemisphere via Mauritius (Nkpa, 2004). Its seeds, as a rich in protein supplement in food and feed, has been well documented (Siddhuraju et al., 2000; Bhat et al., 2008). The crude protein content is known to vary between 20 and 31.44g/100g (Ezeagu et al., 2003). It has been reported by Vadivel and Janaradhanan (2000) and Vijayakumari et al. (2002) that crude protein ranges from 20.2 to 29.6%). Adeboye and Philips (2006) reported a crude protein levels between 19.97 to 20.59% in Nigeria. Higher concentrations of essential amino acids (555 mg/g protein) in *mucuna* seeds has been reported by Adebowale et al. (2005). *Mucuna sloanei* seed is processed into flour and used as soup thickener and stabilizer, where its gelation properties impart gummy texture in soups (Oudhia, 2002; Diallo and Berhe, 2003).

The plants are used in herbalism against a range of conditions such as urinary tract, neurological and menstruation disorders, constipation, edema, fevers, turberculosis, ulcers, parkinson's disease (Katzenschlager et al., 2004) and helminthases like, elephantiasis (Oudhia, 2002).

Starchy roots and tuber form a major staple food group for a large number of persons in most developing countries of Africa, Asia and Latin America. The most popular members of this food group are cassava, cocoyam, yam, Irish and sweet potatoes, unripe bananas and plantain (Okaka, 2009).

Cocoyam is commonly referred to as *Ede* in Ibo land of Nigeria. Cocoyam's *Taro* and *Tannia* have remained the two varieties mainly grown in Nigeria. The taro varied botanically known as *Colosasia esculenta* and commonly called *Coco*-India originated from Asia, while tannia (*Xanthosoma sagittifolium*) originated from America but were both introduced and grown in West Africa (Brown, 2000). These two species *Colocasia esculenta* (Taro) and *Xanthosoma sagittifolium* (Tannia) are the most widely accepted and cultivated varieties in Nigeria and other parts of the tropics and sub-tropic of Africa (Nwagbo, 2013).

Colocasia is thought to have originated into Indo–Malayan region, perhaps in Eastern India and Bangladesh, and spread eastward into South East Asia, Eastern Asia and the Pacific Island; Westward to Egypt and the Eastern Mediterranean, and then Southern and Westward from there into East Africa and West Africa, whence it spread to the Caribbean and Americans. It is known by many local names and often referred to as Elephant–ears when grown as an ornamental plant (Kolchaar 2006; Heuze et al., 2012).

Taro plant is a perennial herb with clusters of long heart or arrow head-shaped leaves that point earthward. It is cultivated in the tropics, and the leaves are classified as large to very large, 20 to 150 cm (7.6 to 5.9 in) long, with a sagittate shape (Brown, 2000), growing on erect stems which may be green, red, black, or variegated. The new leaves and stems push out of the innermost stalk, unrolling as they emerge, with the stem several feet high (Safokantaka, 2004, Ecoport, 2010, Plantvillage, 2012). Taro corms contains considerable amount of starch (70 to 80 g/100g dry Taro) (Quach et al., 2001). Lebot (2009) did report taro corms to be rich in starch (61 to 88%DM) but little of protein (2.3 to 14.8% DM). The corm contains mainly starch and water together with small quantities of protein, fat, ash, vitamins B and C. The carbohydrate content of taro cultivated in different locations varied. The starch extracted from taro corms appears as fine granules in the 0.5 to 5 microns range (Perez et al., 2005), and thus offers smooth textured starch gel. Moreover, the fine starch granule was reported to improve the binding and reduced breakage of snack products (Huang, 2005).

Meanwhile, taro leaves have been said to have a variable but generally high protein content usually in the 16 to 27% DM range (Henze et al., 2012) even though lower values (13 to 16% DM) are also reported. Moreover, the leaves are a good source of thiamin, riboflavin, iron, phosphorus and zinc and a very good source of vitamin C B_6, niacin, potassium, copper and magnesium (Chittavong et al., 2008). Cocoyam is most commonly grown for its starchy edible roots (Plantvillage, 2012) containing several vitamins and minerals. Cocoyam also has appreciable content of crude fibre which aids in digestion and makes the elimination of stool very easy, as well as playing major role in preventing cancer (Nwagbo, 2013).

Flours from 'achi', 'ukpo' and 'ofo' have been found to be used in most States in Nigeria including Imo, Abia, Anambra, Akwa-Ibom and Ondo States. They are used as thickeners in traditional soups (for eating gari, pounded yam or cocoyam and fufu). They are equally used as emulsifiers and flavouring agents in traditional soups due to their gum content. These gums are called the seed gum and food gum (hydrocolliods). These are not true gums but are of simpler structures. These seeds gums are extracted from the seeds when crushed to flour and when in powder form have the ability to swell in water and thus are able to influence the viscosity of the liquid. Apart from this culinary use, it is possible for these gums when used as additives in other foods to impact desirable textural and functional properties to the finished food product particularly the "convenience foods" (Ajayi et al, 2006; Nwosu, 2012).

With appropriate processing method, cocoyam could be a rich source of starch for food and industrial applications and corms have potential for new product development. Stabilizing cocoyam tuber and adding value could greatly improve its utilization in cocoyam producing countries as reported (Owusu-Darko et al, 2014; Bolarin et al., 2018). Cocoyam is almost a neglected crop in Nigeria. It does not compete favourably with other root crops (such as yam and cassava) in terms of production and consumption. *Achi*, *ofo* and *ukpo* suffer the fate as their usefulness have been limited to local traditional culinary practices, which makes them under exploited and at the same time received little attention and recognition from researchers as compared to other legumes such as soybeans, melon, cowpea etc.

Thus, this work is aimed at determining the effect of heat treatments on functional properties of local thickening seeds and blending ratios of cocoyam flour. Since the food thickeners are under exploited and utilized, investigating their functionalities especially as affected by heat treatments and subsequent blends with the cocoyam flour would no doubt increase their level of acceptance and utilization both locally and globally.

MATERIALS AND METHODS

Materials procurement

The food thickeners were *achi* (*Brachystegia eurycoma*), *ofo* (*Detarium microcarpum*), *ukpo* (*Mucuna sloanei*) and cocoyam (*Colocasia esculenta*) were obtained from Afor-Umuaka Market in Njaba Local Government Area of Imo State, Nigeria. The chemicals and equipment/facilities used for this work were obtained from the Department of Food Science and Technology, Federal University of Technology, Owerri, Imo State and Central Laboratory, University of Ibadan, Oyo State, Nigeria.

Preparation of samples

The various seeds/corms of the aforementioned food thickeners were sorted and cleaned to remove dirt and unwholesome ones. The seeds of *achi*, *ofo* and *ukpo* were soaked in cold water at ambient temperature for 24 hours to soften the seed coat, which was later removed with stainless steel knife. The cocoyam corms, on the other hand, were simply peeled with stainless steel knife. The dehulled seeds were further divided into four portions each to obtain samples for boiling, steaming, roasting and raw (raw is the control). The peeled cocoyam corms were simply boiled at the loading rate of 50 g per litre of water for 5 minutes. Meanwhile, the seed-samples which were to be boiled were also done at the same loading rate as the cocoyam corms for 5 minutes. The remaining three portions were individually roasted at 100^{O}C for 30 minutes, steamed for 10 minutes and the third portion kept as the control. Thereafter, all the portions were dried at 60^{O}C for about 3 hours in a Genlab Moisture Extraction Oven (Model-MINO/50) and milled into flour using a disc attrition mill (Figure 1). The resultant flours (*achi*, *ofo* and *ukpo*) varieties and the cocoyam flour were blended together in five different ratios as indicated in Table 1, packaged in airtight containers and labeled accordingly for analyses of their functional properties.

Determination of functional properties

Determination of Swelling Index (SI)

The Swelling Index of the flour samples was determined as reported by Njoku and Banigo (2006). Three grams (3 g) of each flour sample were transferred into a clean dry graduated 50 ml cylinder. The samples were gently leveled and their volumes noted. Then, 30 ml of distilled water was added into each of the samples. The cylinder was swirled and allowed to stand for 1 h while changes in volume (swelling) were noted. The swelling index of the test sample was repeated three times for each sample and the average was calculated.

$$\text{Swelling Index} = \frac{\text{volume occupied by sample after swelling}}{\text{volume occupied by sample before swelling}} \quad \text{Eqn. 1}$$

Water Absorption Capacity (WAC)

This was determined by the volume of water absorbed by

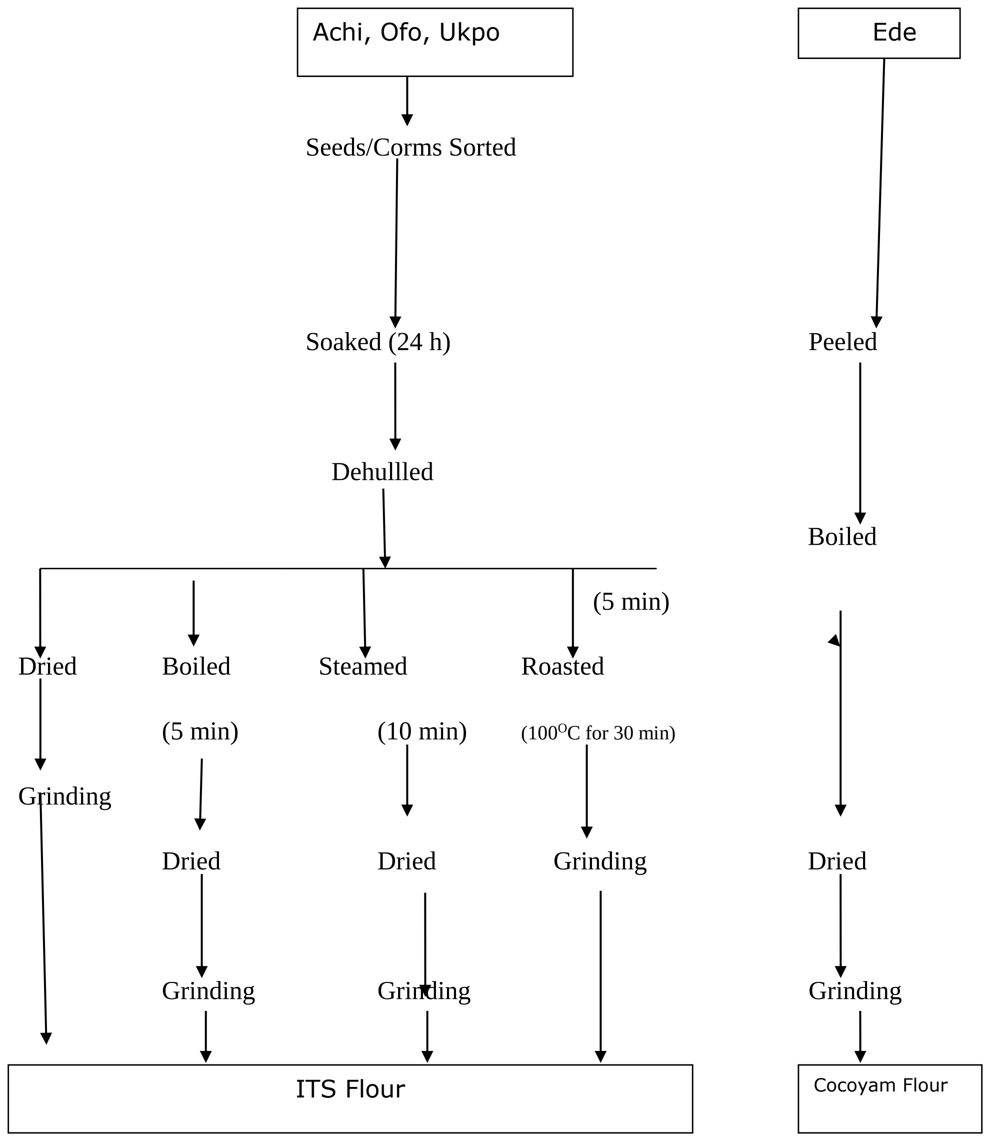

Figure 1. Flow diagram of the processing treatments of thickeners.

Table 1. Blending ratios of indigenous thickening-seeds flour and cocoyam flour.

Indigenous Thickening Seeds (ITS) (*achi*, *ofo*, *ukpo*) Flour (%)	Cocoyam Flour (%)
100	0
75	25
50	50
25	75
0	100

one gramme of the sample. The method of Sosulski (1962) was used. One gramme of sample was weighed out and put into a clean dry centrifuge tube. Ten mililitres (10 ml) of water was added to the tube and mixed very well. The mixture was allowed to stand for 30 minutes before being centrifuged at 1000 rpm for 30 minutes using Techmel Centrifuge (Model–800D). The supernatant was decanted and the volume noted. By difference, the volume

Table 2. Factorial design of experiment: A(3) by B(4) by C(5).

A	B_1	B_2	B_3	B_4	C
	$A_1B_1C_1$	$A_1B_2C_1$	$A_1B_3C_1$	$A_1B_4C_1$	C_1
	$A_1B_1C_2$	$A_1B_2C_2$	$A_1B_3C_2$	$A_1B_4C_2$	C_2
A_1	$A_1B_1C_3$	$A_1B_2C_3$	$A_1B_3C_3$	$A_1B_4C_3$	C_3
	$A_1B_1C_4$	$A_1B_2C_4$	$A_1B_3C_4$	$A_1B_4C_4$	C_4
	$A_1B_1C_5$	$A_1B_2C_5$	$A_1B_3C_5$	$A_1B_4C_5$	C_5
	$A_2B_1C_1$	$A_2B_2C_1$	$A_2B_3C_1$	$A_2B_4C_1$	C_1
	$A_2B_1C_2$	$A_2B_2C_2$	$A_2B_3C_2$	$A_2B_4C_2$	C_2
A_2	$A_2B_1C_3$	$A_2B_2C_3$	$A_2B_3C_3$	$A_2B_4C_3$	C_3
	$A_2B_1C_4$	$A_2B_2C_4$	$A_2B_3C_4$	$A_2B_4C_4$	C_4
	$A_2B_1C_5$	$A_2B_2C_5$	$A_2B_3C_5$	$A_2B_4C_5$	C_5
	$A_3B_1C_1$	$A_3B_2C_1$	$A_3B_3C_1$	$A_3B_4C_1$	C_1
	$A_3B_1C_2$	$A_3B_2C_2$	$A_3B_3C_2$	$A_3B_4C_2$	C_2
A_3	$A_3B_1C_3$	$A_3B_2C_3$	$A_3B_3C_3$	$A_3B_4C_3$	C_3
	$A_3B_1C_4$	$A_3B_2C_4$	$A_3B_3C_4$	$A_3B_4C_4$	C_4
	$A_3B_1C_5$	$A_3B_2C_5$	$A_3B_3C_5$	$A_3B_4C_5$	C_5

A = Indigenous Thickening Seed Flour; i=1-3 (achi, ofo, ukpo); B = Treatment Types on the ITS; J = 1-4 (Boiled, Steamed, Roasted, Raw); C = Blend Ratios with Cocoyam (CY) flour; k=1-5 (100:0, 75:25, 50:50, 25:75, 0:100).

of water absorbed/held by the sample was obtained. The gain in weight is the water absorption capacity of the test sample (Ibeabuchi, 2014). The water absorption capacity of the test sample was repeated three times for each sample and the average was calculated.

$$\mathrm{WAC\ (ml/g)} = \frac{\text{weight gain}}{\text{weight of sample}} \times \mathrm{S.G}$$ ----------- Eqn. 2

Where S.G = Specific Gravity of water was taken to be 1g/ml.

Oil Absorption Capacity (OAC)

This was determined by the volume of oil absorbed by one gramme of the sample. The method of Sosulski (1962) was used. One gramme of sample was weighted out and put into a clean dry centrifuge tube. Ten mililitres (10 ml) of oil (grand pure soya cooking oil, Nigeria) was added to the tube and mixed very well. The mixture was allowed to stand for 30 minutes before being centrifuged at 1000 rpm for 30 minutes. The supernatant was decanted and the volume noted. By difference, the volume of oil absorbed/ held by the sample was obtained. The gain in mass is the oil absorption capacity of the sample (Ogunbusola et al., 2012). The oil absorption capacity of the test sample was repeated three times for each sample and the average was calculated.

$$\mathrm{OAC\ (ml/g)} = \frac{\text{weight gain}}{\text{weight of sample}} \times \mathrm{S.G}$$ ---------------- Eqn. 3

Where S.G = Specific Gravity of vegetable oil was taken to be 0.88 g/ml.

Statistical analysis of data

The mean values of the functional properties were assessed as functions of Indigenous Thickening Seeds (ITS), Treatment Types (TT) and Blending Ratios (BR), which fitted into a 3(ITS) X 4(TT) X 5(BR) factorial design. The standard procedures for three-way Analysis of Variance (ANOVA) as described by Steel and Torrie (1980) were followed. Evaluated parameters included, reduced Sum of Squares (SS), Mean Square of Variance (MS), and Calculated Variance Ratio (Fcal). In cases where significant differences existed, Fisher's LSD (least significant difference) multi-comparison test as described by Roessler (1984) was used to separate the main factors' means. The design of experiment for the physic-chemical analysis is represented in Table 2.

RESULTS AND DISCUSSION

Swelling Index (SI)

Swelling index is the measure of the ability of starch to imbibe water and swell. The results presented in Tables 3, 4 and 5 show that each of the TT and BT factors constitute critical determinant for the swelling index of flours of cocoyam blend with the local thickenings seeds of *achi*, *ofo* and *ukpo*, while the BR factor does not.

Table 3. Mean values of functional properties of the resultant flour blends of local thickening seeds and cocoyam as affected by heat treatments.

Treatment Type (TT)	Parameters		
	SI	WAC (ml/g)	OAC (ml/g)
Boiled	3.35±0.60^{a}	4.56±1.58^{a}	1.39±0.23^{a}
Steamed	2.82±0.44^{b}	3.89±1.24^{b}	1.26±0.27^{a}
Roasted	2.86±0.45^{b}	3.89±1.20^{b}	1.45±0.33^{a}
Raw	3.02±0.46^{b}	4.28±1.78^{ab}	1.44±0.29^{a}
LSD	0.251	0.4426	0.2233

Mean values with the same superscripts within the column are not significantly different from each other while mean values with different superscripts along the same column are significantly different from each other at (P<0.05). SI = Swelling Index; WAC = Water Absorption Capacity; OAC = Oil Absorption Capacity; $LSD_{0.05}$ = Least Significant Difference at 95% confidence level.

Table 4. Mean values of functional properties of the resultant flour blends of local thickening seeds and cocoyam as affected by blend type.

Blend Type (BT)	Parameters		
	SI	WAC (ml/g)	OAC (ml/g)
Achi-CY	2.82±0.78^{b}	3.20±0.82^{c}	1.35±0.39^{a}
Ofo-CY	3.28±0.28^{a}	5.10±1.77^{a}	1.40±0.23^{a}
Ukpo-CY	2.93±0.20^{b}	4.17±1.06^{b}	1.41±0.21^{a}
LSD	0.2174	0.3833	0.1934

Mean values with the same superscripts within the column are not significantly different from each other while mean values with different superscripts along the same column are significantly different from each other at (P<0.05). CY = Cocoyam; SI = Swelling Index; WAC = Water Absorption Capacity; OAC = Oil Absorption Capacity; $LSD_{0.05}$ = Least Significant Difference at 95% confidence level.

Making comparison on the components of each factor, the results showed that with respect to TT factor (Table 3), flour of the boiled sample exhibited higher swelling capacity (3.35±0.60) than the others. That of the steamed sample, roasted and raw samples (though statistically equal at 95% confidence level) have mean values 2.82±0.44, 2.86±0.45 and 3.02±0.46, respectively. Such high swelling capacity witnessed in the flour of the boiled sample is an indicative that pre-milling heat treatment of boiling (under the conditions of this research work) has a significant effect (P<0.05) on the resultant flour blends of cocoyam and the local thickening seeds (*achi*, *ofo* and *ukpo*). The treatment type might have altered the extent of the associative forces within the granules which later manifested in higher swelling abilities of the material.

Among the components of the BT (Table 4), the *ofo*-CY blend exhibited a swelling capacity of 3.28±0.28 which is significantly (P<0.05) higher than that of *ukpo*-CY (2.93±0.20) and *achi*-CY blend (2.82±0.78) at 95% confidence level. Such differences in swelling index could be attributed to varying granular association coupled with the amylase-amylopectin ratio of starches from the various flours (Iwuoha, 2004). While the report of Leach et al. (1959) agrees that amylase acts both as diluents and inhibitor of swelling, that of Moorthy and Ramanujam (1986) added that swelling index of starch is a reflection of the extent of associative forces within the granules, meaning, the higher the swelling index of a given material, the lower the associative forces, and vice versa. And so, lower swelling power as witnessed in the *achi*-CY flour blend and that of *ukpo*-CY blend is indicative of the existence of a more highly ordered arrangement in their granules relative to that of *ofo*-CY blend. This could be attributed to the fact that the *ofo*-CY blend had more of intermolecular carbohydrates bound (Chukwu et al., 2018b) which allowed it to absorb more water to swell than the other samples (Adebowale and Maliki, 2011).

Regarding the components of BR factor (Table 5), significant differences (P≤0.05) does not exist among the mean values of the swelling abilities of the material. This implies that the various blending ratios of ITS-CY do not constitute a critical determinant to the swelling ability of the flour sample. However, the 75% CY sample blend showed the highest swelling index of 3.12±0.53, followed by the 25% CY blend (3.06±0.59), 50% CY (3.01±0.56), Control (2.97±0.67) and lastly, 100% CY blend (2.90±0.00).

Water Absorption Capacity (WAC)

The results presented in Tables 3, 4 and 5 show that each

Table 5. Mean values of functional properties of the resultant flour blends of local thickening seeds and cocoyam as affected by blending ratios.

Blend Ratios, BR (CY:ITS)	Parameters		
	SI	WAC (ml/g)	OAC (ml/g)
0:100*	2.97±0.67[ab]	4.77±1.80[ab]	1.24± 0.28[c]
25:75	3.06±0.59[ab]	5.07 ± 0.62[a]	1.30 ±0.22[bc]
50:50	3.01±0.56[ab]	4.33± 0.84[bc]	1.28± 0.32[bc]
75:25	3.12±0.53[a]	4.22±0.55[c]	1.52± 0.31[ab]
100:0	2.90±0.00[b]	2.40± 0.00[d]	1.59± 0.00[a]
LSD	0.251	0.4426	0.2233

Mean values with the same superscripts within the column are not significantly different from each other while mean values with different superscripts along the same column are significantly different from each other at (P<0.05). BR = Blending Ratio; CY = Cocoyam; SI = Swelling Index; WAC = Water Absorption Capacity; OAC = Oil Absorption Capacity; $LSD_{0.05}$ = Least Significant Difference at 95% confidence level; *0:100 = Control.

of the TT, BT and BR factors constitute critical determinant for the water absorption capacity of flours of cocoyam blend with the local thickening seeds of *achi*, *ofo* and *ukpo*.

Making comparison on the components of each factor, the results showed that with respect to TT, flour of the boiled sample had the highest WAC of 4.56±1.58 ml/g, followed by that of the raw sample (4.28±1.78 ml/g), steamed (3.89±1.24 ml/g) and roasted (3.89±1.20 ml/g). The greater WAC witnessed in the boiled sample complements what was reported in its swelling ability. Such high swelling and absorption capacity could be due to the heat treatment, which according to Onuegbu et al. (2013) increases the cellular water uptake of the flour sample.

Among the components of the BT factor, flour of *ofo*-CY had the highest WAC (5.10±1.77ml/g), followed by that of *ukpo*-CY (4.17±1.06ml/g) and *achi*-CY (3.20±0.82ml/g). These differences, according to Bell-Perez et al (2002) could be attributed to the difference in amylose-amylopectin ratio as well as difference in their chain length distribution. Loose association of the starch polymers, as reported by Ekwu et al (2005) could also bring about the high WAC that was witnessed in the *ofo*-CY flour sample. Also, WAC varied significantly because the water binding sites present on side chain groups of protein were blocked in the lipophilic environment (Appiah et al., 2011; Ogunbusola et al., 2012; Chukwu et al., 2018b). The significant variation in the WAC of the BT samples was due to less availability of polar amino acids. Hence, blending type caused the variation in the WAC of the resultant flours as well as makes it suitable for soup thickening (Omobolanle et al., 2015).

Among the components of the BR factor, flour of the 25% CY blend (5.07±0.62 ml/g) is significantly higher (P<0.05) than the others. This is followed by that of the Control (4.77±1.80 ml/g), 50% CY blend (4.33±0.84 ml/g), 75% CY blend (4.22±0.55 ml/g), and lastly, 100% CY blend (2.40±0.00ml/g). Such differences as observed here could be explained in terms of the differences in the degree of association of starch granules in them (Soni et al., 1985).

Ability to absorb water is a very important property of all flours and starches that are used in food formulations (Ikegwu et al., 2010). Water absorption capacity (WAC) is no doubt very important in the development of ready-to-eat foods, as high absorption capacity as witnessed in boiled sample (among the TT factor), *ofo*-CY (among the BT factor) and 25% CY blend (among BR factor) may assure product cohesiveness (Housson and Ayenor, 2002).

Oil Absorption Capacity, (OAC)

The Oil Absorption Capacity (OAC) of the resultant flour blend of cocoyam and local thickening seeds (*achi*, *ofo* and *ukpo*), as affected by pre-milling heat treatments sand blending ratios, ranged from 1.26 to 1.45 ml/g for the TT factor, 1.35 to 1.41 ml/g for the BT factor, and 1.24 to 1.59 ml/g for the BR factor. Table 3, 4 and 5 show that variations in OAC were caused by the two factors (TT and BT) are not significant (P<0.05), while that caused by the BR factor is quite significant (P<0.05). This implies that each of those two factors does not constitute critical determinant for the OAC of sample materials, except for the BR factor.

Among the TT factor, flour of the roasted sample gave the highest OAC value of 1.45±0.33ml/g, followed by that of the raw sample (1.44±0.29 ml/g), boiled (1.39±0.23ml/g) and steamed (1.26±0.27ml/g). Among the components of the BT factor, flour of the *ukpo*-CY sample is relatively (but not significantly (P<0.05) higher (1.41±0.21 ml/g) than that of *ofo*-CY (1.40±0.23 ml/g) and *achi*-CY blend (1.35±0.39 ml/g).

Regarding components of the BR factor, flour of the 100% CY blend (1.59±0.00 ml/g) is significantly higher (P<0.05) that the others, except for the 75% CY sample (1.52±0.31 ml/g) where there exists statistical equilibrium among its mean values. That of the 25% CY blend had an OAC value of 1.30±0.22 ml/g, followed by the 50% CY sample (1.28±0.32 ml/g) and lastly, the Control sample (1.24±0.28 ml/g). Such differences as witnessed in their (that is, the components of the TT, BT and BR) abilities/capacities to absorb oil can be explained by the nature of their starch structure. This could be the exposure of oil binding sites present on the side chain groups of proteins in a lipophilic environment (Ogunbusola et al., 2012). This property of thickener could enhance emulsion in soup preparation.

Conclusion

The result of this study shown the possibility of blending flours of pre-treated indigenous seeds with cocoyam flour in varying ratios, and their possible effects on the functional properties of flours from such blends. From the study, it was observed that heat treatments (boiling, steaming and roasting of *achi*, *ofo* and *ukpo*) have significant effects on the functional characteristics of the resultant flour blends of indigenous thickening seeds and cocoyam. Here, boiled sample exhibited better functional properties than steamed, roasted and raw samples. Regarding Blend Types, the study showed that *ofo*-CY exhibited better functional properties than *ukpo*-CY and *achi*-CY blends. Among the blending ratios, the 25% CY flour sample exhibited better functional properties than other samples.

Recommendation

This research, however, reveals that subjecting the selected indigenous thickening seeds to pre-heat treatments increases their functionalities, as well as blending their resultant flours with cocoyam flour in varying ratios. It is suggested, therefore, that heat treatments within the conditions of this study, especially, boiling should be given to *achi*, *ofo* and *ukpo* prior to use. The study also suggests the blends of *ofo*-CY, regarding the blending ratios of these thickeners with the cocoyam flour; the study also suggests the blend with 25% cocoyam flour.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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