Full Paper

ASSESSMENT OF THE ANTINUTRIENTS, FUNCTIONAL AND PHYSICOCHEMICAL PROPERTIES OF ACHA (DIGITARIA EXILIS) FLOUR AND KARIYA (HILDERGARDIA BARTERI) PROTEIN CONCENTRATE BLENDS

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ABSTRACT

This study was aimed at producing and assessing the quality of blends from acha and *kariya* protein concentrate. The acha was processed to flour and *kariya* was subjected to various treatments before it was used for production of protein concentrate flour. The flours were formulated to produce blends; ASD-(100% *Acha*), ACD-(80% *Acha* + 20% Kariya protein concentrate) and ACD- (80% *Acha* + 20% raw kariya flour). The flours and the blends were subjected to proximate composition, minerals, functional and pasting properties, and anti-nutrients properties assessments using standard methods. The results showed that the anti-nutrient (oxalate, tannin and saponnin) contents of kariya reduced after various processing methods (soaking, cooking, and defattening). The bulk density ranged between 0.55 and 0.74g/ml, water absorption capacity (100.00 – 220.00%) and reconstitution index (52.00 – 92.67%). The protein, calcium, potassium, and zinc increased with the supplementation with kariya. The samples AED and ASD have higher values of the pasting parameters. The study concluded that the selected processes reduced the anti-nutrients and the inclusion of *kariya* protein concentrate improved the proximate composition of the blends.

Keywords: pasting properties, potassium, soaking; tannin

1. INTRODUCTION

Acha (fonio), a tropical millet native to West Africa, one of the oldest African cereals and one of the most nutritious of all grains (NRC, 1996); rich in methionine and cysteine; amino acids vital to human health and deficient in today's major cereals (Jideani, 1991); has the advantage to be minimally processed which limited the loss of the native nutritional value during milling (NRC, 1996). Acha, whose use is mainly limited to traditional foods such as thick and thin porridges, steam cooked products (e.g., Couscous), and alcoholic and non-alcoholic beverages (Jideani, 1991); can be used as cereal-based foods of low dietary bulk and high calorie density. Such cereal-based food preparation worth investigating.

Enrichment of cereal-based food with other protein source such as legumes, oilseeds, etc. have received considerable attention since investigations have revealed that cereals are deficient in lysine and tryptophan but have sufficient sulphur- containing amino acids which are limiting in legumes (Ikujenlola *et al.*, 2017). In view of these nutritional problems, quite a number of studies have investigated ways of formulating quality cereal-based foods through a combination of available plant based foods to meet the nutritional demands of infants of weaning age (Ikujenlola and Fashakin, 2005; Anuonye *et al.*, 2010; Olapade and Aworh, 2012; Ugwuona *et al.*, 2012; Ijarotimi and Keshinro, 2013; Ikujenlola, 2014; Abiose *et al.*, 2015; Ikujenlola *et al.*, 2017).

Despite all these interventions, it is quite evident that the objective of these efforts which was to develop low-cost foods is still far from being met as many of these products were still not accessible to poor families and therefore has little impact on the prevalence of child malnutrition (Dewey and Brown, 2003). As a means of addressing this problem, the present study is focused on the utilization of locally available nutritious food materials acha and kariya protein concentrate to develop adequate and low-cost cereal-based foods.

Kariya (*Hildegardia barteri)*, primarily an ornamental tree in West Africa whose flowers, which are usually borne on leafless branches, mature into one-seeded pods (Hildergadia Notes, 2007).

The mature pods drop completely when dry and are disposed as refuse in many places, only in few parts of West Africa the kernels are eaten raw or roasted like peanuts (Adebayo *et al.*, 2013), or used as condiments in traditional food preparations. The essential amino acid pattern as reported by Inglett *et al.* (1973) showed that the seeds are high in lysine; therefore, the use of the meal along with the cereal grain would be beneficial in improving the amino acid balance. The use of this seed in cereal-based food production has not been widely reported. This study has the aim of utilizing the two lesser utilized seeds in the formulation of cereal-based food blends with a view to knowing the chemical composition and other quality parameters.

2. MATERIALS AND METHODS

2.1. Materials

Acha grains were purchased from Abuja central market, Abuja. Dried *kariya* pods were gathered from ornamental *kariya* trees in Obafemi Awolowo University, Ile-Ife, Nigeria.

2.2. Methods

2.2.1. Production of Acha Flour

The acha grains were weighed, washed thoroughly to remove dirt and other extraneous materials, sieved, oven dried and milled into flours (Ikujenlola, 2014).

2.2.2. Production of Defatted Fermented Kariya Flour

Dispersed Kariya pods were collected and sorted. The nuts extracted from the pods were sorted to remove extraneous materials such as stones and leaves. The kernels were obtained by shelling the nuts manually which were then cleaned to remove chaff, broken, shriveled and immature kernels. The cleaned *Kariya* kernels were soaked for 24 h, cooked for 30 min, drained and allowed to ferment (in a calabash lined with clean plantain leaves at ambient temperature) for a period of 4 days followed by oven-drying at 60 °C. The dried fermented seeds were comminuted using mortar and pestle to obtain coarse flour. The coarse flour obtained was then ground using Marlex Excella grinder (Marlex Appliances PVT., Daman) and sieved through 200 µm sieve. The resulting flour was defatted using soxhlet extraction method to remove the fats from the seeds to obtain defatted flour (defatted fermented kariya flour). The defatted flour was desolventized by drying in a fume hood and the dried flour was finally ground in a Marlex Excella grinder (Marlex Appliances PVT., Daman) to obtain homogenous defatted flour (Gbadamosi *et al*,. 2012)

2.2.3. Production of Protein Concentrate

Kariya protein concentrate was produced according to the method described by Cheftel *et al.* (1985) and reported by Ikujenlola *et al*. (2017).

2.2.4. Formulation of the Blends

The blends were formulated with a target protein of 20% in accordance to the recommendation of the WHO (PAG, 1971; FAO/WHO/UN, 1991). ASD was formulated to contain 100% Acha; ARD (80% Acha: 20% Raw Kariya Flour); ACD (80% Acha: 20% Kariya protein concentrate).

2.2.5. Production of the Diets

The blends were mixed and pre-gelatinized by cooking for 10 min. The pre- gelatinized blend was dried in an oven at 110 °C for 12 h and milled using attrition mill (Ikujenlola and Adurotoye, 2014).

2.3. Chemical Analyses

2.3.1. Determination of Anti-nutrients of Kariya Flour and Formulated Blends

The anti-nutrient contents of the *kariya* flour samples at different processing steps and the formulated complementary diets were determined using standard methods. The oxalate, tannin and saponin contents were determined using the methods of Falade *et al*. (2004), Price *et al*. (1978), Brunner (1984) respectively.

2.3.2. Determination of Functional Properties of the Blends

The functional properties determined include bulk density, water absorption and oil absorption capacities and reconstitution index using the methods of Okezie and Bello (1988), AACC (1995), Beuchat (1977) and Iombor *et al*. (2009) respectively.

2.3.3. Determination of Proximate Composition of Blends

The proximate composition (protein, fat, ash, moisture and crude fibre) of the blends was determined in triplicate using the standard procedures of Association of Official Analytical Chemists - AOAC (2005). Five grams of each formulated sample were used to determine the moisture content in a hot-air oven (Gallenkamp). Ash was determined by incineration of 2 grams each of the food samples in a Gallenkamp muffle furnace at 550 ºC (Gallenkamp, size 3) (Method No 930.05) (AOAC, 2005). Crude fat was determined by exhaustively extracting 5 grams of each sample in n-hexane in a Soxhlet extractor (Method No 930. 09). Protein (N × 6.25) was determined by the Kjeldhal method (Method No 978.04) using 0.2 gram each of the formulated samples (AOAC, 2005). Crude fibre was determined after digesting 5 grams each of fat-free samples with 1.25% sulphuric acid and 1.25% sodium hydroxide (Method No 930.10) (AOAC, 2005).

The carbohydrate content was determined by subtracting the summed up percentage compositions of moisture, protein, fat, crude fibre, and ash contents from 100 g of the sample [100% - (% moisture + % protein + % fat + % crude fibre + % ash)].

Energy was determined by using the Atwater's conversion factor; 4.0 kcal/g for protein, 9.0 kcal/g fat and 4.0 kcal/g for carbohydrate (Iombor *et al*., 2009).

2.3.4. Pasting Characteristics of the Formulated Blends

The pasting characteristics of the blends were determined using Rapid Visco Analyser (Newport Scientific Pty Ltd. Warriewood NSW 2120, Australia) connected to a computer (PC) with window operating system via a USB port. The moisture content of the sample was first determined to obtain the correct sample weight and amount of water required for the test. An aqueous suspension of sample was then made and spun at 75 rpm. The temperature-time conditions included a heating step from 30 °C to 95 °C at 6 °C/min (after an equilibration time of 1 min at 30 °C), a holding phase at 95 °C for 5 min, a cooling step from 95 °C to 30 °C for 2 min. Readings were displayed on the monitor in a numerical and graphical form. Viscosities are expressed in rapid viscosity units (RVU).

2.3.5. Determination of Minerals of the Formulated Blends

The determination of selected mineral elements was carried out by atomic absorption spectrophotometry method (AOAC, 2005). The formulated sample (0.5 g) was weighed into 75 ml digestion flask and 5 ml digestion mixture was added and left overnight in a hood. It was then digested for 2 hours at 150 °C, then left to cool for 10 min. About 3 ml of 6M Hydrochloric acid was added and digested for another one and half-hours. It was cooled and 30 ml of distilled water was added. The tube was vigorously stirred. A sample aliquot was then transferred to the Autoanalyser (Technicon AAU model) for total mineral analysis at 420 nm. The left over digest was used to determine the other elements (calcium, iron and zinc) on the Atomic Absorption Spectrophotometer (Perkin Elmer, model 402) while sodium and potassium were determined using flame photometer.

3. RESULTS AND DISCUSSION

3.1. Effect of processing on anti-nutritional properties of *kariya* seeds flours and protein concentrates

The results of anti-nutritional factors (oxalate, tannin and saponnin) of processed *Kariya* seed flours and protein concentrates are presented in Table 1. The oxalate content ranged from 3.73 to 8.94 mg/100g with raw *kariya* flour (RKF) having the highest and *kariya* protein concentrate (KPF) the lowest; tannin content ranged from 1.68 to 4.89 mg/`100 g; and saponnin ranged from 0.103 to 0.189 mg/ 100g. It was observed that the various processes (defatting, soaking, cooking and fermentation) to which the seeds were subjected reduced the level of the anti nutrients. There were significant differences ($p \leq 0.05$) in the values obtained for the processed samples. The levels of the anti-nutrients in these samples were in the following order: KPF< GKF< BKF< SKF< RKF. These results agree with the works of Fowomola and Akindahunsi (2008); and Ibukun and Anyasi (2012) that fermentation and other processing methods like soaking and cooking significantly reduce the levels of anti-nutrients (tannin, saponin and oxalate) present in sandbox and sesame flours respectively. Fasoyiro (2006) reported that soaking reduce anti- nutrients by leaching the toxic components in the soak water. These antinutrients have been reported to affect nutritive value of food products by chelating metals such as iron and zinc and reduce the absorption of these nutrients (Gbadamosi and Famuwagun (2016)). The levels of antinutrients in the flour samples were within the recommended tolerable (safe) levels for man (12 mg, 1.5 mg and 100 mg /100g, for oxalate, tannin and saponin respectively) (Health and Safety Publications, 2011).

Table 1: Antinutrient Content of processed Kariya seeds flour (mg/100g)

Samples	Oxalate	Tannin	Saponnin
RKF	8.94±0.05^{a}	4.89±0.07^{a}	0.189±0.006^{a}
SKF	5.05±0.05^{b}	3.86±0.03^{b}	0.148±0.004^{b}
AKF	4.47±0.04^{c}	2.26±0.14^{c}	0.134±0.002^{c}
BKF	3.91±0.02^{d}	1.88±0.01^{d}	0.116±0.001^{d}
GKF	3.86±0.02^{e}	1.83±0.07^{e}	0.110±0.002^{e}
KPF	3.73±0.01^{f}	1.68±0.07^{f}	0.103±0.002^{f}

Mean values in the same column followed by different superscripts are significantly different at $p \leq 0.05$.

RKF: *Raw Kariya Flour;* ***SKF***: *Soaked Kariya Flour;* ***AKF***: *Soaked, Cooked Kariya Flour;* ***BKF***: *Soaked, Cooked, Fermented Kariya Flour;* ***GKF***: *Soaked Cooked Fermented Defatted Kariya Flour;* ***KPF***: *Kariya Protein Concentrate*

3.2. Functional properties of the formulated blends

The functional properties of the formulated blends are presented in Table 2. The bulk density of the formulated blends ranged from 0.73-0.74 g/ml. The bulk densities of the formulated blends from *kariya* base were not significantly different ($P > 0.05$) from each other but differed significantly from the control (0.55 g/ml) ($P < 0.05$).

Table 2: Functional Properties of the Formulated Blends

Sample	Bulk density(g/ml)	Water absorption capacity (%)	Oil absorption capacity (%)	Reconstitution (%)
ACD	0.74±0.01^{a}	130.00±1.00^{b}	110.00±10.00^{b}	61.00±1.73^{c}
AED	0.55±0.01^{b}	220.00±10.00^{a}	150.00±10.00^{a}	92.67±3.06^{a}
ARD	0.73±0.02^{a}	100.00±10.00^{c}	80.00±10.00^{c}	52.00±2.00^{d}
ASD	0.74±0.01^{a}	110.00±100^{c}	100.00±10.00^{b}	70.33±1.53^{b}

Mean values in the same column followed by different superscripts are significantly different at $p \leq 0.05$

ACD: *80% Acha + 20% Kariya Protein Concentrate;* ***AED***: *Commercial Diet (Control);*

ARD: *80% Acha + 20% Raw Kariya;* ***ASD***: *100% Acha*

According to Nelson-Quartey *et al.* (2007) low bulk density flours are desirable in cereal-based food preparation where high nutrient density to low bulk density is desired. Nutritionally, low bulk density promotes easy digestibility of food products, particularly among children with immature digestive system (Osundahunsi and Aworh, 2002). The bulk density values obtained compared favourably with those reported for unmalted acha blends (0.65-075 g/ml) by Ikujenlola (2014). The bulk density is generally affected by the particle size and true density of the matter in flour.

Water absorption capacities of the samples ranged from 100.00 (ARD) to 220.00% (control). The significance of a lower water absorption capacity of the diets is to lower binding capacity which is desirable for producing thin gruels with high caloric density per unit volume for children. Gruels of low water absorption capacity will allow addition of more solid; this will invariably increase the level of nutrients per total solid. This observation is in agreement with the report El Khalifa *et al.*, (2005) on water absorption capacity of fermented sorghum.

The oil absorption capacities of the samples ranged from 80.00-150.00%. ARD has the lowest oil absorption capacity (80.00%) while control sample has the highest oil absorption capacity (150.00%). OAC indicates the ability of a flour to retain flavour and improve mouthfeel (Kinsella, 1976). OAC has been attributed to be due to physical entrapment of oil and the binding of fat to the polar chains of protein. Omueti *et al.* (2009) reported that more hydrophobic proteins show superior binding of lipids, this implies that non-polar amino acids side chains bind the paraffin chains of fat. Based on this report, the lower OAC of ARD may be due to the fact that some of formulated blends (with higher OAC) had their hydrophobic amino acids exposed for lipid binding than the ARD. This implies that ACD, ASD and the control diet will be able to retain more flavour and have better mouthfeel.

The reconstitution index of the formulated blends ranged between 52.00 and 92.67%. The products reconstituted well in hot water and formed gruels of homogeneous consistency. The ability of the samples to absorb water and remain suspended could be responsible for the observed differences among the samples.

3.3. Proximate Composition of the Formulated Blends

The proximate composition of the various formulated sample produced from the blends of acha flour and kariya protein concentrate/raw kariya flour as well as that of the control is presented in Table 3. The crude protein content of the products ranged between 7.73 for ASD (100% acha) and 19.26% for ACD (80% acha flour + 20% kariya protein concentrate). There was significant difference (P≤0.05) between the protein content of the formulated blends and the control sample (commercial cereal-based food) (15.30%). ACD had higher protein than the control indicating that it is capable of meeting the dietary protein requirement of infants.

Table 3: Proximate Composition of Formulated Blends (%)

Parameter	ACD	AED	ARD	ASD	PAG(1971)	SON(1988)
Protein	19.26±0.02^{a}	15.30±0.30^{b}	11.82±0.02^{c}	7.73±0.13^{d}	20(min)	14-17
Fat	9.23±0.03^{b}	9.33±0.31^{b}	44.00±0.25^{a}	4.80±0.20^{c}	10(max)	10(max)
Crude Fibre	0.47±0.06^{c}	1.80±0.20^{a}	1.40±0.20^{b}	0.23±0.03^{cd}	5(max)	5(max)
Ash	0.80±0.10^{c}	3.00±0.20^{a}	1.53±0.25^{b}	0.53±0.06^{cd}	5-10	5
Moisture	5.40±0.46^{c}	5.40±0.20^{c}	6.00±0.10^{b}	7.93±0.15^{a}	5-10(max)	5-10(max)
Carbohydrate	64.84±0.39^{b}	65.17±0.40^{b}	35.25±0.12^{c}	78.77±0.21^{a}	-	-
Energy(kcal)	419.50±1.77^{b}	405.87±2.31^{c}	584.27±2.30^{a}	389.20±1.59^{d}	400	350-400

Mean values in the same roll followed by different superscripts are significantly different at p≤ 0.05
ACD: 80% Acha + 20% Kariya Protein Concentrate; **AED**: Commercial Diet (Control); **ARD**: 80% Acha + 20% Raw Kariya; **ASD**: 100% Acha

There were significant improvements in the protein status of acha flours supplemented with *Kariya* protein concentrate and raw *kariya* flour. This finding confirms earlier reports on the beneficial effect of vegetable protein supplementation because the protein content compared favourably with the results of Ikujenlola (2014) and Olapade and Aworh (2012) who produced blends from malted and unmalted acha, soybean and defatted sesame flours (7.68 – 21.68 %); and extruded acha with cowpea (16.5 – 20.30%) respectively. Complementation could help improve the quality of cereal-based foods fed to children in developing countries (Ibeanu, 2009). The use of only acha as cereal-based food for infants cannot support the fast growing infant; this call for supplementation as also observed by Jideani and Jideani (2011).

The fat content of the blends ranged between 4.80 and 44.00%. ARD (20% Acha + 80% raw kariya) has the highest fat content. There was no significance difference (p>0.05) between the ACD and the control in terms of fat content. Fat add more calories to the blends. This is in-line with FAO/WHO/UN (1991) recommendation that vegetable oils be included in foods meant for infants and children in order to increase the energy densities as well as serve as vehicle for fat soluble vitamins. However, according to Ibeanu (2009) fat makes food difficult to digest and impair its keeping quality. The high fat content in ARD confirms the previous report that *kariya* is high in oil content (40.37%) (Adebayo *et al.*, 2013).

The ash content of the formulated blends ranged between 0.53 for ASD and 1.53% for ARD. The ash content determines the level of the mineral composition of the products. The ash content of the formulated blends was lower than the recommended value by SON (1988) for complementary diet which is 5%.

The crude fibre contents of the formulated blends ranged between 0.23% and 1.40%. The values obtained were significantly different (p<0.05) from the control; but within the recommended value of 5% for crude fibre content by PAG (1971); SON (1988); FAO/WHO (1991). The observed low fibre content of these formulated blends would enable the children to consume more of the food samples; thereby giving the children greater opportunity to meet their daily energy and other vital nutrients requirements (Ijarotimi and Keshinro, 2013).

The moisture content of the blends was between 5.40 and 7.93%. The low moisture content in the formulated blends is required for convenient packaging and transport of products (Nelson-Quartey *et al.*, 2007). The difference in moisture content may be attributed to the differences in the efficiency of drying techniques used in the control. However, values were still within the recommended moisture content of 5-10% recommended by PAG (1971) and SON (1988). These results agreed with the earlier report of Ugwuona *et al.* (2012) who worked on similar cereal-based foods. Low water activity inhibits the growth and proliferation of micro-organism, thereby extending the keeping quality of the product (Ikujenlola, 2014).

The carbohydrate content of the blends ranged between 35.22 and 78.77%. The carbohydrate value of the control was 65.17%. The ASD (100% acha) had the highest value of 78.77% while ARD had the lowest value of 35.22%. It was observed that addition of raw kariya flour and protein concentrate to the acha flour reduced the carbohydrate content of the blends. Carbohydrate is required by human for the supply of energy. The deficiency of it will prevent protein from performing its primary function of growth and development to provision of energy.

The calories in cereal-based foods are provided by protein, fat and carbohydrate. The energy value of the samples varied from 389.20 in ASD to 584.25 kcal in ARD. These values compared favourably with that of the control (405.87 kcal). FAO/WHO (1991) and SON (1988) recommends a range of 400 to 435 and 350 to 400 kcal/100g respectively. The FAO/WHO (1985) has recommended that foods fed to infants should be energy dense, this is necessary for infant to satisfactorily carry out both voluntary and involuntary actions of the body.

3.4. Anti-nutrients Properties of the Formulated Blends

The results of anti-nutritional factors (oxalate, tannin and saponin) of the formulated blends are as presented in Table 4. To this end various processes have been adopted to reduce the levels and effects of the anti-nutritional factors. The results showed that values for the anti-nutrients of the blends ranged from 2.30 to 5.00, 1.55 to 1.98 and 0.027 to 0.817 mg/100g for oxalate, tannin and saponnin respectively and these values were significantly different (p≤0.05) from one another. These results showed that the levels of these anti-nutrients (oxalate, tannin and saponnin) were highest in ARD and the lowest values were observed in sample ASD. The significant reduction in the levels of the anti-nutrient in ACD compared to ARD could be attributed to the combination of processes (soaking, cooking, fermentation, defatting and protein concentration) used in the preparation of the Kariya protein concentrate before blending to acha flour.

These results were comparably lower than the work of Anuonye *et al.* (2010) that extrusion cooking significantly reduces anti-nutrients (tannins, saponins and oxalate) present in acha/soybean blends.

Tannins have been reported to affect nutritive value of food products by chelating metals such as iron and zinc and reduce the absorption of these nutrients and also forming complex with proteins (Weiwen and Michael, 2005).

These results also showed that the level of saponnin content was almost insignificant in all the formulated blends; though ARD still had the highest value and ASD had the lowest value. Saponins have been found to cause haemolytic activity by reacting with the sterols of erythrocyte membrane. The results of this study showed that there was only a trace amount of saponins in the formulated blends (Gbadamosi and Famuwagun, 2016).

Table 4: Antinutrient Content of the Formulated Blends (mg/100g)

Sample	Oxalate	Tannin	Saponnin
ACD	$3.03±0.04^b$	$1.61±0.02^b$	$0.153±0.007^b$
AED	$2.50±0.02^c$	$1.30±0.11^c$	$0.077±0.489^c$
ARD	$5.00±0.04^a$	$1.98±0.14^a$	$0.817±0.071^a$
ASD	$2.30±0.03^d$	$1.55±0.04^b$	$0.027±0.006^c$

Mean values in the same column followed by different superscripts are significantly different at p≤ 0.05

***ACD**: 80% Acha + 20% Kariya Protein Concentrate; **AED**: Commercial Diet (Control);*

***ARD**: 80% Acha + 20% Raw Kariya; **ASD**: 100% Acha*

According to Annan and Plahar (1995) oxalates in large amount binds with minerals like calcium and magnesium forming calcium oxalate, which is insoluble and was not absorbed by the body; hence, interfere with their metabolism, which leads to muscular weakness and paralysis. Boiling can reduce the soluble oxalate content of a food, if the water used for the boiling is discarded because it may cause considerable skin (epidermal) rupture and facilitate the leakage of soluble oxalate into cooking water (Ibukun and Anyasi, 2012).

Processing the raw kariya flour to kariya protein concentrate flour before blending with acha favoured reductions in the anti-nutrients. This was probably due to dilution effects. The concentrations of oxalate, tannins and saponnin in this study were reduced to tolerable levels to avoid any form of detrimental effects for man (12 mg, 1.5 mg and 100 mg /100g, for oxalate, tannin and saponin, respectively) (Health and Safety Publications, 2011). This indicates that the food products could be utilized effectively since the anti-nutritional compositions has been reduced and there would be no interference with the nutrient like protein and minerals in the food samples.

3.5. Pasting Properties of the Formulated Blends

Table 5 shows the pasting characteristics of the formulated blends and control using the computerized Rapid Visco Analyser. When starch-based foods are heated in an aqueous environment, they undergo series of changes known as gelatinization and pasting. These are two of the most important properties that influence quality and aesthetic considerations in the food industry, since they affect texture and digestibility as well as the end use of starchy foods (Adebowale *et al.*, 2005).

Table 5: Pasting properties of the formulated blends

Sample	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Set back (RVU)	Peak Time (min)	Pasting Temperature (^{0}C)
ASD	140.42	97.08	43.33	186.92	89.83	5.61	83.70
ARD	68.29	65.71	2.59	96.54	30.54	5.27	83.75
ACD	65.26	59.75	5.50	101.04	41.29	5.39	83.94
AED	181.84	128.92	45.50	234.08	74.99	5.60	82.95

Mean values in the same column followed by different superscripts are significantly different at p≤ 0.05

ASD: 100% Acha; **ARD**: 80% Acha + 20% Raw Kariya; **ACD**: 80% Acha + 20% Kariya Protein Concentrate; **AED**: Commercial Diet (Control)

Peak viscosity, which is the ability of starch to swell freely before their physical breakdown; ranged from 65.25 to 140.42 RVU (Table 5). ASD had the highest peak viscosity of 140.42 RVU, ACD had the lowest value of 65.25 RVU and the control was 181.84 RVU. High peak viscosity is an indication of high starch content and is related to the water binding capacity of starch (Adebowale *et al.*, 2005). The relative high peak viscosity of ASD might be related to the proportion of starch in the blend, the ratio of amylose to amylopectin and the resistance of the starch granules to swelling (Jideani and Jideani, 2011). The presence of other non-starchy constituents in the other blends may be a contributory factor to the low peak viscosity observed. Low peak viscosities of the cereal-based foods imply that the foods will form a low viscous pastes rather than a thick gel on cooking and cooling (Otegbayo *et al.*, 2006). This means that the gruel was a high caloric density food per unit volume (Desikachar, 1980) rather than a dietary bulk (high volume/high viscosity) (Ikujenlola and Fashakin, 2005).

The trough is the minimum viscosity value in the constant temperature phase of rapid visco analysis profile and measures the ability of paste to withstand breakdown during cooling. It ranged between 59.75 and 97.08 RVU. ASD had the highest trough value of 97.08 RVU and ACD the lowest value of 59.75 RVU. The control had the highest trough value of 128.92 RVU.

The breakdown viscosity ranged from 2.59 to 45.50 RVU. ASD had the highest breakdown viscosity (43.33 RVU) while ARD had the lowest (2.59 RVU). The breakdown viscosity of ASD (43.33 RVU) compared favourably with that of the control (45.50 RVU). The breakdown viscosity value is an index of the stability of starch (Otegbayo *et al.*, 2006). The higher the breakdown in viscosity, the lower the ability of sample to withstand heating and shearing stress during cooking (Adebowale *et al*, 2005). The result obtained implied that both the control and ASD are more stable to heat and mechanical shear than the other blends. The final viscosity is the changed in the viscosity after holding cooked starch at 50^{0}C ranged from 98.54 to 186.92 RVU. Final viscosity indicates the ability of the material to form a viscous paste after cooking and cooling as well as the resistance of the paste to shear force during stirring (Adeyemi and Idowu, 1990). The result of the final viscosity of the blends suggested that the proportion of starch and by extension the amylose content of the other blends are considerably lower than that of ASD and the control.

Setback viscosity of ASD was the highest with the value of 89.83 RVU and ARD had the lowest value of 30.54 RVU. The low setback value of the formulated blends indicates that the blends on cooking will not be cohesive gruels. Since setback values indicates the tendency of paste to undergo retrogradation, the higher the setback value, the lower the retrogradation during cooling of the products (Adebowale *et al.*, 2005). Setback also has a serious implication on the digestibility of starch pastes when consumed (Sanni *et al*, 2004). Higher setback values may result in reduced paste digestibility.

The peak time is a measure of cooking time of the foods. It ranged between 5.27 and 5.61 minutes. The ASD had the highest while ARD the lowest. It is the temperature at which the first detectable increase in viscosity is measured and is an index characterized by the initial change due to the swelling in starch (Otegbayo *et al*., 2006).

The pasting temperature provides an indication of the minimum temperature required to cook a given sample and also indicate energy costs. A higher pasting temperature implies higher water binding capacity, higher gelatinization and lower swelling property of starch due to a high degree of association between starch granules (Sanni *et al*., 2004). The pasting temperatures of the formulated blends ranged from 83.70 to 83.94 °C; higher than the pasting temperature of the control diet (82.95 °C). The pasting temperatures values of the blends were higher than the gelatinization temperature of 70.5 °C reported for Ogi (fermented corn) flour by Oluwamukomi et al., (2005).

3.6. Mineral contents of the complementary blends

Minerals are important components of diets because of their physiological and metabolic function in the body. Table 6 shows the mineral element contents of the formulated blends. Calcium is an important mineral required for bone formulation and neurological function of the body. The calcium content of the formulated blends ranged from 22.60 – 31.20 mg/100g.

ARD had the highest value of calcium content (31.20 mg/100 g) while ASD has the lowest (22.60 mg/100 g). The inclusion of *Kariya* tends to improve the calcium content of the formulated blends; however, the values were significantly lower ($p \leq 0.05$) than the control. The increase in the calcium content of the blends agrees with the reports of Ugwuona *et al.* (2012) and Anuonye *et al.* (2010) who worked on soy-acha mixes and extruded acha blends respectively.

Table 6: Mineral Content of the Blends (mg/100g)

Sample	Calcium	Iron	Zinc	Potassium	Sodium
ACD	27.60±0.60^{c}	4.52±0.70^{b}	3.54±0.15^{b}	40.00±0.69^{d}	81.60±0.36^{d}
AED	280.40±1.23^{a}	6.28±0.30^{a}	6.03±0.64^{a}	962.40±1.58^{b}	132.20±0.31^{c}
ARD	31.20±0.61^{b}	0.24±0.45^{d}	2.45±0.37^{c}	497.20±1.09^{c}	144.40±1.57^{b}
ASD	22.60±1.01^{cd}	2.76±0.84^{c}	2.08±0.29^{d}	973.20±0.62^{a}	146.40±1.24^{a}

Mean values in the same column followed by different superscripts are significantly different at $p \geq 0.05$

ACD: *80% Acha + 20% Kariya Protein Concentrate;* ***AED***: *Commercial Diet;*

ARD: *80% Acha + 20% Raw Kariya;* ***ASD***: *100% Acha*

The iron content of the formulated blends ranged between 0.24 (ARD) and 4.52 mg/100 g (ACD). The iron content of the control (6.03 mg/100 g) was higher than those of all the formulated blends. All the formulated blends except ACD (which is slightly lower) had the iron concentrations below the minimum amount (4.8 mg/100 g) specified in the Codex Alimentarius Standards (FAO/WHO, 1991). The values obtained were higher than 3.60 mg/100 g obtained for iron content of extruded acha blends by Anuonye *et al.* (2010). Iron is essential in the formation of the protein heamoglobin, which carries oxygen throughout the body in red blood cells, and myoglobin, which transports oxygen in the muscles. In addition, as part of many enzymes, iron also helps to regulate metabolism, body temperature, immune function and cognitive development (Olaofe and Sanni., 1988). The zinc content of the formulated blends ranged from 2.08(ASD) to 3.54 mg/100 g (ACD). It was observed that the inclusion of Kariya increased the zinc content of the formulated blends.

Sodium content of the formulated blends ranged from 81.60 (ASD) to 146.40 mg/100 g (ACD). The sodium content of the control (132.20 mg/100 g) was lower than the formulated blends (ASD and ARD) except the ACD. The results for the sodium content were in agreement with Anuonye *et al.* (2010) and Ijarotimi and Keshinro (2013) for complementary foods from extruded acha blends; and fermented popcorn, African locust and Bambara groundnut, respectively.

Potassium is important in the regulation of heart beat, neurotransmission and water balance of the body. This study showed that the blends had potassium content ranging between 40.00 and 973.20 mg/100 g. ACD had the lowest while ASD had the highest. The potassium content of the control (962.40 mg/100 g) was significantly higher than the other formulated diets except the ASD. The potassium content of the blends meets the FAO/WHO (1991) recommended intake of 516 mg for children. This study showed that potassium was the most abundant, and this observation was similar to other findings like Olaofe and Sanni (1988) who reported potassium to be the most abundant mineral in Nigerian agricultural products.

4. CONCLUSION

This study concluded that different processing methods (soaking, cooking, fermentation, defatting and protein concentration) reduced the anti-nutrient contents in *kariya* flour. Based on the findings of this study, acha and *kariya* protein concentrate produced a blend of high protein, fat, ash, energy, iron, zinc and calcium contents which compared favourably with those recommended by PAG. The mineral contents of the formulated blend especially iron and calcium were quite adequate. Also, some of the functional properties compared favourably with the commercial diet. The inclusion of *kariya* reduced the pasting properties (especially the peak viscosity) of acha. Hence, the combination can be considered for formulation of some family foods.

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