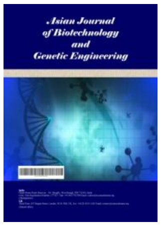

Asian Journal of Biotechnology and Genetic Engineering

3(1): 41-48, 2020; Article no.AJBGE.55754

Rheology and Functional Properties of Complementary Food Made from Maize (*Zea mays*) Supplemented with Crayfish (*Euastacus spp*) and Carrot (*Daucus carota*) Flour

N. N. Umerah[1*], N. M. Oly-Alawuba[2], A. I. Asouzu[3] and C. G. U. Oluah[1]

[1]Department of Food Science and Technology, Enugu State University of Science and Technology, P.M.B. 01660, Enugu, Nigeria.
[2]Department of Nutrition and Dietectics, Imo State University, Owerri, Nigeria.
[3]Ignatius Ajuru University of Education, Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author NNU designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NMOA and AIA managed the analyses of the study. Author CGUO managed the literature searches. All authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Dr. S. Prabhu, Sri Venkateswara College of Engineering, India.
Reviewers:
(1) Xochitl Ruelas-Chacon, Universidad Autónoma Agraria Antonio Narro, Mexico.
(2) Ningappa. M. Rolli, BLDEA's Degree College Jamkhandi, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/55754

Original Research Article

Received 02 February 2020
Accepted 07 April 2020
Published 26 May 2020

ABSTRACT

Background: Studies have shown that inadequate or lack of suitable complementary feeding is the major cause of PEM and micronutrient deficiency that leads to growth faltering and high rates of infection during infancy and early child hood.
Objective: To evaluate the rheology and functional properties of complementary food made from local food blends.
Methods: One kilogram (1kg) each of maize, crayfish and carrot were purchased from Ogbete main market Enugu, Nigeria. The maize, crayfish and carrot flours were blended and coded in the ratio of 100:0:0, 70:25:5, 70:20:10, 70:15:15, 70:10:20 and 70:5:25 respectively and used to produce porridges. The porridges were evaluated for rheology and functional properties using standard methods.

**Corresponding author: E-mail: nkemumerah@yahoo.com;*

Results: The pasting properties of the porridges were Peak viscosity 90.73-92.31 RVU, trough viscosity 31.42-59.91 RVU and breakdown viscosity 42.87-67.03 RVU. The water absorption capacity, bulk density, oil absorption capacity, swelling index, gelation temperature and swelling capacity of the flour ranged between 33.41-120.56%, 1.02-1.11g/ml, 1.36-5.62%, 42.53-72.50%, 47.67-90.71% and 3.80-8.27% respectively.
Conclusion: The study revealed that acceptable and nutrients dense porridge can be produced from blends of maize, crayfish and carrot flour which could be used as alternative to expensive commercial products to improve nutritional status of infants and growing children.

Keywords: Complementary food; maize; crayfish; carrot; rheology; pasting.

1. INTRODUCTION

Food diversification is one of the best measures to improve the nutritional status of individual and curb food insecurity in the society. The traditional complementary foods normally used in Nigeria are either made of maize or millet or sorghum which are deficient in energy and other nutrients [1]. The gruel may be too watery with low energy density or too bulky, causing reduction in infant consumption rate. Improper production and processing of complementary food at this period may results in infant morbidity and mortality as well as delayed mental and motor development [2].

There is need for low cost but nutrient dense complementary foods that can be easily prepared by home makers and care givers from locally available food crops using the simple processing techniques [3,4,5].

Rheology is the deformation and flow of materials both solids and liquids [6]. It is concerned with the properties of matter that determines its behavior when a mechanical force is applied to it. It has to do with the determination of viscosity.

There are lots of home-made complementary foods made in Nigeria which ranges from pap from maize, millet, sorghum or cereals with soybeans. It is commonly known that cereals are high in fibre but low in protein, energy and micronutrients. This feature of cereals poses a problem during formulation of complementary foods. Homemade complementary foods from cereals do not meet up with the RDI of nutrients for infants due to viscosity of the gruel. The gruel tends to be too watery due to consistency or too bulky with low nutrient density. The quality of the protein is too poor that it cannot support growth and lead to body maintenance which is the sole aim of complementary foods. Naismith [7] have associated the etiology of protein energy malnutrition in children to the frequent use of maize pap and millet gruel during weaning period.

Poor combination and formulation has contributed to the poor performance of homemade complementary foods. Cereals are generally low in lysine and tryptophan but fair in methionine and cysteine [8]. Legumes are relatively high in proteins and fat but contain moderate quantities of tryptophan and threonine. This foodstuff can form a good supplement to cereals. Moreover, cereals and legumes are low in micronutrients. Fruits and vegetables are good sources of micronutrients. Animal source foods like crayfish, egg and milk are source of quality protein with high bioavailability. Studies showed that combination of cereals and legumes or tubers with vegetables and animal source food rather than the single diet is a better support for growth and development [9].

Therefore, dietary diversification and supplementation from cereal (Maize), animal source food (crayfish) and vegetables (carrot) when properly processed and blended could provide quality nutrient of high biological value which could curb both PEM and micronutrient malnutrition in infancy. This is the thrust of the present work.

2. MATERIALS AND METHODS

2.1 Procurement of Raw Materials

The maize, crayfish and carrots used for the study were purchased from Ogbete main market, Enugu, Enugu State of Nigeria.

2.1.1 Preparation of maize

The malted maize flour was prepared according to the method of Bolarinwa et al. [10]. One kilogramme (1kg) of maize grains were manually sorted to remove dirt and other extraneous materials. These seeds were then steeped in water at 29°C for 24hours. Changing of water at 6 hours interval was observed during steeping.

The resultant steeped seeds were spread on jute bag and were covered with white cotton cloth to germinate for 72 hours. The sprouted seeds were oven dried at a temperature of 50°C in order to terminate enzyme activities. The plumule was separated from the seed and the malted seeds were dried and milled into flour with an attrition mill and stored in a polythene bag for further use.

2.1.2 Preparation of carrot flour

The carrot flour was prepared according to the method of Aremu et al. [11]. One kilogram of carrot was manually sorted to remove the dirt and other contaminants. The sorted carrots were cleaned with 2 liters of portable water and cut into smaller slices with kitchen knife. The carrot slices were placed into a stainless pot and blanched with 2.5 liters of portable water at 80°C for 10 mins on a hot plate. The blanched carrot slices were drained, spread on the trays and dried in a tray dryer (Model EU 850D, UK) at 60°C for 10 h with occasional stirring of the slices at intervals of 30 mins to ensure uniform drying. The dried slices were milled in a hammer mill and sieved through a 500 micron mesh-sieve. The flour produced was packaged in a lidded plastic container, labeled and kept in a refrigerator until further use.

2.1.3 Formulation of composite blends

Maize, crayfish and carrot flours were thoroughly mixed together at varying proportions of 100:0:0, 70:25:5, 70:20:10, 70:15:15, 70:10:20 and 70:5:25 in a kenwood blender (Mini-processor, Model A 90LD, Thom Emi Kenwood Small Appliances Ltd, Hampshire, UK) to obtain homogenous composite blends. The composite blends were packaged in plastics containers, labeled and stored in the refrigerator for further use.

2.2 Study Design

This study was carried out using complete randomized design (CRD).

2.2.1 Preparation of porridges from composite blends

The porridges were prepared according to the method of Madukwe et al. [12]. Fifty grams (50 g) of each sample of the composite blends were dissolved in 40 ml of portable water at ambient temperature to form the slurry. Hundred milliliters (100 ml) of boiling water was added to each of the slurry with continuous stirring until it developed into gel. Two grams (2 g) of granulated sugar were added to each of the sample and stirred repeatedly until well distributed. The samples were allowed to cool to 40°C (serving temperature) and divided into two lots. The first lot was kept in thermos flask to maintain the serving temperature and used for sensory evaluation after 6 h. The second lot was packaged in a plastic container and kept in a refrigerator for chemical analysis.

2.3 Determination of Functional Properties

2.3.1 Water absorption capacity (WAC)

Approximately (2.5 g) was suspended in 30 ml distilled water at 30°C in a centrifuge tube, stirred for 30 minutes intermittently and then centrifuged at 300 rpm for 10 minutes. The supernatant is decanted and the weight of the gel formed was recorded. The WAC was calculated as gel weight per gram dry sample Sosulski et al. [13]

WAC = Bound water (g) x 100

Weight of sample

2.3.2 Oil absorption capacity (OAC)

Flour samples (1 g) were suspended in 5 ml of water in a centrifugal tube. The slurry was shaken on a platform tube rocker for 1 minute at room temperature and centrifuged at 3000 rpm for 10 minutes. The supernatant was decanted and discarded. The adhering drops of water was removed and reweighed. OAC are expresses as the weight of sediment/initial weight of flour sample (g/g) [14].

2.3.3 Bulk density

Bulk density of the flour samples was determined according to the method of Udoro et al. [15]. A 10 ml graduated cylinder, was gently filled with the sample, the bottom of the cylinder was gently tapped on a laboratory bench several (about 50) times until there were no further diminution of the sample level after filling to the 10 ml mark. Bulk density was calculated as weight of sample per unit volume of sample (g/cm3).

$$\text{Bulk density} = \frac{X1\ (g)}{X2\ (g)}$$

Where,

X1 = Weight of the sample, X2 = Volume of the sample.

2.3.4 Swelling properties

The method used was as described by Okaka and Potter [16]. About 25 g of flour was measured into a 100 ml measuring cylinder. The measuring cylinder was then filled with water to 100 ml bench mark. The mixture was shaken several times and allowed to settle. The volume of the flour was recorded after 15 minutes. The percentage swelling in the volume was determined by the difference in volume divided by the initial volume thus

$$\%\ \text{swelling properties} = \frac{\text{C} - \text{B}}{\text{A}}$$

Where,

A = initial volume (equivalent volume of the 25 g flour sample)
B = volume before swelling
C = Volume after swelling

2.4 Determination of Gelation Capacity

The gelation capacity was determined according to the method of Onwuka [17]. Five percent of the sample suspension was prepared in the test tube with 10 ml of distilled water. The test tube containing the sample suspension was heated in a boiling water bath with continuous stirring for 1 h, followed by rapid cooling under running tap water at room temperature. The gelation capacity or the least gelation concentration of the sample was determined when the sample from the inverted test tube did not fall or slip.

2.5 Determination of Pasting Properties

The pasting properties of the porridges were determined using Rapid Visco Analyzer (RVA) (Model Newport Scientific Pty. Ltd., Warne-Wood NSW 2012, Astralia) according to the method of AOAC [18]. Three grams of the sample were weighed into a dried empty canister and 30 ml of distilled water was dispersed into each canister containing the sample to form the slurry. The slurry was thoroughly mixed and each canister was filted into the RVA. The slurry was heated from 50°C with 2 min holding time. The rate of heating and cooling were at a constant rate of 11.25°C per min. The viscocity was expressesd in centipoise (cP). The parameters measured in RVA unit were Breakdown viscosity (The difference between the peak viscosity and the minimum viscosity at the end of the heating stage). Final viscosity (The viscosity at the end of the cooling stage). Peak time (The time for the paste to reach the peak viscosity). Pasting temperature (The temperature at the sharp increase in viscosity of the porridge suspension after the commencement of the heating stage). Set back viscosity (The difference between the maximum viscosity during cooling and the minimum viscosity during heating). Trough (The minimum viscosity which measures the ability of the paste to withstand breakdown during cooling). Peak viscosity (The measure of the ability of starch to form paste).

3. RESULTS AND DISCUSSION

3.1 Functional Properties of the Samples

The functional properties of the sample is presented in table 1. The water absorption capacity (WAC) of the samples ranged from 33.40-120.56 ml/g. WAC is an indication of a food product to associate with water in a situation where water is limiting [19]. The sample substituted with 25% crayfish and 5% carrot had the highest water absorption capacity. Our results are in agreement with the work done by Onabanjo et al. [20]. The major compounds that enhance water absorption capacity are proteins and carbohydrates owing to their hydrophilic constituents such as polar groups and side chains [21]. Animal source protein like crayfish is hydrophilic due to its high content of glutamic (12.84/100 g) and aspartic acid (11.94/100 g), in proteins, such amino acids act as polar sites for water interaction [22]. The result showed that the bulk density ranged between 1.02-1.11 ml/g. The sample substituted with 25% crayfish and 5% carrot had the highest level of bulk density 1.11 ml/g. Bulk density is important in determining the packaging requirement and material handling in processing and preparation of food products [23]. The oil absorption capacity (OAC) of the samples were between 1.36-5.62 ml/g. An increase in the supplementation of crayfish caused an increase in the OAC. The sample substituted with 25% crayfish and 5% carrot had the highest OAC of 5.62 ml/g. The sample substituted with 25% crayfish and 5% carrot had the highest OAC of 5.62 ml/g. OAC of a sample determines the ability of protein to bind fats [24]. The gelation capacity of the sample ranged from 47.67-90.71ml/g. Gelation capacity increases with increase in the substitution with crayfish. The sample substituted with 25% crayfish and 5% carrot had the highest level 90.71ml/g of gelation capacity. Gelation capacity indicates the solubility of the native proteins in the continuous phase (water) in the formulated sample [25]. The high gelation capacity of the sample showed that the samples can readily form gels when stirred with boiling water within a short period.

Table 1. Functional properties of the composite flour

Sample	WAC	Bulk density	OAC	Swelling index	Gelation capacity	Swelling capacity
A	33.41 ± 0.66^{f}	1.02 ± 0.01^{c}	1.36 ± 0.20^{c}	42.53 ± 1.03^{f}	47.67 ± 0.97^{f}	3.80 ± 0.44^{d}
B	120.56 ± 0.01^{a}	1.11 ± 0.00^{a}	5.62 ± 0.65^{a}	72.50 ± 1.08^{a}	90.71 ± 0.23^{a}	8.27 ± 0.86^{a}
C	102.38 ± 1.18^{b}	1.07 ± 0.05^{b}	4.50 ± 0.74^{ab}	68.70 ± 0.94^{b}	83.66 ± 0.85^{b}	7.46 ± 0.64^{ab}
D	96.70 ± 0.65^{c}	1.05 ± 0.04^{b}	3.28 ± 0.66^{b}	62.20 ± 0.65^{c}	78.52 ± 0.28^{c}	6.59 ± 0.32^{b}
E	72.48 ± 0.33^{d}	1.05 ± 0.21^{b}	2.34 ± 0.11^{bc}	53.28 ± 0.76^{d}	64.60 ± 0.34^{d}	4.60 ± 0.13^{c}
F	62.43 ± 0.02^{e}	1.04 ± 0.06^{bc}	1.62 ± 0.03^{c}	48.37 ± 0.29^{e}	52.29 ± 0.94^{e}	4.20 ± 0.45^{c}

Values are mean of 3 replication, mean with different superscript letters along the same column are significantly different at P<0.05. Keys: Sample A = 100:0:0, B = 70:25:5, C = 70:20:10, D=70:15:15, E= 70:10:20 and F=70:5:25 for Maize, crayfish and carrot respectively

Table 2. Pasting properties of the composite flour

Sample	Peak Vis (RVU)	Trough Vis (RVU)	Breakdown Vis(RVU)	Final Vis(RVU)	Setback Vis(RVU)	Peak ime (min)	Pasting Tempt.(°C)
A	92.51 ± 1.04^{f}	8.24 ± 0.95^{e}	41.78 ± 1.34^{f}	37.56 ± 0.70^{f}	77.30 ± 1.08^{d}	77.30 ± 1.08^{d}	68.53 ± 0.85^{f}
B	92.69 ± 1.23^{e}	32.67 ± 0.67^{d}	47.30 ± 0.97^{e}	49.85 ± 0.88^{e}	80.25 ± 0.09^{c}	64.29 ± 0.50^{d}	71.47 ± 0.71^{e}
C	92.69 ± 1.23^{e}	36.06 ± 1.04^{c}	51.20 ± 1.54^{d}	52.80 ± 0.22^{d}	81.45 ± 0.03^{b}	64.67 ± 0.04^{d}	76.75 ± 0.64^{d}
D	92.79 ± 0.53^{c}	43.02 ± 0.63^{c}	56.01 ± 1.18^{c}	60.20 ± 0.90^{c}	81.91 ± 0.67^{b}	67.17 ± 0.83^{c}	78.93 ± 0.18^{c}
E	92.84 ± 1.06^{b}	45.37 ± 1.11^{b}	62.23 ± 1.02^{b}	62.90 ± 0.54^{b}	83.44 ± 1.05^{a}	69.74 ± 0.55^{b}	85.87 ± 1.12^{b}
F	92.84 ± 1.06^{b}	49.99 ± 0.76^{a}	64.93±1.90a	70.16 ± 1.01^{a}	84.49 ± 0.53^{a}	71.18 ± 0.15^{a}	90.23 ± 1.09^{a}

Values are mean of 3 replication, mean with different superscript letters along the same column are significantly different at P<0.05. Keys: Sample A = 100:0:0, B = 70:25:5, C = 70:20:10, D=70:15:15, E=70:10:20 and F=70:5:25 for Maize, crayfish and carrot respectively

3.2 Pasting Properties of the Samples

The pasting characteristics of the samples is presented in table 2. The peak viscosity of the samples ranged from 92.51-92.90RVU. The sample with 100% maize had the least peak viscosity while the sample substituted with 25% carrot and 5% crayfish had the highest peak viscosity. Peak viscosity is the measure of the ability of starch to form paste on cooking. The increase in the peak viscosity of formulated sample is not a good attribute since gruel/porridges made from high peak viscosity sample will easily become solid in cooking and will not give room for more food which will provide nutrient and energy. Onweluzo and Nnamichi [26] observed that high peak viscosity sample discourages the addition of more nutrients and energy constituents which are much needed by children and adolescent. The trough viscosity of the sample was between 28.24- 49.99 RVU. The sample substituted with 25% carrot and 5% crayfish had the highest level of trough viscosity 49.99 RVU while the sample with 100% maize had the least trough viscosity of 28.24 RVU. Trough viscosity measure the ability of the paste to withstand breakdown during cooling [10]. Breakdown viscosity of the sample were between 41.78-64.93RVA. The sample with 100% maize had the least breakdown viscosity (41.78RVU) while the sample substituted with 25% carrot and 5% crayfish had the highest breakdown viscosity of 64.93 RVU. The breakdown viscosity is a measure of the degree of paste stability or starch granule disintegration during [27]. This implies that the sample with 100% maize having low breakdown viscosity will form a more stable paste during heating than the sample substituted with 25% carrot and 5% crayfish which had high breakdown viscosity. The ability of starch to withstand heating at high temperature and shear stress is an important factor in food processing. Elofsson et al. [28] noted that measurement of breakdown viscosity is important in foods since it contributes to the textural and rheological properties of various food products. The final viscosity of the samples ranged from 37.56-70.16 RVU. The sample with 100% maize flour had the least final viscosity (37.56 RVU) while the sample substituted with 25% carrot and 5% had the highest final viscosity (70.16 RVU). Final viscosity is an index for determining the stability of the cooked paste [29]. The setback viscosity of the sample ranged from 77.30-84.49 RVU. The sample with 100% maize had the least setback viscosity while the sample substituted with 25% carrot and 5% crayfish had the highest viscosity. There is increase in the setback viscosity of the formulated sample. Setback viscosity is an index for evaluating the retrogradation tendency of the paste prepared from a starchy food [30]. Adeyemi and Idowu [31] noted an increase in setback viscosity of their formulated samples with increase in substitution level. This increased the retrogradation level during cooling and increase the staling of the products. Oduro et al. [32] observed that high setback viscosity value is associated with cohesive paste while a low setback viscosity is associated with a non-cohesive paste. In this study, it was observed that the formulated samples with high setback viscosity had an increase in starch retrogradation, reordering of the starch molecules and syneresis of the gel. The peak time of the samples ranged from 60.26-71.18 mins. There is increase in the peak time of all the formulated samples. The peak time is the time taken by each sample to attain its respective peak viscosity. Porridge with lower peak viscosity will cook faster and have lower peak time than the one with higher peak viscosity. The sample with 100% maize had the least peak viscosity (92.51RVU) and least peak time (60.26 mins) while the sample substituted with 25% carrot and 5% crayfish had the highest peak viscosity (92.90 RVU) and highest peak time (71.18 mins). The pasting temperature of the samples were between 68.53-90.23°C. The sample substituted with 25% carrot and 5% crayfish had the highest pasting temperature while the sample with 100% maize had the least pasting temperature. Pasting temperature indicates the temperature at which the porridge form gel. The pasting temperature provides an indication of the minimum temperature required to cook a given sample, which can also have implication in energy usage [29]. The ability of protein to form gel and provide a structural matrix for holding water, flavor, sugar and food ingredients is useful in food application [33]. The substituted samples with high pasting temperature will not be suitable for products that require low gel strength and elasticity.

4. CONCLUSION

It was observed from this work that porridges made by supplementation of maize flour with crayfish and carrot flour had an effect on the rheological properties of the porridge. Porridges made by supplementing maize flour with crayfish and carrot flour increased the water absorption capacity, oil adsorption capacity, bulk density, gelation properties of the porridges, it also increased the peak visocisty, trough viscositty, breakdown viscosity, peak time and pasting temperature of the porridge. Further studies on the microbial studies of functional foods made from blends of maize flour, crayfish flour in order to ascertain the storage stability of these blends is advised.

ETHICAL APPROVAL

Animal ethic committee approval has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Yusufu PA, Egbunu FA, Egbujeh SID, Opega GL, Adikwu MO. Evaluation of complementary food prepared from sorghum, African yam bean (*Sphenostylis stenocarpa*) and mango mesocarp flour blends. Pakistan Journal of Nutrition. 2013; 12(2):205-208.
2. Krebs NF, Hambidge KM. Complementary feeding: Clinically relevant factors affecting timing and composition. American Journal of Clinical Nutrition; 2007.
DOI: 10.1093/ajcn/85.2.639s
3. Asouzu AI, Umerah NN. Rheology and acceptance of pap (*Zea mays*) enriched with *Jatropha carcus* Leaves to improve iron status in children. Asian Journal of Biochemistry, Genetics and Molecular Biology AJBGMB. 2020;3(2):22-34.
[Article no.AJBGMB.53626]
4. Okoye JI, Umerah NN, Ani EC. Quality evaluation of porridges produced from millet, *Pigeon pea* and crayfish flours. Journal of Environmental Science, Toxicology and Food Technology. 2019; 13(7):69-76.
5. Rahda GJ, Kumar PR, Prakash V. Preparation and characterization of protein hydrolysate from an oilseed flour mixture. Food Chemistry. 2007;106:1166-1174.
6. Bingham. The origins of Rheology: A short Historical excursion- Research Gate; 1920.
7. Naismith DJ. Gastroenterology abstracts and citations. Protein-calorie malnutrition in Egypt. Medical Journal of Australia. 1973; 2(13):636-637.
8. FAO. Guidelines on formulated complementary foods for older infants and young children. CAC/GL 8-1991. 1997;1-10.
9. Badamosi EJ, Ibrahim LM, Temple VJ. Nutritional evaluation of a locally formulated weaning food, JUTH-PAP.

West African Journal of Biological Sciences. 1995;3:85-93.
10. Bolarinwa IF, Olajide JO, Oke MO, Olaniyan SA, Grace FO. Production and quality evaluation of complementary foods from malted millet, plantain and soybean blends. International Journal of Science and Engineering Research. 2016;7(5): 663-674.
11. Aremu MO, Osinfade BG, Basu SK, Ablaku BE. Development and nutritional quality evaluation of Kersting's groundnut-ogi for African weaning diet. American Journal of Food Technology. 2011;6:1021-1033.
12. Madukwe EU, Okoye V, Ayogu RNB, Okechukwu F. Chemical and organoleptic evaluation of fermented maize (*Zea mays*) gruel supplemented with fermented cowpea (*Vigna unguiculata*) flour and roasted melon seed (*Citrullus vulgaris*) paste. African Journal of Biotechnology. 2013;12(36):5549-5553.
13. Sosulski FW, Garatt MO, Slinkard AE. Functional properties of ten legume flours. International Journal of Food Science and Technology. 1976;9:66–69. [Google Scholar]
14. Udoro EO, Kehinde AT, Olasunkanmi SG, Charles TA. Studies on the physic-chemical, functional and sensory properties of Gari Processed from Dried Cassava Chips. Journal of Food Process Technology. 2014;5(1):1-8.
15. Okaka JC, Potter NN. Functional and storage properties of cow pea-wheat flour blends in bread making. Journal of Food Science and Technology. 1977;42:828–833. [CrossRef][Google Scholar] DOI: 10.1111/j.1365-2621.1977.tb12614.x
16. Onwuka GI. Food and instrumentation analysis: Theory and practice. Naphthali publishers Ltd, Lagos, Nigeria. 2005;46-50.
17. AOAC. Official Methods of Analysis. Association of Official Analytical Chemists, Washington, DC; 2010 22 USA; 2005.
18. Giami SY, Amasisi T, Ekiyor G. Comparison of bread making properties of composite flour from kernel of roasted and boiled African bread fruit (*Treculia africana*) seeds. Journal of Material Resources. 2004;1(1):16-25.
19. Malomo O, Ogunmoyelu OOB, Adekoyeni OO, Jimo O, Ogunsina BSIO, Olaoye AO, Babawale BD. Nutritional and physical properties of Kariya seeds. International Agrophysiology. 2012;25:97-100.
20. Onabanjo OO, Akinyemi CO, Agbon CA. Characteristics of complementary foods produced from sorghum, sesame, carrot and crayfish. Journal of Natural Science and Engineering. 2009;8(1):71-83.
21. Nyembwe PM, Dekock H, Taylor RNJ. Potential of defatted Marama flour-cassava starch composites to produce gluten free bread-type dough. Journal of Food Science and Technology. 2018;92:429-434.
22. Elbany M. Production and quality evaluation of nutritious high quality biscuits and potato puree tablets supplemented with crayfish *Procombarus clarkia* protein products. Journal of Applied Sciences Research. 2014;10:43-53.
23. Beuchat LR. Functional and electro-phoretic characteristics of succinylated peanut flour protein. Journal of Agric. Food Chemistry. 1977;25(2):258-261.
24. Kinsella JE. Functional properties of food proteins: A review. Critical Reviews in Food Science and Nutrition. 1996;7:217-280.
25. Graham RD, Welch RM. Breeding for micronutrients in staple food crops from human nutrition perspectives. Journal of Experimental Botany. 1996;55(39):353-364.
26. Onweluzo JC, Nnamchi MO. Production and evaluation of porridge-type breakfast product from *Treculia africana* and Sorghum bicolor flours. Pakistan Journal of Nutrition. 2009;8:731-736.
27. Usman OG, Ameh U, Alifa ON, Ameh MU. Vitamin and mineral evaluation of mixed fruit jam from blends of pineapple, orange and sour plum. Pakistan Journal of Food Science. 2015;25(3):137-143.
28. Elofson C, Dejimek P, Poulson M, Burlina H. Characterization of a cold gelling whey concentrate. International Journal of Diary Science. 1997;7:601-607.
29. Ragaee S, Abdel-Aal EM. Pasting properties of starch and protein in selected cereals and quality of their food products. Food Chemistry. 2006;95:9-18.
30. Sadhu KS, Singh N, Malhi NS. Some properties of corn grains and their flours. Physiochemical, functional and chapatti-making properties of the flours. Food Chemistry. 2007;101:938-946.
31. Adeyemi IA, Idowu MA. Evaluation of pre-gelatinized maize flour in the development

of maissa, a baked product. Nigerian Food Journal. 1990;8:63-73.
32. Oduro I, Ellis WO, Aryeetey SK, Ahenkora K, Otoo JA. Pasting characteristics of starch from new varieties of sweet potatoes (*Ipomoea batatas*). Journal of Tropical Sciences. 2000;40:25-28.
33. Ishiwu CN, Onyeji AC. Properties of an instant gruel based on blends of maize (*Zea mays*) starch, African yam bean (*Sphenostylis stenocarpa*) flour and soybean (*Glycine max*) flour. Nigeria Journal of Nutritional Sciences. 2004;25: 16-19.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/55754