**PHYSICOCHEMICAL, PASTING AND SENSORY CHARACTERISTICS OF SORREL SEED (**Hibiscus Sabdariffa L**) PROTEIN ISOLATE FORTIFIED MAIZE (**Zea mays L**) OGI**

*Sanni T. A, Ogunbusola E.M & Adubiaro H.O.*

1Department of Food Science and Technology, Federal University Oye Ekiti, Nigeria
2Department of Industrial Chemistry, Federal University Oye Ekiti
*Corresponding Author’s email: toibudeen.sanni@fuoye.edu.ng*

**Abstract**

The use of sorrel seed protein isolate as supplements in enhancing the nutrients contents of commonly used maize grain weaning food was investigated in this study. Protein isolate was obtained from sorrel seed while maize Ogi was produced using the standard traditional method. The maize ogi samples A, B, C and D was fortified with sorrel seed protein isolate in the ratios; 100:0 (100% maize Ogi as the control), 95:5, 90:10 and 85:15 of the maize ogi to sorrel seed isolates respectively, while . Standard procedures were used to analyze the samples proximate composition, The pasting and organoleptic properties of the samples were evaluated using a Rapid Visco Analyzer and a Nine-point Hedonic scale respectively. Results showed that the samples protein content ranged between 10.21% and 23.34%, ash content was 3.0 – 3.4, moisture content, 2.3 and 3.8%, fibre content ranged between 1.4 and 2.6%, fat content 6.6 - 10.8% and carbohydrates 59.15- 72.32. Enquiry on the functional properties showed that the water absorption capacity ranged between 71.65% and 76.58%, Oil absorption capacity between 53.39% and 59.11% and bulk densityyn 0.53% and 0.74%. For the pasting characteristics, the samplespeak viscosity ranged between 1527.50- 2243.00 RVA, through, 1034.00 - 1472.00 RVA, breakdown; 495.50 - 775.00 RVA, final viscosity; 1837.50 - 2784.00 RVA, setback; 809.50-1313.00 RVA, peak time; 5.43- 5.62 min and peak temperature; 78.03- 84.51°C. Sensory evaluation showed significant difference (P<0.05) across the attributes analyzed. Fortified Ogi with ratios; 95:5 or 5% inclusion of sorrel seed protein isolate was the most preferred among the supplements, while ratios; 85:15 or 15% was the least preferred among all the samples due to its taste. The study showed that maize ogi fortified with sorrel seed protein isolates exhibited higher nutritional properties and could be used as weaning food for infants.

**Keywords; maize-ogi; protein isolate; pasting characteristics; sorrel seeds**

**Introduction**

Protein-energy malnutrition has both health and economic consequences. It is a problem that is widespread throughout the world and a common deficiency disease especially in the developing countries (Aremu et al., 2011). The high cost and meager supply of animal proteins have necessitated research efforts geared towards the study of food properties and the potential utilization of protein from locally available food crops, especially from the under-utilized or relatively neglected high protein oilseeds and legumes (Enujiugha & Ayodele-Oni, 2003). Plant proteins provide nearly 65% of the world’s protein supply for humans, with 45–50% from cereals and legumes (Mahe et al., 1994). Consumption of such products plays a major role in combating malnutrition, which is a serious problem in
most African countries. Various plant protein sources may be combined to obtain products with improved protein quality (Rodríguez – Bürger et al, 1998). Among plant–based protein sources, cereals are important sources of dietary proteins as well as energy for people in most of the developing countries (Massey 2003).

Maize constitutes about 90% of the cereals consumed in Southern Nigeria (Ekpenyong et al., 1977). Maize consists of 9.4 g of protein and 74 g of carbohydrates (USDA, 2007). The grain is often processed into a fermented product known as “ogi”. Ogi is a staple food in West Africa and it serves as a weaning food for infants and is considered a common staple food in most of the African countries. The product serves different categories of people in terms of its uses as weaning food for babies, breakfast cereal for adults, a meal to enhance breast milk production in nursing mothers and as a recovery diet for the (Afolayan & Abuah, 2010).

However, the protein content of maize is low while a significant proportion of it is lost during processing into ogi (Enujiugha, 2006). Therefore, protein fortification has the potential to enhance the nutritional value of ogi. From literature, the nutritive value of ogi has been improved by fortification with amino acids (Adeniji & Potter, 1978) and plant proteins (Ajanaku et al., 2012). Similarly, the protein content of maize meal was increased by combining it with soy flour (Kolapo & Oladimeji, 2008) and with blends of roasted soybean and peanut meals (Aminigo & Ossai, 1999). In this vein, researches showed that soy bean (Glycine max L) can supply more potential protein than any other crops (Messina 1999) and could be an excellent source of low cost protein. In recent times however, soy bean has gone beyond the income reach of many in the underdeveloped countries especially in Africa. The price has risen appreciably that has necessitated the need to explore other sources of plants protein concentrates, which ideally should be crops grown in the tropical countries. A good substitute is the orrel seed that has a high crude protein content and is comparable to other seeds like the passion fruit (Passifloraedulis), Ama-ranthus seeds, black seeds (Nigella sativa L.) and Pisumsativum seeds (Sanni & Akanbi, 2013). Previous studies had significantly shown that sorrel seeds contained high amounts of proteins, dietary fiber, and minerals such as phosporus, magnesium and calcium (Hainida et al, 2008). In the light of this, the current study investigated the effect of sorrel seed protein isolate fortification on ogi’s nutritive value and sensory properties. The study aims at evolving an inexpensive, nutritionally balanced food in the form of fortified ogi for the populace especially the rural people.

Materials and Methods
During the study, the white varieties of the maize (Zea mays L) grains were obtained from the local markets in Ikole-Ekiti, Ekiti state, Nigeria while the sorrel (Hibiscus Sabdariffa L) seeds used was obtained from the local markets in Kaduna state, Nigeria

Preparation of ogi
Ogi was prepared using a method described by Akingbala et al. (1981) with slight modifications Maize was cleaned by picking out all broken kernels together with other foreign particles and then sorted. Thereafter, the maize kernels were steeped for 72 hours at room temperature (27 °C) and the grains wet milled, using a grinding machine (Mini-Processor Model A90LD, Thorn Emi Kenwood Small Appliance Ltd., Hampshire,
The resultant milled slurry was then wet sieved using a muslin cloth to remove bran, hull and germs. This was thereafter dried at 50°C for 48 hours in hot air oven to obtain the dry *ogi* powder.

**Preparation of sorrel seed flour**
Roselle seeds were cleaned by removing dust, stones, and plant debris manually. The seeds were milled using a laboratory scale hammer miller and sieved through a 60cm mesh screen to obtain the sorrel seed flour.

**Preparation of Protein Isolate**
A modified method reported by Gbadamosi et al. (2012) was adopted for the preparation of protein isolates from sorrel seeds. 100g of sorrel flour was suspended in water in the ratio 1:20 and it was stirred in a magnetic stirrer for 10 mins, and the pH of the medium was adjusted to 10.0 and stirred for 4 hours at a constant pH. The slurry was centrifuged at 4500 g for 30 min at room temperature. The supernatant was collected and the pH was adjusted to 4.5 to precipitate the protein. The mixture was centrifuged at 4500 g for 30 min and the precipitate obtained was washed twice with distilled water, re-suspending in distilled water and the pH was then adjusted to 7.0 (neutral) and then centrifuged at 4500 g for 10mins. The precipitate was lyophilized and the protein isolate was obtained and was stored at -4°C in tightly sealed containers in a freezer for further analysis.

**Preparation of the Maize Sorrel Seed Isolate Composite Flour**
The Sorrel seed protein isolate flour was added to maize flour at substitution levels of 0%, 5%, 10% and 15% respectively. These were designated as sample A, B, C and D respectively. About 100% maize flour served as control. The blended flour samples were then packaged into water-proof and air-tight polyethylene films kept at 4°C prior to analysis.

**Determination of Proximate Composition**
Proximate composition includes moisture, crude protein, crude fat, crude fibre, ash and nitrogen free extract. Moisture content was evaluated by oven dehydration method at 105°C up to constant weight. Crude protein was evaluated by using Kjeldhal method and the crude fat was extracted by ether extraction method using Soxhlet apparatus (AOAC, 2010). Crude fibre was determined through acid n and alkali digestion method. Ash content was determined in the muffle furnace at 550 °C over a 6 hours period. For all these determinations, powdered and oven dried samples were used in triplicate in accordance with the standard procedures. Carbohydrate was calculated by difference (AOAC, 2010) methods.

**Functional Properties**
**Water Absorption Capacity (WAC)**
Water absorption capacity of the blends was determined by a modification of the method described by Sathe & Salunkhe (1997). A sample (200mg) of the blends was transferred into a weighed centrifuge tube and 10 ml of distilled water was added. Using a glass stirring rod, the sample and water was mixed thoroughly for 30 seconds at every 10 minutes interval over 30 minutes period. The flour particles that adhered to the side of the centrifuge tube were scrubbed down with the stirring rod to prevent it from drying. The suspension was then centrifuged (MSE Harrier 15/80, Sanyo, UK) at 4500g for 20 minutes. The supernatant was decanted, and the tubes were allowed to drain at a 45° angle for 10 minutes and then weighed. Water absorption was expressed as percentage increase of the sample weight (equation 1)
Oil Absorption Capacity (OAC)

Oil absorption capacity of the blends was determined following the method described by Lin & Zayas (1987). A 200 mg of the blend was weighed into a tarred 50 ml centrifuge tube and 10 ml of pure Gino oil was added. The mixture was mixed with a glass stirring rod for 30 seconds, allowed to stand for 30 minutes and then centrifuged (MSE Harrier 15/80, Sanyo, UK) at 4500 g for 20 minute. The supernatant was decanted and the tubes were allowed to drain at a 45° angle for 30 minutes before being weighed. Oil absorption capacity was then expressed as percentage increase of the sample weight (equation 2)

\[ OAC (%) = \frac{\text{final weight of sample} - \text{initial weight of sample}}{\text{initial weight of sample}} \times 100 \]  

(1)

Bulk Density

Bulk density of the blends was determined according to the method of Okezie & Bello (1988). A 10 ml graduated cylinder which was tarred, and gently filled with the sample. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to the 10ml mark.

Bulk density was calculated as weight of sample per unit volume of sample (g/ml) (equation 3).

\[ \text{Bulk density (g/ml)} = \frac{\text{weight of sample (g)}}{\text{volume of sample (ml)}} \]  

(2)

Pasting Characteristics

The pasting profile of the samples was studied according to the method described by Enujuigha. (2006) using a Rapid Visco-Analyzer (RVA) 4500, (Central Laboratory Federal University of Technology, Akure, FUTA Nigeria) with the aid of a thermocline windows version 1.1. The RVA was connected to a PC where the pasting properties and curve were recorded. Sample suspension was then prepared by adding equivalent weight of 3.08 g dry starch to distilled water to make a total weight of 25.4 g suspension in the RVA sample canister.

Sensory evaluation

Ogi was prepared by making the flour into slurry and heating it on fire with constant stirring using a clean stirrer until it forms a thick paste. The prepared ogi was then dished into sample plates labeled randomly. Sensory evaluation of the composite ogi samples were carried out by 10 panelist comprising students of the Federal University Oye-Ekiti, Nigeria who were familiar with the product. It was served hot on randomly coded plates. The parameters tested were the products appeal, colour, mouth feel, taste and flavour with the aid of a nine-point Hedonic scale ranging from ‘9 = like extremely’ to ‘1= dislike extremely’.

Statistical Analyses

Statistical analysis of all data was done to obtain descriptive and inferential statistics. Statistically significant differences (p<0.05) in all data were determined by General Linear Model procedure (GLM) while Least Significant Difference (LSD) was used to separate the mean.
Results and Discussion

Proximate Composition

The proximate composition of maize ogi fortified with sorrel seed protein isolate in different proportion is shown in Table 1. The moisture content of the control sample (100%) ogi was significantly different from those of 5% (95:5), 10% (90:10), and 15% (85:15) fortification levels. Samples 5% (95:5) and 10% (90:10), were not significantly different from each other but were different from sample 15% (85:15). The moisture content of the samples ranged between 2.3% and 3.8% which indicates a promising long shelf life for the product if its properly packaged and stored. Highest moisture content (3.8%) of the blends was observed in the 85% blends, while the 100% maize had the least moisture content of 2.3%. It was observed that all the samples were within the normal moisture range for dried foods at 10% (Ogunlakin et al. 2012). The moisture content of the study maize ogi was relatively lower than that (8.63%) reported by Abioye & Aka (2015). The moisture content of other blends ranged between 3.5% and 3.8% which agreed with the findings of Aremu et al. (2011). The moisture content of the maize ogi fortified with sorrel seed protein isolate was lower than the moisture content of ogi from blends of fermented maize, conophor nut and melon seed reported by Ojo & Enujiugha (2016). The moisture in food determines its keeping quality and the rate of absorption and digestion. It also determines the rate at which enzymatic activities take place on the food. The fibre content of samples A, sample B were not significantly different but they significantly differ from sample C and sample D. The fibre content of the sample ranged between 1.35% and 2.6%. Sample D (2.6%) has the highest fibre content while sample A has the lowest fibre content (1.35%). The fibre content of maize ogi was higher (1.0%) than that of maize ogi supplemented with African Oil bean reported by Enujiugha (2006). Fibre in food lowers the blood pressure independently and reduces the risk of cardiovascular diseases. Adequate intake of fibre is essential for normal functioning of the bowel and prevention of disease. Fibre in the diet plays a crucial role in the functioning of gastrointestinal system.

The protein content of the samples ranged between 10.21 and 23.34. Sample D (23.34%) had the highest protein content while sample A (10.21%) which is the 100% maize ogi had the lowest protein content. The protein content of the supplemented samples were significantly higher than the control, while sample B and sample C are not significantly different from each, sample D is significantly higher than the other blends. The protein content for the maize ogi was relatively higher than the 4.10% for sorghum ogi, supplemented with pawpaw fruit reported by Kolawole et al., (2010) and also higher than the 7.85% for maize ogi supplemented with periwinkle reported by Inyang & Effiong, (2016). The inclusion of sorrel seed protein isolate in maize ogi blend significantly increased the crude protein composition. This indicates that using sorrel seed protein isolate could be good source of daily protein intake and subsequently the amino acid requirement for early childhood development, which is also essential for the synthesis of protein in muscle brain, blood and other tissues in the human body as well as hormones and enzymes. (Enujiugha, 2006)

The ash content of the samples ranged between 3.0% and 4.4%. Sample D (4.4%) had the highest ash content while sample A (3.0%) had the lowest ash content. The result showed that the ash content of sample...
100:0, 95:5 and 90:10 are not significantly different from each other but are significantly different from sample D. The ash content of the maize ogi was higher than the ash content of maize ogi (1.67%) reported by Abioye et al. (2015). The ash content of whole maize ogi was lower than the ash content (3.1%) of the 15% inclusion of moringa leaves powder into maize ogi reported by Abioye et al. (2015). The variations may be due to mineral content of the soils where the maize was variously planted. The ash content for the maize Ogi was higher than the (0.10%) for sorghum ogi reported by Kolawole et al., (2010) and the (0.81%) for Maize ogi reported by Inyang & Effiong., (2016). Ash content is an indication of the mineral contents of the samples and the values obtained implies that they can serve as micro elements. The reported values of ash in the samples indicate that they are sources of mineral elements. The fat content of the samples ranged between 6.6% and 10.8%. Sample A had the highest fat content (10.8%) while sample D had the lowest fat content (6.6%), Sample B and sample C had 8.4 % and 7.6% respectively. The fat content of sample A is significantly higher than that of the other samples. The defatting treatment employed in the production of the protein isolate might be responsible for this outcome.

The fat content of maize ogi was higher than the (4.05%) for maize ogi reported by Inyang & Effiong, (2016). The fat content for the other blends were higher than the values reported for Maize ogi-Periwinkle flour blends by Inyang & Effiong, (2016). The carbohydrate content of the samples ranged between 59.19% and 72.32%. 100% maize ogi which is sample A (72.32%) had the highest carbohydrate content while sample D (59.19%) had the lowest carbohydrate content. The carbohydrate content of Maize ogi observed in this study was lower than the 86.66% reported by Inyang & Effiong, (2016) and also lower than the 79.3% reported by Enujiughia (2006). The differentials in the levels of carbohydrate in these research output could be as a result of processing methods as was opined by Aremu, (1993). The carbohydrate content of the maize Ogi was higher (65.3%) than the carbohydrate content of sorghum Ogi reported by Ajanaku et al., (2012). Carbohydrate in foods is the key source of energy. Carbohydrate is widely available in normal diets but the preferred sources of carbohydrate are cereals which contain adequate fibre and other nutrients.

**Functional and physico-chemical properties**

The result of the functional and physico-chemical properties of the Maize ogi fortified with sorrel seed protein isolate in different proportion are shown in Table 2. Water absorption capacity of the study showed that sample D had the highest, while the control, sample A had the lowest. The values of the water absorption capacity of the samples ranged between 71.57% and 76.58%. The result gotten for the maize ogi was lower than the (84.00%) for sorghum ogi and maize ogi, supplemented with periwinkle (84%) reported by Ajanaku et al., (2012) and Iyang & Effiong, (2016) respectively. Water absorption capacity is the ability of flour to absorb water and swell for improved consistency in food (Osundahunsi et al., 2003) and increases with increase in protein content (Chavan et al., 2001). The result of this study showed that the values of the oil absorption capacity of the samples ranged between 53.39 and 59.11%. Sample D (59.11%) had the highest value for Oil Absorption Capacity.
while sample A had the lowest value (53.5%). Oil absorption capacity variations follows the sample pattern as that of WAC and the same reason that explains that of WAC also applies here. Oil absorption capacity is important since oil acts as flavour retainer and increases the mouth feel of foods (Aremu et al., 2007).

The bulk density of the Ogi fortified with sorrel seed protein isolate are presented in Table 2. The bulk density of the samples ranged from 0.53 to 0.74 g/m with the whole maize Ogi having the lowest bulk density while the sample D which is the 15% inclusion of sorrel seed protein isolate into the maize Ogi had the highest bulk density value. The bulk density for maize Ogi was relatively lower than (0.728%) for sorghum Ogi reported by Kolawole et al. (2010). Bulk density depends on the combined effects of interrelated factors such as the intensity of attractive inter-particle forces, particle size, and number of contact points. It is a vital parameter that determines the suitability of flours for ease of packaging and transportation (Shittu et al., 2012). It is also an important factor that needs to be put into consideration during infants’ food formulations, as low density foods are most preferable. The pH of the samples shows slightly acidic characteristics which implied the presence of some organic acids. The aqueous solutions of the sample had pH values varied between 4.29 and 4.69 with whole maize ogi being the lowest value and the maize ogi with 15% inclusion had the highest pH. The pH for the maize ogi was higher than the (3.52) for sorghum ogi reported by Kolawole et al. (2010) and was also higher than the (4.11) for sorghum ogi reported by Ajanaku et al., (2012). There was no significant difference between samples B and C but these samples but were significantly lower than sample D. This may be due to increased proportion of the protein isolate in sample D. The pH values obtained were slightly acidic, which may be an indication of the presence of some organic acids. The pH of food product is important since it affects functional properties such as solubility, emulsifying activity and foaming properties and the keeping quality of food products (Chavan et al., 2001; Odoemelam, 2003; Khalid et al., 2003; Gbadamosi et al., 2012).

**Pasting Characteristics**

The result of the pasting properties of maize ‘ogi’ fortified with sorrel seed protein isolate is shown in Table 4. The peak viscosity of the ‘ogi’ samples ranged between 1529.00 RVA and 2242.0 RVA. The 100% ‘ogi’ sample had the highest peak viscosity while inclusion of 15% of sorrel seed protein isolate has the lowest. The peak viscosity in the ‘ogi’ samples reduced with increase in the level of substitution with sorrel seed protein isolate. This is an indication that sorrel seed protein isolate has no ability to gel. This trend was also observed in some of the earlier studies, Aminigo & Akingbala (2004) on the substitution of ‘ogi’ with okra seed flour and in the study of Theodore et al., (2009) on the substitution of ‘ogi’ with Bambara-nut. Two factors could interact to determine the peak viscosity of cooked starch paste: the extent of granule swelling (swelling capacity) and solubility. Higher swelling index is indicative of higher peak viscosity while higher solubility as a result of starch degradation results in reduced paste viscosity (Enjuigba, 2006).

The trough of the ‘ogi’ samples ranged between 1030.00 and 1470.00 RVA. 100% ‘ogi’ sample had the highest value of 1470.00 RVA while 15% inclusion of sorrel seed protein isolate in the maize had the lowest value of 1030.00 RVA. The trough
which shows the holding capacity of the starch granules showed that 100% maize ‘ogi’ had superior holding capacity due to the crystalline and strength of the starch molecules in it. This implied that 100% maize ‘ogi’ has ability to withstand breakdown cooling. The breakdown viscosity value is an index of the stability of starch (Fernande et al 1989). The value in this study ranged between 499.00 and 772.00 RVA. 100% maize ‘ogi’ had the highest value of 772.00 RVA while 15% inclusion of sorrel seed protein isolate into the maize had the lowest value of 499.00 RVA. The breakdown viscosity values for all the samples were lower than the peak viscosity values and this could be altered by nature of the material, degree of mixing, the temperature used and shear applied to the mixture (Newport Scientific,1998). The final viscosity which is the change in the viscosity after holding cooked starch at 50°C, indicates the ability of the material to form a viscous gel or paste after cooking and cooling as well as the resistance of the paste to shear force during stirring (Adeyemi et al. 1990).

The final viscosity of the Ogi samples ranged between 1838.00 and 2781.00 RVA. 100% maize ‘ogi’ had the highest of 2781.00 RVA while 15% inclusion of sorrel seed protein isolate had the lowest value of 1838.00 RVA. The final viscosity was also affected by the mixture of sorrel seed protein isolate into the maize. Setback viscosity is an indication of the stability of cooked paste against retrogradation and can be used to predict the storage life of a product prepared from the flour (Eniola et al., 1981). The setback value ranged between 808.00 and 1311.00 RVA. From the result 100% maize ‘ogi’ had the highest value of 1311.00 while 15% inclusion of sorrel seed protein isolate in the maize had the lowest value. The setback revealed the gelling ability or retrogradation tendency of the amylase present in the starch. The low setback values of the sample indicate low rate of retrogradation. The implication of this is that maize ogi fortified with sorrel seed protein isolate may not retrograde fast (Eniola et al., 1981).

Sensory Evaluation of Ogi Fortified with Sorrel Seed Protein Isolate
The result for the descriptive sensory evaluation is shown on Table 4. A Nine point Hedonic scale ranging from 9 (like extremely) to 1 (dislike extremely) was used. The average score by the panelists showed a moderate to high taste, sample D had the least value for taste (5.4) while sample A which was the control had the highest value (8.0). Sample 95:5 had 6.1, Sample C had (5.7) and sample D (5.4) were not significantly different from each other. Taste is an important sensory attribute of any food. The colour of sample A (8.0) was generally accepted by the panelist than that for the other samples. Sample D had lowest value and sample B (6.4) was slightly lower than sample A. Food colour is considered to be the most important sensory parameter governing consumer choice of the foods and
Drinks that they prefer, purchase and eventually consume (Spence, 2015). Flavour is defined as a “complex combination of the olfactory (nasal) and gustatory (oral) sensations perceived during tasting”. It is also an important characteristic of food (Iwe, 2002). ‘Good’ aroma from food excites the taste buds, making the system ready to accept the product, while ‘poor’ aroma may cause outright rejection of food before they are tasted. The mean value for sample A was higher than that for the rest of the samples. The mean values for samples B and C were not significantly different from each other, but were better than that for sample D (5.5) that had the least value.

The mean values for the overall acceptability showed that the control sample had the highest value (8.3), followed by sample B (6.5) sample C (6.0) and sample D had the least value (5.6). The overall acceptability showed that sample A was preferred/liked very much by the panelists, sample B and sample C were slightly preferred/liked while sample D was slightly not preferred/disliked because of its higher inclusion of sorrel seed protein isolate. However the maize ogi taste could be adjusted with the addition of sweeteners into the maize ogi, if the high protein content is to be put into consideration. Meanwhile, the other two supplements, that is B and C, could be adopted weaning food formula, as they are rich enough in protein and also moderately liked by the consumers.

**Conclusion**

The study showed that maize ogi could be enriched with sorrel seed protein isolates in order to wean infants. This is more so since the maize protein fortification enhances the protein content of ogi. The protein fortification will ensure the building up of the infant’s body tissues. The sensory evaluation in this study revealed that the 15% blend had the highest amount of protein content, but the average means for the taste could be improved with addition of sweetener.

**References**


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Table 1: Proximate Composition

<table>
<thead>
<tr>
<th>Samples</th>
<th>Moisture %</th>
<th>Fat%</th>
<th>Protein%</th>
<th>Ash%</th>
<th>Fibre %</th>
<th>Carbohydrate %</th>
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</thead>
<tbody>
<tr>
<td>100:0 (A)</td>
<td>2.3±0.41a</td>
<td>10.8±0.20b</td>
<td>10.21±2.5a</td>
<td>3.0±1.0a</td>
<td>1.40±0.36a</td>
<td>72.32±1.89b</td>
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<tr>
<td>95:5 (B)</td>
<td>3.5±0.15bc</td>
<td>8.4±0.54a</td>
<td>14.59±2.5b</td>
<td>3.1±0.15a</td>
<td>1.50±0.40a</td>
<td>69.00±1.91b</td>
</tr>
<tr>
<td>90:10 (C)</td>
<td>3.2±0.20b</td>
<td>7.6±1.40a</td>
<td>16.04±2.4c</td>
<td>3.2±1.93a</td>
<td>2.57±0.38b</td>
<td>67.56±3.99b</td>
</tr>
<tr>
<td>85:15 (D)</td>
<td>3.8±0.26c</td>
<td>6.6±1.57a</td>
<td>23.34±2.4a</td>
<td>4.4±2.34b</td>
<td>2.60±0.26b</td>
<td>59.19±2.69a</td>
</tr>
</tbody>
</table>

Values reported are means ± Standard deviation of duplicate determinations. Mean values with different superscript within the same column are significantly (p < 0.05) different.

KEYS: Sample A - whole maize Ogi (100%), sample B - blends of maize Ogi with sorrel seed protein isolate at ratio 95:5, sample C - blends of maize Ogi with sorrel seed protein isolate at ratio 90-10, sample D - blends of maize Ogi with sorrel seed protein isolate at ratio 85:15.

Table 2: Functional and Physico-Chemical Properties

<table>
<thead>
<tr>
<th>Treatments</th>
<th>100.0</th>
<th>95:5</th>
<th>90:10</th>
<th>85:15</th>
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</thead>
<tbody>
<tr>
<td>WAC</td>
<td>71.57±1.48c</td>
<td>75.58±3.47b</td>
<td>76.43±1.58a</td>
<td>76.58±2.10a</td>
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<td>OAC</td>
<td>53.39±4.53a</td>
<td>56.71±1.56a</td>
<td>58.82±0.99a</td>
<td>59.11±1.38a</td>
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<tr>
<td>Bulk Density (g/m)</td>
<td>0.54±0.27a</td>
<td>0.62±0.30b</td>
<td>0.67±0.09b</td>
<td>0.74±0.06c</td>
</tr>
</tbody>
</table>

Values reported are means ± Standard deviation of duplicate determinations. Mean values with different superscript within the same column are significantly (P < 0.05) different.

KEYS: WAC - water absorption capacity, OAC - oil absorption capacity.

Table 3: Pasting Characteristics

<table>
<thead>
<tr>
<th>Samples</th>
<th>Peak (RVA)</th>
<th>Trough (RVA)</th>
<th>Breakdown (RVA)</th>
<th>Final viscosity (RVA)</th>
<th>Set Back (RVA)</th>
<th>Peak Time (RVA)</th>
<th>Pasting Temp (RVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100:0</td>
<td>2243.00 ± 1.41a</td>
<td>1472.50 ± 3.54a</td>
<td>775.00 ± 4.24a</td>
<td>2784.50 ± 4.95a</td>
<td>1313.00 ± 2.83a</td>
<td>5.43 ± 0.04c</td>
<td>78.03 ± 0.81d</td>
</tr>
<tr>
<td>95:5</td>
<td>1763.50 ± 3.54b</td>
<td>1224.00 ± 4.24b</td>
<td>545.00 ± 7.07b</td>
<td>2145.50 ± 7.78b</td>
<td>916.50 ± 6.36b</td>
<td>5.62 ± 0.02a</td>
<td>82.13 ± 0.25c</td>
</tr>
<tr>
<td>90:10</td>
<td>1628.50 ± 2.12c</td>
<td>1091.00 ± 1.41c</td>
<td>533.50 ± 2.12c</td>
<td>1971.50 ± 3.54c</td>
<td>873.50 ± 4.95c</td>
<td>5.49 ± 0.03b</td>
<td>84.28 ± 0.46d</td>
</tr>
<tr>
<td>85:15</td>
<td>1527.50 ± 2.12d</td>
<td>1034.00 ± 5.66d</td>
<td>495.50 ± 4.95d</td>
<td>1837.50 ± 0.71d</td>
<td>809.50 ± 2.12d</td>
<td>5.46 ± 0.02c</td>
<td>84.51 ± 0.35b</td>
</tr>
</tbody>
</table>

Values reported are means ± Standard deviation of duplicate determinations. Mean values with different superscript within the same column are significantly (p < 0.05) different.

KEYS: Sample A - whole maize Ogi (100%), sample B - blends of maize Ogi with sorrel seed protein isolate at ratio 95:5, sample C - blends of maize Ogi with sorrel seed protein isolate at ratio 90:10, sample D - blends of maize Ogi with sorrel seed protein isolate at ratio 85:15.

Table 4: Sensory Evaluation for the Maize Ogi Fortified with Sorrel seed protein Isolate in different proportion.

<table>
<thead>
<tr>
<th>Samples</th>
<th>100.0</th>
<th>95:5</th>
<th>90:10</th>
<th>85:15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taste</td>
<td>8.0±1.15a</td>
<td>6.1±0.99b</td>
<td>5.7±1.16a</td>
<td>5.4±0.97c</td>
</tr>
<tr>
<td>Colour</td>
<td>8.0±0.67a</td>
<td>6.4±0.97b</td>
<td>6.2±0.92b</td>
<td>5.5±1.08c</td>
</tr>
<tr>
<td>Flavour</td>
<td>8.3±0.67a</td>
<td>6.3±0.95b</td>
<td>6.1±0.74b</td>
<td>5.5±1.08c</td>
</tr>
<tr>
<td>Acceptability</td>
<td>8.3±0.67a</td>
<td>6.5±0.97b</td>
<td>6.0±0.67bc</td>
<td>5.6±0.69c</td>
</tr>
</tbody>
</table>

Values reported are means ± Standard deviation of duplicate determinations. Mean values with different superscript within the same column are significantly (P < 0.05) different.

Table 5: pH Evaluation for the Maize Ogi Fortified with Sorrel seed protein Isolate in different proportion.

<table>
<thead>
<tr>
<th>Samples</th>
<th>100.0</th>
<th>95:5</th>
<th>90:10</th>
<th>85:15</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.29±0.01c</td>
<td>4.37±0.00b</td>
<td>4.44±0.01b</td>
<td>4.69±0.06a</td>
</tr>
</tbody>
</table>

Values reported are means ± Standard deviation of duplicate determinations. Mean values with different superscript within the same column are significantly (P < 0.05) different. OAC - oil absorption capacity, WAC - water absorption capacity.