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Production and functional property of maize-millet based complementary food blended with soybean

Akinsola A. O.[1*], Idowu M. A.[2], Babajide J. M.[2], Oguntona C. R. B.[3] and Shittu T. A.[2]

[1]Department of Home Economics, Federal College of Education (Special), Oyo, Oyo State, Nigeria.
[2]Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.
[3]Department of Nutrition and Dietetics, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.

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Traditional complementary foods are mainly based on cereal grains which when cooked get gelatinized and swollen thereby making the diet viscous and bulky for infants and young children. This study was carried out to investigate the effect of fermentation, germination, and roasting methods on the functional properties of maize-millet-soybean mix with a view to producing less bulky and nutrient dense complementary food. Fermented, germinated, roasted, and untreated (control) grains were dried in an air oven at 55°C for 48 h to 10% moisture content, milled and sieved separately into fine flours (450 microns). Four complementary food samples were formulated and analyzed for wettability, dispersibility, water absorption capacity, swelling power, solubility index and pasting properties. Results showed that fermentation, germination, or roasting methods significantly ($p<0.05$) affect functional property of the complementary food samples. The swelling power of fermented sample was higher, while solubility of germinated sample was higher than other samples. The water absorption capacity of the complementary food samples ranged from 1.27 in germinated maize-millet-soybean to 1.61 in control sample. Fermented sample had the highest peak, trough and final viscosities, while germinated sample had the least. The study showed that germination significantly reduced water holding capacity and swelling power of the complementary food, and is recommended for producing nutrient dense complementary from maize-millet-soybean mix.

Key words: Complementary food, gelatinize, functional property, processing method.

INTRODUCTION

Complementary foods play a vital role on child growth and development since it complements for both nutritional and developmental needs of the infant when breast milk alone is no longer sufficient (Temesgen, 2013). According to WHO (2003), good quality weaning food must have high nutrient density, low viscosity, bulk density and appropriate texture along with high energy, protein and micronutrient contents and should have a consistency that allows easy consumption (Balasubramanian et al., 2014). Several studies have

*Corresponding author. E-mail: akinsola4gold@gmail.com, Tel: 2348034800734.

reported that most of the complementary foods consumed by the infants in many parts of world are deficient in essential macronutrients and micronutrients leading to malnutrition, which is one of the serious problems in developing countries. Protein energy malnutrition (PEM) generally occurs during the crucial transitional phase when children are weaned from liquid (that is, breast milk) to semi-solid or fully adult (family) foods. Milk and cereals are nutrient-rich sources that are commonly used in complementary foods (Aderonke et al., 2014), but are associated with different medical conditions like allergies and lactose and gluten intolerance.

Various blends of cereal grains with legumes have been developed through fermentation, germination, and or roasting. While functional properties of such food products during product formulation have been frequently neglected, more emphasis is placed on nutritional quality and quantity. Functional properties of complementary foods vary with type of grains, processing and cultural practices of the people. Ikegwu (2010) reported that type of starch granules present in the complementary foods significantly affect functional properties when its absorb water, swell and thickens to form a paste, with an accompanying change in appearance of the heated suspension. The transition from a suspension of starch granules to a paste when heated is accompanied with increase in viscosity and bulkiness. Many factors may also influence the degree and kind of association that may occur. The amount of water-bound associated with starch granules which increase as the heat starts to disrupt the inter-granules influences the swelling and functional properties of the flour.

The increase in paste viscosity when a hot paste is cooled is governed by the retrogradation tendency of the starch granules, and largely determined by the affinity of hydroxyl groups in one molecule for another which occurs mainly between the amylose molecules (June et al., 1991). Moreover, the high cost of commercial complementary foods coupled with household food insecurities and global economic meltdown now demands for effective strategies for improving the nutritional status of infants and young children by promoting the use of high quality complementary foods which could be of better functional properties and high nutrient dense, low dietary bulk and viscous at cottage level production. This study is therefore designed to develop nutrient-dense, safe, low-cost complementary food from the combination of fermentation, germination, and roasting methods on the functional properties of maize-millet-soybean mix for possible use as a complementary food for infants and young children.

MATERIALS AND METHODS

The yellow maize (*Zea mays*), finger millet (*Eleusine coracana*), and soya beans (*Glycine max*) used in this study were purchased at Lafenwa Market, Abeokuta, Ogun State, Nigeria.

Preparation of control samples

The three raw materials of four kilogram each were divided into four portions and each portion of the raw material was subjected to processing method of fermentation, germination, and roasting, while the fourth portion served as control. A portion of each of the raw material were thoroughly cleaned to remove extraneous material, winnowed, washed, drained and dried at 55°C for 48 h to bring the moisture content to about 10%. The dried samples were first re-winnowed before milling using locally fabricated machine and sieved to approximately mesh size of 450 microns. The maize, millet, and soybean flours obtained were mixed at a ratio of 50:30:20, respectively, and served as control samples.

Preparation of fermented flours

Each portion of the raw materials was soaked with distilled water in volume of water three times its weight (ratio of 1:3 weight/volume) and allowed to ferment in closed plastic bucket at 28°C for 48 h as described by Adeyemi and Beckley (1986). After fermentation, each of the raw materials was drained in a cleaned plastic sieve for 10 min, re-washed, and dried at 55°C for 48 h to bring the moisture content to about 10%. The sample was then packaged separately in airtight plastic container till further use.

Preparation of sprouted flours

Another portion of each raw material was germinated using the method described by Kulkarni et al. (1991). Each cleaned and washed grain were soaked in a volume of water three times the weight of grains (3:1) for 12 h in a container at ambient temperature. The steeping water was drained off using cleaned plastic sieve. Each of them was then spread on a jute sack placed on a wooden platform and covered with another jute sack for germination at room temperature (28°C) for 48 h and watered every 12 h to enhance the sprouting processing. After 48 h, the germinated samples were collected and washed, drained and dried at 55°C for 48 h to bring the moisture content to about 10%. The sample was then packaged separately in airtight plastic container till further use.

Preparation of roasted flours

The last portion of each raw material was clean, washed and allowed to drain for 10 min, transferred to aluminum trays, and roasting at 120 ± 5°C (maize and millet), and 130 ± 5°C (soybeans) for 10 and 15 min, respectively. All the processed (fermented, sprouted and roasted) grains were allowed to cool, winnowed and milled using a milling (locally fabricated) machine and sieved to approximately mesh size of 450 microns. The maize, millet, and soybean flours obtained were mixed at a ratio of 50:30:20, respectively for each treatment. The sample was then packaged separately in airtight plastic container till further use.

Functional properties determination

Bulk density was determined by the method of Wondimu and Malleshi (1996), while wettability index was done according to the

Table 1. Functional properties of maize-millet-soybean complementary foods.

Functional property	SC	SF	SG	SR
Bulk Density	0.58±0.09[a]	0.66±0.07[a]	0.60±0.01[a]	0.59±0.00[a]
Wettability (s)	10.63±0.13[a]	11.78±1.26[a]	25.54±2.97[c]	14.91±0.98[b]
Dispersibility (%)	65.75±1.40[a]	68.75±1.37[b]	63.50±0.21[a]	70.25±2.76[b]
Foaming Capacity (cm^3)	1.84±0.23[a]	12.50±0.14[c]	14.00±0.71[d]	4.76±0.31[b]
Water Absorption Capacity (g/cm^3)	1.61±0.24[a]	1.46±0.55[a]	1.27±0.70[a]	1.45±0.23[a]

Values are mean ± standard deviation of triplicate scores. SC: Control sample; SF: Fermented maize-millet-soybean; SG: Germinated maize-millet-soybean; SR: Roasted maize-millet-soybean. Mean values in the same row with different superscript are significantly different (p< 0.05).

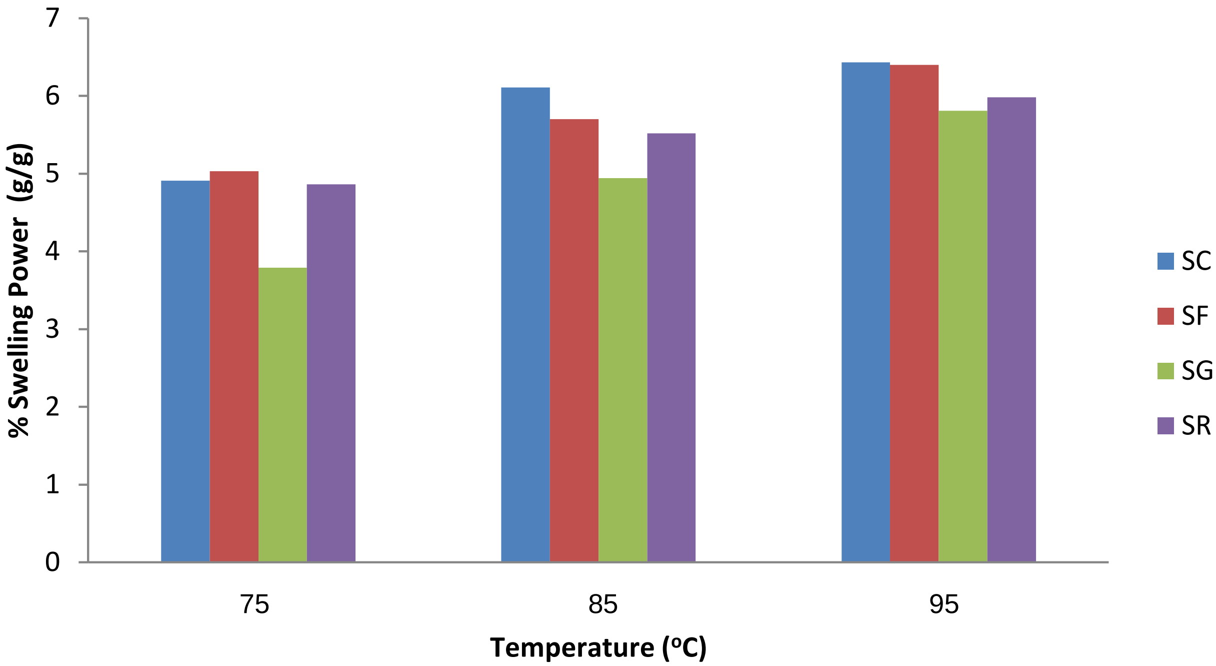

Figure 1. Swelling power of maize-millet-soybean complementary flours. SC: Control sample; SF: Fermented maize-millet-soybean; SG: Germinated maize-millet-soybean; SR: Roasted maize-millet-soybean.

procedure described by Okezi and Bello (1988). Dispersibility was carried out according to the method described by Kulkarni et al. (1991). The method of Padmashree et al. (1987) was used for the determination of foaming capacity, while water absorption capacity was determined using the method described by Sosulski (1962). The swelling power and solubility index of each sample was determined using the method of Leach et al. (1959), while pasting characteristics was determined by the method described by Ikegwu (2010).

Statistical analysis

A one-way analysis of variance and Duncan's test were used to establish the significance of differences among the mean values at the 0.05 significance level. Results were expressed as mean of triplicate analyses. The statistical analyses were performed using SPSS software (Systat statistical program version 21, SPSS Inc., USA).

RESULTS

The functional properties of the complementary food samples are presented in Table 1. Bulk density of the complementary food samples ranged from 0.58 in SC (control) sample to 0.66 in SF (fermented) sample. There is no significant difference (p<0.05) in the bulk density values. The wettability ranged from 10 in SC (control) sample to 18 s in SFR (fermented-roasted) sample, while dispersibility ranged from 63.5% in SG (germinated) sample to 70.25% in SR (roasted) sample. The swelling power (Figure 1) at 75°C for the complementary flours ranged from 3.79 to 5.18 for SG (germinated) sample and SF (fermented) sample, respectively, while solubility index (Figure 2) at 75°C ranged from 1.53 in SR (roasted) sample and 14.27 in SG (germinated) sample. At 85°C,

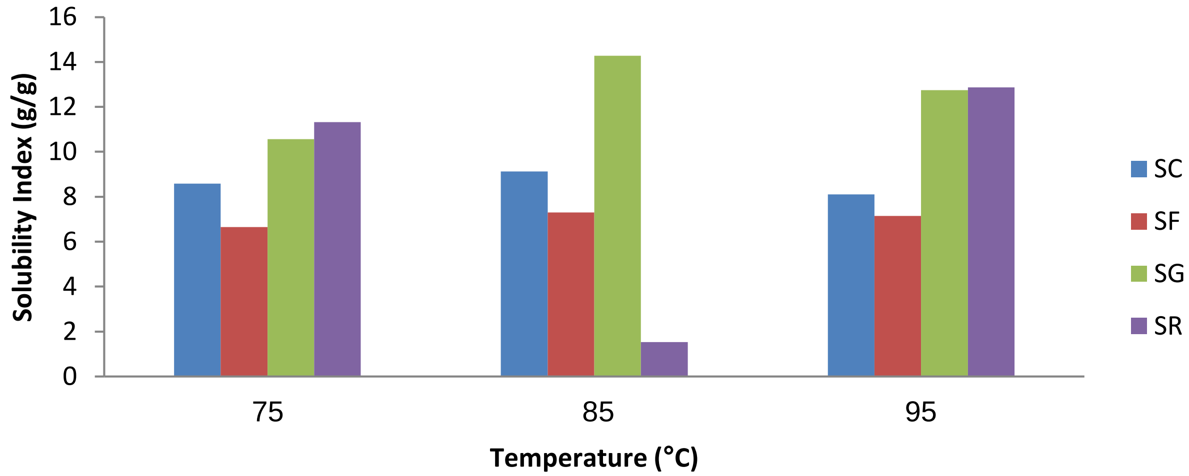

Figure 2. SC: Control sample; SF: Fermented maize-millet-soybean; SG: Germinated maize-millet-soybean; SR: Roasted maize-millet-soybean.

Table 2. Paste property of the complementary samples.

Parameter	SC	SF	SG	SR
Peak viscosity (RVU)	26.71±0.53[d]	19.66±0.41[c]	3.34±0.23[a]	5.92±0.47[b]
Trough (RVU)	21.96±0.18[d]	18.00±0.59[c]	2.96±0.30[a]	4.71±0.53[b]
Breakdown (RVU)	1.75±0.35[ab]	1.46±0.18[a]	6.29±0.06[c]	1.21±0.06[a]
Final viscosity (RVU)	42.21±0.53[d]	32.25±0.35[c]	0.50±0.24[a]	18.92±0.70[b]
Setback (RVU)	27.25±0.35[d]	24.25±0.35[c]	3.46±0.06[a]	14.21±0.18[b]
Peak Time (min)	6.54±0.53[b]	6.94±0.04[c]	4.17±0.00[a]	6.86±0.03[bc]
Pasting Temp (°C)	50.25±0.07[a]	50.28±0.11[a]	50.30±0.00[a]	50.30±0.07[a]

Values are mean ± standard deviation of triplicate scores. SC: Control sample; SF: Fermented maize-millet-soybean; SG: Germinated maize-millet-soybean; SR: Roasted maize-millet-soybean. Mean values in the same row with different superscript are significantly different ($p < 0.05$).

the swelling power of the complementary food samples ranged from 4.94 to 5.71 for SG (germinated) sample and SC (control) sample respectively, while solubility index at 85°C ranged from 1.63 in SR (roasted) sample to 13.89 in SG (germinated sample). Swelling power at 95°C ranged from 5.82 in SG to 6.17 in SC (control) sample, while solubility index at 95°C ranged from 7.23 in SF (fermented) sample to 13.22 for SR (roasted) sample, respectively.

The pasting characteristics of the complementary food samples are as presented in Table 2. Peak viscosity and trough of all the samples were significantly affected ($p > 0.05$) when compared with the control sample. The result shows that germinated sample reach their peak viscosity and trough earlier than fermented and roasted samples. Breakdown viscosity ranged from 1.21 RVU to 6.29 RVU in SR and SG samples respectively, while final viscosity during heating ranged from 0.50 RVU in SG (germinated) sample to 42.21 RVU in SC (control) sample. The setback value ranged from 3.46 RVU to 27.25 RVU for SG (germinated) sample and SC (control) sample, respectively, while peak time ranged from 4.17 min in SG sample to 6.94 min in SF sample. There were significant differences ($p < 0.05$) in the setback of the complementary foods. There is no significant difference ($p > 0.05$) in pasting temperature of all the complementary food samples.

DISCUSSION

Fermentation, germination and roasting methods employed in this study significantly reduced ($p < 0.05$) the water absorption capacity and viscosity of the complementary food samples and could enhance the volume consumed per meal. Germination reduces swelling power better than other processing methods employed in this study. This result agreed with that of Wadud et al. (2004), who work on vegetable protein-based complementary foods, complementary foods based on cereals and legumes, and Ezeocha and Onwuka (2010), who worked on the physicochemical and nutritional quality of maize and soybean complementary foods, respectively. There were no significant differences ($p>0.05$) in bulk densities of the complementary food with values between 0.58 and 0.66. Low bulk density of food products had been reported to provide nutrient dense meal for infants and young children, as more of the products can be eaten resulting in high nutrient intake per meal for the baby (Nnam, 2000). Bulk density could also be affected by moisture content and reflects particle size distribution of the complementary flours (Wadud et al., 2004). Complementary foods were also significantly different ($p<0.05$) in their wettability and dispersibility. Germinated sample had the highest wettability among the other formulated samples, while roasted sample had the highest dispersibility. The control sample however, had the lowest wettability and dispersibility. This showed that germination and roasting could increase wettability and dispersibility of food products. These results are in agreement with Ezeocha and Onwuka (2010) work on complementary foods based on cereals and legumes that germination and/or roasting significantly affect wettability and dispersibility of soybean based complementary foods. The zero foaming capacity observed in the heat treated (roasting) complementary food sample of this study was similar to those observed with heat treated flours by other authors (Padmashree et al., 1987).

Obatolu and Cole (2000) earlier reported that mild heat treatment caused surface denaturation of protein and resulted in better foaming properties of complementary blends of soybean and cowpea with un-malted and malted maize. Prinyawiwatkul et al. (1997) also reported that denaturation decreases protein solubility, which in turn decreased foaming capacity of cowpea based formulated complementary foods. These authors also reported that foam volume and specific gravity are indices of texture lightness of food products. This result agreed with the work of Solomon (2005) and Anigo et al. (2009), who reported that heat treatment prevented foaming in dry flours or powder of sorghum, millet, and acha, while germination enhance foaming capacity in dry flour or powder of sorghum, millet, and acha. Wadud et al. (2004) and Solomon (2005) reported that processing methods, time and temperature amongst other factors affect the functional properties of a food product. The complementary foods were significantly different ($p<0.05$) in their water absorption capacity (WAC) values. The SC (control) and SF (fermented maize-millet-soybean) had the highest WAC as they retained water more than other complementary food samples. Increase in protein content after sprouting might be due to enzymatic changes, hormonal changes or a compositional change following the degradation of other constituents (D'souza, 2013). The enzymes produced during sprouting lead to the hydrolysis of starch and proteins with release of sugar and amino acids. Proteolytic enzymes improves amino acid availability mainly lysine, methionine and tryptophan (Bolanle et al., 2012). Water absorption capacity (WAC) observed in this study is probably related to the low viscosity patterns and weak internal organization resulting from starch granules as reported by Singh et al. (2003), who worked on cookie-making properties of corn and potato flours, respectively.

This study showed that germination, fermentation, and roasting methods significantly ($p<0.05$) decreased WAC of the complementary food samples. Germinated complementary food samples had the lowest WAC as compared with samples processed using other methods. This may be as a result of the malting process which hydrolyzed starch and thereby reduce the water holding capacity. The result agreed with the earlier reports of Ezeocha and Onwuka (2010) that germinated food flours generally had low WAC as a result of hydrolyzation of starch granules, thereby reducing their water holding capacity. Flour from SG samples had the least swelling power, while SC (control) sample had the highest. All the complementary food samples were significantly different ($p>0.05$) in their swelling capacity. Generally, the low level of swelling power obtained for germinated samples may have been caused by the presence of protein, lipid, and amylase activity which increased during germination of the seed. Hence, when cooked, the hydrolyzed starch swells less, retains less water, has lower viscosity, and increases the nutrient and energy densities per unit volume of the blended flour. Significant differences ($p<0.05$) were observed in the solubility index of all the complementary foods.

Flour from germinated sample had the highest value, while flour from SR (roasted) sample had the least solubility index. It is possible that the heat treatment (roasting) weakened and destroyed protein structure of SR samples thereby inhibiting its solubility. Weaning food of high viscosity and high bulk density is usually unacceptable to infants as it makes feeding taskful and causes choking. Infants can easily consume sufficient quantity of food if it is low in viscosity/bulk density because it allows incorporation of more solids in mixture leading to an increase in nutrient density of the gruel. Low viscosity and low bulk density weaning food with a high nutrient content is a desirable characteristic in complementary foods (Onweluzo and Nwabugwu, 2009). There were significant differences in peak viscosities of all the complementary flours. Peak viscosity of the SF (fermented maize-millet-soybean) was generally higher than peak viscosities of samples processed using other methods (germination and roasting).

Peak viscosity is indicative of the strength of pastes, which are formed from gelatinization during processing in food applications. It may also be as a result of amylase activity in the complementary flour which resulted in the viscosity changes (Niba et al., 2001). There were significant differences ($p<0.05$) in trough of the complementary flours with the fermented sample having the highest value. Trough is the minimum viscosity value in the constant temperature phase of the RVA profile and measures the ability of paste to withstand breakdown during cooling (Ezeocha and Onwuka, 2010). This study showed that fermentation increased both peak and trough viscosity more than germination, roasting method. These results agreed with the reports of Wadud et al. (2004), Ezeocha and Onwuka (2010), and Ikegwu (2010), that germinated food products were less bulky, highly nutritional, and good functional property than fermented, or fermented combined with roasted food sample.

There were significant differences ($p<0.05$) in breakdown viscosity among the complementary food samples. Higher breakdown viscosity values were obtained in germinated sample compared with samples processed using other methods as a result of alpha-amylase that was developed during malting which might have degraded the starch granules in the raw food material. Adebowale et al. (2005) reported that the lower the breakdown viscosity, the lower the ability of the sample to withstand heating and shear during cooking. The results of this study showed that all the complementary samples had low breakdown viscosity. Hence, the blended flours would be able to withstand heating and shear stress during cooking because of their low peak and breakdown viscosity values. Less stability of starch paste or gel after cooling is often accompanied with low value of breakdown viscosity as earlier reported by Shimelis et al. (2006). This implies that gels of flour sample from SF (42.3 RVU) may be more stable after cooling compared to gels of flours obtained from using other processing methods (10.5 – 26.1 RVU).

There were significant differences ($P>0.05$) in final viscosities of the complementary flours. Final viscosity indicates the ability of starch-based food to form a viscous paste or gel after cooking and cooling (Ikegwu, 2010). The fermented sample had highest final viscosity, while germinated (SG) sample had the least value. The marked increase in final viscosity observed in the fermented sample might be due to alignment of chains of amylose in the starch as reported by Ikegwu (2010), and Niba et al. (2001) who reported that final viscosity are important in determining ability of a sample of material to form a gel during processing could be used to improve and optimize food texture; hence measurement of final and peak viscosities is relevant in food formulation. This study showed that fermentation and germination could influence setback viscosity of the complementary flours. High value (27.3 RVU) of setback viscosity was obtained in control sample, while least value (3.5 RVU) was obtained in germinated sample. Setback viscosity is an indication of gel stability and potential for retrogradation and syneresis, while Sanni et al. (2004) reported that the lower the setback during cooling of paste is a reflection of the retrogradation tendency of the paste. This means that control (SC) sample will retrograde faster after reconstitution for feeding while germinated (SG) sample will retrograde slowly. Also, fermented sample will retrograde faster than germinated and roasted samples.

There were significant differences ($p<0.05$) in the peak time of all the complementary foods. The same trend as observed for peak, trough, and final viscosities was also observed for peak time in all the complementary foods. The fermented sample had higher peak time than germinated and roasted samples. This is in agreement with the reports of Aguilera and Rojas (1996) that thermal time significantly has effect on rheological properties of whey protein cassava starch gels. Complementary food is usually prepared into gruel before been given to the child. The pasting temperature obtained in this study, shows that there were no significant differences ($p>0.05$) in all the complementary flours. Pasting temperature is the temperature at onset of rise in viscosity of a starch-based food product or material. When the temperature is above the gelatinization temperature, starch granules began to swell and viscosity on shearing (Adebowale et al., 2005; Ikegwu, 2010). These results are in agreement with the findings of Gernah et al. (2012) and Victor (2014), who reported that processing methods like sprouting and fermentation are valuable in reducing the viscosity of infant gruels, increase total solids and nutrient density of weaning food. This decrease in viscosity due to sprouting might be due to the enzymatic breakdown of macromolecules such as polysaccharides and polypeptides to smaller units, such as dextrins and peptides, respectively (Gernah et al., 2012).

Pasting characteristics is important in predicting the behaviour of food paste during and after cooking. Pasting temperature is one of the pasting properties which provide an indication of the minimum temperature required to cook a given sample, energy cost involved and other components stability (Ikegwu et al., 2009). Attainment of the pasting temperature is essential in ensuring swelling, gelatinization, and subsequent gel formation during processing. This result showed that the formulated complementary sample form a paste in hot water below boiling point, and functional property of the germinated sample was better than other processing method samples in terms of wettability, dispersibility, water absorption capacity, swelling and pasting property.

Conclusion

The study showed that production of maize-millet-soybean complementary food for infants and young children using germination method is better than fermentation and roasting methods.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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