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Effects of Fermentation on the Nutritional Quality of QPM and Soybean Blends for the Production of Weaning Food

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Abstract

The purpose of this work was to study the effects of fermentation on quality protein maize (QPM) and soybean blends with respect to the nutritional quality including physico-chemical and functional properties; microbiological and sensory analyses, minerals and antinutrients composition. Quality protein maize-soybean blend flours were fermented for 24 and 48 hrs by natural and controlled fermentations. In contrary concentration of tannins and phytate were reduced significantly due to the fermentation process. Micronutrients increment in (mg/100 g) for P, Fe and Zn was 32.57 to 61.9; 3.98 to 7.20 and 2.61 to 4.21; respectively were revealed. Fermentation significantly ($p<0.05$) decreased the antinutrients which resulted a significant increase in micronutrients. Microbiological result revealed significant reduction of undesirable coliform count and increment of LAB with increase in fermentation time. Sensory quality result showed that gruel prepared from the fermented blended flours at 24 hrs of fermentation time and <250 µm particle size was found acceptable. In line with the result of this study, natural and controlled fermentation uniformly reduced antinutrients composition and improved the nutritional quality of the weaning blends via increased energy and nutrient densities. Fermentation of cereal and legume blends is low-cost and safe technique to save life of children suffering from protein-energy malnutrition.

Keywords: Antinutrients; Fermentation; Micronutrient; Nutritional quality; Blends; Weaning food

Introduction

Fermentation is widely applied in the processing of cereals for the preparation of a wide variety of dishes in Africa and it contributes to the development of acceptable texture, flavour and improves the nutritional quality, digestibility and safety of foods [1]. Fermentation has also been identified to significantly improve the nutritional value (protein quality) of maize-based foods and as well reduce their antinutrients [2].

The high dependence on maize as a staple food in tropical Africa, coupled with the low nutritive value of the commodity has led to the investigation of simple traditional methods in the improvement of the chemical and functional qualities of maize-based foods [3]. The use of legumes such as soybean has been successfully used to increase the nutritional value of cereal foods. Soybean has high protein content and constitutes the natural protein supplements to staple diets. Protein quality is synergistically improved in cereal-legume blends because of the lysine, tryptophan and methionen contributed by the quality protein maize [4]. Soybean products are frequently incorporated into products used for the treatment or prevention of malnutrition. Enriching weaning foods with soy is a convenient, inexpensive, and highly effective way to upgrade the quality of traditional weaning foods and to provide the nutrition a growing child needs. Soy works together with grain proteins to achieve an overall increase in the value of the protein. Adding even small quantities of soy can greatly increase protein content and quality of weaning foods [5]. However, raw ingredients such as cereals and legumes that are used to prepare fermented foods contain significant amounts of antinutreints. These components may decrease the nutritional value of foods by interfering with mineral bioavailability and the digestibility of proteins and carbohydrates [6].

There is urgent need for provision of weaning foods rich in protein, low-cost and suitable for provision of infants' nutritional needs in order to reduce child malnutrition which is a major global health problem [7]. Blends with a cereal-legume ratio of 70: 30 have been introduced in many communities for use in the preparation of complementary foods with augmented protein quality. These foods should meet World Health Organization estimated energy and nutrient needs from complementary foods [8]. The rationale of this study was to investigate the influence of fermentation on antinutrients composition, functional properties, physico-chemical and sensory characteristics of QPM-based soybean blended weaning foods in order to increase energy, nutrient densities and mineral bioavailability in a weaning gruel.

Materials and Methods

Research materials collection and sample preparation

Bako Hybrid Quality Protein Maize (BHQPY-545) and soybean (Afgat) varieties were collected from Bako and Hawassa Agricultural Research Centers; respectively. All experiments were performed at Addis Ababa Institute of Technology, Food Engineering laboratory, Ethiopian Health and Nutrition Research Institute and Kality Food Processing Share Company. Quality protein maize and soybean samples were prepared according to the method described [9].

Blend formulation

Formulations of high-protein-energy weaning blends were based on the material balance method, targeting 18% protein, 59% carbohydrates [10] and minimum energy value of 380 kcal per 100 g dry matter, according to WFP requirement specifications for particularly the age group of 6 to 18 months. Therefore, the blend ratio of 82:18; QPM: soybean was formulated.

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Natural and controlled fermentation process

Fermentations (NF, CF) were performed using the methods described [11]. After fermentation the samples were dried and grounded and finally placed into plastic containers and stored at 4°C.

Proximate composition and determination of energy value

After blend formulation both NF and CF fermentation process for 0, 24 and 48 hours with particle size distribution of <500 µm and <250 µm. The dried samples were analyzed for the parameters such as protein, crude fat and crude fiber using the method of AOAC and total carbohydrates were calculated by difference [12].

Determination of nutrient and anti-nutrient concentration

The micronutrients: iron, zinc and phosphorus were analyzed using atomic absorption spectoscopy. The antinutrients such as tannins and phytate were determined by the modified Vanillin assay [10].

Determination of functional properties of blends

Bulk density was determined by the method of Narayana [13]; dispersibility in water was determined by the method of Kulkarni [14]; water and oil absorption capacities were determined according to method described by Nwosu, Coffman [15,16]; respectively.

Microbiological analysis

Analyses of mold and yeast; aerobic plate count (APC), coliform count, fecal coliform count and *E.coli* were done using standard methods of ISO: 7954 [17].

Sensory quality assessment

The prepared weaning foods as gruel from famix provided from FAFA, QPM-Soybean blend flour and blend fermented for 24 and 48 hrs were evaluated by semi-trained panelists. The gruels were prepared by mixing about 10 g of blend flour dissolved in 200 ml distilled water and cooked at 92°C for 15 min. The panelists were asked to rank the gruel on the basis of appearance (color), odor, and taste using a nine point hedonic scale (where 1 = dislike extremely and 9 = like extremely). Overall acceptability of the samples was also rated on same scale with 9 = extremely acceptable and 1 = extremely unacceptable [18].

Results and Discussion

Effect of fermentation on proximate composition and energy value of QPM-soybean blends

Fermentation time significantly ($p<0.05$) affects protein content of blend flour (Table 1). As fermentation time increased from 0 to 24 h and 48 hrs, protein content of blends were 14.71%, 17.43% and 17.52%; respectively. The protein content of blends before and after fermentation (0,12 and 24 hrs) was higher than the minimum protein requirement (14%) of WFP specification for corn-soya blend and within the range (16.00%-19.97%) reported by Lalude [19].

As fermentation time increases the fat content of fermented blends increases from 8.42% to10.9% with respect to the fermentation time of 0, 24 and 48 hrs (Table 1). This is due to the removal of soluble carbohydrates during fermentation. According to the findings of Amankwah the fat content of formulation of weaning food from fermented maize, rice, soybean and fishmeal was 9.38% and 8.75% [20]. The experimental value is within the range with this value. The value of crude fat content of the blend before and after fermentation (8.42%, 10.2%, and 10.9% to 8.86%) is higher than the value of WFP specification for the minimum requirement of 6% fat of corn-soya blend. And it is comparable with the value of famix infant food (≥7%). The fat content of current study is also within the range with the value (9.0%) of Nutrend- commercially sold Nigerian weaning food.

The value of crude fiber after fermentation (4.49%, 5.32% for particle size distribution of <250 µm and 5.19%, 4.67% for particle size distribution of <500 µm for natural fermentation) and (5.91%, 5.63%) for particle size distribution of <250 µm and (6.88%, 5.96%) for particle size distribution of through <500 µm for controlled fermentation) at 24 and 48 h fermentation time respectively (Table 1). Fermentation time is significantly ($p<0.05$) decreased the crude fiber contents of blend. According to high fiber contents of weaning foods may inhibit mineral absorption and reduce the digestibility of proteins in foods [21]. According to WHO specification the maximum requirement is (5%). Therefore, the experimental values of the blends after fermentation are close to this value. Fermentation time had significantly ($p<0.05$) decreasing effect on the total carbohydrates content of blend (66.63%, 64.16%, 63.9%) and (66.63%, 61.91%, 60.49%) for particle size distribution of <250 µm and <500 µm at 0, 24 and 48 h fermentation time respectively as can be seen from the This is possibly due to the degradation of carbohydrates by microorganisms and the decreasing effect of fermentation upon the amount of Non-Digestible Carbohydrates (NDC) which are fibers (Table 1). All the experimental values of blend before and after fermentation are comparable with values (67.21% and 63.32%) research findings by Mbata for fermented maize flour and Bambara groundnut-maize fortified flour [22]. It was reported that the total carbohydrate content of maize-soybean blend for the production of Ogi is (61.76%); that is lower than the value of the current study [23].

In the case of controlled fermentation, the calorific values of the blends are decreased, even though there are some fluctuations in natural fermentation. This may be due to the value difference of the nutrients (protein, fat and carbohydrate) by the effect of fermentation process. The calorific value of the blend shown in the Table 1, are in agreement with the researcher reported by Griffith [24]. The calorific value for weaning food revealed in the range of 395 to 509 kcal which is in agreement with the value (398.9 kcal) for “Nutrend” (Nestle, Nigeria-weaning diet) obtained commercially and the research finding reported by (441 kcal) [19]. The value is also within the range provided by WHO specification (380 kcal) for the weaning food from corn-soya blend.

Influence of fermentation process on antinutrients reduction of QPM-soybean blends

During the preparation of many fermented foods, tannins are reduced before the fermentation step because of their presence in the seed coats of raw ingredients. In several fermented foods, the seed coat or testa is removed from the substrate before fermentation. Consequently, the antinutrients potential caused by the presence of tannins is of little concern [11]. Fermentation process further reduced tannins content of the blend (Table 2). Therefore, fermentation time significantly ($p<0.05$) affected tannins content of the blend. The phytate concentration present in raw materials and foods of plant origin are suggested to be a major factor responsible for lowering the availability of minerals and some proteins as reported [11]. Fermentation duration, type and particle size distribution greatly affects the composition of antinutients.

Effect of reduction of antinutrients on micronutrients composition of blends

The P, Fe, Zn and Ca concentrations of the blends before fermentation were (32.57 mg/100 g, 3.98 mg/100 g, 2.61 mg/100 g,

Fermentation type and particle size distribution	**Flour samples**	**Crude protein (%)**	**Crude fat (%)**	**Crude fiber (%)**
Before fermentation	Blend	$14.72^{g} \pm 0.03$	$8.42^{ef} \pm 0.01$	$7.33^{ac} \pm 0.02$
(<250 µm), NF	Blend24	$17.43^{e} \pm 0.02$	$10.20^{b} \pm 0.14$	$4.49^{h} \pm 0.08$
	Blend48	$17.52^{de} \pm 0.01$	$10.90^{g} \pm 0.28$	$5.32^{fg} \pm 0.01$
(<500 µm), NF	Blend24	$17.57^{de} \pm 0.06$	$10.20^{b} \pm 0.07$	$5.19^{g} \pm 0.06$
	Blend48	$17.85^{b} \pm 0.04$	$10.80^{de} \pm 0.21$	$4.67^{h} \pm 0.06$
(<250 µm), CF	Blend24	$17.30^{f} \pm 0.21$	$9.40^{c} \pm 0.14$	$5.91^{e} \pm 0.02$
	Blend48	$17.67^{cd} \pm 0.04$	$8.50^{ef} \pm 0.35$	$5.63^{ef} \pm 0.05$
(<500 µm), CF	Blend24	$17.72^{bc} \pm 0.01$	$9.36^{c} \pm 0.06$	$6.88^{b} \pm 0.04$
	Blend48	$19.44^{k} \pm 0.05$	$8.86^{d} \pm 0.02$	$5.96^{e} \pm 0.04$

Fermentation type and particle size distribution	**Flour samples**	**Carbohydrates (%)**	**Calorific value kcal/100g**
Before fermentation	Blend	$66.63^{d} \pm 0.02$	400.81^{b}
(<250 µm), NF	Blend24	$66.90^{d} \pm 0.28$	412.67^{f}
	Blend48	$65.01^{e} \pm 0.08$	412.25^{f}
(<500 µm), NF	Blend24	$66.74^{d} \pm 0.03$	412.63^{f}
	Blend48	$67.97^{d} \pm 0.05$	404.01^{h}
(<250 µm), CF	Blend24	$64.16^{f} \pm 0.11$	410.75^{d}
	Blend48	$63.90^{g} \pm 0.42$	387.06^{g}
(<500 µm), CF	Blend24	$61.91^{h} \pm 0.36$	387.54^{g}
	Blend48	$60.49^{i} \pm 0.06$	384.60^{j}

All values are means ± SD, Values in the same column with different superscripts for each type of analysis are significantly different ($P < 0.05$).

Where CF-Controlled fermentation and NF-Natural fermentation

$QPMf_{24}$ - QPM flour fermented for 24 hours, $QPMf_{48}$ - QPM flour fermented for 48 hours, $Blend_{24}$- Blend fermented for 24 hours and $Blend_{48}$ - Blend fermented for 48 hours.

Table 1: Proximate chemical composition of blends

Fermentation type and particle size distribution	Flour Samples	Tannins (mg/100g)	Phytate (mg/100g)
Before fermentation	Blend	$21.95^{c} \pm 0.67$	$249.2^{a} \pm 0.14$
<250µm, NF	Blend24	BDL	$155.75^{d} \pm 0.53$
	Blend48	BDL	$133.06^{e} \pm 0.04$
<500µm, NF	Blend24	$3.10^{c} \pm 0.21$	$155.51^{d} \pm 0.36$
	Blend48	BDL	$147.50^{f} \pm 0.35$
<250µm, CF	Blend24	$6.93^{e} \pm 0.02$	$143.20^{g} \pm 0.14$
	Blend48	$4.98^{d} \pm 0.06$	$139.22^{i} \pm 0.16$
<500µm, CF	Blend24	$8.94^{f} \pm 0.04$	$146.64^{h} \pm 0.45$
	Blend48	$5.05^{d} \pm 0.11$	$138.65^{i} \pm 0.46$

Values in the same column with different superscripts for each type of analysis are significantly different ($P < 0.05$).

Where-BDL: Below detection limits

Table 2: Content of tannins and phytate of blends.

and 34.08 mg/100 g) respectively. In the case of NF, for particle size distribution of <250 µm and <500 µm P of the blend is (32.57 mg/100 g, 61.90 mg/100 g, 61.20 g/100 g) and (32.57 mg/100 g, 59.60 mg/100 g, 55.30 mg/100 g) during 0, 24, and 48 h fermentation time respectively. As can be seen from the Table 3, P as fermentation increases from 0 to 24 h and 0 to48 h increases too. The same is true for minerals: Fe; Zn and Ca that shows similarly increasing in values as fermentation time increased. This is due to the minerals of the grain that are not readily available for microorganisms as they are complexed with phytate, at pH values of <5.5 the endogenous grain phytase hydrolyses phytate and minerals are released from the complex [25].

Largely, fermentation time significantly ($p<0.05$) affect the mineral composition of the blend. The Ca, P, and Fe content are higher than the values (22 mg/100 g, 26 mg/100 g, 1.0 mg/100 g) reported by for Nutrend [19]. Values of iron and zinc are within the range of WHO standards (3.25 mg/100 g, 5 mg/100 g) for the manufacture of corn soya blend for infants. The micronutrients values (17 to 25 mg/100 g for Ca; 7.19 to 10.98 mg/100 g for Fe and 1.78 to 2.01 mg/100 sg for Zn) are in agreement with the values for sorghum based weaning food [11].

Effect of fermentation viscosity of QPM-soybean blends

As indicated in Table 4, the viscosity of the blend is (5.31×10^{-3}Pa.s) and the viscosity of blend gruel during fermentation of 24 h and 48 h is (4.38×10^{-3}Pa.s, 4.21×10^{-3}Pa.s); respectively. From the results, fermentation time had significantly ($p<0.05$) decreasing effect on the viscosity of the blend. A prolonged time of starch gelatinization was observed while preparing gruels of fermented blend. This possibly is due to the degradation of starch granules during fermentation and this might cause for the reduction of starch swelling while cooking.

Effect of fermentation on viscosity of QPM-soybean blends

As indicated in Table 5, the viscosity of the blend is (5.31×10^{-3}Pa.s) and the viscosity of blend gruel during fermentation of 24 h and 48 h is (4.38×10^{-3} Pa.s, 4.21×10^{-3} Pa.s) respectively. From the results, fermentation time had significantly ($p<0.05$) decreasing effect on the viscosity of the blend. A prolonged time of starch gelatinization was observed while preparing gruels of fermented blend. This possibly is due to the degradation of starch granules during fermentation so that

Fermentation type and particle size distribution	Flour Samples	P (mg/100g)	Fe (mg/100g)	Zn (mg/100g)	Ca (mg/100g)
Before fermentation	Blend	$32.57^{c} \pm 0.40$	$3.98^{ef} \pm 0.06$	$2.61^{f} \pm 0.08$	$34.08^{c} \pm 0.17$
<250 µm, NF	Blend24	$61.90^{a} \pm 0.64$	$7.20^{a} \pm 0.14$	$4.21^{g} \pm 0.15$	$24.91^{d} \pm 0.64$
	Blend48	$61.20^{ah} \pm 0.14$	$4.74^{c} \pm 0.03$	$3.81^{cd} \pm 0.08$	$21.34^{e} \pm 0.24$
<500 µm, NF	Blend24	$59.60^{d} \pm 0.42$	$6.22^{d} \pm 0.16$	$3.98^{gc} \pm 0.06$	$24.92^{d} \pm 0.65$
	Blend48	$55.30^{e} \pm 0.21$	$3.42^{b} \pm 0.03$	$3.65^{d} \pm 0.06$	$22.53^{f} \pm 0.37$
<250 µm, CF	Blend24	$58.50^{f} \pm 0.35$	$4.31^{e} \pm 0.22$	$2.89^{e} \pm 0.06$	$65.02^{g} \pm 0.01$
	Blend48	$56.30^{g} \pm 0.21$	$4.21^{ef} \pm 0.15$	$2.81^{e} \pm 0.04$	$64.97^{g} \pm 0.02$
<500 µm, CF	Blend24	$60.60^{h} \pm 0.42$	$3.99^{ef} \pm 0.06$	$2.84^{e} \pm 0.03$	$65.42^{g} \pm 0.30$
	Blend48	$54.30^{i} \pm 0.21$	$3.88^{f} \pm 0.07$	$2.71^{ef} \pm 0.04$	$64.77^{g} \pm 0.54$

Values in the same column with different superscripts for each type of analysis are significantly different (P < 0.05).

Table 3: Micronutrient composition of blends.

Blend with respective fermentation time	Viscosity (Pa.s)
Blend	$5.31\times10^{-3b} \pm 0.22$
Blend24	$4.38\times10^{-3e} \pm 0.26$
Blend48	$4.21\times10^{-3e} \pm 0.15$

Values in the same column with different superscripts for each type of analysis are significantly different (P < 0.05).

Table 4: Viscosity of gruel from blends at a temperature of 50˚C.

cause for the reduction of starch swelling while cooking. According to Plahar in terms of starch stability, fortification with soy flour is a cause for strengthening of the starch granules [26].

Impact of fermentation on functional properties of QPM-soybean blends

Bulk density and dispercebility: As fermentation time increase from 0 to 24 and 48 h, the bulk density significantly decreases for QPM-Soybean blends. The bulk density of QPMf before fermentation is (0.84 and 0.92) and after fermentation of 24 and 48 h is (0.62, 0.59 and 0.63, 0.6) for particle size distribution between <250 and <500 µm; respectively. The bulk density of QPMf before fermentation is significantly (p<0.05) higher than that of after fermentation. The values (0.66 and 0.61) of the current research finding is in agreement with that of reported Lalude [19], of a weaning food prepared from sorghum based and Nutrend. Similarly, the values are comparable with value (0.68) reported by Mesfin [27]. As fermentation time increased the value of dispercebility significantly (p<0.05) increased from 0.65%, 69% to 66%, 67% and 65%, 69% for fermentation time of 24 and 48 h and particle size distribution of <250 and <500 µm; respectively. The values of both bulk density and dispersability of QPMf and blend are higher than the values (0.55 gm/ml and 32.93%) reported by Ahima respectively [28].

Water and oil absorption: As indicated in Table 5, water absorption of both QPMf and blend is significantly (p<0.05) decreased when fermentation time increased from 0 to 24 h and from 0 to 48 h. Ahima reported that the water absorption of flour from commercially sold floury maize and Maize-soy flour blend is (194.65% and 172.98% respectively) [28]. This result indicated that the water absorption of QPMf and blend is lower than that of the researches findings. In the current study the unfermented and fermented blends found to contain comparable amount of water absorption with (134%) that is reported by Emmanuel, cowpea-fortified nixtamalized food. Oil absorption capacity of QPMf (1.4 ml, 2.3 ml) is higher than of blend (1.2 ml, 1.7 ml) with particle size distribution of <250 µm and <500 µm. Similarly, QPMf fermented for 24 hrs and 48 hrs (4.2 ml, 5.2 ml and 4.8 ml, 5.0 ml) is significantly higher than that of fermented blend (2.2 ml, 3.0 ml and 1.9 ml, 2.8 ml) for particle size of <250 µm and <500 µm respectively. These results indicated that blending QPMf with soybean flour significantly (p<0.05) decreased the oil absorption of the blend. Therefore, blend ratio and fermentation time has significantly (p<0.05) a decreasing effect on the oil absorption. The values obtained from current study are higher than that of (1.22 ml-2.23 ml) reported by Mensah of extrusion cooking of full-fat soy flour [29]. Similarly, oil absorption of both fermented QPMf and blend are higher than the value (1.82 ml, 1.44 ml) for different varieties reported by Assefa of improved varieties of soybean in Ethiopia [30].

Sensory quality attributes of value added products

The average results of taste evaluation by the panelist for the control, fermented for 24 h, unfermented blend and fermented for 48 h were 8.9 (like extremely); 7.8 (like very much); 7.2 (like moderately) and 5.8 (like slightly) respectively. The overall acceptability of gruel fermented for 24 h with the average value of 8.5 is not significantly different (p>0.05) compared with that of the control. The result of the others ranged 5.9 to 7.1. This might be due to all the products are evaluated without flavoring agents. Similar results on weaning and commentary food products were report by Abbey, Beruk [31,32] (Table 6).

Microbiological quality of blends

In Table 7 mould count, yeast count, Aerobic Bacteria plate Count (APC), coliform count and others are shown. The result indicated that as fermentation time increased, the undesirable microorganism, mould count, decreased significantly for both type of fermentation. The molds isolated in the current study are commonly present as contaminants and do not appear to play any significant important role in the fermentation process. This shows clearly that the importance of fermentation in the aspect of food preservation.

At 0 hr fermentation time, the yeast count was found to be $<1\times10^{1}$ cfu/g, which is considered to be no yeast colonies in the count, but during 24 and 48 h fermentation, the values were increased upon both Natural and Controlled Fermentation. This shows that fermentation time significantly (p<0.05) affect the yeast count. The coliform count at the start of fermentation was found to be 4.3×10^{2} cfu/g and upon increasing fermentation time, 24 and 48 h the count was decreased to 3.1×10^{2} cfu/g and 3.2×10^{2} cfu/g in the case of NF and almost eliminated ($<1\times10^{1}$ cfu/g) in the case of CF. The expected decrease or elimination of coliform is in agreement with the value (2.85 cfu/g, 0 cfu/g, 0 cfu/g) for 0, 24 and 48 hrs fermentation time reported by Mbata of fermented maize flour fortified with bambara groundnut [22]. The aerobic bacteria plate count, (APC) as shown in the Table 7 is 1.8×10^{2} cfu/g at 0 h fermentation time and (2.6×10^{3} cfu/g, 2.4×10^{3} cfu/g) in the case of NF and (6.7×10^{3} cfu/g, 5.7×10^{3} cfu/g) for CF during 24 and 48 hrs fermentation time; respectively. Aerobic plate counts taken at 24 h

Types of flour	Bulk density (g/ml)	Dispersibility (%)	Water absorption (%)	Oil absorption (ml/g of sample)
QPMF$_{<250}$	$0.84^{a} \pm 0.01$	$65^{a} \pm 0.71$	$139.09^{a} \pm 0.06$	$1.4^{af} \pm 0.07$
QPMF$_{<500}$	$0.92^{b} \pm 0.02$	$69^{c} \pm 0.35$	$136.27^{b} \pm 0.19$	$2.3^{b} \pm 0.11$
QPMF$_{<250, 24}$	$0.62^{efg} \pm 0.01$	$66^{a} \pm 1.41$	$129.23^{c} \pm 0.16$	$4.7^{c} \pm 0.21$
QPMF$_{<250, 48}$	$0.59^{fg} \pm 0.02$	$67^{ab} \pm 2.12$	$137.17^{d} \pm 0.12$	$5.2^{d} \pm 0.12$
QPMF$_{<500, 24}$	$0.63^{efg} \pm 0.01$	$65^{ab} \pm 0.71$	$139.73^{a} \pm 0.52$	$4.8^{ce} \pm 0.14$
QPMF$_{<500, 48}$	$0.60^{g} \pm 0.02$	$69^{c} \pm 1.41$	$144.80^{e} \pm 0.57$	$5.0^{de} \pm 0.07$
Blend$_{<250}$	$0.77^{c} \pm 0.01$	$57^{e} \pm 1.06$	$142.00^{f} \pm 0.35$	$1.2^{f} \pm 0.11$
Blend$_{<500}$	$0.79^{c} \pm 0.03$	$64^{a} \pm 0.35$	$136.33^{b} \pm 0.23$	$1.7^{ag} \pm 0.12$
Blend$_{<250, 24}$	$0.74^{d} \pm 0.01$	$67^{bc} \pm 1.41$	$140.37^{g} \pm 0.26$	$2.2^{bh} \pm 0.14$
Blend$_{<250, 48}$	$0.67^{e} \pm 0.02$	$60^{d} \pm 0.71$	$146.00^{h} \pm 0.21$	$3.0^{i} \pm 0.13$
Blend$_{<500, 24}$	$0.75^{cd} \pm 0.01$	$66^{ab} \pm 0.02$	$126.13^{i} \pm 0.09$	$1.9^{gh} \pm 0.07$
Blend$_{<500, 48}$	$0.65^{ef} \pm 0.03$	$65^{a} \pm 2.12$	$132.83^{j} \pm 0.59$	$2.8^{i} \pm 0.21$

Values in the same column with different superscripts for each type of analysis are significantly different ($P < 0.05$).

Table 5: Bulk density, dispensability, water and oil absorption of blends.

Sample code	Appearance	Odor	Taste	Overall acceptability
Control (Famix)	$8.30^{a} \pm 0.65$	$8.80^{a} \pm 0.24$	$8.90^{a} \pm 0.23$	$8.90^{a} \pm 0.34$
Blend$_{< 500}$	$6.00^{b} \pm 1.73$	$6.67^{b} \pm 1.15$	$7.30^{b} \pm 0.58$	$7.00^{b} \pm 0.00$
Blend$_{<250}$	$6.40^{b} \pm 1.20$	$6.69^{b} \pm 0.84$	$7.10^{b} \pm 0.51$	$7.20^{b} \pm 0.57$
Blend$_{24<500}$	$7.70^{cd} \pm 0.00$	$7.33^{c} \pm 0.58$	$7.70^{c} \pm 0.56$	$8.30^{c} \pm 0.43$
Blend$_{48<500}$	$7.00^{e} \pm 0.58$	$5.70^{d} \pm 1.13$	$5.70^{d} \pm 0.60$	$6.00^{d} \pm 0.26$
Blend$_{24<250}$	$7.80^{ac} \pm 0.44$	$7.54^{e} \pm 0.78$	$8.10^{e} \pm 0.47$	$8.50^{ac} \pm 0.62$
Blend$_{48<250}$	$7.50^{d} \pm 0.39$	$5.90^{d} \pm 0.95$	$6.00^{d} \pm 0.86$	$5.80^{d} \pm 0.18$

All values in the same column with different superscripts for each type of analysis are significantly different ($P < 0.05$).

Table 6: Sensory quality evaluation of weaning food.

Isolated microorganisms	Microbial count load (cfu/g) of blend samples				
	0	24, NF	48, NF	24, CF	48, CF
Mold count at 25 ˚C /5-7 days	2.1×10^{4}	4×10^{2}	3.2×10^{2}	5×10^{2}	4×10^{2}
Yeast count at 22˚C /5-7 days	Nil	2.9×10^{2}	3.2×10^{2}	2.0×10^{2}	3.5×10^{2}
APC at 30˚C/72 h	1.8×10^{2}	2.6×10^{3}	2.4×10^{3}	6.7×10^{3}	5.7×10^{3}
Coliform count	4.3×10^{2}	3.1×10^{2}	3.2×10^{2}	Nil	Nil
Fecal coliform count	Nil	Nil	Nil	Nil	Nil
E.coli count	Nil	Nil	Nil	Nil	Nil
S.coccus spp	Nil	Nil	Nil	Nil	Nil

Values in the same column with different superscripts for each type of analysis are significantly different at $P < 0.05$.

Table 7: Microbiological quality of blends at different fermentation time for NF and CF.

intervals of fermentation indicated that the increased growth of yeasts and lactic acid bacteria gradually throughout fermentation while the decrease in numbers of molds and coliforms.

Conclusions

In this research, it was observed that fermentation process significantly changed the nutritional value of the weaning blends by reducing antinutrients. The maximum reduction of phytate due to fermentation effect can lead to the increment of the bioavailability of micronutrients. Subsequently, 47.4% (P), 47.9% (Ca), 44.7% (Fe) and 38% (Zn) increment was observed. The fermentation process affected the energy value and nutrient densities of the weaning blends. Gruels prepared from fermented blend flours were less viscous and the dietary bulkiness nature was improved. The microbial load of blend samples at different fermentation time for NF and CF found acceptable; and the sensory quality evaluation of the prepared gruel was acceptable by panelists. An infant food of higher energy and nutrient density formulated and prepared from a formulation of 82% quality protein maize and 18% soybean had the strongest impact on nutritional quality; and should be viewed as an option in the development of infant weaning foods in order to reduce child malnutrition problem in the Ethiopian context.

Accordingly, the use of cereal based legume blends with augmented protein quality could help rural communities predominantly to make better use of their available resources; and the same time can improve nutrient density and fulfill the minimum daily requirements for energy, protein and micronutrients. Promotional efforts should be made to transfer technique of this high-protein-energy weaning blends formulation and processing technology to food manufacturing industries and household women in order to diminish child mortality in Sub-Saharan African Countries.

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