Formulation and Nutritional Evaluation of Finger Millet based Food Products

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Abstract

This study was carried out to develop nutrient dense and acceptable food products from composite flour comprised of finger millet, ground nut, orange fleshed sweet potato and soya bean flours. There was a significant difference in water absorption capacity, swelling power, water solubility and oil absorption capacity among the composite flours. The moisture, ash, protein, fat, fiber and carbohydrate contents of the formulations were ranged from 8.141 - 9.67, 1.03 - 3.17, 4.38 - 17.17, 0.02 - 15.59, 2.85 - 13.87 , 60.41 - 71.57%, respectively. Injera made from composite flour consisting of 75:25 finger millet and soya bean, respectively, were more preferred by panelists than other proportions. Sensory attributes result showed that porridge made from composite flour formulated from 60:20:20 of finger millet, soya bean and sweet potato were highly preferred by panelists in all sensory attributes. On the other hand, sensory acceptability of kita made from composite flour formulated from 70:20:10 of finger millet, soya bean and sweet potato, respectively, were achieved highest sensorial scores. Therefore, blending of finger millet with nutritious legumes, root and tubers crops would be recommended in the development of nutritional and sensorial acceptable value added food products for different purposes.

Keywords: Finger millet, Composite flour, Proximate composition, Injera, Porridge

Introduction

Nutrient compositions of most cereal based food products are inadequate to meet the nutrient requirement for all age groups. Enrichment of cereal with easily affordable legumes, root and tubers having superior nutrients are important approach to produce nutrient dense and sensorial acceptable food products. Millets have been cultivated since prehistoric times in regions of Asia and Africa, and used for food and feeds. Cereal and cereal-based food products provide more than 56% of the energy and 50% of the protein consumed worldwide (BNF, 2004). Nutritionally, millets are equivalent to other cereal grains (FAO, 1995) and has potential health benefits in management of diabetes mellitus, obesity and hyperlipidemia (Takhellambam *et al*., 2016). Even though several millet varieties are available, finger millet is often mentioned separately from other small millets as it has thrice the amount of calcium as milk which is critical for women and babies. In addition, low glycemic index and gluten free nature of finger millet grains represent as an ideal food for peoples with celiac disease and diabetes (Ramashia *et al.,* 2019). Thus, finger millet is a good source of diet for growing children, lactating women, old age people and patients (Desai *et al*., 2010).

In nutrition point of view, protein–energy malnutrition is still a major public health issue in developing countries and mostly associated with 50-60% of under-five mortality (Muller and Krawinkel, 2005; Faruque *et al*., 2008). To overcome this situation, the development of food products using composite flour has been used for decades. Protein and micronutrient deficiencies might be high in millet growing areas of Ethiopia as millets has less protein and fat contents compared to other cereals. Thus, there is a need to enrich millet based traditional foods with other grains and tubers. Soybean flour contains about 35-45% of protein, on dry weight basis and therefore it is considered an excellent source of protein (Serrem *et al.,* 2011) with all essential amino acids required for proper growth and repair of damaged human tissues. Similarly, groundnuts are also leguminous crop which has substantially high protein content (Uvere *et al*., 1999). On the other hand, orange fleshed sweet potato contains high levels of carotenoids, particularly, hydrogen carotenoids and beta carotene (provitamin A) (Kosambo et al., 1998). Sweet potato (*Ipomoea batatas* L.) is one of the most traditional root crops in many countries. Vitamin A deficiency is a wide spread nutritional and health problem affecting particularly children and cause illnesses, impaired growth, development, vision, and immune systems, and in severe cases results in blindness and death (Ruel, 2001). In addition to its nutritional value, the use of composite flours has a few advantages in terms of the saving of hard currency; promotion of high yielding, native plant species; and encourages the use of locally grown crops as flour (Hugo et al., 2000; Hasmadi *et al*., 2014). Mepba et al. (2007) revealed that the experience gained in the use of composite flours has clearly demonstrated for reasons of both product technology and consumer acceptance. The improvement of local food staples and utilization of locally produced staple crops in the development of high energy foods rich in micronutrients has been a subject of research over the years to meet the protein and energy need of vulnerable populations (Muller and Krawinkel, 2005). This has shown high economic advantage when composite flour made from cereals, tubers and legumes are used to develop such food products.

Value addition and improving health benefits of millets by combining with other grains and tubers with advanced technologies for their processing opens new avenues for the product diversification (Sudha *et al.*, 2016). In Ethiopia, millet is utilizing in the form of injera, unfermented porridge, bread, kita, and local beverages like farso/tella and areki. Injera is fermented, sour bread consumed as a staple food in Ethiopia and other neighboring countries. Porridge is a major weaning food particularly in developing countries and is a food-based intervention to reduce malnutrition and nutrition insecurity in infants and children.

Blend of cereals, legumes and tubers in the formulation of composite flour can improve functional properties, nutrient contents and sensorial attributes. Therefore, the present study was designed to develop nutrient dense finger millet based composite flour and products using soybean, ground nut and sweet potato mixes for injera, porridge and kita product making.

Materials and Methods

Sample collection and preparation

Finger millet (*Tadesse*) variety which is widely cultivated by local surrounding farmers was obtained from Melkassa Agricultural Research Center. Soybean (*Belessa-95*) and Orange fleshed sweet potato were collected from Pawe and Hawassa Agricultural Research Centers, respectively. Groundnut was purchased from a nearby local market. The collected samples were subjected manual cleaning operation to remove extraneous matter and damaged grains. The grain of finger millet was washed, sun dried and decorticated using hand pounding pestle for 5 min and then grinded using laboratory milling machine and kept in clean air tight polyethylene bag for blending and analysis. The cleaned soya bean grain was soaked in 1:3 (w/v) ratios by using tap water in medium size of plastic container for 12hrs at room temperature. Soaked soya bean was washed using tap water and the excess water was drained. Then it was boiled for 2hrs at 100 ^{0}C, the husk was separated and washed. The washed and dehulled soya beans grain was sun dried and milled to fine flour using laboratory milling machine and the flour was kept in clean air tight polyethylene bag for blending and farther analysis. Ground nut grain was cleaned, roasted and the husk was removed, after that milled to fine flour and kept in clean air tight polyethylene bag for formulation. The raw tuber of sweet potato was washed in tap water to remove dirt and soil, peeled and sliced into pieces, blanched, and then flour was produced.

Composite flour formulation

Two types of composite flours were prepared, type I and type II. Type I is formulated for injera, and type II for porridge and kita making (Table 1). The formulated composite flour then mixed thoroughly with homogenizer into smooth homogenous powder and stored in airtight containers at room temperature until used.

Flour functional properties characterization

Swelling power, solubility, water absorption capacity and oil absorption capacity were evaluated to determine composting effect of finger millet flour with the legumes and orange fleshed sweet potato. Swelling power and solubility of the composite flour and ingredients were conducted at 30, 55 and 95°C. A 0.4 g flour samples (dry basis, db) were mixed with 12.5 ml of water, equilibrated at the respective temperature for 5 min and then centrifuged at 5000 rpm for 15 min.

The swelling volume was then calculated by converting the height of the resultant gels to a volume basis, and the results reported as g/g of dry flour. The supernatant was carefully removed and the difference of the initial and final volume due to swelling was observed for measuring solubility and expressed per gram of the initial weight of the dry flour. Water and oil absorption capacity were determined using standard methods (Hassan *et al.*, 2013). All experiments were repeated three times and values presented as the mean of the three observations.

Table1. Ingredient formulation ratios

Composite flour	Ingredients in percentage (%)			
	Finger millet	Soya bean	Ground nut	Sweet potato
Control	100	0	0	0
Type I	65	35	0	0
	70	30	0	0
	75	25	0	0
	80	20	0	0
	85	15	0	0
Type II	60	20	20	0
	70	20	10	0
	60	20	0	20
	70	20	0	10

Proximate composition determination

Proximate compositions: Moisture content, fat content, protein content, ash content and crude fiber were determined following standard method (AOAC, 2000). Utilizable carbohydrate was determined using formula described below. Utilizable carbohydrate (%) = 100 - [protein (%) + crude fat (%) + crude fiber (%) + ash (%) + moisture (%)]. The energy value was calculated using the Atwater and Benedict coefficients according to the following formula:

Energy (Kcal/100 g) = % Utilizable carbohydrates × 4 (Kcal) +% proteins × 4 (Kcal) +% fat × 9 (Kcal) (Atwater and Benedict, 1899)

Injera preparation

Injera was prepared using a standardized injera making procedure (Yetneberk *et al.*, 2004). The procedure involved milling whole millet grain into flour, preparation of a dough, and fermentation of the dough after adding yeast (a batter from a previous batch) and fermenting at room temperature for 48 hrs. After fermentation, 80g of the fermented dough was thinned with 30 mL of water and cooked in 200 ml of boiling water for 1 min. The gelatinized batter was cooled to 45°C at room temperature and added back to the fermenting dough. After thorough mixing, 100 ml of water was added and the batter was fermented at room temperature for 3 hrs. Additional water (20 ml) was added to the fermented dough to bring to batter consistency. About 500g of the fermented batter was poured in a circular manner on a 50cm diameter hot clay griddle, covered and baked for 2 min.

Porridge preparation

Porridge was prepared using traditional method by adding 250 g of composite flour in 400 ml of cold water before adding to 450 ml of boiling water. The mixture was brought to boil under continuous stirring, then left to boil for additional 15 min.

Kita preparation

Kita was prepared by kneading 250g of composite flour in 150 ml of water and baked on a heated mitad (stove).

Sensory evaluation

Consumer acceptability of developed injera, porridge and kita were evaluated using semi trained panelists based on five point hedonic scale ((1= dislike very much, 5= like very much). Thoroughly, 15 semi-trained panelists, consisting of men and woman who regularly consume those foods were selected. The panelists were provided with the randomly sequenced baked/cooked product samples presented on the tray after cooled to room temperature. Selected attributes for injera evaluation were color, texture, aroma, taste, eye evenness, rollability, underneath color and overall rate. Porridge was evaluated for its mouth feel, aroma, color, taste and overall acceptability. Panelists evaluated the sensory acceptability of kita based on its texture, aroma, color, taste, appearance and overall acceptability.

Data analysis

One-way ANOVA analysis of variance was used for statistical analysis. Generalized linear model (GLM) procedure for least square means and Duncan's Multiple Range Test (DMRT) for significant difference between means were used.

Result and Discussion

Functional properties

The results of functional properties of composite flour are presented in Table 2. Water solubility index (WSI) reflects the presence of soluble molecules and is a measure of starch degradation. Statistically significant ($p<0.05$) difference was observed among water solubility of finger millet and soya bean composite flours. WSI of the composite flours was varied from 11.64 to 13.17g/g. The WSI values observed in this study were slightly higher than water solubility recorded in multigrain (millets, rice, wheat, chickpea and soya bean) composite flour reported by Singh et al. (2012). Swelling power is regarded as quality criterion in some good formulations such as bakery products. The swelling power is an indication of presence of amylase which influences the quantity of amylose and amylopectin present in the flour. Swelling power is also related to the water absorption index of the starch-based flour during heating (Loss *et al*., 1981). The higher the swelling power, the higher the associate forces. The swelling power of the composite flours ranged from 120.36-145.83% and there was not significance difference between formulates ($p>0.05$).

The Water Absorption Capacity (WAC) measures the volume occupied by the starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion. The WAC is important in the development of ready to eat foods, and a high absorption capacity may assure product cohesiveness (Houson and Ayenor, 2002). Results of the present study showed that highest WAC (21.58 g/g) was observed in composite flour formulated from 70% finger millet, 20% soya bean and 10% sweet potato, and the lowest (12.34 g/g) observed in composite flour formulated from 75% of finger millet and 25% of soya bean flour. Oil absorption capacity (OAC) measures the ability of the flour protein to physically bind fat by capillary attraction. Oil absorption capacity values ranged from 100 g/g to 150 g/g. The results of OAC of composite flour obtained in the present study were higher than the report of Adebayo and Okoli (2017) for lima bean, sorghum and wheat composite flour. The authors reported a range of 95.66 to 96.89.

Table 2 Functional properties of composite flours

Composite flour	Trt	Ingredients in percentage				Functional properties			
		Finger millet	Soya bean	Groundnut	Sweet potato	Swelling power	Solubility	OAC	WAC
Control	0	100							

Proximate composition of composite flour

The results of proximate composition for composite flour are shown in Table 3. It was found that moisture content of the composite flour was significantly ($p<0.05$) varied among each other. It ranged from 8.14% to 10.06 % for both types composite flour with the highest moisture content (10.06%) recorded for composite flour formulated from 85% finger millet and 15% soya bean flour and the lowest moisture content (8.14%) recorded for composite flour produced from 60% finger millet, 20% soya bean and 20% groundnut flour. Low moisture content in food samples increases the shelf life of food products through inhibition of microbial growth and biochemical reaction (Alozie *et al*., 2009). Ash value refers the amount of total mineral present in a given food sample. The higher ash value in the food sample is an indication of high mineral content. Statistically, the highest and lowest ash values were recorded for composite flour consisting of 70:30, finger millet and soybean flour and 70:20:10, finger millet, soybean, ground nut flour, respectively. Total ash content obtained in the current study was closely related to ash value reported by Bolarinwa et al. (2016) for malted sorghum and soya bean based composite flour.

Protein content of the composite flour increased significantly as soya bean and ground nut proportion increased in the formulation (Table 3). The protein content range obtained in the current study (4.37 to 17.16%) is in consistent with the protein content (7.3 to 19.2%) of malted sorghum, soya bean and wheat based composite flour (Bolarinwa *et al*., 2015). Soya beans have been reported to be a significant source of protein (Serrem *et al*., 2011). Several authors reported that Bambara ground nut also has substantially high protein content (Uvere *et al*., 1999). Increment of protein content with level of Bambara ground nut was also reported by Gbenyi et al. (2016) for extruded food products produced from different proportions of sorghum and bambara groundnut composite flour.

Table 3: Proximate composition of composite flours

Trt.	Ingredients (%)				Proximate composition						
	FM	SB	GN	SP	Moisture (%)	Ash (%)	Fiber (%)	Protein (%)	Fat (%)	Utilizable CHO (%)	Energy (Kcal/100g)
0	100	0	0	0	10.48±0.66[a]						

A crude fiber content range of 5.58 to 13.43%, and 2.85 to 5.92% was observed for composite flour type I and type II, respectively. An increment in fiber content was noticed as the proportion of finger millet increased. The crude fiber content of composite flour in the present study was remarkably higher than fiber content (1.64 - 1.79%) reported by Kshirnagar et al. (1994) for four weaning foods made up of finger millet, peanut, green gram and skimmed milk powder. The highest percentage of crude fat was observed with type II composite flours and ranged from 6.57 to 15.58%. Crude fat content of composite flour in the present study increased as soya bean and ground nut supplementation level increased. This could be due to the presence of appreciable amount of fat in both soya bean and groundnut. The related research finding reported by Falola et al. (2013) indicated that the fat content of rice and soya bean composite flour increased as soy flour proportion increased.

The highest utilizable carbohydrate content (71.57%) in this study was recorded for 100% finger millet flour while the lowest (60.41%) was noted for composite flour composed of 75% finger millet and 25% soya bean flour. This indicates that utilizable carbohydrate content of the finger millet based composite flour in this study might not improve with soya bean, ground nut and sweet potato incorporation. The obtained utilizable carbohydrate content (60.41-68.71%) in this study was in line with carbohydrate content (65.95%) reported by Damian et al. (2018) for complementary food produced from 50:15:35 of sweet potato, finger millet and soya bean flour, respectively.

Energy value exhibited significant difference ($p < 0.05$) for developed composite flour in the present study. Accordingly, the highest energy value (428.83 Kcal/100g) in this study was recorded for 3:1:1of finger millet, soya bean and groundnut flour, respectively, whereas the lowest (297.67 Kcal/100g) energy value was obtained from composite flour composed of 75% finger millet and 25% soya bean flour. The highest energy value recorded could be attributed by high protein and fat contribution from soya bean and ground nut flour.

The energy value recorded in the present study was lower than energy value (340 - 398 kcal /100g) reported by Bhaskaran et al. (2001) for eight composite mix composed of cereals (finger millet, pearl millet or sorghum, wheat), legumes (defatted soya flour, bengal gram dhal), jaggery and vegetable fat. On the other hand, the energy value of composite flour formulated from finger millet, soya bean, ground nut, and sweet potato in the present study was higher than energy value (357- 374 kcal/100g) reported by Gahlawat and Sehgal (1994) for formulated mix having 70:30:25 ratios of cereals, green gram and jaggery. This might be due to significant variation of protein, fat and carbohydrate contribution for energy from individual components used for ingredient formulation. Cereal, tubers and legume are known for their good source of fiber. However, the level of fiber in each category is highly varied. The crude fibre of the composite flour in this work was ranged from 2.85 to 13.43 % and there was a significant variation.

Sensory evaluation

The sensory characteristic of finger millet based value-added injera is presented in Table 4. A significant ($p<0.05$) variation was observed between formulations in their color, texture, flavor, taste, eye distribution, underneath color, rollability and overall acceptance. Among formulations, injera made from 70% FM+30% SB was perceived differently and rated higher in its color and taste. The most acceptable texture, flavor, underneath color and rollability were noticed with 75% FM+25% SB. Obviously *injera* with a characteristics of white color (Gebrekidan and Gebre Hiwot, 1982), even eye distribution, less sourness and bitterness, rollable and less stick is preferred by consumers. It was observed that numerous and even distribution of eyes were formed with injera prepared from 65% FM+35% SB formulation Injera eye is a honeycomb like structure of the top surface of the product and it's formed during baking/cooking due to escaping of CO_2 bubbles (Yetneberk *et al*., 2005). According to Taylor and Emmambux (2008), as the temperature of the tef batter rises during baking, the carbon dioxide in the batter comes out of solution and at the same time, the starch in the batter gelatinizes increasing the viscosity of the batter. This creates gas bubbles in the batter that turn into cells as the gas escapes and the batter sets. Pyle (2005) also pointed that the small bubbles of CO_2 resulting from fermentation play a crucial role as nuclei for pore development and without these nuclei a porous structure in the final product may not be formed.

Table 4. Sensory characteristic of injera prepared from finger millet and soybean composite flour

Formulations	Color	Texture	Aroma	Taste	Eye evenness	Underneath color	Rollability	Overall acceptance
100% FM	4.13±0.23[a]	4.13±0.46[ab]	4.13±0.31[a]	3.87±0.11[ab]	4.13±0.12[ab]	3.96±0.17[ab]	3.92±0.19[ab]	4.00±0.13[a]
65%FM+35%SB	3.60±0.20[b]	3.60±0.35[ab]	3.53±0.31[b]	4.0±0.34[ab]	4.47±0.12[a]	3.84±0.0[ab]	3.89±3.89[ab]	3.94±0.04[ab]
70%FM+30%SB	4.27±0.31[a]	3.67±0.23[ab]	3.80±0.53[ab]	4.07±0.11[a]	3.93±0.31[b]	3.95±0.08[ab]	3.88±0.14[ab]	3.93±0.18[ab]
75%FM+25%SB	3.87±0.23[ab]	4.00±0.00[a]	4.33±0.23[a]	3.60±0.40[b]	4.20±0.20[ab]	4.0±0.11[a]	4.03±0.08[a]	4.03±0.09[a]
80%FM+20%SB	4.25±0.19[a]	3.65±0.25[ab]	3.60±0.16[b]	3.70±0.11[ab]	4.15±0.44[ab]	3.87±0.06[ab]	3.79±0.05[b]	3.82±0.07[b]
85%FM+15%SB	3.90±0.14[ab]	3.40±0.28[b]	3.80±0.00[ab]	3.80±0.00[ab]	4.10±0.14[ab]	3.80±0.06[b]	3.78±0.09[b]	3.86±0.06[ab]

Mean followed with the same letter within column are not significantly different at $p > 0.05$; FM, finger millet; SB, soya bean; Values are mean ± standard deviation

Rollability is one of the most important injera sensory attribute as it describes the ability of injera being rolled without breaking. The result showed that formulations 75% FM+25% SB and 85% FM+15% SB had the highest and the lowest rollability respectively. This difference could be due to realignment of amylose and amylopectin compositions of starch which might affect the textural and nutritional attributes of injera. The overall acceptability of the injera is made from the formulations 75% FM+25% SB was also found be higher than other formulation.

Porridge is also another product which can be made from cereals and it's a food commonly eaten as a breakfast. The sensory results of porridge from the four formulations are shown in Table 5. The results ranged from 3.07 to 4 for aroma and overall acceptance, 2.87 to 3.87 for color, 2.93 to 3.6 for mouth feel, and 3.2 to 4 for taste. No significant (p>0.05) difference were observed in color, mouth feel and taste of the porridge products. However, the formulations 60% FM+20% SB+20% SP and 70% FM+20% SB+10% GN were rated higher and lower in their mouth feel and taste, respectively. Formulation 60% FM+20% SB+20% SP perceived highest in its aroma and overall acceptance, while 70% FM+20% SB+10% GN perceived the lowest.

Table 5. Sensory characteristic of finger millet based porridge

Formulations	Aroma	Color	Mouth feel	Taste	Overall acceptance
60%FM+20%SB+20%GN	3.47 ± 0.31^{ab}	2.87 ± 0.42^{a}	3.00 ± 0.48^{a}	3.2 ± 0.20^{a}	3.47 ± 0.31^{ab}
70%FM+20%SB+10%GN	3.07 ± 0.50^{b}	2.87 ± 0.81^{a}	2.93 ± 0.83^{a}	3.2 ± 0.60^{a}	3.07 ± 0.50^{b}
60%FM+20%SB+20%SP	4.00 ± 0.60^{a}	3.87 ± 0.57^{a}	3.60 ± 0.69^{a}	4.00 ± 0.28^{a}	4.00 ± 0.60^{a}
70%FM+20%SB+10%SP	3.47 ± 0.31^{ab}	3.47 ± 0.50^{a}	3.4 ± 0.52^{a}	3.33 ± 0.05^{a}	3.47 ± 0.31^{ab}

Mean followed with the same letter within column are not significantly different at p> 0.05. FM, finger millet; SB, soybean; SP, sweet potato

Table 6 illustrates the sensory characteristics of kita products prepared from different proportion of finger millet, soybean, groundnut and sweet potato. The color, texture, aroma, taste, appearance and over all acceptability results indicated that there was no significant difference between the formulations (p>0.05). Formulation 70% FM+20% SB+10% SP perceived utmost and scored highest in its color, texture, taste, appearance and overall acceptance, whereas 70% FM+20% SB+10% GN formulation rated lowest. An increased in sweet potato and groundnut proportions resulted in lower consumer acceptability.

Table 6. Sensory characteristics of finger millet based kita

Formulations	Color	Texture	Aroma	Taste	Appearance	Overall acceptance
60%FM+20%SB+20%GN	3.67±0.31[ab]	3.53±0.50[a]	3.47±0.76[a]	3.35±1.19[a]	3.27±0.64[a]	3.8±0.60[a]
70%FM+20%SB+10%GN	3.13±0.31[b]	3.27±0.61[a]	3.07±0.41[a]	3.23±0.68[a]	2.80±0.80[a]	3.53±0.50[a]
60%FM+20%SB+20%SP	3.80±0.52[a]	3.47±0.61[a]	3.67±0.50[a]	3.32±0.43[a]	3.4±0.34[a]	3.73±0.23[a]
70%FM+20%SB+10%SP	3.93±0.50[a]	3.8±0.20[a]	3.33±0.23[a]	3.44±0.31[a]	3.53±0.31[a]	3.80±0.34[a]

Mean followed with the same letter within column are not significantly different at $p > 0.05$; FM, finger millet; SB, soybean; SP, sweet potato

Conclusions

This study has shown that protein, fat and energy level of composite flour increased with substitution level of soybean and groundnut. Crude fiber, ash and carbohydrate content of composite flour were increased as incorporation level of finger millet and sweet potato flour increased. Incorporation of sweet potato and groundnut flour have substantial role in partial improvement of some functional properties of the composite flour. Correspondingly, water solubility and water absorption capacity were increased as the substitution level of orange fleshed sweet potato and groundnut increased. In addition, this study reflected that acceptable, convenient nutrient dense and low cost food products could be produced from formulations which contained higher finger millet, higher soybean and lower groundnut and sweet potato contents for kita and porridge. Taste and texture were the most influencing factors on kita and porridge preference.

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