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FULL PAPER

Nutritional composition of fortified finger millet (*Eleusine coracana*) flours fortified with vitamin B_2 and zinc oxide

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Abstract

Fortification is the process of adding minerals and vitamins that have been lost during flour processing to improve the nutritional composition and reduce micronutrient deficiencies. The study was conducted to determine the nutritional composition of Finger millet (FM) flours fortified with vitamin B_2 and zinc oxide (ZnO). The milky cream (MC), brown, black and pearl millet (PM) flours were used as reference samples. Flours were completely randomized in three replicates. Determination of the physicochemical properties, vitamin B complex, macro and trace minerals concentration were conducted for flour and reference samples. The moisture of brown instant fortified finger millet (IFFM) flour was significantly ($p < 0.05$) higher for MC and black IFFM flours as compared to other flours. The MC raw finger millet (RFM) flour had a significantly ($p < 0.05$) highest amount of Zn, 2.64±0.01 mg/100 g when compared to other flours. The MC flour showed significantly ($p < 0.05$) higher values for vitamin B_2 in both RFFM and IFFM flours when compared to other flours. MC flours may be preferred by the consumers due to its semblance to the maize white flour. The anticipation of the study was to produce and characterise FM flour fortified with vitamin B_2 and ZnO that may be utilised for value-added products.

1. Introduction

Finger millet is a cereal grain that belongs to the family *Poaceae* and is a gluten-free grain (Gebre, 2019). FM is ranked 4th among other millets in the world in importance after sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*) and foxtail millet (*Setaria italica*). It is cultivated in some parts of African countries such as Ethiopia, Zimbabwe, and South Asian country India (Opole, 2019). FM is referred to as *mufhoho* (Tshivenda) in South Africa (Ramashia *et al.,* 2019) and *dagussa* in Ethiopia (Kumar *et al.,* 2016). FM consists of different varieties: black, reddish-brown, and white (Gebre, 2019). It is a rich source of calcium which strengthens bones, and teeth. FM has potential health benefits in all age groups and people with chronic diseases (Ramashia *et al.,* 2019). The grains contain zinc (Zn), amino acids, and vitamin B complex. The grain contains the highest amount of carbohydrates, protein, fat, and crude (Saleh *et al.,* 2013). FM contains antioxidant properties such as polyphenols that protect the body against degenerative diseases (Udeh *et al.,* 2017). FM is utilised to produce weaning foods, traditional beer, and extruded products (Shobana *et al.,* 2013).

Food fortification is the addition of micronutrients to cereal flours (Akhtar *et al.,* 2011). FM flours are fortified with minerals and vitamins after processing to replace nutrients that may be lost during the sieving process (Saleh *et al.,* 2013). Fortification of flours with vitamin B_2 and ZnO helps to overcome the problem of malnutrition and micronutrient deficiencies such as sore throat, pneumonia, and diarrhea (Gupta *et al.,* 2015). Wheat, rice, and maize flours are fortified with vitamins B complex such as B_1, B_2, B_6, niacin and minerals such

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as iron (Fe) and Zn (Department of Health, 2008). The South African government launched the fortification programme of wheat flour in 2003. Over 90% of wheat flour and 70% of maize flour are fortified in South Africa with vitamins A, B_1, B_2, B_3 and Zn (Department of Health, 2008). Tripathi and Platel (2011) reported that FM flour has been fortified with ferrous fumarate and ferric pyrophosphate. An amount of 2 - 4 mg/100 g vitamin B_2 has been added to wheat flour during fortification. Almost 60 - 80% of vitamin B_2 is removed during cereal grain milling (Tripathi and Platel, 2010). ZnO is the most important ingredient used for fortification and it is generally regarded as safe (GRAS) for human consumption (Brown *et al.,* 2008). The recommended amount of 50 mg into 1 kg (Triphathi *et al.,* 2012). However, information regarding the fortification of FM flour with vitamin B_2 and ZnO is rare (Akhtar *et al.,* 2011). The main advantage of adding fortificants to flour is to meet the nutritional requirements which also improves the health, productivity and well-being of humans (Gebremariam *et al.,* 2014). Therefore, this study aimed to produce instant FM flours fortified with vitamin B_2 and ZnO and to determine the nutritional composition of flours.

2. Materials and methods

2.1 Finger millet grains and sample preparation

Mixed cultivars of finger millet grains were purchased in Thohoyandou open market, South Africa and sorted in different varieties. Pearl millet (PM) grain was used as a reference sample. The chemicals were purchased from Merck, Midrand, South Africa. A total of 250 g of sorted FM grain varieties: MC (80%), black (85%) and brown (97%) were soaked using distilled water for 24 hrs at room temperature (Gupta *et al.,* 2015). Complete randomized design (CRD) in three replicates was used for samples. The soaked grains were dried at 60°C for 24 hrs using hot air oven to a moisture of 10 to 12% after which the grains were milled to flour using a miller (Retsh ZM 200 miller, Germany) at 18 000 rpm for 3 mins. Approximately, 100 g of FM flour was weighed and mixed with 200 mL of boiling water. The mixed flour was cooked to porridge at 92°C for 25 mins using an electric stove (Defy Kitchenaise 621, South Africa) and the porridge was cooled in a controlled temperature of 20 to 25°C at a relative humidity of 35 to 50% (FDA, 2018). The cooled porridge was spread on a drying tray covered with aluminium foil and allowed to dry at 50°C for 8 hrs. Dried porridge was then milled to instant flour at 18000 rpm for 3 mins and sieved with 100 µm pore size sieve. A hundred grams of each FM flours were fortified with vitamin B_2 (3 mg) and ZnO (5 mg) and mixed using mixer blender (Majeed *et al.,* 2013). The flours were placed and sealed in a polythene bag for further analysis. The following treatments were used:

Raw finger millet flours (100 g) = RFM flours (MC, black, brown) and raw PM flour

Raw fortified finger millet flours (100 g) + ZnO (5 mg) + vitamin B_2 (3 mg) = RFFM flours (MC, black, brown) and fortified PM flour (RFPM).

Instant finger millet flours (100 g) = IFM flours (MC, black, brown) and instant PM flour (IPM)

Instant fortified finger millet flours (100 g) + ZnO (5 mg) + vitamin B_2 (3 mg) = IFFM flours (MC, black, brown) and instant fortified PM flour (IFPM)

2.2 Determination of physicochemical properties of finger millet flours

2.2.1 Moisture content of finger millet flours

Moisture content was determined using an air oven dryer. Dry coded, clean crucibles were placed in the oven dryer for about 30 mins, cooled and weighed using AACC method 44-15.02, AACC (2000). The weight of the crucibles was determined and recorded. Approximately 4 g of flour were weighed into the crucibles and crucibles were dried at 105°C for 24 hrs. The result of moisture content (%) was calculated using equation 1.

$$\%\ moisture = \frac{W2-W3}{W2-W1} \times 100 \quad (1)$$

Where W_1 = weight of the empty crucible, W_2 = weight of crucible + flour before drying and W_3 = final weight of crucible + flour after drying

2.2.2 Ash content of finger millet flours

A sample of 4.0 g of flour per treatment was weighed into a clean crucible AACC (2000): method 08-01.01. The crucibles were placed in a muffle furnace and ignited for 24 h at 550°C. The muffle furnace was turned off and left closed until the temperature dropped to 250°C or lower. The door was opened carefully to avoid losing ash that may be fluffy. Tongs were used for transferring crucibles from the muffle furnace to desiccators with a porcelain plate and desiccant. The crucibles were placed inside a desiccator and cooled before weighing. Ash content was calculated using equation 2.

$$\%\ ash = \frac{W3-W1}{W2-W1} \times 100 \quad (2)$$

Where W_1 = weight of the empty crucible, W_2 = weight of crucible + flour and W_3 = weight of crucible + ash.

2.2.3 Determination of crude protein of finger millet flours

Total nitrogen and protein (N x 6.25) content of fortified FM flours were determined using the Kjeldahl method (Ramashia *et al*., 2018). Approximately, 1 g of FM flour was transferred into a digestion tube. A total of 2 tablets of selenium catalyst were poured and mixed with FM flour and 25 mL of sulphuric acid (96%) were added to the digestive tube. The tubes were then heated slowly in the digestion apparatus until the digest was clear. The digested flours and 100 mL conical flask containing two drops of an indicator were placed under the condenser for distillation.

Approximately 10 mL of clear supernatant was then transferred into the apparatus and 10 mL of 46% sodium hydroxide was added and then rinsed with distilled water. The colour changed from pink to yellow when the first distillation drops were added and mixed with the boric acid indicator solution. A total of 150 mL of the distillate was collected and titrated with 0.0174 N sulphuric acid until the colour changed from yellow to pink. Total nitrogen (N) was determined using equation 3.

$$\%N = \frac{(a \times N \times Mw \times 100)}{(b \times c)} \times 100 \qquad (3)$$

Where N = Normality of sulphuric acid (0.0174), a = Titer volume (10 mL), Mw = Molecular weight of N_2 (0.014), B = g flour taken for analysis (0.1 g), c = mL digest taken for distillation (10 mL) and % crude protein = 6.35 x %N

2.2.4 Crude fibre of finger millet flours

The crude fibre of the FM flour was analyzed using the method of Ramashia (2018). A total of 1 g of flour was weighed in triplicate into 400 mL beaker. The flour was boiled under reflux for 30 mins together with 200 mL solution containing 1.25 g H_2SO_4 and potassium hydroxide per 100 mL of solution. The solution was filtered through line on a flaunted funnel and washed with water. The residue was transferred to a beaker and boiled for 30 min with 100 mL of solution. It was dried in an oven dryer at 105°C for 1 hr and weighed. The residue was incinerated in a muffle furnace at 540°C for 3 h, cooled in a desiccator for 1 hr and later weighed. Crude fibre was calculated using equation 4.

$$Crude\ fibre\ (\%) = \frac{W2 - W3}{W1} \times 100 \qquad (4)$$

Where W_1 = weight of flour used, W_2 = weight of crucible + flour and W_3 = weight of flour + crucible + ash

2.2.5 Determination of pH of finger millet flours

The pH values of flour were determined using a Crison digital pH meter (Crison instrument, SA) as described by Cornejo-Villegas *et al.* (2010).

2.3 Mineral analysis of flours using inductively coupled argon plasm atomic emission spectroscopy (ICP-AES)

Approximately 2 g of flour were ashed in a muffle furnace at 550°C for 3 hrs. The ashed samples were treated with 10 mL concentrated hydrochloric acid (50% HCl) with the addition of 5 mL nitric acid (33%) and placed on a water bath for 1 hr. A total of 10 mL of HCl was added and placed in a water bath for 15 min, transferred to 100 mL volumetric flask, filled to mark with distilled water and then mixed (Lima *et al.,* 2010). After sample preparation, the selected element concentration was determined using the ICP-AES. Sodium, potassium, magnesium, calcium, manganese, iron, zinc, copper and phosphorus were analysed. The minerals were quantified against the Indium standard solutions of known concentrations which were analysed concurrently (Kunyanga *et al.,* 2013).

2.4 Determination of vitamin B complex

The water-soluble vitamins were determine using method of The South African Grain Laboratory (2017) using Ultra-Performance Liquid Chromatography with a Photo Diode Array Detector (UPLC-PDA) modified from the method of Chen et al. (2009). The method was suitable for determining vitamins B_1, B_2, B_3 and B_6 on RFM, RFFM, IFM and IFFM flours. The vitamins were extracted with 0.1 N HCl, centrifuged and diluted. They were detected with PDA-detector using PDA channel 1: 265 nm at 2.23 nm and PDA channel 2: 280 nm at 4.8 nm. Water Acquity H-class UPLC with empower 3 software and Acquity UPLC HSS T3 1.8 µm, 2.1 x 100 mm column (Waters, Millipore Corp., Milford, MA). The column was operated at 30°C. The standards used were thiamine mononitrate DSM–South Africa, niacinamide Sigma-Aldrich (N5536), nicotinic acid Sigma ≥ 99.5% (72309), pyridoxine hydrochloric Sigma-Aldrich (P4722) and riboflavin Sigma≥ 98% (R4500).

2.5 Statistical analysis

Data were subjected to analysis of variance using SPSS version 25 (SPSS, IBM, Chicago USA) and means were separated using the Duncan Multiple Range Test (Kibar and Kibar, 2017). Significance was accepted at 95% confidence interval ($p < 0.05$).

3. Results and discussion

3.1 Physicochemical properties

The results of RFM, RFFM, IFM and IFFM flours including the reference flours on a dry weight basis are shown in Table 1. The moisture of RFM varied from

Table 1. Some proximate composition and pH values of finger millet flour treatments

Cereal flours	Moisture	Ash	Crude fibre	Crude protein	pH values
			Raw finger millet		
Milky cream	11.67±1.44[a]	3.13±0.29[a]	1.90±0.01[c]	9.53±0.02[b]	6.15±0.02[c]
Brown	7.60±2.35[d]	2.77±0.35[b]	1.94±0.00[c]	8.06±0.02[c]	6.26±0.02[a]
Black	10.83±1.44[b]	2.27±0.92[d]	2.16±0.51[b]	7.91±0.02[d]	6.22±0.01[b]
Pearl millet	9.17±1.44[c]	2.73±0.67[c]	2.19±0.53[a]	11.23±0.02[a]	6.60±0.01[a]
			Raw fortified finger millet		
Milky cream	2.95±0.63[b]	3.19±0.65[c]	1.90±0.01[d]	9.72±0.02[b]	6.18±0.02[b]
Brown	2.17±1.13[c]	2.80±1.41[d]	2.91±0.00[a]	6.23±0.03[d]	6.23±0.03[a]
Black	2.92±1.18[b]	4.82±1.45[b]	2.84±0.06[b]	9.41±0.02[c]	6.23±0.02[a]
Pearl millet	3.00±2.14[a]	5.17±1.35[a]	2.19±0.53[c]	11.06±0.02[a]	6.14±0.01[c]
			Instant finger millet		
Milky cream	6.25±1.25[b]	5.83±1.44[a]	5.83±2.89[a]	5.83±1.44[b]	5.98[d]±0.02d
Brown	3.57±0.51[c]	3.70±1.37[b]	3.17±1.89[b]	3.00±1.13[c]	6.26[c]±0.01[c]
Black	1.87±0.05[d]	2.82±0.03[d]	2.91±0.00[c]	2.88±0.03[d]	6.39[b]±0.01[b]
Pearl millet	9.88±0.02[a]	3.00±0.03[c]	2.88±0.03[c]	11.24±0.02[a]	6.48[a]±0.01[a]
			Instant fortified finger millet		
Milky cream	7.92±0.80[c]	3.71±0.14[c]	2.43±0.53[c]	9.73±0.02[b]	5.73±0.04[d]
Brown	8.63±1.59[a]	5.55±3.47[a]	2.91±0.44[b]	7.82±0.03[d]	5.98±0.03[c]
Black	3.75±0.75[d]	3.96±0.60[b]	2.93±0.03[b]	9.52±0.03[c]	6.08±0.03[b]
Pearl millet	8.00±4.63[b]	3.25±0.59[d]	2.21±0.53[d]	11.18±0.02[a]	6.15±0.01[a]

Values are mean±standard deviation, n = 3. Values followed by the same letters in the same column are not significantly different ($p < 0.05$).

7.60±2.35 to 11.67±1.44% in which MC had the highest value, 11.67±1.44% and the lowest value was obtained from brown flour, 7.60±2.35%. MC had the highest moisture of 2.95±2.35% while the brown flour had the lowest moisture of 2.17%±1.13% on RFFM flours. The highest moisture was obtained from MC, 6.25±1.25% while brown, 5.83±1.44% and black, 5.83±2.89% for IFM both had the lowest values. MC showed significantly high moisture ($p < 0.05$) as compared to RFM, RFFM and IFM on brown and black. The moisture of IFFM ranged from 3.75 to 8.63% in which the highest value was obtained from the brown flour, 8.63%±1.59% and the lowest value from black flour 3.75±0.75%. Brown flour, however, showed significantly higher value on IFFM compared to the MC and black flours. Thus, the addition of vitamin B_2 and ZnO did not show any effect on moisture in all flours. Obadina *et al.* (2016) reported the moisture on native PM flour of 12.39% on a dry basis. Similar results were obtained by David *et al.* (2014) who reported moisture of 6.66% for FM flours. The addition of fortificants on instant flours increased the moisture of fortified flours for MC and brown flours samples (Table 1). Low moisture indicates that flours can be stored for longer periods without spoilage, hence showing better shelf stability. This is a good indicator of the quality of the dry flour which contributes to low residual moisture in baked products. Such desirable quality is important as it leads to the reduction of microbial growth leading to flours that can be stored in appropriate packaging material under good conditions (Adegunwa *et al.,* 2014; Falade *et al.,* 2014). The ash of RFM ranged from 2.27±0.92 to 3.13±0.29% with MC containing the highest value of 3.13±0.29% and the lowest value of 2.27±0.92% from black RFM flour. Sample MC showed a significantly higher value than RFM. Black flour contained the highest value of ash, 4.82±1.45% on RFFM while brown flour had the lowest value of 2.80±1.41%. Brown flour of IFM had the highest value of 3.70±1.37% and the lowest value was found on black flour (2.82±0.03%) while IPM flour had a significantly lower value of 3.00±0.03%.

Ash of IFFM varied from 3.71±0.14 to 5.55±3.47%, with the highest value found in brown flour and the lowest value in MC. Ash of fortified flours increased after adding fortificants. Siroha *et al.* (2016) reported ash of PM flour from different varieties that varied from 1.65 to 1.90%. The addition of vitamin B_2 and ZnO significantly increased the ash of flours (Akhtar *et al.,* 2008). The crude fibre of RFM ranged from 1.90±0.01 to 2.16±0.51% with the highest value obtained from black flour and the lowest value from MC flour. RFFM had the highest value of crude fibre on brown flour, 2.91±0.00% and the lowest value on MC of 1.90±0.01%. The crude fibre of IFM was highest for MC flour, 5.83±1.44% and the lowest value of 2.91±0.00% in the black variety. Black flour had the highest value of 2.93±0.03% and the lowest value on MC of 2.43±0.53% for IFFM. MC flours showed significantly lower values as compared to brown and black FM flours. Similar results were obtained by David *et al*. (2014) who reported crude fibre of 3.10% on FM flours. The crude fibre was not affected by the technological process because instant FM flours increased after adding the fortificants. FM is a rich source of dietary fibre as compared to other millet species and this makes it a unique millet (Saleh *et al.,* 2013). Akhtar *et al.* (2008) reported that fibre of wheat flours was not affected by the presence of fortificants. The results of crude fibre showed a significant effect on flours after adding the fortificants as the fortified flours had the highest values as compared to unfortified flours. MC flours show no significant difference when compared to the raw flour and raw fortified flour, which had values of 1.90%. This was an indication of the level of non-digestible carbohydrates and lignin in food. The values obtained are considered appropriate because they aid in the absorption of glucose, fat and increase fecal bulk. Crude fibre is important in the enhancement of digestibility. However, its presence in great quantities can cause intestinal irritation, lower digestibility and decrease nutrient usage (David *et al.,* 2014).

The crude protein of RFM varied from 7.91 to 9.53% with sample MC recording the highest crude protein while black flour had the lowest crude protein. RPM (11.23±0.02%) had a significantly higher value than RFM. RFFM had the highest crude protein on MC, 9.72% and lowest crude protein on 6.23%. Crude protein of IFM varied from 2.88±0.03 to 5.83±1.44%, with MC recording the highest value of 5.83±1.44% compared to the brown (3.00±1.13%) and black (2.88±0.03%) IFM flours. IFFM had the highest crude protein value of 9.73±0.02% for MC and the lowest value of 7.82±0.03% for brown flour. At 11.18±0.02% (Table 1). Thus, the addition of vitamin B_2 and ZnO did not show any significant effect on crude protein in all treatments since there was no destruction of amino acids on the FM flours. However, the crude protein of brown and black IFM flours decreased due to the destruction of amino acids during cooking and redrying of flours (Sade, 2009). Cornejo-Villegas *et al.* (2010) observed protein levels of 9.49% for traditional instant corn flour.

The pH values of MC flours decreased from 6.22 to 6.06 for RFM flours with black flour recording the highest pH values of 6.22 and the lowest values of 6.06 for brown flour. Both brown and black RFFM showed a significantly higher value of 6.2. RFPM flour had a significantly lower value of 6.14 than all RFFM flours (MC, brown and black). IPM and black flours had significantly higher values of 6.48 and to IFM flours (MC with a pH value of 5.98 and brown with 6.26). The pH values of IFFM flours varied from 5.73 to 6.15, with the highest pH values recorded for black flour at 6.08 and the lowest pH value for MC at 5.73. Cornejo-Villegas *et al.* (2010) reported pH values which ranged from 7.03 to 7.44 on traditional instant corn and commercial instant corn flours. The pH values decreased which indicate the quality of FM flours, thus inhibiting microbial growth and contributing to flavour of processed fortified FM flour (Singh *et al.,* 2012).

3.2 Mineral composition of flour samples

Table 2 shows the mineral content of flour samples examined. The highest calcium (Ca) value of 385.49±2.83 mg/100 g in black RFM and the lowest value of 118.68±0.21mg/100 g was found on milky cream RFM flour sample. RPM showed a significantly lower Ca value of 27.37±0.13 mg/100 g compared to RFM (MC, brown and black). Results of RFFM flour indicates that Ca ranged from 132.76 to 372.15 mg/100 g with the highest value of Ca found in black RFFM flour and the lowest value in milky cream RFFM flour. Black RFFM showed a significantly higher value than MC and brown RFFM flours. Calcium of black IFM flour ranged from 132.16±1.15 to 390.66±2.30 mg/100 g with RFPM flour showing significantly lower values of 41.28±0.27 mg/100 g compared to MC, brown and black IFM flours. Black IFFM flour had the highest Ca of 368.51±4.52 mg/100 g while the lowest value was found on MC which recorded a Ca content of 121.97±2.04 mg/100 g. IFPM flour had a significantly low value of 34.00±0.07 mg/100 g. Addition of vitamin B_2 and ZnO decreased the Ca content of both fortified raw and instant fortified flours. Fortification of RFM flours led to an increase in the concentration of calcium (Ca) in MC from 118.68 to 132.76 mg/100 g and brown flours from 354.87 to 365.09 mg/100 g but decreased this concentration in black flour variety from 385.49 to 372.15 mg/100 g (Figure 1). Although the addition of ZnO decreased concentration of Ca in IFFM flours. Analysed data further showed that MCFM flour contains lower values of Ca (118.68 mg/100 g) as compared to other flours. For example, RFM flours range from 354.87 to 385.49 mg/100 g. Thus, Ca decreased after adding ZnO on IFFM, but there was no resultant negative effect on fortified flours.

Upadhyaya *et al*. (2011) and Saleh *et al.* (2013) showed similar results of Ca in FM flours with a concentration of 162 - 358.00 mg/100 g. Swami *et al.* (2013) reported that FM grains are a rich source of Ca with varying concentrations of 300 - 350 mg/100 g. Devi *et al.* (2011) observed the Ca of 344 mg/100 g on FM flours. Cornejo-Villegas *et al*. (2010) reported the mineral (g/100 g) of traditional instant corn flour of 3.26 while commercial instant corn flour had a Ca

Table 2. Mineral contents of finger millet flour treatments (mg/100 g)

Flours	Ca	Fe	K	Mg	Mn	Na	P	Zn
Raw finger millet								
MCFM	118.68±0.21^{c}	4.02 ±0.08^{d}	279.75±1.41^{d}	140.57±0.56^{c}	5.23±0.02^{c}	1.28±0.05^{d}	262.06±0.97^{d}	2.64±0.01^{b}
BRFM	354.87±0.08^{b}	4.29±0.05^{c}	466.90±0.54^{c}	186.67±0.15^{a}	18.17±0.05^{b}	4.07±0.00^{b}	303.39±0.54^{b}	2.57±0.01^{c}
BLFM	385.49±2.83^{a}	6.21±0.07^{b}	530.84±16.33^{a}	183.82±2.15^{b}	20.64±0.15^{a}	4.78±0.12^{a}	293.18±4.92^{c}	2.62±0.04^{b}
PM	27.37±0.13^{d}	36.62±0.15^{a}	493.64±8.53^{b}	122.05±0.94^{d}	1.98±0.00^{d}	3.44±0.08^{c}	310.16±2.40^{a}	4.79±0.02^{a}
Raw fortified finger millet								
MCFM	132.76±2.70^{c}	3.94±0.07^{c}	300.06±18.30^{d}	147.80±5.18^{c}	5.85±0.13^{c}	1.22±0.09^{d}	283.41±5.75^{c}	9.44±0.12^{c}
BRFM	365.09±2.14^{b}	3.92±0.00^{c}	463.47±5.60^{c}	185.32±0.23^{a}	18.20±0.09^{b}	3.98±0.05^{b}	309.49±1.16^{b}	9.72±0.08^{b}
BLFM	372.15±0.04^{a}	6.89±0.08^{a}	482.36±2.10^{b}	174.93±0.55^{b}	18.20±0.09^{b}	4.08±0.02^{a}	309.49±1.65^{b}	9.72±0.03^{b}
PM	26.25±1.15^{d}	30.29±0.08^{b}	506.74±0.15^{a}	123.41±0.37^{d}	1.93±0.01^{d}	3.62±0.01^{c}	320.46±0.22^{a}	10.28±0.02^{a}
Instant finger millet								
MCFM	132.16±1.15^{c}	5.22±0.08^{d}	296.16±0.15^{d}	150.43±0.37^{c}	5.69±0.01^{b}	4.98±0.01^{d}	296.35±0.22^{c}	3.11±0.02^{b}
BRFM	379.81±1.66^{b}	5.29±0.06^{c}	493.17±11.16^{c}	199.66±1.68^{a}	19.11±0.00^{a}	12.28±0.26^{a}	332.84±1.02^{b}	2.89±0.02^{c}
BLFM	390.66±2.30^{a}	7.62±0.00^{b}	510.11±13.95^{b}	188.66±1.18^{b}	20.85±0.02^{a}	9.36±0.21^{b}	312.99±0.09^{c}	2.93±0.01^{c}
PM	41.28±0.27^{d}	46.84±0.67^{a}	527.46±2.16^{a}	129.93±0.66^{d}	2.35±0.01^{d}	8.81±0.11^{c}	336.05±0.09^{a}	5.29±0.00^{a}
Instant fortified finger millet								
MCFM	121.97±2.04^{c}	4.76±0.02^{d}	278.97±10.95^{d}	141.51±1.04^{b}	5.47±0.14^{b}	6.04±0.22^{b}	288.75±0.67^{c}	8.92±0.01^{a}
BRFM	339.25±1.53^{b}	5.02±0.00^{c}	432.41±0.92^{c}	177.39±0.15^{a}	5.39±0.03^{c}	6.04±0.22^{b}	288.75±0.67^{c}	8.92±0.01^{a}
BLFM	368.51±4.52^{a}	8.87±0.04^{b}	499.04±6.08^{a}	177.19±1.11^{a}	19.79±0.05^{a}	23.91±0.32^{a}	303.44±1.07^{b}	8.44±0.05^{b}
PM	34.00±0.07^{d}	41.32±0.17^{a}	475.57±10.39^{b}	118.93±1.13^{c}	2.28±0.01^{d}	5.27±0.11^{c}	321.79±0.38^{a}	8.37±0.02^{c}

Values are mean±standard deviation, n = 3. Values followed by the same letters in the same column are not significantly different ($p < 0.05$). Ca = calcium, Fe = Iron, K = potassium, Mg = magnesium, Mn = manganese, Na = Sodium, P = phosphorus and Zn = zinc. MCFM = milky cream finger millet, BRFM = brown finger millet, BLFM = black finger millet and PM = pearl millet.

concentration of 0.12 mg/100 g. The grains are gluten-free and rich in fibre which helps to reduce incidents of celiac disease in people; can be utilized as preventive drug entities for osteoporosis due to its exceptionally high Ca content (162 - 358.0 mg/ 100 g); and can cause rickets in children (Cilla *et al.,* 2018). Studies from works of other authors have also shown that FM is a good source of Ca for growing children, pregnant women and elderly people (Jideani, 2012) because it is important for normal growth of body tissue such as strengthening bone and teeth (Subastri *et al*., 2015).

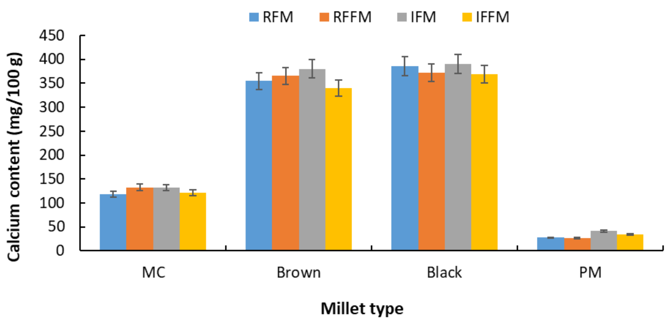

Figure 1. Calcium content in mg/100 g of finger millet flours. Error bars are standard deviation of mean values. MC = milky cream, PM = pearl millet, RFM = raw finger millet, RFFM = raw fortified finger millet, IFM = instant finger millet and IFFM = instant fortified finger millet

Copper (Cu) of RFM ranged from 0.46±0.04 to 0.60±0.02 mg/100 g (Table 2) with both brown and black RFM flours showing significantly higher ($p < 0.05$) value as compared to milky cream RFM flour. Brown RFM flour contained the highest Cu of 0.60±0.02 mg/100 g while the lowest value was obtained from MC RFM flour at 0.46 mg/ 100 g. Brown RFFM flour showed a significantly higher value than other FM flours such as MC and black RFFM flours. The highest Cu of 0.71±0.02 mg/100 g was obtained on brown IFM flour, while the lowest value on MC was 0.54±0.05 mg/100 g. A significantly higher Cu concentration of 0.64±0.02 mg/100 g was observed for black IFFM flour, compared to MC, 0.53±0.01 mg/100 g and brown, 0.61±0.00 mg/100 g IFFM flours. However, the addition of vitamin B_2 and ZnO decreased the Cu of both instant fortified flours. Siwela (2009) reported a Cu concentration of 0.18 - 0.79 mg/100 g for FM grains.

Black RFM flour had the highest Fe concentration of 6.21±0.07 mg/100 g and the lowest concentration of 4.02±0.08 mg/100 g was observed for milky cream RFM flour. The Fe content of RFFM flours ranged from 3.92 - 6.98 mg/100 g, with black flour showing a significantly higher value compared to the MC and brown RFFM flours. Conversely, RFPM flour had a significantly higher Fe concentration of 30.29 mg/100 g compared to all RFFM flours. At a concentration of 7.62±0.00 mg/100

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g, black IFM flour had significantly higher Fe compared to IFM flours such as MC with 5.22±0.08 mg/100 g and brown with a concentration of 5.29±0.06 mg/100 g. At a concentration of 46.84±0.67 mg/100 g, IPM flour had a significantly higher Fe as compared to IFM flours. Fe of black IFFM flour ranged from 4.76±0.02 to 8.87±0.04 mg/100 g. Black IFFM flour had a significantly higher value of 8.87±0.04 mg/100 g than IFM flours with MC at 4.76±0.02 and brown at 5.02±0.00 mg/100 g. IFPM flour showed a significantly higher Fe value of 41.32±0.17 mg/100 g than IFFM flours as indicated in Table 2. The addition of vitamin B_2 and ZnO decreased Fe of both raw and instant fortified flours. Similar results of Fe were reported by Sade (2009) on PM flour (8.8 mg/100 g). The availability of Fe in the human body may help to prevent anemia, especially among low socioeconomic groups (Serna-Saldivar, 2010).

Potassium (K) of RFM flours ranged from 279.75±1.41 to 530.84±16.33 mg/100 g, with black flour showing a significantly higher value compared to MC and brown RFM flours. The K of RFFM varied from 300.06 - 482.36 mg/100 g, with black flour recording the highest concentration and the lowest concentration found in milky cream RFFM flour. Black RFFM flour showed a significantly higher value than that of the MC and brown RFFM flours. RFPM flour had the highest concentration of K which was 506.74 mg/100 g. The highest concentration of K was obtained from black IFM flour, 510.11±13.95 mg/100 g while the lowest value of 296.16±0.15 mg/100 g was obtained from milky cream IFM flour. Results also showed that IPM flour had significantly higher K when compared to IFM flours. Similarly, black IFFM flour had the highest concentration of K (499.04±6.08 mg/ 100 g) while the lowest value of 278.97±10.95 mg/ 100 g was found on milky cream IFFM flour. Significantly higher K content was observed on black flour as compared to other IFFM flours. The addition of vitamin B_2 and ZnO decreased K of both raw and instant fortified flours. Shobana *et al.* (2013) reported a concentration of 0.43 - 0.49 mg/100 g for K in FM grains.

Table 2 shows the highest value of Magnesium (Mg) on brown RFM flour and the lowest value on MC flour. RPM showed a significantly lower concentration as compared to MC, brown and black RFM flours. Brown RFFM flour recorded the highest Mg content of 185.32 mg/100 g and the lowest concentration of 147.80 mg/100 g from MC flour. The raw fortified pearl millet sample had a significantly lower value (123.41 mg/100 g) as compared to RFFM flours. Brown IFM flour had a significantly higher Mg value of 199.66±1.68 mg/100 g compared to IFM flours, where MC recorded an Mg concentration of 150.43±0.37 mg/100 g and black a concentration of 188.66±1.18 mg/100 g. IPM flour showed a significantly lower Mg value of 129.93±0.66 mg/100 g compared to IFM flours. Mg content of IFFM flours which included brown at 177.39±0.15 mg/100 g and black at 177.19±1.11 mg/100 g showed significantly higher values than milky cream IFFM flour which had a concentration of 141.51±1.04 mg/100 g. IFPM flour had significantly lower 118.93±1.13 mg/100 g value than IFFM flours. The addition of vitamin B_2 and ZnO increased Mg of both raw and instant fortified flours. Shimelis *et al.* (2009) reported Mg of 78 - 201.0 mg/ 100 g on FM grains. FM flours are a good source of Mg which has been shown to reduce the severity of asthma and the frequency of migraines, lower high blood pressure and reduce the risk of heart attack (Verma and Patel, 2013).

Black RFM flour showed the highest manganese (Mn) concentration of 20.64±0.15 mg/100 g and the lowest value from milky cream RFM flour of 5.23±0.02 mg/100 g. RPM flour had significantly lower Mn values of 1.98±0.00 mg/100 g compared to RFM flours (Table 2). Results of Mn on RFFM flours ranged from 18.20 - 5.85 mg/100 g where brown and black flours had significantly higher values than the MC and brown RFFM flours. RFPM flour had significantly lower 1.93 mg/100 g concentration of Mn than RFFM flours. Black IFM flour had the highest Mn value of 20.85±0.02 mg/100 g while the lowest value was obtained from milky cream IFM flour which had 5.69±0.01 mg/100 g. At 2.35±0.01 mg/100 g, IFPM flour had a significantly lower Mn value than IFM flours. The highest value of Mn was found on milky cream IFFM flour at 5.47±0.14 mg/100 g while the lowest was observed on black IFFM flour at 19.79±0.05 mg/100 g. Similar Mn concentration was reported by Shimelis *et al.* (2009) while Siwela (2009) reported Mn concentration of between 17.61- 48.43 mg/100 g.

Sodium (Na) of RFM flours varied from 1.28±0.05 to 4.78±0.12 mg/100 g, with black RFM flour recording a significantly higher value as compared to MC and brown RFM flours. Black RFFM flour contained the highest Na value of 4.08 mg/100 g while the lowest value was obtained from milky cream RFFM flour at 1.22 mg/100 g. The highest concentration of Na (12.28±0.26 mg/100 g) was found in brown IFM flour while at 4.98±0.01 mg/100 g, MC had the lowest concentration. Results thus show that brown IFM flour was significantly higher in MC and black IFM flours. At 6.04±0.22 mg/100 g, Na concentration of the MC and brown IFFM flours increased, with black IFFM flour showing a significantly higher Na value of 23.91±0.32 mg/100 g compared to other IFFM flours. IFPM flour had significantly lower Na concentration of 5.27±0.11

mg/100 g than IFFM flours. The addition of vitamin B_2 and ZnO decreased the Na of both raw and instant fortified flours. Na content of grains examined by other authors was found to be 9.2 mg/100 g on PM flour (Sade, 2009).

Phosphorus (P) of brown RFM flours had the highest value of 303.39±0.54 mg/100 g on P and the lowest value of 262.06±0.97 mg/100 g on MC RFM flour, while brown flour had a significantly higher value compared to MC and black RFM flours at 310.16±2.40 mg/100 g. The mean value of P ranged from 283.41 - 309.49 mg/100 g with the highest value of 320.46 mg/100 g found in RFPM flour. RFPM flour also showed a significantly higher value compared to other RFFM flours. The phosphorus of brown IFM flour had a significantly higher value of 332.84±1.02 mg/100 g compared to IFM flours of MC which had 296.35±0.22 mg/100 g and black which had 312.99±0.09 mg/100 g. IPM flour showed a significantly higher value on P compared to IFM flours. Both the MC and brown IFFM flours had the same value of P, 288.75±0.67 mg/100 g. Black IFFM showed a significantly higher value of P, 303.44±1.07 mg/100 g, with IFPM samples showing a significantly higher value, 321.79±0.38 mg/100 g. Swami *et al*. (2013) showed that FM grains with a concentration of 283 mg/100 g are a rich source P. Cornejo-Villegas *et al.* (2010) reported a P of 1.32 mg/100 g on traditional instant corn flour and 0.25 mg/100 g on commercial instant corn flour. Sade (2009) reported a P of 360 mg/100 g on PM flour.

Milky cream RFM flour sample had the highest zinc (Zn) value of 2.64 mg/100 g and had a significantly higher value than RFM flours of brown which was 2.57 mg/100 g and black which was 2.62 mg/100 g. RPM showed a significantly higher ($p < 0.05$) concentration of Zn than RFM (4.79 mg/100 g). Both brown and black RFFM flours had the highest Zn concentration of 9.72 mg/100 g and a significantly higher ($p < 0.05$) value compared to milky cream RFFM flour which had 9.44 mg/100 g. RFPM 10.28 mg/100 g showed a significantly higher value as compared to RFFM flours. Zn of IFM flours ranged from 2.89±0.02 to 3.11±0.02 mg/100 g. Milky cream flour which had 3.11±0.02 mg/100 g showed a significantly higher value of Zn compared to brown which had 2.89±0.02 mg/100 g and black IFM flours which had 2.93±0.01 mg/100 g. IPM flour had a significantly higher value of 5.29±0.00 mg/100 g compared to IFFM which had 8.92±0.01 mg/100 g. At 8.44±0.05 mg/100 g, black IFFM, showed significantly lower value while IFPM had a significantly lower value of Zn as compared to IFFM flours. The addition of vitamin B_2 and Zn increased the Zn of fortified flours for both raw and instant fortified flours. Gibson *et al.* (2016) reported the daily recommended amounts of Zn ranged from 2 -14 mg/day on different age groups including pregnant and lactating women. The results of Zn fortificant obtained from this study were within this specified range. The results were similar to those of Takhellambam *et al.* (2016). Zinc with a concentration of 0.97 - 2.56 on FM grains, has been reported by Singh and Raghuvanshi (2012) and Shobana *et al.* (2013). Triphathi *et al.* (2012) reported the fortification of sorghum and PM with Zn. Zinc deficiency is recognized as a global health problem that leads to cognitive function impairment, memory impairment problems with spatial learning and neuronal atrophy (Gupta *et al.*, 2015). The main issue of Zn deficiency is the unlimited consumption of animal foods or fats in developing countries (Akhtar *et al*., 2011; Kunyanga *et al*., 2013). Although animal foods are rich sources of Zn, grains can also contribute to Zn availability in diets as they are rich in the minerals. FM flours fortified with ZnO shows further importance in that they may assist in reducing child mortality globally by 63% in sub-Sarahan Africa (Shrimpton *et al*., 2005) and 95.4% in southeast Asia (Tripathi and Platel, 2010). New innovative approaches may however be implemented to boost fortification of foods with ZnO. In this study, milky cream RFM and IFM flour showed a significantly higher ($p < 0.05$) Zn as compared to other flours (Figure 2). Brown and black RFFM flours had the same Zn content, which was significantly higher, while MC and brown RFFM flours also had a similar concentration of Zn which also showed a significantly higher value. There is a need for the fortification of FM flours with Zn to replace the Zn which is lost during food processing.

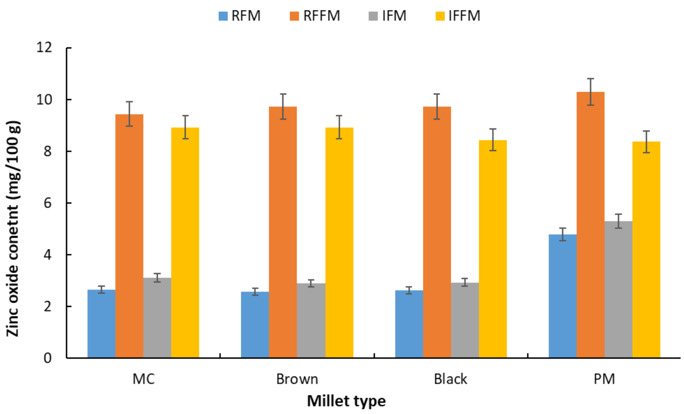

Figure 2. Zinc oxide content in mg/100 g of finger millet flours. Error bars are standard deviation of mean values. MC = milk creamy, PM = pearl millet, RFM = raw finger millet, RFFM = raw fortified finger millet, IFM = instant finger millet and IFFM = instant fortified finger millet

3.3 Vitamin B complex composition in flour samples

Results of the analysis showed that black RFM flour had the highest concentration of vitamin B_1 (0.43±0.01 mg/100 g) while the lowest concentration was found in both MC (0.27±0.24 mg/100 g) and brown RFM flours (0.27±0.24 mg/100 g) (Table 3). RFM flour showed significantly higher vitamin B_1 (0.60±0.03 mg/100 g) with RFFM flours having the highest amount of vitamin B_2 in MC flour (114.82±8.56 mg/100 g) while the lowest value was obtained in brown flour (26.24±5.84 mg/100 g). In the works of Kumar *et al*. (2016), concentrations of 0.42 and 0.33 mg/100 g were reported for vitamin B_1 in FM and PM flours. Vitamin B_2 of IFFM flours ranged from 0.85±0.03 mg/100 g - 1.41±0.19 mg/100 g with the highest vitamin obtained from MC flour and the lowest from black flour. The MC flour showed significantly higher ($p < 0.05$) values of vitamins B_1 and B_2 in both RFFM and IFFM flours. Vitamin B_2 was found in RPM and IPM flours having concentrations of 0.27±0.03 mg/100 g and 0.08±0.07 mg/100 g. Vitamin B_2 was also identified in fortified flours of RPM and IPM and was not present in RFM and IFM flours. Results obtained from this study are similar to those reported by Kumar *et al*. (2016) who showed that FM and PM flours had vitamin B_2 concentrations of 0.19 and 0.25 mg/100 g. Lebiedzi'nska and Szefer (2006) reported vitamin B_2 of 0.210, 0.132, 0.067, 0.028 and 0.024 mg/100 g in buckwheat flour, groats, corn flour, rice flour, rice instant and barley respectively. Zieliṅski *et al.* (2005) reported the daily recommended vitamin B_2 intake which ranged from 0.4 – 1.8 mg/day in all age groups.

Vitamin B_2 is sensitive to processing conditions, especially light, heat, reducing and oxidizing agents and other physical and chemical stress. Vitamin B_2 is stable when added to FM flours and the addition of fortificants may not reduce its shelf-life (Zieliṅski *et al.,* 2005). Losses of up to 66% may be due to the technological processes involved during processing such as soaking, cooking, drying and milling. Other vitamins such as vitamins B_3 and B_6 were not found in all FM flours. Kumar *et al.* (2016) also studied the concentration of vitamin B_3 in FM and PM flours and reported a concentration of 1.1 and 2.3 mg/100 g and the concentration of vitamin B_6 in FM and PM flours as 18.3 and 45.5 mg/100 g. Vitamin B complex is important micronutrients that help to maintain the health of the human body. Deficiency of vitamin B_2 is a serious concern in many developing countries especially in Africa (Akhtar *et al*., 2011). Currently, there is a growing demand for consuming fortified foods such as cereal, flours and bread in the world including Africa. Vitamin B_2 and B_3 are thus added on maize in the United States of America, South Africa and Nigeria (Triphathi and Platel, 2010).

4. Conclusion

The study revealed that moisture content and pH of flours decreased upon the addition of fortificants which shows that the flour may have a long shelf-life during storage. The reference samples had the highest protein

Table 3. Vitamins B complex of finger millet flour treatments mg/100 g

Cereal flours	Vitamin B_1	Vitamin B_2	Vitamin B_3	Vitamin B_6
Raw finger millet				
Milky cream	0.27±0.24^c	ND	ND	ND
Brown	0.27±0.23^c	ND	ND	ND
Black	0.43±0.01^b	ND	ND	ND
Pearl millet	0.60±0.03^a	0.27±0.03^a	ND	ND
Raw fortified finger millet				
Milky cream	ND	114.82±8.56^a	ND	ND
Brown	ND	26.24±5.84^c	ND	ND
Black	ND	68.77±13.19^b	ND	ND
Pearl millet	ND	27.27±0.03^c	ND	ND
Instant finger millet				
Milky cream	ND	ND	ND	ND
Brown	ND	ND	ND	ND
Black	ND	ND	ND	ND
Pearl millet	ND	0.08±0.07^a	ND	ND
Instant fortified finger millet				
Milky cream	ND	1.41±0.19^b	ND	ND
Brown	ND	1.20±0.03^d	ND	ND
Black	ND	0.85±0.03^c	ND	ND
Pearl millet	ND	4.50±0.03^a	ND	ND

Values are mean±standard deviation, n = 3. Values followed by the same letters in the same column are not significantly different ($p < 0.05$). ND = not detected.

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content and pH value as compared to finger millet flours, while the ash content of MC flours increased after adding ZnO. The observed increase in the ash content in flour samples resulted in a corresponding increase in the concentration of minerals such as Zn and Mg in the FM flours. However, a reported decrease in minerals such as Fe, K and Na were observed in instant fortified flours used in the study. Vitamin B_2 was not detected in unfortified flour but only in fortified flour samples. The highly sensitive nature of vitamin B_2 to processing conditions, makes the nutrient to be easily lost in processed foods. The addition of vitamin B_2 in foods as fortificants will therefore replace the lost valuable nutrient due to processing, thus making vitamin B_2 available for bioabsorption and utilization in the human body. Among the three FM flours studied, MC, brown RFFM and IFFM flours which are gluten-free, showed distinct attributes that make them suitable for further food applications and valorization.

Conflict of interest

The authors declare no conflict of interest.

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