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Effects of Processing on Nutritional and Sensory Quality of Pearl Millet Flour.

Maryann Mukethi Kindiki[1, 2]* Arnold Onyango[1] Florence Kyalo[1]
1. Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, P.O. Box 62000-00200, Nairobi, Kenya
2. Metrology/Testing Department, Kenya Bureau Of Standards (KEBS), P.O. Box 54974-00200, Nairobi, Kenya

Abstract
Malnutrition is a common occurrence in the arid and semi-arid lands (ASALs) of Kenya. Well-formulated complementary foods in the market are not affordable by mothers living in these resource-poor communities. Therefore nutrition efforts should be geared towards achieving affordable and nutritious complementary foods for children who are the most vulnerable group in the society.
The study evaluated the effects of germination of pearl millet (*Pennisetum glaucum*) for up to 5 days followed by fermentation (24 hrs) and roasting on proximate composition, iron, zinc, calcium and phytates contents. Results showed that this process decreased calcium and phytic acid levels significantly ($p<0.05$) while protein, ash, crude fiber, iron and zinc levels were increased. The germinated, fermented and roasted flour gave porridge of superior sensory quality than flour from untreated millet.
Keywords: Germination/sprouting, fermentation, roasting, millet.

1. Introduction

Arid and semi-arid lands (ASALs) cover up to 80% of Kenyan land and makes home to over 10million people (Draft national policy for sustainable development of ASALs of Kenya-2004). This predisposes a large population to under-nutrition due to inadequate food supply round the year. Complementary feeding is the transition from exclusive breast-feeding to family foods and it is a period of great vulnerability for infants (FAO, 2011). This is the period when many children face the risk of malnutrition and it is important to ensure that they are fed properly with nutritious and safe foods (WHO, 2011). However, the well-formulated complementary foods in the Kenyan market are not affordable by mothers in resource-poor communities. Micronutrient deficiencies particularly iron, zinc, and calcium are of great public health concern (National Nutrition Action Plan, 2012-2017). In spite of these nutrients being present in plant foods, their bioavailability from such foods is usually poor (Gibson, 1994; Sandberg, 2002).

Pearl millet (*Pennisetum glaucum*) is the most widely grown type of millet because of its ability to establish and thrive in harsh conditions of low rainfall, high temperatures and poor soil fertility. Its optimum germination temperature varies little across pearl millet genotypes or races, averaging about 34^{o}C with a base temperature between 8 and 13.5^{o}C, and an upper limit of between 47 and 52^{o}C (Mohamed, Clark & Ong, 1988a). Because of its tolerance to difficult growing conditions, it is well situated in environment that is less productive and unsuitable to less tolerant crops.

However pearl millet contains significant amounts of antinutrient (phytates) which affect the bioavailability of minerals such as Ca, Zn and Fe which should be reduced to improve millet nutrition (Abdelrahaman *et al*.,2005). Processes such as germination, malting, fermentation, thermal and mechanical treatments of grains improve their digestibility, nutrient bioavailability and sensory properties while reducing their antinutrient content (Egli et al., 2002 and Chavan J.K et al,1989). These treatments help maximize the bioavailability of iron and zinc from cereals and pulses (Lestienne et al, 2005a; Liang et al, 2008; Luo et al, 2009). Germination can increase iron bioavailability up to two folds (Tontisirin et al, 2002). In many countries, fermentation and germination processes have been used to formulate weaning foods (Devadas, 1998).

In this study the effects of germination followed by roasting and fermentation for 24 hours on the nutritional and sensory qualities of pearl millet were evaluated. The study established improved nutrition and sensory quality of pearl millet through application of germination followed by fermentation and roasting.

2. Materials and methods

Sample preparation

Pearl millet was obtained from retail markets, blended, cleaned and scrubbed to remove grain hairs.
Germination: the grains were washed in running tap water to remove foreign material, put into large nylon bags and steeped in static water for 8 hours. The nylon bags were covered with wet cloths to maintain saturation during germination for 1 to 5 days at different temperatures of20^{O}C, 30^{O}C, 40^{O}C, and 50^{O}C. After the predetermined germination periods, the grains were drained of excess water and prepared for fermentation.
Fermentation: the germinated grains were mixed with distilled water (1:3 w/v), and allowed to ferment at 37°C

for 24 hours and then drained of excess water and dried at 60°C.

Roasting; roasting of the pearl millet grains was done in an open pan to develop the nutty flavor.

Chemical analyses of samples: Treated and untreated millet samples were ground to flour fineness and subsequently analyzed for proximate composition, iron, zinc, calcium and phytates content. Proximate composition was determined by AOAC (1995) methods. iron, zinc and calcium contents were determined by atomic absorption AAS (AOAC 1995). Analysis of phytic acid was done by HPLC method of Camire and Clydesdale (1982).

Sensory evaluation: fifteen (15) panelists evaluated the treated (germinated, fermented and roasted) pearl millet flour as porridge against the corresponding untreated sample. The team subjected the samples to 9 - point hedonic scale, where 9 = liked extremely and 1 = disliked extremely and the preference scores were statistically analyzed.

Statistical analysis: all data obtained were subjected to One- and Two- way analysis of variance (ANOVA), using GENSTAT statisticalpackage. Means were separated by Duncan's multiple range tests (Steel and Torries, 1980)and significance was accepted at $P < 0.05$.

3. Results and discussion

3.1. Effect of germination followed by 24-hours fermentation and roasting on the ash content of pearl millet

Table 1: Effect of germination followed by 24-hours fermentation and roasting on the ash content of pearl millet flour (on dry weight basis)

Germination condition	0 hours	24 hours	48 hours	72 hours	96 hours	120 hours
Room temperature	2.15 ± 0.002^{a1}	2.24 ± 0.005^{b1}	2.62 ± 0.010^{c1}	2.79 ± 0.011^{e1}	2.83 ± 0.010^{d1}	2.84 ± 0.004^{d1}
20°C	2.15 ± 0.006^{a1}	2.22 ± 0.012^{b1}	2.57 ± 0.006^{c1}	2.78 ± 0.012^{e1}	2.83 ± 0.006^{d1}	2.82 ± 0.012^{d1}
30°C	2.15 ± 0.003^{a1}	2.25 ± 0.006^{b1}	2.64 ± 0.006^{c1}	2.82 ± 0.006^{e1}	2.84 ± 0.020^{d1}	2.85 ± 0.006^{d1}
40°C	2.14 ± 0.006^{a1}	2.24 ± 0.006^{b1}	2.60 ± 0.006^{c1}	2.79 ± 0.015^{e1}	2.84 ± 0.006^{d1}	2.84 ± 0.006^{d51}
50°C	2.14 ± 0.006^{a1}	2.24 ± 0.006^{b1}	2.58 ± 0.010^{c1}	2.78 ± 0.015^{e1}	2.83 ± 0.017^{d1}	2.82 ± 0.006^{d1}

Values are mean ± S.D

Values in the same row with different superscript letters are significantly different at 5% level and values in the same column with different superscript numbers are significantly different at 5% level.

Two- way analysis of variance of fermented samples showed there was significant interaction between different periods of germination which significantly ($P < 0.05$) increased the ash content of the pearl millet from 2.14 - 2.15% in untreated sample to a maximum of 2.85% achieved after 120 hours of germination at 30°C and fermentation for 24 hours as shown in table 1. Obizoba and Atii (1994) reported that fermentation at room temperature for 36, 48, and 72 hours increased the ash content of pearl millet. Similarly, Malleshi and Desikachar (1986) reported that germination at 25°C for 48 h increased the ash content of pearl millet. Thus, a combination of germination and fermentation might result in greater increase in ash content than in individual treatments. In this study the combined effects of germination followed by fermentation were studied, with varying germination conditions and constant fermentation conditions of 37°C for 24 hrs. One- way analysis of variance showed germination at varying periods significantly ($P < 0.05$) influenced the level of ash of pearl millet. The ash content increased as germination progressed with time. However different temperature treatments at the same period of sprouting showed no significant difference in ash content. Germination at 30°C produced the highest ash contents attributed to the optimum germination condition at about 30°C (Mohamed, Clark & Ong, 1988a). Shah et al (2011) found an increase in ash content during the germination of two mung bean varieties and suggested that such an increase was as a result of the reduction in fat and carbohydrate contents. The same may be true in this study where fat content was also found to decrease with germination time (table 3).

3.2. Effect of germination followed by 24-hours fermentation and roasting on the fibre content of pearl millet

Table 2: Effect of germination followed by 24-hours fermentation and roasting on the fibre content of pearl millet flour (on dry weight basis)

Germination condition	0 hours	24 hours	48 hours	72 hours	96 hours	120 hours
Room temperature	2.59 ± 0.001^{a1}	2.76 ± 0.005^{b3}	2.98 ± 0.002^{c4}	3.12 ± 0.010^{d2}	3.22 ± 0.015^{d2}	3.45 ± 0.012^{e3}
20°C	2.59 ± 0.010^{a1}	2.69 ± 0.026^{a2}	2.88 ± 0.015^{b2}	3.05 ± 0.010^{c2}	3.13 ± 0.010^{c2}	3.42 ± 0.015^{d3}
30°C	2.59 ± 0.012^{a1}	2.85 ± 0.015^{b4}	3.07 ± 0.012^{c3}	3.16 ± 0.020^{c2}	3.42 ± 0.015^{d3}	3.47 ± 0.021^{d3}
40°C	2.59 ± 0.015^{a1}	2.66 ± 0.025^{b12}	2.79 ± 0.015^{c12}	2.93 ± 0.020^{cd2}	2.95 ± 0.020^{cd2}	3.10 ± 0.021^{d2}
50°C	2.58 ± 0.012^{a1}	2.63 ± 0.010^{b1}	2.71 ± 0.015^{c1}	2.85 ± 0.015^{d1}	$2.88 \pm 0.^{010d1}$	2.97 ± 0.006^{e1}

Values are mean ± S.D

Values in the same row with different superscript letters are significantly different at 5% level and values in the same column with different superscript numbers are significantly different at 5% level.

Two- way analysis of variance of fermented samples showed significant interaction between different periods of

germination and different germination temperatures which significantly (P< 0.05) increased the fibre content of pearl millet from a minimum of 2.58 – 2.59% in untreated (0-hours germination, no fermentation) samples to a maximum of 3.47% achieved after 120 hours of germination at 30^{O}C as shown in table 2. Dendy (1995) and Malleshi and Desikachar (1986) reported a similar observation that recorded an increase in fibre content of pearl millet on malting. On the other hand, Abdelnour (2001) reported that fermentation reduced the fibre content of pearl millet but his finding was based on dehulling treatment which was absent in this study. Optimum temperatures for germination vary little across pearl millet genotypes or races, averaging about 34^{o}C with a base temperature between 8 and 13.5^{o}C, and an upper limit of between 47 and 52^{o}C (Mohamed, Clark & Ong, 1988a). High temperatures (>45^{o}C) may result in poor crop establishment (Soman, et.al., 1987). The greater increase in fibre content after germination at 30°C is consistent with greater depletion of carbohydrates and fats at this temperature.

3.3. Effect of germination followed by 24-hours fermentation and roasting on the fat content of pearl millet

Table 3: Effect of germination followed by 24-hours fermentation and roasting on the fat content of pearl millet flour (on dry weight basis)

	0 hours	24 hours	48 hours	72 hours	96 hours	120 hours
Room temperature	3.42 ± 0.010^{e1}	2.58 ± 0.007^{d12}	2.31 ± 0.010^{b2}	2.31 ± 0.012^{b2}	2.29 ± 0.010^{b2}	1.97 ± 0.005^{a2}
20^{O}C	3.42 ± 0.015^{e1}	2.87 ± 0.015^{d4}	2.67 ± 0.015^{c3}	2.41 ± 0.015^{b3}	2.36 ± 0.015^{b3}	2.13 ± 0.015^{a3}
30^{O}C	3.42 ± 0.006^{d1}	2.50 ± 0.010^{c1}	2.27 ± 0.010^{b1}	2.24 ± 0.006^{b1}	2.26 ± 0.015^{b1}	1.82 ± 0.015^{a1}
40^{O}C	3.42 ± 0.012^{d1}	2.63 ± 0.012^{c2}	2.62 ± 0.012^{c3}	2.52± 0.006^{b4}	2.28 ± 0.010^{a2}	2.31 ± 0.012^{a4}
50^{O}C	3.40 ± 0.015^{c1}	2.70 ± 0.015^{b3}	2.66 ± 0.006^{b3}	2.63 ± 0.015^{b5}	2.44 ± 0.180^{a4}	2.43 ± 0.015^{a5}

Values are mean ± S.D

Values in the same row with different superscript letters are significantly different at 5% level and values in the same column with different superscript numbers are significantly different at 5% level.

Two- way analysis of variance of fermented samples showed there was significant interaction between different periods of germination and different germination temperatures which significantly (P< 0.05) decreased the fat content of pearl millet from a maximum of 3.39 - 3.42% in untreated (0-hours germination, no fermentation) samples to a minimum of 1.82% in samples that were germinated for 5 days (120 hours) at 30^{O}C. Many researchers (Malleshi and Desikachar, 1986; Dendy, 1995; Elmaki et al, 1999; and Shah et al, 2011) have attributed the observed reduction in fat content to germination. Obizoba and Atii, 1994 also reported that fermentation process leads to reduction in fat content due to the utilization of fat as energy source by the fermenting organisms.

One- way analysis of variance showed significant differences in fat contents during different germination periods and at different germination temperatures. The highest fat contents were obtained in untreated samples (no fermentation and no germination) and samples germinated at 50^{O}C respectively. At 50^{O}C, germination was limited by unfavorable condition (Soman, et.al., 1987) and thus fat content of pearl millet remained high as germination and subsequent fat reduction was minimal. Lowest fat contents were obtained during the fifth day (120 hours) of germination and at germination temperature of 30^{O}C respectively which as explained previously are conditions that supported maximum germination and significant reduction of fat content.

3.4. Effect of germination followed by 24-hours fermentation and roasting on the protein content of pearl millet

Table 4: Effect of germination followedby 24-hours fermentation and roasting on the protein content of pearl millet flour (on dry weight basis)

Germination condition	0 hours	24 hours	48 hours	72 hours	96 hours	120 hours
Room temperature	9.11 ± 0.010^{a1}	10.15 ±0.005^{b4}	10.92 ± 0.012^{c45}	11.29± 0.010^{d3}	11.60 ± 0.002^{e4}	11.75 ± 0.005^{f45}
20^{O}C	9.11 ± 0.006^{a1}	10.08 ±0.010^{b3}	10.89 ± 0.010^{c4}	11.25 ± 0.012^{d3}	11.55 ± 0.012^{e3}	11.73 ± 0.021^{f4}
30^{O}C	9.11 ± 0.006^{a1}	10.25 ±0.015^{b5}	10.96 ± 0.017^{c5}	11.36 ± 0.015^{d4}	11.66 ± 0.035^{e5}	11.78 ± 0.006^{f5}
40^{O}C	9.11 ± 0.012^{a1}	10.03 ±0.010^{b3}	10.66 ± 0.015^{c3}	11.13 ± 0.015^{d2}	11.63 ± 0.015^{e45}	11.66 ± 0.012^{e3}
50^{O}C	9.12 ± 0.006^{a1}	9.88 ±0.006^{b2}	9.94 ± 0.010^{b2}	10.16 ± 0.020^{c2}	10.28 ± 0.017^{cd2}	10.31 ± 0.021^{d2}

Values are mean ± S.D

Values in the same row with different superscript letters are significantly different at 5% level and values in the same column with different superscript numbers are significantly different at 5% level.

Two- way analysis of variance of fermented samples showed there was significant interaction between different periods of germination and different germination temperatures which significantly (P< 0.05) increased the protein levels of pearl millet from a minimum of 9.11 - 9.12% in untreated (0-hours germination, no fermentation) samples to a maximum of up to 11.78% in samples that were germinated for five days (120 hours) at 30^{O}C.Similar results were observed by Nnam (2000)and Akpapunam *et al.*, (1996) who also reported an

increases in protein content of various cereals and legumes during germination and fermentation. This increase during germination can be attributed to synthesis of enzymic protein by germinating seeds (WHO, 1998, Nzeribe and Nwasike, 1995). Marero *et al*., (1989) attributed the increase in protein during germination of cereals to the production of some amino acids during protein synthesis in excess of the requirement and accumulation in free amino acid pool. Fermentation may have also played a role in increase in protein content as it has been observed by other researchers (Alhag,1999, and Obizoba and Atii,1994. However Abdalla et al. (1996) observed a non-significant reduction in protein content of pearl millet during fermentation.

One- way analysis of variance showed there were significant differences in protein contents during different periods of germination and at different germination temperatures. Highest protein contents were obtained at germination temperature of 30^{O}C and during the fifth day (120 hours) of germination. The 30°C is within the optimum range for millet germination (Mohamed, Clark & Ong, 1988a) and thus it promoted maximum protein synthesis as explained previously.

3.5. Effect of germination followed by 24-hours fermentation and roasting on the iron, zinc and calcium contents of pearl millet

Table 5: Effect of germination followed byby 24-hours fermentation and roasting on the iron content of pearl millet flour (µg/g)

Germination condition	0 hours	24 hours	48 hours	72 hours	96 hours	120 hours
Room temperature	148.28 ± 0.512^{a1}	169.75 ± 2.154^{b34}	179.30 ± 0.846^{c3}	192.04 ± 2.223^{d4}	195.81 ± 1.203^{d4}	206.44 ± 2.006^{e4}
20^{O}C	147.86 ± 1.187^{a1}	159.11 ± 2.064^{b1}	177.29 ± 1.349^{c3}	190.14± 1.021^{d4}	194.63 ± 1.320^{d4}	203.59 ±0.877^{e4}
30^{O}C	148.51 ± 0.470^{a1}	172.68 ± 4.438^{b4}	181.83 ± 1.721^{c34}	193.04 ± 1.723^{d4}	196.67 ± 1.987^{d4}	208.20 ±0.392^{e4}
40^{O}C	148.80 ± 0.159^{a1}	166.91 ± 1.814^{b3}	171.36 ±0.932^{bc2}	177.47 ± 0.734^{c3}	182.93 ± 1.700^{cd3}	183.84 ± 3.545^{cd23}
50^{O}C	148.55 ± 0.230^{a1}	161.99± 1.261^{b2}	168.51 ± 0.680^{bc12}	172.90± 2.251^{c2}	175.23 ± 0.8702^{cd}	176.48 ± 1.531^{cd12}

Values are mean ± S.D

Values in the same row with different superscript letters are significantly different at 5% level and values in the same column with different superscript numbers are significantly different at 5% level.

Table 6: Effect of germination followed by 24-hours fermentation and roastingon the zinc content of pearl millet flour (µg/g)

Germination condition	0 hours	24 hours	48 hours	72 hours	96 hours	120 hours
Room temperature	44.54 ± 0.012^{a1}	55.84 ± 0.255^{b2}	58.48 ± 0.616^{b2}	71.68 ± 0.672^{c3}	75.45 ± 0.805^{cd3}	76.46 ± 1.223^{d}
20^{O}C	44.76 ± 0.198^{a1}	54.97 ± 0.345^{b2}	56.82 ± 0.361^{b2}	67.35 ± 0.489^{c2}	70.84 ± 0.367^{cd23}	71.52 ± 0.294^{d}
30^{O}C	44.61 ± 0.045^{a1}	56.67 ± 0.707^{b2}	59.13 ± 0.397^{b2}	73.17 ± 0.488^{c3}	78.05 ± 0.385^{d34}	79.46 ± 0.203^{d}
40^{O}C	44.68 ± 0.169^{a1}	51.46 ± 1.280^{b12}	55.28 ± 0.949^{b2}	64.59 ± 0.337^{c2}	66.45 ± 0.175^{c2}	67.94 ± 390^{c}
50^{O}C	44.75 ± 0.224^{a1}	47.95 ± 0.937^{a1}	50.82 ±0.180^{ab1}	52.34 ± 0.110^{b1}	51.15 ± 0.405^{b1}	51.93 ± 0.645^{b}

Values are mean ± S.D

Values in the same row with different superscript letters are significantly different at 5% level and values in the same column with different superscript numbers are significantly different at 5% level.

Table 7: Effect of germination followedby 24-hours fermentation and roastingon the calcium content of pearl millet flour (mg/100g)

Germination condition	0 hours	24 hours	48 hours	72 hours	96 hours	120 hours
Room temperature	16.28 ± 0.001^{f1}	14.53 ± 0.001^{e1}	13.49 ± 0.002^{d1}	13.44 ± 0.002^{c1}	12.70 ± 0.001^{b2}	12.38 ± 0.002^{a2}
20^{O}C	16.28 ± 0.001^{f1}	14.61 ± 0.002^{e1}	13.57 ± 0.002^{d1}	13.31 ± 0.002^{c1}	12.81 ± 0.002^{b2}	12.40 ± 0.001^{a2}
30^{O}C	16.27 ± 0.003^{f1}	14.48 ± 0.002^{e1}	13.42 ± 0.001^{d1}	13.16 ± 0.001^{c1}	12.63 ± 0.001^{b2}	12.11 ± 0.002^{a2}
40^{O}C	16.29 ± 0.002^{f1}	15.68 ± 0.001^{e2}	14.93 ± 0.002^{d2}	14.85 ± 0.002^{c2}	10.58 ± 0.002^{a1}	10.58 ± 0.001^{a1}
50^{O}C	16.28 ± 0.001^{f1}	15.72 ± 0.003^{e2}	15.08 ± 0.003^{d3}	14.91 ± 0.001^{c2}	14.69 ± 0.003^{b3}	14.51 ± 0.002^{a3}

Values are mean ± S.D

Values in the same row with different superscript letters are significantly different at 5% level and values in the same column with different superscript numbers are significantly different at 5% level.

Two- way analysis of variance of fermented samples showed there was significant interaction between different periods of germination and different germination temperatures which significantly (P< 0.05) increased the iron and zinc contents of pearl millet (Tables 5 and 6). One way analysis of variance showed that iron and zinc contents significantly increased as germination progressed with the maximum levels for every temperature treatment obtained during the fifth day (120 hours) of germination and minimum level at 0 hours of germination. The best temperature treatment was 30°Cwhich produced the highest iron and zinc contents. Nnam (2000) working with 'hungry rice-acha' reported related result of an increase in iron level of sprouted cereal of up to two folds. Obizoba and Atii reported similar findings for zinc as they observed that sprouting for 24, 36, 48, 72 and 92 h significantly increased zinc content of pearl millet.

Calcium content of pearl millet ranged between 10.58-16.28mg/100g which was within range (Adam et al 2009). Two- way analysis of variance of fermented samples showed there was significant interaction between different periods of germination and different germination temperatures which significantly (P< 0.05) decreased the calcium contents of pearl millet (Table 7). One- way analysis of variance showed significant (P< 0.05)

differences in calcium contents during different periods of germination and for different germination temperatures.

Highest iron and zinc contents (table 5 and 6 respectively) were both obtained at temperature of 30°C of sprouting which can be attributed to optimum germination condition that resulted to highest increase in iron and zinc contents of peal millet. Highest calcium contents were obtained in samples that were germinated at a temperature of 50°C and samples that were not germinated respectively. This was a deviation from the behavior of the latter two minerals and the contrary results may be attributed to minimal germination at this temperature thus calcium level almost remained unchanged but there was significant (P< 0.05) differences in iron contents since millet is able to establish in difficult environmental condition of about 50°C as reported by Mohamed, Clark & Ong, (1988) who observed an upper limit temperature of 52°C for germination of pearl millet and recorded varying optimum level with pearl millet genotypes. Ganesh Kumar et al (1978) working with green gram and cowpea also reported reduction of calcium content by 40% after 72 hours of germination which was attributed to leaching.

3.6. Effect of germination followed by 24-hours fermentation and roasting on the phytic acid content of pearl millet

Table 8: Effect of germination followed by 24-hours fermentation and roasting on the phytic acid content of pearl millet flour (mg)

Germination condition	0 hours	24 hours	48 hours	72 hours	96 hours	120 hours
Room temperature	516.33 ± 0.577^{f1}	369.33 ± 1.155^{e1}	316.33 ± 0.577^{d2}	282.67 ± 1.155^{c12}	259.33 ± 1.528^{b12}	248.33 ± 0.577^{a2}
20°C	516.33 ± 0.577^{f1}	387.67 ± 1.155^{e3}	329.67 ± 0.577^{d23}	304.67 ± 0.577^{c3}	281.67 ± 1.528^{b3}	267.67 ± 1.442^{a3}
30°C	515.67 ± 1.155^{f1}	360.67 ± 1.528^{e1}	302.33 ± 1.528^{d1}	271.33 ± 0.577^{c1}	252.67 ± 2.082^{b1}	236.33 ± 1.155^{a1}
40°C	516.33 ± 1.155^{f1}	378.00 ± 1.00^{e2}	321.33 ± 0.577^{d2}	289.67 ± 1.528^{c2}	269.33 ± 0.577^{b2}	257.00 ± 1.000^{a23}
50°C	515.42 ± 0.160^{f1}	383.73 ± 2.005^{e3}	338.84 ± 3.825^{d3}	316.08 ± 2.106^{c34}	296.67 ± 2.503^{b4}	274.91 ± 1.241^{3}

Values are mean ± S.D

Values in the same row with different superscript letters are significantly different at 5% level and values in the same column with different superscript numbers are significantly different at 5% level.

Two- way analysis of variance of fermented samples showed significant interaction between different periods of germination and different germination temperatures which significantly (P< 0.05) decreased the phytic acid levels of pearl millet (Table 8) from maximum amounts obtained before germination to lower levels obtained during day 5 (120 hours) of germination. The decrease in phytic acid levels with germination and fermentation can be attributed to increased activity of the enzyme phytase during germination and fermentation (Nkama et al., 2001). Sutardi and Buckle (1985) also reported similar result of reduced phytic acid during germination and fermentation.

One- way analysis of variance showed different germination periods and temperatures significantly (P< 0.05) influenced phytic acid contents of pearl millet. Highest phytic acid contents were obtained in samples that were germinated at a temperature of 50°C and samples that were not germinated respectively due to low activity of the enzyme phytase. This may be attributed to minimal germination at this condition (Mohamed, Clark & Ong, 1988a). Khetarpaul and Chauhan (1990) reported that phytic acid was reduced during fermentation due to the action of the phytase released by microorganisms during fermentation.

3.7. Sensory evaluation of formulated complementary composite flour

Table 9: sensory evaluation of pearl millet flour (evaluated as porridge)

	Colour	Taste	Aroma	Texture	General acceptability
A (Treated Sample)	8.602 ± 0.540^{a}	8.411 ± 0.335^{a}	8.000 ± 0.501^{a}	8.093 ± 0.410^{a}	8.218 ± 0.663a
B (Untreated Sample)	7.754 ± 0.324^{b}	6.295 ± 0.102^{b}	6.685 ± 0.226^{b}	8.004 ± 0.225^{a}	5.906 ± 0.804b

Values are mean ± S.D

Values in the same column with different superscripts are significantly different at 5% level.

Sample A derived from treated samples(germination at 30°C for 5days followed by fermentation for 24 hours and subsequent roasting) scored highly in all sensory attributes; colour, taste, aroma, texture and overall acceptability (table 9) as evaluated using 9- point hedonic scale as opposed to sample B derived from untreated (no germination, no fermentation)samples which scored relatively lower in all sensory attributes with statistical analysis showing significant difference(P< 0.05) in all attributes except texture that indicated no significant difference. The results indicates clearly that treatments significantly imparted desirable sensory characteristics with regard to colour, taste, aroma and general characteristics. Germination, roasting and fermentation of pearl millet could have contributed majorly to the high preference of treated samples due to the developed aroma.

4. Conclusion

Germination followed by fermentation and roasting was found to significantly improve the chemical composition and nutritive value of pearl millet especially ash, fibre, fat, protein, minerals (iron and zinc) and

antinutrient (phytates reduction). Germination, roasting and fermentation significantly (P< 0.05) improved the organoleptic preferences of pearl millet improving the colour, taste, aroma, texture and general acceptability which is important for increasing food intake not just for pearl millet but also other foods which can be blended with pearl millet.The latter processing procedures therefore helped obtain various objectives; palatability, nutrition and food consumption. The processes in this study therefore can be recommended for utilization of pearl millet for development of composite flours for nutritionally vulnerable groups including children, the aged, the sick, the pregnant and breastfeeding women.

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