Journal of Food Technology 7 (3): 92-97, 2009
ISSN: 1684-8462

Proximate, Antinutritional Factors and Functional Properties of Processed Pearl Millet (*Pennisetum glaucum*)

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Abstract: The effect of germination, roasting and fermentation on the proximate composition, antinutritional factors and functional properties of pearl millet was investigated. Pearl millet seeds were subjected to the different processing methods; samples were dried and milled into fine flours, respectively. Standard methods were used to evaluate the flours for proximate, minerals, antinutritional factors and functional properties. The visco-elastic property was determined using the Rapid Visco Analyzer (RVA). Germination and fermentation increased the crude protein content of pearl millet seed flour. The carbohydrate content decreased during fermentation, while germination and roasting significantly ($p<0.05$) increased the carbohydrate level resulting in significant increase in the energy density of the flour. Processing had varied effects on the mineral composition of the flours, it also reduced the antinutritional factors Processing significantly ($p<0.05$) increased the water absorption capacity, oil absorption capacity, least gelation concentration and bulk density of the flours, hence flours could be used in food systems where the above qualities are desirable.

Key words: Germination, fermentation, toasting, proximate, antinutritional, functional properties, pearl millet

INTRODUCTION

Millets are indigenous African cereals that, unlike wheat or rice are well adapted African semi-arid and sub-tropical agronomic conditions. Millets grow under difficult ecological conditions and tolerate poor soils and a certain degree of drought better than any other cereal crops. There are nine species of millet cultivated around the world and pearl millet (*Pennisetum glaucum*, synonyms: *P. americanum*, *P. yphoides*) is the most widely grown species in Africa. In 2001, 10.7 million tons of millet were produced in Sahelian Africa (Burkina Faso, Gambia, Mali, Niger, Nigeria, Senegal and Chad). This represents in these countries an average of 495 kcal per person per day and up to 1014 and 609 kcal per person per day in Niger and Burkina Faso, respectively. Indeed, in many African countries, millet is often the main component of many meals and is essentially consumed as steam-cooked products (couscous), thick porridges (Tô) and thin porridges (Ogi), which can be used as a complementary food for infants and young children and is also used in brewing beer. Pearl is nutritionally better than most other cereals; it has high levels of calcium, iron, zinc, lipids and high quality proteins (Klopfenstein and Hoseney, 1995). But, as in other cereal grains, nutritional quality is considerably lowered by the presence of anti-nutritional factors leading to poor digestibility of proteins, carbohydrates and minerals. In developing countries, the low bioavailability of minerals (especially iron and zinc) in cereal-based foods is a crucial problem for infants and young children. The main anti-nutritional factors acting on iron and zinc bioavailability are phytates, certain phenolic compounds and fibres (Camara and Amaro, 2003). Depending on their localization in cereal grain, the proportions of these anti-nutrients in diet can be reduced by decortication, malting, germination etc (Khetarpaul and Chauhan, 1991; Akingbala, 1991; Sharma and Kapoor, 1996), a process which may also modify mineral content and bioavailability. This study would like to evaluate the effect of some processing methods on the proximate, antinutritional and functional properties of pearl millet, so as to consider its possible usage in other food system.

MATERIALS AND METHODS

Sources of raw material: Pearl millet grains (*Pennisetum gluacum*) were purchased from Oja Oba in Akure, Nigeria.

Preparation of flours

Germinated Millet Flour (GMF): About 200 g of millet grains were soaked the seeds overnight in distilled water at room temperature. The seeds were placed on muslin cloth and continuous watering was done for 48 h for the seed to germinate. The sprouted seeds were then dried at 60°C, the dried germinated seeds were milled to obtain the germinated millet flour (Fig. 1).

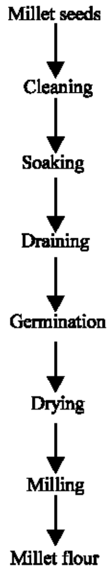

Fig. 1: Flowchart for the production of Germinated Millet Flour (GMF)

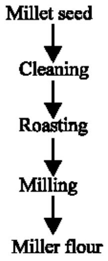

Fig. 2: Flowchart for the production of Roasted Millet Flour (RMF)

Roasted millet flour: About 200 g of millet grains were cleaned and roasted in acid washed sand for 10 min at 80°C. The roasted seeds were milled to obtain the roasted millet flour (Fig. 2).

Fermented millet flour: About 200 g of millet grains were steeped in water for 72 h after which they were rinsed with clean water and dried in an oven at 45-50°C for 10 h. The dried seeds were milled to obtain the fermented millet flour (Fig. 3).

The flours obtained from the three processing techniques including the control were kept in air tight polyethylene bags and stored in a cool (4°C) dry place until use.

Proximate analysis of processed millet flour: The crude protein (Kjeldahl, N×6.25), fat (solvent extraction), crude fiber, ash and moisture were determined according to AOAC (1990) methods.

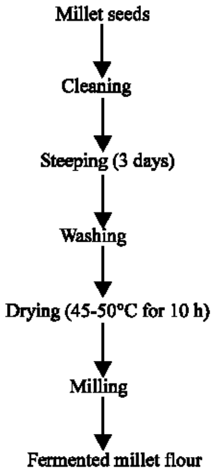

Fig. 3: Flowchart for the production of Fermented Millet Flour (FMF)

The carbohydrate content of each sample was determined by difference

-%Carbohydrate = 100 - (%moisture + %Protein + %Crude Fibre + %Fat + %Ash)

Total energy was calculated using Atwater factors:

Energy value = %Protein ×4 + %Carbohydrate ×4 + %Fat ×9

Determination of mineral composition: Na and K content of the processed flour samples were determined using flame photometry methods (AOAC, 1990). The concentrations of Ca, Fe and Zn were determined after wet digestion with a mixture of perchloric and nitric cid using atomic absorption spectro-photometry (AAS, model sp9, pye unicam, UK). While, P was estimated colorimetrically by the ammonium molybdate method (AOAC, 1990).

Determination of antinutritional factors: Tannin content of the processed flour samples was determined as described by Makkar and Goodchild (1996), while the total phenolics content of the processed flour samples was determined using the method of Singleton and Lamuela (1999).

Determination of funtional properties: The Water and Oil Absorption Capacity (WAC and OAC) were determined using the method of Sathe *et al.* (1982a) as modified by Fagbemi (2008) and expressed as percentage increase of the sample weight. Packed and Loosed Bulk Density (PBD and LBD) were determined by the method of

Narayana and Narasinga Rao (1984) as modified by Fagbemi (2008). Least gelation concentration (LGC) was determined using Deshpande *et al.* (1982) method as modified by Fagbemi (2008). Analyses were carried out in triplicate.

Pasting properties of processed flour samples: Pasting properties of processed flour samples were determined using Rapid Visco analyzer-RVA (Newport Scientific PTY).

Statistical analysis: Data collected were subjected to Analysis of Variance (ANOVA) and means were separated using Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Table 1 shows the Proximate Composition of Raw Millet Flour (RWMF), Germinated Millet Flour (GMF), Roasted Millet Flour (RMF) and Fermented Millet Flour (FMF) on dry weight basis. The protein content ranged from 14.0-18.7%. Significant increase ($p<0.05$) was observed in the crude protein content of the processed flours compared with the control. The highest increase was observed in the germinated millet flour (18.7%). The crude protein of the fermented millet flour (17.5%) is similar to value reported for fermented *Treculia africana* seed flour (Fasasi *et al*., 2004). The increase in protein of the fermented and germinated flour may be due to protein synthesis. Fermentation and germination may be a desirable processing technique to increase the protein content of millet seed. The lowest protein content (15.7%) observed in roasted millet may be attributed to the destruction of amino acids as a result of heat (Mauron, 1982).

The carbohydrate content of control millet was 76.3%, which is greater than carbohydrate content of germinated millet flour (71.1%) and roasted millet flour (72.6%). Decrease in carbohydrate content of germinated seed flour may be due to the utilization of some of the sugars during the growth metabolic activity. Fermented Millet Flour (FMF) has the highest carbohydrate content of 76.5%.

The fat content of processed millet flour ranged from 2.4-7.2%. The fat content obtained for Germinated Millet Flour (GMF) is 5.6%, which is less than the value reported for African breadfruit seed (11.39%) according to Fasasi *et al.* (2004). Significant increase ($p<0.05$) was observed in the fat content of Fermented and Germinated Millet Flour (FMF and GMF) respectively. The low fat content recorded in fermented sample will help in increasing the shelf life of the samples by decreasing the chances of rancidity and will also contribute to the low energy value of the sample. Roasted Millet Flour (RMF) with a fat content of 7.2% will get rancid quickly, but will have a high energy value, since heat processing promotes lipid oxidation.

The ash content of processed millet flours ranged from 1.9% in FMF to 2.7% in RMF. The ash content obtained for roasted millet flour (RMF) is 2.7% which is higher than that of Germinated Millet Flour (GMF) which is 2.1%. Fermentation was observed to reduce the total ash; this reduction may be due to the leaching of the soluble inorganic salts during fermentation. The ash content indicates a rough estimation of the mineral content of the product.

The crude fibre content of the samples ranged from 1.8-2.0%. The Raw Millet Flour (RWMF) has the highest fibre content while germinated and roasted millet flour has fibre content of 1.8%, respectively. The high crude fibre content in Germinated Millet Flour (GMF) and the reduction in the crude fibre content of Fermented Flour (FMF) may be due to sugar utilization in the seed for metabolic sprouting activity leaving fibrous seeds and enzymatic degradation of the fibre during fermentation (Ikenebomah *et al*., 1986). Similar observations have been reported for fluted pumpkin (Giami and Bekebain, 1992) and cowpea (Padmashree *et al*., 1987).

Energy values obtained for the millet flour samples ranged from 397-418 kcal. Fermented Millet Flour (FMF) has the lowest energy value 397 kcal which can be attributed to the low fat content. Roasted Millet Flour (RMF) gave the highest energy value of 418 kcal when compared to the Raw Millet Flour (RWMF) and other processed millet flour. This indicates that roasting is suitable in increasing the energy value of food to meet the

Table 1: Proximate composition of raw, germinated, fermented and roasted millet flour (Dry weight basis)

Samples	Crude protein (%)	Fat (%)	Ash (%)	Crude fibre (%)	Cho (%)	Energy (kcal)
RWMF	14.0 ± 1.16^{b}	5.7 ± 0.34^{ab}	2.1 ± 0.03^{ab}	2.0 ± 0.04^{a}	76.3	412
GMF	19.4 ± 1.54^{a}	5.6 ± 0.23^{ab}	2.1 ± 0.02^{ab}	1.8 ± 0.02^{ab}	71.1	412
RMF	15.7 ± 0.00^{b}	7.2 ± 1.09^{a}	2.7 ± 0.20^{a}	1.8 ± 0.01^{ab}	72.6	418
FMF	17.5 ± 1.17^{ab}	2.4 ± 0.28^{b}	1.9 ± 0.05^{b}	1.8 ± 0.02^{b}	76.5	397

±Standard deviation of three replicates. Mean values followed by different superscript within column are significantly different at ($p<0.05$). RWMF: Raw Millet Flour, GMF: Germinated Millet Flour, RMF: Roasted Millet Flour, FMF: Fermented Millet Flour energy requirement by man. Reduction in the energy value of Germinated Millet Flour (GMF) may be due to the decrease in fat and carbohydrate value.

Table 2 shows the mineral content of the raw, germinated, fermented and roasted millet flour samples. A significant reduction ($p<0.05$) in total phosphorus and calcium contents were observed in all the processed millet flour samples when compared with the raw millet flour samples. The high phosphorus value (350 mg/100 g) in Fermented Millet Flour (FMF) may be due to the synthesis of phosphorus by phytase enzyme during fermentation. Germination and roasting significantly reduced the iron contents. Magnesium content decreased during fermentation and germination treatments and slightly reduced in roasting treatment.

The Ca/P and Ca/Mg value ranged between 0.08-0.17 and 0.36-0.43 mg/100 g, respectively. The values are very low compared with the recommended value of 1.0 and 2.2, respectively (NRC, 1989). This may be due to the low value of calcium when compared to phosphorus and Magnesium. Calcium, magnesium and phosphorus are important in teeth and bone formation and the control of calcium in the blood (NRC, 1989). Diet based on millet must be supplemented with Ca to prevent deficiency diseases.

Sodium content of processed millet flour samples reduced significantly ($p<0.05$) with germination having the lowest content (7.8 mg/100 g) followed by roasting (8.3 mg/100 g).

The K/Na of processed millet flours ranged between 2.53 and 3.26. These values are greater than the recommended value of 1.0 (NRC, 1989) hence, the consumption of the processed flour could be accompanied by salting with Nacl to enhance balance of body fluids. Its consumption without salting with Nacl may lead to mineral imbalance in those fed solely on it (Balogun and Fetuga, 1986). According to Dogra *et al*. (2001), different processing methods reduces the mineral contents of pearl millet, the decrease in mineral content with germination might be due to metabolic loss and transfer of nutrients to the growing embryo (Shulka *et al*., 1986), the reduction in mineral content with roasting might be attributed to the loss of nutrients, while heating at high temperature (Malik *et al*., 2002).

Table 3 shows the anti-nutritional content of the samples. The Raw Millet Flour sample (RWMF) contains a high concentration of both tannin and total phenol and this was reduced by the processing methods. The germinated millet flour has 0.38 mg/100 g Tannin and 0.14 mg/100 g total phenol. The fermented millet flour has 0.30 and 0.12 mg/100 g of Tannin and Total phenol respectively. The roasted millet flour has the lowest tannin and total phenol content of 0.29 and 0.11 mg/100 g, respectively. Decrease in anti-nutritional factors during fermentation and germination could be attributed to leaching of polyphenols in the soaking water (Jood *et al*., 1987) and increased enzymatic treatment during germination (Bishnoi *et al*., 1994). Shinde *et al*. (1991), reported that roasting or high temperature resulted in the reduction of total phenols and tannins.

Table 2: Mineral composition of raw, germinated, fermented and roasted millet flour (mg/100 g)

Samples	P	Ca	Mg	Ca/P	Ca/Mg	Fe	K	Na	K/Na
RWMF	360	42	97	0.17	0.43	8.8	30	9.2	3.26
GMF	330	27	72	0.08	0.37	7.9	24	7.8	3.08
RMF	300	31	87	0.10	0.36	8.1	21	8.3	2.53
FMF	350	34	80	0.09	0.43	8.5	27	8.6	3.14

Table 3: Antinutritional factors in raw, germinated, fermented and roasted millet flour (mg/100 g)

Samples	Tannin	Total phenol
RWMF	0.51	0.21
GMF	0.38	0.14
RMF	0.29	0.11
FMF	0.30	0.12

Table 4a: Functional properties of raw, germinated, fermented and roasted millet flour

Samples	OAC (%)	WAC (%)	LGC (%)
RWMF	150 ± 0.06^{b}	226 ± 0.03^{ab}	10
GMF	180 ± 0.06^{a}	270 ± 0.06^{a}	18
RMF	180 ± 0.06^{a}	230 ± 0.00^{ab}	12
FMF	166.7 ± 0.07^{ab}	260 ± 0.06^{a}	8

RWMF: Raw Millet Flour, GMF: Germinated Millet Flour, RMF: Roasted Millet Flour, FMF: Fermented Millet Flour

Table 4a shows the functional properties of raw millet flour, germinated millet flour, roasted millet flour and fermented millet flour. The Oil Absorption Capacity (OAC) of the flour samples ranged between 150-180%. Roasting and germination gave the highest OAC, thus suggesting that germination and heat treatment resulted in increased OAC. This observation is consistent with the reports of Padmashree *et al*. (1987) and Pawer and Ingle (1988) who reported increase in OAC of germinated cowpea and moth bean flour, respectively.

The Water Absorption Capacity (WAC) of flour samples ranged from 226-270% in the processed millet flour samples. The highest WAC was observed in the Germinated Millet Flour (GMF) which has WAC of 270%, the high WAC obtained in GMF may be due to changes in the quality and quantity of proteins in the flour upon germination (Del Rosario and Flores, 1987). The high carbohydrate content observed in Fermented Millet Flour (FMF) may be associated with the increased WAC (260%) since they undergo gelatinization and swelling when heated.

The Least Gelation Concentration (LGC) of the samples ranged from 8-18% $w\ v^{-1}$, processing significantly ($p<0.05$) influenced the LGC. Roasting and

Table 4b: Visco-elastic properties of raw, germinated, fermented and roasted millet flour

Treatments	Peak 1	Trough1	Breakdown	Final viscosity	Setback	Peak time	Pasting temp
RWMF	71.42	35.67	35.75	91.50	55.83	4.86	63.90
GMF	1.17	-9.00	10.17	-10.17	-1.17	3.39	63.70
FMF	125.25	86.67	38.58	129.00	42.33	4.95	64.70
RMF	96.58	60.17	36.42	106.25	46.08	4.37	65.75

RWMF: Raw Millet Flour, GMF: Germinated Millet Flour, RMF: Roasted Millet Flour, FMF: Fermented Millet Flour

germination increased the LGC, while it was reduced by fermentation, the variation in the relative ratios of constituents like protein, lipids and carbohydrates may have influenced the observed LGCs (Sathe *et al*., 1982). The value (12%) obtained for Roasted Millet Flour (RMF) is between the range reported for cowpea flour (10-14%) Sathe *et al*. (1982). The values obtained for roasted and germinated millet flour (12 and 18% w v^{-1}) suggests that it may be used in puddings and as thickeners.

Table 4b shows the visco-elastic properties of the processed millet flours. The peak viscosity of processed millet flour ranged from 1.17-125.25 RVU, the value obtained for RWMF was 71.42 RVU, the final viscosity of the processed flour ranged from -10.17 to 129RVU, while for the RWMF value obtained was 91.50RVU. Low viscosities of 1.17 RVU (Peak viscosity) and -10.17RVU (final viscosity) observed in Germinated Millet Flour (GMF) is nutritionally beneficial in infant formulas (Fasasi *et al*., 2005; Osundahunsi and Aworh, 2002). The final viscosity is a measure of the stability of the granule, this shows that Fermented Millet Flour (FMF) with the highest final viscosity of 129 RVU will be more stable under certain conditions than other processed samples.

The setback is an index of retrogradation, higher setback (46.08 RVU) in Roasted Millet Flour (RMF) indicates cohesive paste and that starch will retrograde faster than other processed millet flour under the same conditions.

The pasting temperature ranged between 63.7°C and 65.75°C. The pasting temperature provides an indication of minimum temperature required for cooking the samples; the pasting temperatures obtained for the processed millet flour were quite close.

CONCLUSION

Germination has been found to significantly increase the crude protein content of millet flour; the high protein content is of advantage in weaning food formulations. Germination also resulted in high water absorption capacity and oil absorption capacity, hence germinated millet flour would be of use in food systems where these properties are required. Roasting of millet reduces the anti-nutritional factors that have reduced the preference of millet as a weaning food.

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