FOOD PRODUCTS FROM MALTED PEARL MILLET

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The effect of malting on pearl millet (*Pennisetum glaucum* (L.) R.Br.) nutritional and functional properties was investigated. Two varieties of pearl millet, SDMV 89004 and SDMV 91018 were used. The grains were steeped at 25 °C for 8 h with a cycle of 2 h wet and 2 h dry air rest. The steeped grains were then germinated for 5 days at 25 °C.

Generally, the nutritional and functional quality parameters (Water Solubility Index, Water Absorption Index, Nitrogen Solubility Index, soluble nitrogen, *in vitro* protein digestibility, total carbohydrate, the percentage of the total carbohydrate which was enzyme susceptible, crude fat, protein content and phytic acid) were significantly improved ($p < 0.05$) by germination time and affected by variety. The results indicate that malting has the potential to be used in the development of food products of improved nutritional and functional properties. Of particular significance is the fact that malting reduced the anti-nutritient phytic acid in pearl millet and almost eliminated the grain's mousy odour. Additionally, the fact that malting can be carried out at potentially low cost without sophisticated and expensive equipment is very important to the rural communities of Africa and India who rely on pearl millet foods for their energy and nutritional requirements.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) (Fig. 1), known as *mexoeira* and *hanzelo* in Mozambique, is a drought-tolerant cereal crop grown primarily as a food grain in Southern Africa. The main constraints in utilization of pearl millet in the industry include: the small size of the grain and the large germ.[1] The utilisation of millets is also limited due to the presence of various anti-nutrients, poor digestibility of proteins and carbohydrates and low palatability However, various processing technologies are able to affect positively the physicochemical composition of food grains in order to improve their nutritional value. Such primary processing technologies include malting and fermentation.

Figure 1.- Pearl millet grains of variety SDMV 89004 (average mass of each kernel: 8.9 mg)

The objectives of this study were: (1) to determine the effect of malting on pearl millet physico-chemical, nutritional and functional properties; (2) to determine the effects of malting on the enzyme responsible for the off-odour which appear in pearl millet when is ground; (3) to determine the effect of malting on anti-nutrients in pearl millet, i.e. phytate.

EXPERIMENTAL

Materials

(1) pearl millet grain, variety SDMV 910018, planted at Estação Agrária de Chockwé, Mozambique; (2) pearl millet grain, variety SDMV 89004, kindly donated by SADC/ICRISAT, Matopos Research Station, Bulawayo, Zimbabwe.

The raw materials were kept under cold storage (≤ 10 °C) conditions until used. Pearl millet non- and germinate grains of variety SDMV 89004 are shown in Figures 1 and 2, respectively.

Malting process

The malting of the two varieties of pearl millet was done at CSIR, Pretoria. The malting process comprised three main stages: Steeping, germination and drying.

Samples of pearl millet grain (5 kg) were washed 4 to 5 times, in running tap water (22-24 °C) to remove foreign material. The grain was then put in large nylon bags and closed with rubber bands and spin-dried (30 s at 300 x g) to remove excess surface-held water. After the spin-drying process, exactly 500 g of grain per sample was placed in nylon bags and closed with rubber bands. The grain in nylon bags was re-weighed, then steeped in static water, 25 °C, with a cycle of 2h wet, 2 h dry air rest for 8 h. During the dry stands the grain was held in still air at 20–22 °C. After the steeping period, the grain in nylon bags was spin-dried (30 s at 300 x g) and weighed.

The steeped grain was then germinated in the in nylon bags for 1, 3 and 5 d at 25 °C. Germination was carried out in a water-jacketed incubator (Forma Scientific, Marrietta, Ohio, USA) in an atmosphere of near water-saturation with continuous flow of moist air. The malting bags were covered with wet cloths to maintain the water saturation. Twice daily, the malting bags were removed from the incubator, weighed and then steeped for 10 min in tap water (22–24 °C), then spin-dried (30 s at 300 x g), re-weighed and returned to the germination cabinet.

The germinated grain was dried at 50 °C for 24 h in a forced draught air oven.

Analytical methods

Moisture, Protein (N x 6.25), Fat, and Ash content – Determined by AOAC Methods.[4]

Total carbohydrate (TC) and the total carbohydrate that was enzyme-susceptible (TCES) – By an enzymic method using α-amylase and amyloglucosidase.[5]

Phytic acid (PA)– By a modification of the method of Garcia-Villanova *et al.*[6]

Water Absorption Index (WAI) and Water Solubility Index (WSI) - By the method of Anderson *et al.*[7]

Nitrogen Solubility Index (NSI) – By AACC Method.[8]

In vitro protein digestibility (IVPD) – By the method of Mertz *et al.*[9] as modified by Hamaker *et al.*[10]

Amino acid (AA) analysis – By the Pico.Tag Method[11]

Odour generation and evaluation of the odour generated – Non- and germinated milled pearl millet were mixed with water 30% (w/v) and placed in Petri dishes. The samples were then air-dried in a fume cupboard at ambient temperature overnight. About 3 g samples were sealed in 27 ml glass bottles "polytops" for at least 1 h before being evaluated for odour generation. Twelve trained panellists carried out evaluations of treated pearl millet samples. These panellists were trained using fresh samples (no odour) and treated, i.e. wetted and dried grits (odour present). The trained panellists were asked to sniff the headspace over treated samples and compare it with a control samples. Panellists were asked to rate each coded sample on numeric scale of 1 (least intense, i.e. no odour) to 9 (most intense, i.e. strong odour present).

Pasting properties – Were determined using a Rapid Visco-Analyser model 3D (RVA) (Newport Scientific, Warriewood, Australia). Four g whole flour of grain and germinated of pearl millet (14% moisture basis) were separately mixed with 25 ml of distilled water. A programmed heating and cooling cycle was used. The suspension was held at 50 °C for 1 min, heated to 90 °C for 7.5 min at the rate of 6 °C/min, held at 90 °C for 5 min before cooling to 50 °C in 7.5 min and holding at 50 °C for 1 min. Peak viscosity (PV), hot paste viscosity (shear thinning) and setback were recorded.

Statistical analysis - Analysis of variance (ANOVA) with the least significant difference test (LSD-Test) was applied. The level of 95% was considered as significantly different.

RESULTS AND DISCUSSION

Figure 2 shows five-day germinated pearl millet malt. As can be seen there is extensive root and shoot growth during germination. During germination there is a reduction in TC content of the pearl millet varieties an and increase in the percentage of the TCES (Fig. 3). This can be attributed to the fact that some of the endosperm starch is consumed during germination to provide energy.

Figure 2.- Pearl millet malts of variety SDMV 89004 germinated for 5 days (average mass of each kernel: 8.9 mg; average length of the roots and shoots: 15-20 mm

The fact that the reduction in carbohydrate content was higher in variety SDMV 89004 than SDMV 91018 could be related to its higher germinability (data not shown). Variety SDMV 89004 had higher DP and higher carbohydrate content. This also indicates that the carbohydrate content of pearl millet was affected by the grain variety and as well as by the respiratory activity of the grains.

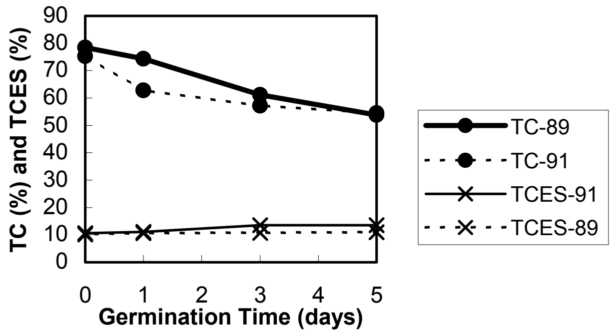

Figure 3 Effect of germination time on the total carbohydrate and percentage carbohydrate that was enzyme-susceptible of pearl millet malts made from varieties SDMV 910018 and SDMV 89004

The reduction of carbohydrate during germination observed in this research would contribute to a decrease in the energy value of food products prepared from germinated flours. In adults it is important that the amount of energy ingested be matched to the amount of energy expended. However, this decrease is compensated by the fact that carbohydrate of malted pearl millet would be more available than that of non-germinated grains. In infants the amount of energy ingested is more than they expend since they use the rest of the energy to build up their bodies. It is crucial that the reduction of the level of carbohydrates (starch) should not be very high if the malts are meant for the preparation of traditional southern African food products, such as opaque beers, called *uphutsu* in Mozambique, porridges, and traditional unleavened pancakes, called *makati* in Mozambique, as well as weaning foods for infants called *nthlatu* in the south of Mozambique, where minimum carbohydrate reduction may be advantageous.

The changes in the susceptibility of starch to enzyme attack which took place during the germination of pearl millet are advantageous in respect of producing a product with improved nutritional quality, which can be used as an ingredient in various food products, particularly weaning foods for infants. The lower PA content in pearl millet of variety SDMV 89004 may be the reason for the higher percentage of the TCES observed in this variety compared to SDMV 91018. PA may decrease starch digestibility by binding with calcium, which is known to be necessary for alpha-amylase activity[12]

The non-significant differences in WAI observed between the two varieties may be attributed to the fact that both pearl millet varieties had similar starch amylose contents. The decrease in the WAI and the increase in the WSI with germination time for both varieties (Fig. 4) may have to do with the fact that during the germination process the carbohydrate content decreased as a result of hydrolysis by the amylase enzymes. The increase in WSI with germination is of significance since it gives an indication that germination can be used to increase the amount of soluble materials, such as starch and amino acids, which can be easily digestible.

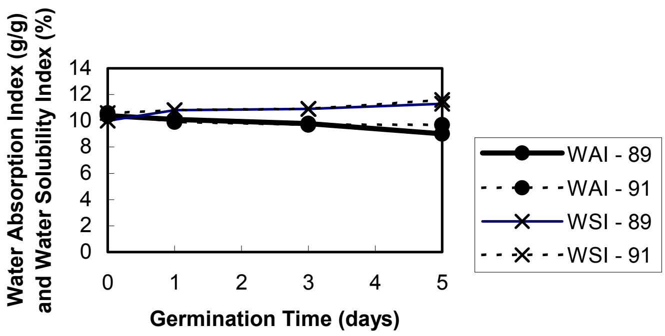

Figure 4 Effect of germination time on the water absorption index and water solubility index of pearl millet malts made from varieties SDMV 910018 and SDMV 89004

Fat content was reduced due to malting (Fig. 5). Since fat provides twice as much energy as carbohydrates, the reduction in fat content observed during germination implies a reduction in the energy value of pearl millet malt compared to grain. However, in the case of pearl millet, this reduction may bring an increase in palatability of pearl millet food products. The development of fatty acids, which occur mainly due to the action of lipase, cause bitterness and can make pearl millet meals unacceptable

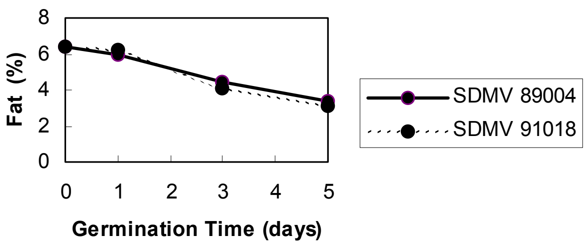

Figure 5 Effect of germination time on the fat content of pearl millet malts made from varieties SDMV 910018 and SDMV 89004

In both pearl millet varieties, malts had lower protein content than the grains (Fig. 6). The slight decrease in protein content of pearl millet germinated grains with germination time can be attributed to the loss of low molecular weight nitrogenous compounds during the steeping process and rinsing of the grains during germination. The increase in NSI during malting (Fig. 7), which can be due to gradual degradation of reserve protein into amino acids and short peptides caused by rising the levels of protease enzymes is a compliment of the increase in IVPD observed in both pearl millet varieties (Fig. 8). The increase in IVPD can be attributed to an increase in soluble proteins, due to partial hydrolysis of storage proteins by endogenous proteases produced during the germination process. Such partially hydrolysed storage proteins may be more easily available for pepsin attack.[13] The decrease in anti-nutrients (PA) may have also contributed to the high levels of IVPD observed.

Although a change in the amino acid profile was observed due to germination (Table I), the total amino acid content remained the same since the protein content did not change. Contrarily to SDMV 89004, the lysine content of the pearl millet of the variety SDMV 91018, which represented about 75 % of the FAO Scoring Pattern[14], increased throughout germination. The difference in lysine content between the two varieties could be due to slight differences in the proportion of germ in both pearl millet varieties investigated. The increase in the lysine content of the protein of germinated pearl millet of variety SDMV 91018 is related to the transamination (change of one amino acid into another one), which may have occurred during

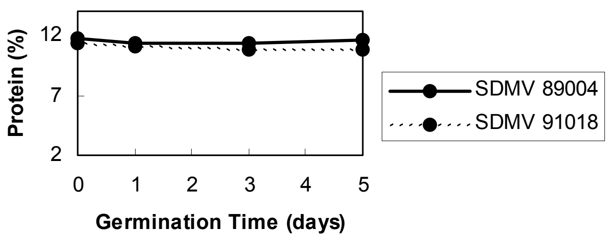

Figure 6 Effect of germination time on the protein content of pearl millet malts made from varieties SDMV 910018 and SDMV 89004

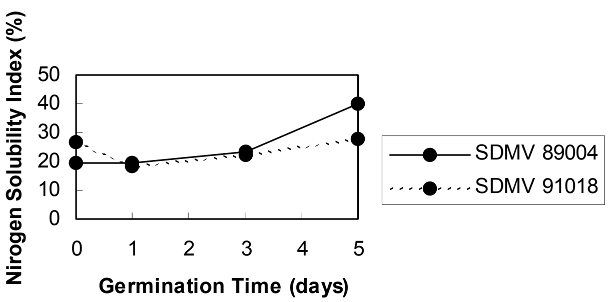

Figure 7 Effect of germination time on the nitrogen solubility index of pearl millet malts made from varieties SDMV 910018 and SDMV 89004

germination affecting the amino acid profile of pearl millet. This transamination was also reported in sorghum.[3] The level of leucine in pearl millet malts was generally higher than the FAO Scoring Pattern.

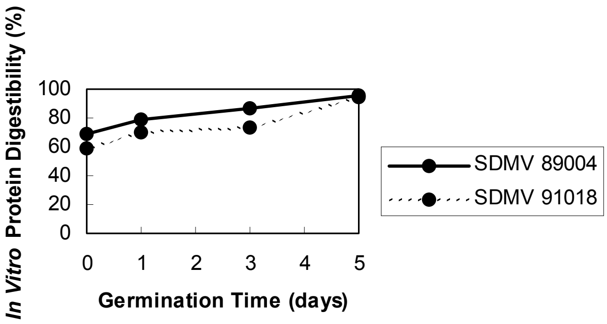

Figure 8 Effect of germination time on the *in vitro* protein digestibility of pearl millet malts made from varieties SDMV 910018 and SDMV 89004

The fact that phytic acid content was reduced with germination time (Fig. 9) is presumably due to phytase activity. The decrease in pearl millet phytic acid observed in this research will improve the nutritional quality of pearl millet malt food products by increasing the bioavalability of proteins and minerals.

The malting process drastically reduced the pasting peak viscosity of pearl millet malts in both varieties investigated (Table II). The reduction in peak viscosity may be attributed to the high alpha-amylase activity of malts, hence the reduction of viscosity was higher in variety SDMV 89004 which had higher alpha-amylase activity than SDMV 91018. Additionally, the decrease in starch content observed in both pearl millet varieties investigated may have also contributed somewhat to the reduction in flour paste viscosity.

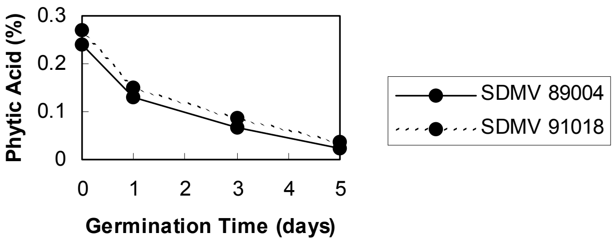

Figure 9 Effect of germination time on the phytic acid content of pearl millet malts made from varieties SDMV 910018 and SDMV 89004

In the SADC region and most other African countries, porridges of high viscosity are more preferable for adults, because porridge is generally eaten with the fingers. Low viscosity porridges are suitable for consumption by infants as weaning foods due to their limited stomach capacity and the ability to chew.[15] The period of a human being's development from the neonatal stage to the preschool stage is critical to growth. During this period, adequate food intake (including that of weaning foods) is vital to good nutritional status. The low viscosities observed after germinating both pearl millet varieties is a good indication that malted pearl millet is suitable as a diastatic adjunct to reduce the viscosity of cereal-based weaning porridges.

The fact that germination successfully reduced the mousy odour of pearl millets (Table III) is important for the rural communities of Africa and India, where pearl

Amino Acid	Control ()[a]	Germination Time (Days) 1	3	5	FAO Scoring Pattern [a]
Essential amino acids					
Valine	(4.8-7.0)				5.0
SDMV 89004	3.6	3.7	3.5	2.9	
SDMV 91018	3.2	3.2	3.8	3.6	
Methionine	(1.5-2.9)				3.5
SDMV 89004	1.9	1.6	1.6	1.1	
SDMV 91018	1.5	1.5	1.6	1.5	
Isoleucine	(3.6-5.9)				4.0
SDMV 89004	2.2	2.2	2.0	1.5	
SDMV 91018	1.7	1.7	2.6	2.4	
Leucine	(8.0-25.1)				7.0
SDMV 89004	8.2	8.5	7.4	5.7	
SDMV 91018	7.7	7.5	8.6	8.1	
Phenylalanine	(4.4-5.6)				6.0
SDMV 89004	4.3	4.8	4.6	3.9	
SDMV 91018	4.3	4.3	4.6	4.5	
Lysine	(1.7-6.5)				5.5
SDMV 89004	3.3	3.2	2.9	2.9	
SDMV 91018	2.7	2.7	4.0	4.1	
Histidine	(1.8-2.6)				4.0
SDMV 89004	1.9	2.1	2.0	1.9	
SDMV 91018	1.9	2.0	2.2	2.2	
Threonine	(1.2-4.8)				4.0
SDMV 89004	4.2	4.7	4.3	4.0	
SDMV 91018	4.1	4.2	4.3	4.3	
Non-essential amino acids					
Aspartic acid	(4.9-10.3)				
SDMV 89004	8.2	8.9	9.9	10.3	
SDMV 91018	8.1	7.7	10.4	12.7	
Glutamic acid	(12.3-25.4)				
SDMV 89004	19.3	22.8	19.9	16.1	
SDMV 91018	19.8	20.1	18.2	17.0	
Serine	(3.7-5.6)				
SDMV 89004	6.6	7.1	6.6	6.0	
SDMV 91018	6.6	6.6	6.4	6.5	
Glycine	(2.8-5.8)				
SDMV 89004	4.3	4.1	3.5	3.6	
SDMV 91018	3.8	3.8	3.8	3.8	
Arginine	(3.2-8.1)				
SDMV 89004	6.0	6.0	5.3	4.9	
SDMV 91018	5.3	5.3	5.5	5.2	
Alanine	(7.5-10.5)				
SDMV 89004	8.7	9.1	8.7	8.0	
SDMV 91018	8.6	8.9	8.2	8.2	
Proline	(5.9-14.2)				
SDMV 89004	6.4	7.1	7.0	6.1	
SDMV 91018	6.4	6.4	6.4	6.3	
Tyrosine	(1.7-4.8)				
SDMV 89004	3.0	2.9	2.8	2.7	
SDMV 91018	2.5	2.5	3.5	3.4	

Table I Amino acid composition of the protein of the two pearl millet varieties (g/100 g protein)

millet is a staple food, since it will increase the palatability and could increase the consumption of pearl millet food products. Since the exact compound, which causes the mousy odour, as well as the mechanism in which the mousy odour is promoted, are not known for certain, one could speculate that the phenolic pigments, which are responsible for the mousy odour, may have been leached out during the germination process. In fact the reduction of the C-glycosylflavone,[16] the major flavone known to be present in pearl millet grains and mainly concentrated in the germ, could be noticed by the changes in the colour from the natural grey colour characteristic of pearl millet grain to the light brown (tan) of the pearl millet malts. The decrease in mousy odour observed during the pearl millet malting process can also be attributed to the decrease in pH due to the growth of lactic acid bacteria. The colour of phenolic pigments can be changed as a function of pH.

CONCLUSIONS

The finding that most of the physico-chemical, nutritional and functional properties of pearl millet are improved by malting, in particular that the mousy odour of damp pearl millet is almost eliminated, is of considerable significance with regard to increasing pearl millet food utilisation. This is especially so since malting is a primary

Samples/ Germination Time	**Peak Viscosity (cP)**	**Hot Peak Viscosity (cP)**	**Cool Paste Viscosity (cP)**	**Set Back (cP)**	**Peak Time (min)**
SDMV 89004					
	4188^{a}	1416^{a}	5076^{a}	3660^{a}	8.6^{a}
1 day	552^{b}	84^{b}	192^{b}	108^{b}	7.6^{b}
3 days	108^{c}	48^{c}	72^{c}	24^{c}	5.1^{c}
5 days	84^{d}	36^{d}	48^{d}	12^{c}	4.9^{c}
SDMV 91018					
	6084^{a}	1704^{a}	7320^{a}	5616^{a}	8.6^{a}
1 day	948^{b}	480^{b}	1320^{b}	840^{b}	7.0^{b}
3 days	168^{c}	72^{c}	108^{c}	36^{c}	6.3^{c}
5 days	108^{d}	36^{d}	60^{d}	24^{c}	5.5^{d}

Means values with different letters in each block are significantly different from each other ($p < 0.001$).
Hot peak viscosity – The ability of starch to withstand heating and shear stress.
Cool paste viscosity – Final viscosity.
Set back = cool paste viscosity – hot peak viscosity.

Table II Pasting properties of non- and germinated pearl millet varieties

processing technology that can be carried out at potentially low cost without sophisticated and expensive equipment. Pearl millet malting could be highly beneficial to rural communities in Africa and India that rely on pearl millet for their energy and other nutritional requirements. Malt pearl millet could also be a useful ingredient in the production of value-added, nutritious convenience foods for the urban communities.

Panelists	Variety SDMV 89004				Variety SDMV 91018			
	Germination Time (days)							
	0	1	3	5	0	1	3	5
1	9	5	3	2	8	4	2	2
2	8	4	4	1	8	6	2	2
3	8	4	2	1	9	4	2	1
4	9	4	2	1	9	5	2	1
5	9	5	3	2	8	4	3	2
6	9	5	4	2	8	5	3	1
7	9	4	3	1	7	5	2	1
8	8	4	2	1	8	4	2	2
9	9	5	3	1	8	5	2	2
10	9	5	2	1	9	5	2	2
11	9	5	1	1	8	4	1	2
12	9	4	3	1	9	5	2	1
Mean	8.8[a]	4.6[b]	2.7[c]	1.3[d]	7.5[a]	4.7[b]	2.1[c]	1.6[d]

The level of intensity in the scale is 1– least intense and 9 – most intense mousy odour

Table III Sensory evaluation of mousy odour in non- and germinated pearl millet varieties

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