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Effect of processing (sprouting and/or fermentation) on sorghum and maize. I: Proximate composition, minerals and fatty acids

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Sorghum and maize porridge are used as infant weaning foods in many African countries. Porridges prepared from the cereals have high viscosity; to reduce viscosity, the cereals are initially sprouted and made into flour or fermented before use. This paper compares the effects of these preparatory methods on the proximate composition, mineral and fatty acid characteristics of the sprouted and/or fermented sorghum and maize.

The preparatory methods had no effect on the proximate composition. The cereals are poor in calcium, iron and zinc. They are low in $\omega3$ fatty acids but rich in the $\omega6$ fatty acids. Germination increased the gross energy of the cereals. Porridges prepared from these cereals need to be supplemented by other foods.

INTRODUCTION

Cereals provide a major food resource for man. In Africa, south of the Sahara, sorghum and maize are the most popular cereals consumed by both adults and infants. They are eaten in large quantities and are the main sources of both major and minor nutrients. They are prepared as gruel and used in feeding infants. Due to their high viscosity on cooking, a large amount of water is used during preparation to obtain the right consistency. This obviously decreases the nutrient density. Methods developed to reduce viscosity (Mosha & Svanberg, 1983) include sprouting and fermentation of the cereals before use. It is important to obtain information on the total nutrient composition of the diet prepared from the cereals treated in this manner.

This paper presents the proximate composition content of some minerals and fatty acid pattern of sprouted and/or fermented sorghum and maize.

MATERIALS AND METHODS

Materials

Brown sorghum (*Sorghum bicolor*) and white maize (*Zea mays*) were bought on the open market in Zambia and transported to Bergen, Norway, where sample preparation and analytical procedures were undertaken.

The grains were thoroughly sorted. Bad grains, stones and other debris were removed. Some of the grains were washed three times with tap water and later twice with distilled water. They were then soaked in distilled water for 12 h. They were spread in 1-cm layers between wet cotton cloth on the floor and watered with distilled water each morning. They were allowed to germinate for 72 h at room temperature (25°C). The sprouted seeds were frozen and freeze-dried. Together with their sprouts, they were milled using a laboratory mill.

One part water and four parts germinated milled flour were thoroughly mixed to form a dough. This was fermented at 30°C for 48 h.

Some ungerminated grains were soaked in distilled water overnight at room temperature and milled into flour. One part water to three parts flour were mixed into dough.

A third batch of the grains (ungerminated and unfermented) were simply milled into flour. This batch served as the control.

The samples used for the determination of fatty acids were wet milled and stored at –18°C to avoid oxidation.

Methods

Moisture and ash were determined by gravimetric methods after AOAC (1990) and Mortensen and Wallin

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(1989), respectively. Protein (N × 6·25) was determined as described by Crooke and Simpson (1971) after digestion in a Tecator block digestor (Høgannås, Sweden) at about 370°C. Gross energy was determined using a Gallenkamp Autobomb automatic adiabatic bomb calorimeter (London, UK). Fat and fatty acids were determined as described by Losnegard *et al.* (1979) and Lie *et al.* (1987), respectively.

In the determination of minerals the samples were digested in $HNO_3/HClO_4$ (9/1) as described by Julshamn *et al.* (1982). Calcium, iron and zinc were measured by atomic absorption spectrophotometry (AAS). The elements Ca, Fe and Zn were determined by acetylene-air-flame atomic absorption. Standard curves were used for the determination of the elements in question.

Statistical *t*-tests were used to show any significant changes; $P < 0.05$ was considered as significant.

RESULTS AND DISCUSSION

All analyses were run in duplicate and 5% deviation was accepted. Proximate composition is a quick way of scanning the nutritional quality of food and food substances. Table 1 shows the proximate composition of the cereals and their respective processed forms. There was a 61% reduction in dry matter when the grains were sprouted. This is due to imbibition of water prior to germination.

The protein content of both cereals was about 10%. This value agrees very well with the protein content range of cereal in the literature (Akinere & Bassir, 1967; Passmore & Eastwood, 1986; FAO, 1989). Processing did not have any marked effect on the crude protein and fat. The fat content of maize was slightly higher than that of sorghum. This might be due to genera variations. Even within the same genera, variations may exist between varieties (FAO, 1989).

Table 1. Proximate composition (per 100 g, dry matter basis)

Samples	Dry matter (g)	Protein (g)	Fat (g)	Ash (g)	Energy (kJ)
Maize					
MUG	92·2	10·1	3·6	1·0	1691
MUGFD	51·1*	9·7	3·8	0·9	1711*
MG	58·7*	9·4	3·7	0·8	1777*
MGFD	50·8*	10·4	3·8	0·6	1707*
Sorghum					
SUG	89·7	10·4	3·1	1·6	1688
SUGFD	51·8*	10·2	2·9	1·9	1667
SG	54·5*	10·5	2·5*	1·2	1784*
SGFD	50·8*	10·5	2·2*	0·9	1670

MUG = maize as purchased.
MUGFD = maize ungerminated fermented dough.
MG = maize germinated.
MGFD = maize germinated fermented dough.
SUG = sorghum as purchased.
SUGFD = sorghum ungerminated fermented dough.
SG = sorghum germinated.
SGFD = sorghum germinated fermented dough.
* $P < 0.05$.

There was very little ash in the samples and this was relatively stable in all samples except samples which were both germinated and fermented when there were notable reductions. This is in accordance with Akinere and Bassir (1967) on steeped maize flour and fermented ogi (gruel) from maize with respect to the whole maize meal. This might be due to leaching of the minerals during steeping prior to fermentation.

The gross energy of the grains is shown in Table 1. The energy contents were similar in all samples except the germinated grains which had substantially higher values than the others. This shows that sprouted grains have the potential to increase the energy density in porridge. Porridges made from sprouted cereal meal have low viscosity (Mosha & Svanberg, 1983). During germination complex carbohydrates are broken down to simpler sugars (Ray, 1972). These findings, together with the increase in energy density, make porridge made from germinated cereals ideal in infant feeding, especially in the less developed countries. Simple sugars are easily available for absorption and the amount of energy and the overall nutrient density obtained for a unit volume of porridge are increased. This will certainly be beneficial to infants who have limited digestive capacities and who cannot eat a lot to meet their nutrient requirement.

Table 2 shows the mineral content of the grains. The values for Ca, Zn and Fe reflect the ash content. The cereals—sorghum and maize—are therefore very poor sources of minerals. Rich food sources are needed for supplementation to ensure good health and nutrition.

The nutritional value of fat is limited to the energy content of the triglycerides, their content of essential fatty acids and the fat-soluble vitamins they contain. Thus, any processing method that damages the fat may lead to loss of nutritional value. The fatty acid components of maize and sorghum samples, as well as those that have been germinated and/or fermented, are presented in Table 3. The grains have high proportions of palmitic acid (16 : 0), oleic acid (18 : 1ω9) and linolenic (18 : 3ω3). This fatty acid pattern is common to the graminae family as shown by Hilditch and Williams (1964). Differences exist in the genera sorghum and maize.

Table 2. Composition of elements in maize and sorghum (mg/kg, dry weight)

Samples[a]	Calcium	Iron	Zinc
Maize			
MUG	46·9	19·2	18·6
MUGFD	50·2*	20·9	19·2
MG	91·1*	16·3*	20·3
MGFD	99·0*	22·1*	18·9
Sorghum			
SUG	102·0	27·5	19·3
SUGFD	118·0*	32·1*	20·3
SG	180·0*	24·2*	18·0
SGFD	193·0*	26·8	19·0

[a] For description of abbreviations see Table 1.
* $P < 0.05$.

Table 3. Fatty acid composition of the lipids (% total lipids)

Fatty acid	14:0	16:0	16:1ω7	17:0	18:0	18:1ω9	18:2ω6	18:3ω3	20:0	20:1ω9	22:0	22:0	Others	Sum mono.[a]	Sum sat.[b]	Sum Poly.[c]
Maize[d]																
MUG	0·1	13·9	0·2	0·1	2·2	34·2	46·9	1·1	0·5	0·2	0·2	0·2	0·3	34·6	17·1	48·1
MUGFD	0·1	14·5	0·2	0·1	2·2	34·5	35·5	1·0	0·5	0·3	0·2	0·2	0·5	34·9	17·9	46·6
MG	0·1	13·6	0·1	0·1	2·4	32·9	48·0	1·3	0·6	0·2	0·3	0·3	0·6	33·3	17·1	49·3
MGFD	0·2	18·8	0·2	0·1	3·1	40·2	29·4	0·7	0·7	0·4	0·4	0·4	6·0	40·8	23·5	30·1
Sorghum[d]																
SUG	0·1	13·2	0·5	0·1	1·3	41·2	40·1	3·0	0·2	0·2	0·1	0·2	1·1	41·9	15·2	42·4
SUGFD	0·1	13·4	0·5	0·1	1·4	41·1	39·3	1·9	0·2	0·2	0·1	0·2	1·7	41·8	15·6	41·4
SG	0·1	12·6	0·4	0·1	1·8	37·6	41·5	3·6	0·3	0·2	0·2	0·4	1·5	38·3	15·5	45·4
SGFD	0·2	16·1	0·5	0·1	2·3	41·0	39·5	2·3	0·4	0·3	0·3	0·3	7·2	41·8	19·7	32·2

[a] Sum of monounsaturated fatty acid.
[b] Sum of saturated fatty acid.
[c] Sum of polyunsaturated acid.
[d] For description of abbreviations see Table 1.

The palmitic content of the total lipids of both cereals was between 13 and 14%. There was an increase of 3 and 4% in sorghum and maize, respectively, when the grains were germinated and then fermented. The combined effect of germination and fermentation also resulted in a considerable reduction of linoleic acid (18 : 2ω6) content and an increase in unidentified acids. Thus, germination followed by fermentation alters the types and ratios of fatty acids in the cereals. The individual processing methods, that is germination or fermentation, however, had no significant effects on the fatty acid pattern.

As shown in Table 3, 18 : 2ω6 is one of the major fatty acids in the grains. Deficiency symptoms—retarded growth, increased skin permeability and malfunctions in many organs—have been associated with the absence of linoleic acid in the diet. It may be inferred that porridge prepared from these cereals, germinated or fermented, when given in large amounts, will be to the advantage of infants and children. It must be noted, however, that if the essential fatty acids in the cereals are protected from oxidation, which inevitably will occur during handling and processing, they can provide the daily requirement for individuals in the Third World where large amounts of cereals are eaten and are sometimes the sole food item.

The fatty acid patterns of the cereals show very little or no change of the ω3 series. These fatty acids cannot be synthesised *de novo* in humans. Docosahexaenoic acid (DHA) (22 : 6ω3) is also important in brain function (Weber, 1989) and shortage of the ω3 acids gives rise to disorders in the central nervous system. Breast milk contains eicosapentaenoic acid (EPA) (20 : 5ω3) and DHA, but industrially-processed baby foods contain no ω3 acids (Weber 1985). The question is, what happens when weaning starts? Maize and sorghum are low in those acids. The only solution will be to look for another food to supplement the fatty acids. Fish, which is rich in these essential fatty acids, (Bligh *et al.*, 1988; Steiner Asiedu *et al.*, 1991) is a good supplement.

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