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Changes in nutrient composition, phytate and cyanide contents and α-amylase activity during cereal malting in small production units in Ouagadougou (Burkina Faso)

T. Traoré [a,b,*], C. Mouquet [a], C. Icard-Vernière [a], A.S. Traoré [b], S. Trèche [a]

[a] *Research unit "Nutrition, Alimentation, Sociétés", Institut de recherche pour le développement, BP 64501, F-34394, Montpellier Cedex 5, France*
[b] *CRSBAN, Department of Biochemistry/Microbiology, University of Ouagadougou, 03 BP 7131, Ouagadougou 03, Burkina Faso*

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Abstract

The different traditional processes used in cereal malting were characterised and some biochemical modifications occurring in seeds during malting were studied to examine the possibility of using malted cereal flours to reduce the viscosity of gruels prepared from infant flours. Five production units (PU) of malted red sorghum seeds, two PU of malted millet seeds and one PU of malted maize seeds were selected as a function of the ability of the malt flours to fluidify high energy density gruels. Each of the 8 PU were monitored throughout the malt production process in order to describe rigorously the different steps in their malting process and to establish a detailed general production diagram. Samples were collected after soaking, germination, maturation, drying, and degerming and at the final product. They were analysed for nutrient, phytate and cyanide contents and α-amylase activity. For the 3 types of cereals, malting increased protein content while it decreased lipid and ash contents. A significant increase was observed in sucrose, glucose and fructose contents during malting, in particular during the germination step. The decrease in phytate content during malting was more obvious in millet seeds than in red sorghum and maize seeds. α-amylase activity increased during malting in all 3 types of cereals but more in red sorghum seeds than in millet and maize seeds. Cyanide content considerably increased during malting, particularly in red sorghum seeds. Sucrose content decreased during maturation while glucose and fructose contents increased. Traditional manual degerming reduced fibre and ash contents in all 3 types of cereals. Degerming had little effect on phytate content but reduced cyanide content to an acceptable level for human consumption even if it did not allow the complete elimination of cyanide. Unfortunately, degerming was accompanied by a decrease in α-amylase activity. The maturation step should be eliminated from the malting process (biochemical characteristics were not much affected as a result) and degerming of the seeds has to be systematically conducted after sun drying to achieve a significant reduction in cyanide content. Flours from malted red sorghum or millet seeds presented useful characteristics (α-amylase activity and nutrient contents) for incorporation in infant flours to improve the energy and nutrient density of gruels.

Keywords: Malting; Cereal; α-Amylase; Phytate; Cyanide

1. Introduction

Malting of cereals is a processing procedure traditionally used in many African countries for the manufacture of alcoholic drinks (Dewar, Taylor, & Berjak, 1997; Taylor & Dewar, 2001). Malting consists in the germination and drying of cereal seeds, the prime objective being to promote the development of hydrolytic enzymes that are not active in raw seeds (Dewar et al., 1997). The main enzymes produced during germination that intervene in the hydrolysis of starch are α- and β-amylases (Palmer, 1989). The α-amylases are liquefying enzymes. In Burkina Faso, traditional malting of cereals consists of several stages: steeping of seeds (in water), germination, maturation (during which the seeds are piled and protected from light), and finally sun drying. In addition to the use of malted cereal flours in the manufacture of beer, a further use is their

* Corresponding author. Present address: Centre IRD, 01 BP 182, Ouagadougou 01, Burkina Faso. Fax: +226-31-03-85.
E-mail address: ttahirou@ird.bf (T. Traoré).

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incorporation in infant flours to increase the energy density of the gruels which is facilitated by the action of alpha-amylase (Malleshi, Daodu, & Chandrasekhar, 1989; Onyeka & Dibia, 2002; Wahed, Mahalanabis, Begum, Rahman, & Islam, 1994).

It is generally recognised that the insufficient energy density of complementary foods is an etiological factor of protein energy malnutrition in young children (WHO, 1998). In Burkina Faso, gruels are prepared with flours manufactured in the household or locally in small production units. They have a fluid consistency and an energy density of approximately 40 kcal/100 g (Trèche, unpublished data). The limited gastric capacity of infants was about 30–40 ml/kg body weight, (Sanchez-Grinan, Person, & Brown, 1992) and the low daily frequency of consumption (generally 2 gruels per day) means that the foods that are used to complement mother's milk do not in fact meet the infant's energy requirements. In this context, the use of enzymatic treatments that reduce the viscosity of highly concentrated gruels and give them a semi-fluid consistency can have positive effects on the young children's energy intake (Brown et al., 1995; Darling et al., 1995; Den Besten, Glatthaar, & Ijsselmuiden, 1998; Moursi, Mbemba, & Trèche, 2003; Vieu, Traoré, & Trèche, 2001).

Several sources of amylase (animal, bacterial or plant α-amylase) can be used to simultaneously confer the suitable energy density and consistency to the gruels (Trèche, 1999). In Burkina Faso, the most suitable solution seems to be the use of malted cereal flours, as this does not differ markedly from existing food habits and also benefits from the technological know-how of the population. The malting of cereal seeds also has the advantage of reducing the phytate content (Mahgoub & Elhag, 1998; Svanberg, Lorri, & Sandberg, 1993), which should improve the bioavailability of some essential minerals (iron, calcium, zinc, phosphorus, etc.) for the young children. However, the variability of the amylolytic activity of the germinated cereal flours as well as the length of time needed for preparation and possible risks of toxicity related to the presence of cyanides in the roots and the shoots of germinating seeds (Ahmed, Mahgoub, & Babiker, 1996; Aniche, 1990; Ikediobi & Olugboji, 1988; Okoh, Ikediobi, & Olugboji, 1988; Panasiuk & Bills, 1984; Shayo, Nnko, Gidamis, & Dillon, 1998; Uvere, Adenuga, & Mordi, 2000) require better knowledge of their modes of production in the malting production units.

The objective of this study was to characterise the traditional processes of cereal malting in Ouagadougou to determine the best conditions for producing malted cereal flours intended for incorporation in infant flours. This work consisted firstly, in characterizing the different traditional processes used for cereal malting, and secondly, in highlighting the different biochemical modifications that occur in seeds during malting.

2. Materials and methods

2.1. Cereal seeds

Seeds of red sorghum (*Sorghum bicolor*), millet (*Pennisetum glaucum*), and maize (*Zea mays*) were purchased by the producers from their usual suppliers in Ouagadougou. The cereals used came from the 1999–2000 crop.

2.2. Selection of the malting production units and sampling

198 production units (PU) were listed in 4 sectors out of a total of 30 sectors in Ouagadougou. There is a high concentration of malting production units which are famous for the quality of their traditional beer in these 4 sectors: 191 PU of malted sorghum, 3 PU of malted millet and 4 PU of malted maize. The PU of malted sorghum were gathered into 20 groups characterized by a single flow-sheet. A production unit from each group was selected by drawing lots. All malted millet and maize PU were retained due to their low number. In order to select the PU that produced flours with high amylolytic activity, the malt samples from the 27 PU were incorporated in a local infant flour at the rate of 8% and gruels were prepared at concentrations close to 25 g of dry matter per 100 g of gruel. The flow distance (mm/30 s) of the gruels was measured using a Bostwick consistometer according to the method used by Vieu et al. (2001). From the results (Fig. 1), 8 PU that process either red sorghum (5 PU), or millet (2 PU), or maize (1 PU) were selected as a function of the ability of the malt flours to fluidify high-energy density gruels. Each of the 8 PU were monitored throughout the malt production process in order to describe rigorously the various stages of their malting technique and to establish a detailed flow-sheet for each. During monitoring, samples were taken at the main stages of the process. Samples taken in the selected PU were freeze-dried except for one sample of the end product. The freeze-dried samples were ground (particle size <500 μm) and stored at 4 °C until analyses.

2.3. Biochemical analyses

2.3.1. Proximate composition

Dry matter contents (DM) were determined by oven drying at 105 °C to constant weight. Protein contents ($N \times 6.25$) were determined by the method of Kjeldahl (Standard NF.V03-050, 1970). Lipid contents were determined by the method of extraction with Soxtec (adaptation of the method with Soxhlet) (extraction solvent

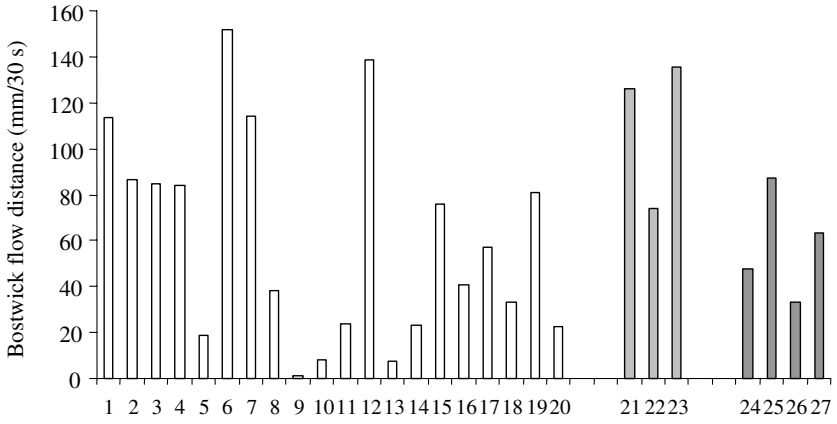

Fig. 1. Comparison of the Bostwick flow distance (mm/30 s) of gruels prepared at a concentration of 25 g DM/ 100 g of gruel using malted cereal flours from 27 different production units (PU) in Ouagadougou (1–20: PU of malted red sorghum; 21–23: PU of malted millet; 24–27: PU of malted maize).

used was ether oil). Dietary fibre contents were determined by the gravimetric and enzymatic method of Prosky, Asp, Schweizer, Devries, and Furda (1988). Ash content was determined by incineration in a furnace at 530 °C.

2.3.2. Soluble sugars

Soluble sugars were extracted from a sample of malt flour mixed with ethanol solution (80% v/v) that had been agitated for 30 min in a thermostated bath at 90 °C and then centrifuged at 5000 rpm for 10 min at 4 °C. The supernatant was retrieved and the same procedure applied to the residue. The two mixed supernatants were dry evaporated overnight using a Speed vac centrifugal evaporator (JOUAN RC 10–10, Saint Herblain, France), then stored at 4 °C, before the determination of sugar contents by ionic chromatography using a Dionex DX 500 apparatus (Sunnyvale, CA, USA). After evaporation, the residue was mixed in millipore water and filtered. Glucose, fructose and sucrose contents were determined using a Carbo PA1 column. Detection was made by pulsed amperometry and the eluant used was 90 mM sodium hydroxide solution. The results were expressed in g/100 g DM.

2.3.3. α-Amylase activity

α-Amylase activity was determined using a colorimetric method developed by Megazyme (Wicklow, Ireland). It consists of hydrolysis with the α-amylase of sample extracts of a specific substrate (Azurine cross linked or AZCL-amylose). α-amylase activity is expressed in Ceralpha units per gram of dry matter (U/g DM; ICC Standard No. 303, Megazyme International, Ireland).

2.3.4. Phytate

Phytate contents were determined according to the method described by Talamond, Gallon, and Trèche (1998). After the extraction of phytates in acid solution (HCl 0.5 M), inositol-6-phosphate (IP6) content was determined by ionic chromatography using a Dionex DX 4500i apparatus equipped with an Omnipac pax-100 column. Detection was by conductivity. The values are expressed in g IP6/100 g DM.

2.3.5. Total cyanide

Total cyanide contents were determined using a colorimetric method according to Ikediobi and Olugboji (1988) and Okoh et al. (1988). After extraction in phosphate buffer (0.1 M) of free cyanide in the malt samples and hydrolysis of bound cyanide by sodium hydroxide solution (0.1 M), total cyanide content was determined by spectrophotometry using a Spectroquant kit (Merck 114800). The results are expressed in ppm (mg HCN/kg).

All measurements were carried out in duplicate except those of α-amylase activity which were carried out in triplicate.

3. Results and discussion

3.1. Description of the traditional malting process

The general production process of the germinated cereal flours and the stages at which the samples were taken are presented in Fig. 2. After a steeping phase (5–25 h), the seeds are germinated for 57–96 h in canaries, on a cemented floor or on plastic bags. After germination, three PU are passed through a maturation step, where the seeds are piled in heaps and protected from the light with a cover or inside the house. The products are next sun dried for 32–82 h. The dried seeds are then degermed (in some of the PU) and crushed to produce malt flour, the end product.

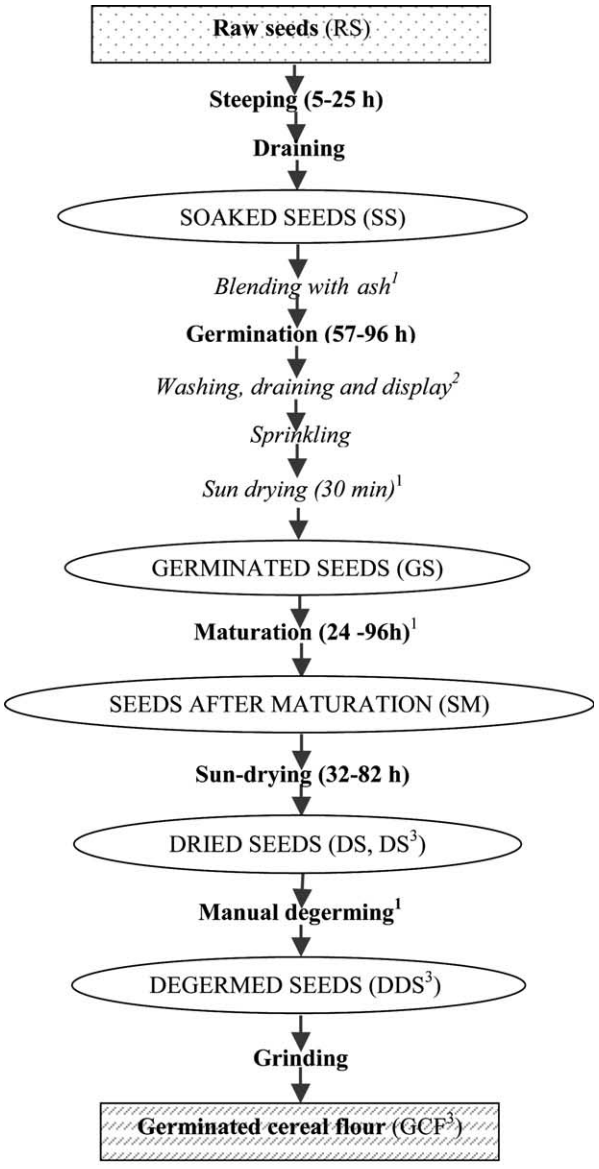

Fig. 2. General diagram of the traditional process of cereal malting observed in Ouagadougou.

3.2. Biochemical changes at different steps of the malting process

3.2.1. Dry matter content

The average dry matter contents at each stage in the manufacture of malt flours are presented in Fig. 3. We observed a considerable decrease in dry matter content at the end of the steeping stage in red sorghum, millet and maize seeds (32%, 33% and 34%, respectively). The metabolic processes of germination start during the steeping of the seeds (Taylor & Dewar, 2001) and adequate hydration of seeds is needed for the enzymatic modifications of the substrate in the endosperm during

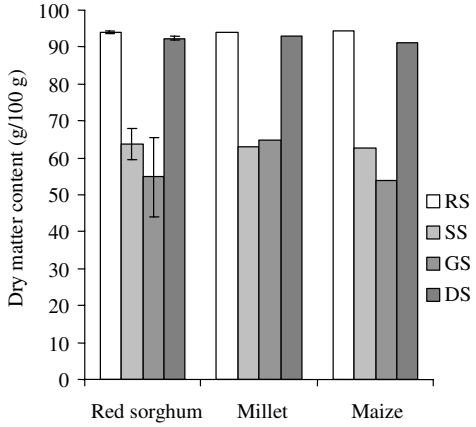

Fig. 3. Changes in dry matter content during the preparation of malted cereal flours (RS: raw seeds; SS: soaked seeds; GS: germinated seeds; DS: dried seeds). Values are means (± SD) for red sorghum ($n = 5$) and means for millet ($n = 2$).

germination (Agu & Palmer, 1998). Steeping is thus a very important stage in the malting process. Our results are comparable with those reported by some authors who carried out experimental tests of malting in laboratory conditions (Agu & Palmer, 1996; Helland, Wicklund, & Narvhus, 2002; Uvere et al., 2000). In red sorghum and maize, we observed a decrease in the dry matter content of germinated seeds of 14% compared to soaked seeds. This shows that the decrease in dry matter content continues during germination as long as the seeds are periodically watered or washed so as to be maintained under the moist conditions that are appreciated by dolo makers. Helland et al. (2002) and Uvere et al. (2000) also noted an increase in water content during germination of sorghum and maize.

3.2.2. Nutrient contents

Table 1 shows the changes in proximate composition and soluble sugar content during the processing of the 3 types of cereal into malt. In general, malting slightly increased protein content (11%, 7% and 2%, respectively for red sorghum, millet and maize). The increase in protein content was biggest in red sorghum. Shayo et al. (1998) also observed, in 2 varieties of millet from Tanzania, an increase in protein content of 5% after 48 h of germination at 30 °C. This increase in protein content is attributed to a passive variation due to a decrease in the carbohydrate compounds used for respiration (Opuku, Ohenhen, & Ejiofor, 1981). The modifications in lipid content were significant (26%, 23% and 16% for red sorghum, millet and maize, respectively) as observed by other authors. While steeping led to a slight increase in lipid content in the 3 types of cereals, germination is the stage in which the decrease in lipid content is greatest (27%, 20% and 23% for red sorghum, millet and maize, respectively). Similar observations were made by Elmaki, Babiker, and El Tinay (1999), who noticed that

Table 1
Mean nutrient contents (g/100 g DM) and variation observed during the preparation of malted flours, (in brackets: variation in relation to the previous stage)

	Raw seeds	Steeped seeds	Germinated seeds	Dried seeds	% of total variation
Global composition					
Protein (N × 6.25)					
Red sorghum ($n = 5$)	8.4 ± 0.3	9.0 ± 0.4 (+6%)	9.5 ± 0.8 (+6%)	9.3 ± 0.5 (−2%)	+11
Millet ($n = 2$)	9.7	10.0 (+3%)	10.6 (+6%)	10.4 (−2%)	+7
Maize ($n = 1$)	7.7	7.7 (−1%)	7.9 (+3%)	7.9 (−1%)	+2
Lipid					
Red sorghum ($n = 5$)	3.4 ± 0.2	3.5 ± 0.3 (+4%)	2.6 ± 0.3 (−27%)	2.5 ± 0.3 (−2%)	−26
Millet ($n = 2$)	5.2	5.5 (+6%)	4.4 (−20%)	4.0 (−9%)	−23
Maize ($n = 1$)	4.2	4.5 (+9%)	3.5 (−23%)	3.5 (0%)	−16
Fibre					
Red sorghum ($n = 5$)	6.0 ± 0.4	5.7 ± 0.6 (−5%)	6.1 ± 0.4 (+8%)	6.2 ± 0.5 (+1%)	+3
Millet ($n = 2$)	3.6	3.1 (−12%)	3.0 (−4%)	3.7 (+23%)	+4
Maize ($n = 1$)	3.9	3.5 (−9%)	3.4 (−4%)	3.6 (+7%)	−7
Ash					
Red sorghum ($n = 5$)	3.37 ± 0.27	2.41 ± 0.58 (−28%)	2.13 ± 0.46 (−12%)	1.97 ± 0.40 (−8%)	−41
Millet ($n = 2$)	1.31	1.13 (−14%)	1.95 (+73%)	1.54 (−21%)	+17
Maize ($n = 1$)	1.24	1.23 (−1%)	1.40 (+14%)	1.38 (−1%)	+11
Soluble sugars					
Sucrose					
Red sorghum ($n = 5$)	0.64 ± 0.05	0.39 ± 0.21 (−39%)	1.37 ± 0.68 (+251%)	2.45 ± 1.14 (+79%)	+283
Millet ($n = 2$)	1.26	0.44 (−65%)	2.29 (+420%)	3.88 (+69%)	+208
Maize ($n = 1$)	1.34	0.44 (−67%)	3.57 (+711%)	3.32 (−7%)	+148
Glucose					
Red sorghum ($n = 5$)	0.09 ± 0.02	0.17 ± 0.15 (+89%)	3.20 ± 1.88 (+1782%)	3.94 ± 2.81 (+23%)	+4478
Millet ($n = 2$)	0.06	0.04 (−33%)	1.64 (+4000%)	1.79 (+9%)	+2883
Maize ($n = 1$)	0.08	0.06 (−25%)	2.38 (+3867%)	1.79 (−25%)	+2138
Fructose					
Red sorghum ($n = 5$)	0.06 ± 0.02	0.07 ± 0.03 (+17%)	0.73 ± 0.41 (+940%)	0.85 ± 0.44 (+16%)	+1517
Millet ($n = 2$)	0.05	0.03 (−40%)	0.87 (+2800%)	0.52 (−40%)	+940
Maize ($n = 1$)	0.06	0.05 (−17%)	0.42 (+740%)	0.29 (−31%)	+383

Values are means ± SD for red sorghum and means for millet.

steeping and germination of 2 varieties of sorghum from Sudan were followed by a significant decrease in lipid content. This decrease could be explained by the fact that lipids are used to produce the necessary energy for the biochemical and physiological modifications that occur in the seed during germination (Elmaki et al., 1999). Fibre content did not show any marked variation during the malting process. The malting process considerably reduced ash content in red sorghum. Steeping was the stage in which the biggest decrease (28%) occurred. On the other hand, ash content increased in germinated millet and maize (73% and 14%, respectively), but during the drying of germinated millet, there was a decrease of 21% in ash content. In the case of sorghum, the observed ash contents are comparable with those reported by Elmaki et al. (1999).

Sucrose contents in raw maize seeds (1.34 g/100 g DM) and raw millet seeds (1.26 g/100 g DM) were higher than in raw red sorghum seeds (0.64 g/100 g DM). During steeping, there was a decrease in sucrose content in all 3 types of cereals. The stages of germination and drying led to a very significant increase in sucrose content (283%, 208% and 148%, in red sorghum, millet and maize, respectively). Glucose contents in the 3 types of cereals were comparable and very low. Germination was the determining process in the production of glucose whose content respectively reached 3.20, 1.64 and 2.38 g/100 g DM in red sorghum, millet and maize. The seeds of red sorghum, millet and maize had comparable fructose contents that were very low but increased during germination. Glucose and fructose contents increased considerably throughout the process. The production of glucose and fructose during malting was higher than that of sucrose. Nirmala, Subba Rao, and Muralikrishna (2000) also observed a significant increase in glucose, fructose and sucrose contents during the germination of millet. The increase in glucose and fructose contents was much bigger than that of sucrose after 96 h of germination. This increase could be due to the action of an invertase that hydrolyses sucrose into glucose and fructose.

3.2.3. Alpha-amylase activity

Changes in α-amylase activity during the malting process of red sorghum, millet and maize is presented in Fig. 4. The raw seeds and the steeped seeds of the 3 types of cereals did not present any measurable α-amylase activity using the megazyme kit.

The strongest activity was observed in red sorghum and millet (respectively 56 and 42 U/g DM) at the end of germination. Optimum α-amylase activity at the end of the drying of maize was 26 U/g DM. The observed α-amylase activity at the end of the germination of red sorghum (average duration 74 h) is comparable with that obtained by Agu and Palmer (1997) with some of the varieties of red sorghum after 96 h of germination at 20 °C and after 72 h of germination at 30 °C. Uvere et al. (2000) observed maximum α-amylase activity after 72 h of germination at 30 °C in some varieties of red sorghum from Nigeria. The results obtained for maize after germination (21 U/g DM) are comparable with those obtained (19 U/g) by Helland et al. (2002), although the duration of germination was very different (66 and 168 h respectively). The drying stage caused a decrease in α-amylase activity of 16% in red sorghum and millet, but in maize an increase of 26% after drying was observed. There is marked variability of α-amylase activity from one PU to another using the same type of raw material. This is shown by the high standard deviations obtained for the PU using red sorghum. The clear variability between different PU of malted red sorghum seeds may be due either to the know-how of dolo (traditional beer) makers or to the quality of the raw material (variety and origin of the seeds, storage conditions). Red sorghum presented the highest α-amylase activity compared to millet and maize. Thus, germinated red sorghum appears to be potentially more useful as a source of α-amylase for the formulation of infant flours than germinated millet and maize.

3.2.4. Phytate content

Changes in phytate content during the cereal malting process are presented in Fig. 5. The seeds of red sorghum had the highest phytate content (0.83 g IP6/100 g DM), followed by maize (0.71 g IP6/100 g DM) and millet (0.53 g IP6/100 g DM). Steeping in the traditional conditions, i.e., 14 h for sorghum, 8 h for millet and 25 h for maize did not reduce phytate content. These results differ from those of Mahgoub and Elhag (1998) who observed that steeping for 12 and 24 h reduced the phytate content by 8–14% and 16–21% in 4 varieties of sorghum, respectively. Svanberg et al. (1993) observed that steeping maize for 24–48 h reduced phytate content by approximately 59%. This reduction in phytate content during steeping could be due to the solubilisation of phytic acid salts (Mahgoub & Elhag, 1998) and its use as primary source of energy during germination step. This leads us to think that there was no diffusion of phytate during steeping or that the duration of steeping was not sufficient to involve in the diffusion of phytate into the steeping water. The germination stage had a substantial effect on the reduction in phytate content. This reduction is due to the action of endogenous phytases that degrade the phytate into inorganic phosphorus and inositol and its intermediate forms. Germination made it possible to reduce phytate content by 53%, 67% and 27% in red sorghum, millet and maize after 74, 62 and 66 h respectively. The degradation of phytate was greater in millet than in red sorghum and maize. The observed decrease in phytate content in the case of red sorghum is low compared with that reported by Mahgoub and Elhag (1998) (86% after 96 h of germination). This difference is probably due to the fact that the average duration of germination observed (74 h) was shorter in our study. Inversely, the decrease in the phytate content of millet after 62 h of germination (67%), is greater than that observed by Makokha, Oniang'o, Njoroge,

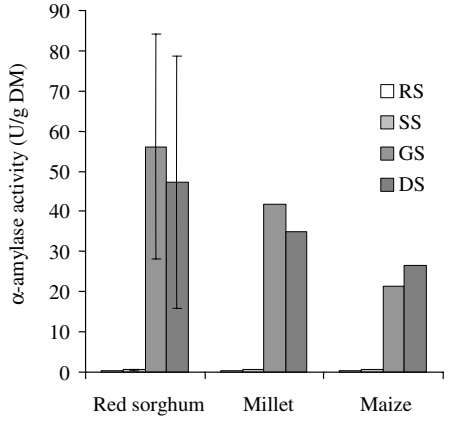

Fig. 4. Changes in α-amylase activity during the preparation of malted cereal flours (RS: raw seeds; SS: soaked seeds; GS: germinated seeds; DS: dried seeds). Values are means (± SD) for red sorghum ($n = 5$) and means for millet ($n = 2$).

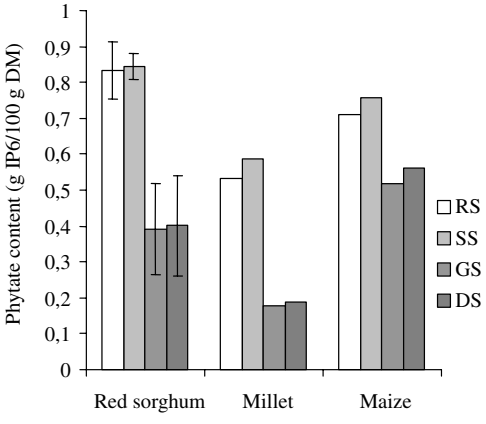

Fig. 5. Changes in phytate content during the preparation of malted cereal flours (RS: raw seeds; SS: soaked seeds; GS: germinated seeds; DS: dried seeds). Values are means (± SD) for red sorghum ($n = 5$) and means for millet ($n = 2$).

and Kamar (2002), which was only 45% after 96 h of germination.

3.2.5. Total cyanide content

Changes in total cyanide content during the malting process are presented in Fig. 6. Total cyanide contents of raw seeds were low (38, 46 and 34 ppm respectively in red sorghum, millet and maize). The cyanide content of raw seeds of millet in our study is comparable with that observed by Shayo et al. (1998). The raw seeds of red sorghum had a cyanide content slightly higher than that obtained by Panasiuk and Bills (1984), Ikediobi and Olugboji (1988), Aniche (1990) and Ahmed et al. (1996). The steeping of seeds led to an increase in cyanide content (73, 85 and 84 ppm, respectively in red sorghum, millet and maize). During germination, the cyanide content increased considerably to reach maximum values of 324, 168 and 108 ppm at the end of the germination stage in red sorghum, millet and maize, respectively. These results are much lower than those reported by Ahmed et al. (1996) in sorghum and by Shayo et al. (1998) in millet after 72 h of germination. The sun-drying stage allowed a reduction of respectively 38% and 67% in cyanide content in millet and maize. However, in the case of red sorghum, the cyanide content increased during drying by up to 21%. Dada and Dendy (1988) and Panasiuk and Bills (1984) observed that drying of germinated sorghum at 50 °C did not reduce cyanide content. This suggests that cyanide exists in seeds in the form of non-volatile cyanogenic glycosides. These cyanogenic glycosides are degraded by endogenous autolytic enzymes, the α-glucosidase and the hydroxynitrile lyase, which become more active at 55 °C (Aniche, 1990). In the germinated millet and maize, the amount of cyanide content per 100 g of dry matter remained considerably lower than the average fatal dose of cyanide for humans, i.e., 50–60 mg for an adult (Panasiuk & Bills, 1984). However, the concentration of cyanide in germinated seeds of red sorghum is higher than the maximum cyanide content recommended in lima beans (200 ppm) in several countries (Panasiuk & Bills, 1984).

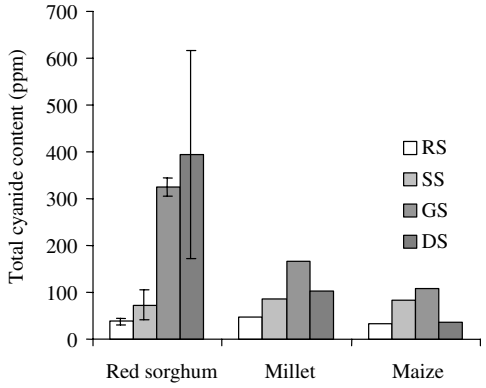

Fig. 6. Changes in total cyanide content during the preparation of malted cereal flours (RS: raw seeds; SS: soaked seeds; GS: germinated seeds; DS: dried seeds). Values are means (± SD) for red sorghum ($n = 5$) and means for millet ($n = 2$).

3.3. Effect of some specific sub-processes

3.3.1. Maturation

A maturation step was applied by only 3 PU of malted red sorghum. According to the producers, this stage allows various biochemical reactions to take place plus the development of mould, and in this way enhances the flavour of the traditional beer. Table 2 shows the effect of the maturation step on the nutrient content of red sorghum. Protein, lipid and dietary fibre contents were not modified, but ash content decreased by 17%. As far as soluble sugar contents are concerned, the maturation step reduced the sucrose content by 30% and increased glucose and fructose contents respectively by 89% and 85%. This marked increase in glucose and

Table 2
Effect of maturation on nutrient (g/100 g DM), phytate (g IP6/100 g DM) and total cyanide (ppm) contents and on α-amylase activity (U/g DM) in red sorghum seeds

	Germinated seeds	Seeds after maturation	% of variation
Global composition			
Protein ($N \times 6.25$)	10.0 ± 0.5	10.1 ± 0.3	+1
Lipid	2.7 ± 0.3	2.5 ± 0.2	−7
Fibre	5.9 ± 0.4	6.0 ± 0.5	+2
Ash	2.05 ± 0.51	1.71 ± 0.18	−17
Soluble sugars			
Sucrose	1.24 ± 0.34	0.87 ± 0.38	−30
Glucose	4.16 ± 1.52	7.85 ± 1.82	+89
Fructose	0.82 ± 0.22	1.52 ± 0.21	+85
Phytate	0.33 ± 0.07	0.30 ± 0.1	−9
Total cyanide	320 ± 20	340 ± 80	+6
α-Amylase activity	41.2 ± 5.4	43.2 ± 21.4	+5

Values are means ± SD; $n = 3$.

Table 3
Effect of degerming on nutrient (g/100 g DM), phytate (g IP6/100 g DM) and total cyanide (ppm) contents and on α-amylase activity (U/g DM) in red sorghum ($n = 5$), millet ($n = 2$) and maize ($n = 1$) seeds

	Dried seeds	Degermed seeds	% of variation
Global Composition			
Protein ($N \times 6.25$)			
Red sorghum	9.6 ± 0.5	8.7 ± 0.4	−10
Millet	10.7	9.7	−9
Maize	7.8	7.0	−11
Lipid			
Red sorghum	2.5 ± 0.3	2.5 ± 0.3	−2
Millet	3.8	4.3	+11
Maize	3.5	3.5	+2
Fibre			
Red sorghum	6.4 ± 0.5	5.5 ± 0.2	−14
Millet	3.6	3.2	−10
Maize	3.6	3.2	−13
Ash			
Red sorghum	1.92 ± 0.32	1.61 ± 0.41	−16
Millet	1.62	1.19	−27
Maize	1.38	1.10	−20
Soluble sugars			
Sucrose			
Red sorghum	2.53 ± 1.15	2.11 ± 0.94	−17
Millet	4.04	3.84	−5
Maize	3.75	3.67	−2
Glucose			
Red sorghum	4.24 ± 2.94	3.93 ± 2.51	−7
Millet	1.86	1.74	−7
Maize	2.15	2.29	+6
Fructose			
Red sorghum	0.92 ± 0.47	0.59 ± 0.24	−36
Millet	0.56	0.34	−39
Maize	0.37	0.23	−3
Phytate			
Red sorghum	0.43 ± 0.12	0.39 ± 0.14	−12
Millet	0.20	0.25	+23
Maize	0.52	0.53	+3
Total cyanide			
Red Sorghum	375 ± 210	96.4 ± 24.2	−74
Millet	95.2	27.1	−72
Maize	34.5	16.7	−52
α-Amylase activity			
Red Sorghum	58.0 ± 37.6	43.4 ± 33.5	−25
Millet	37.6	27.0	−28
Maize	13.7	11.6	−15

Values are means ± SD for red sorghum and means for millet.

fructose contents is probably due to sucrose and starch hydrolysis during maturation and leads to the development of the sweet taste of malt which is much desired by producers. Maturation had no effect on phytate and total cyanide contents or on α-amylase activity (Table 2).

3.3.2. Degerming

After drying, roots and shoots are separated from the seeds by rubbing the seeds between the hands, and then removed by winnowing. The effect of the elimination of the roots and the shoots of germinated cereal seeds on nutrient composition and other components is presented in Table 3. Degerming reduced protein content by about 10%, but lipid content was not much affected. It reduced dietary fibre contents in red sorghum, millet and maize respectively by 14%, 10% and 13%. The degerming of germinated seeds resulted in quite a significant loss in total minerals, ash content reduced by 16–27%. Degerming had no effect on sucrose and glucose contents.

Fructose reduced in degermed red sorghum and millet by 36–39%.

Degerming had little effect on phytate content but allowed a considerable reduction in cyanide content (74%, 72% and 52%, respectively in red sorghum, millet and maize). Indeed cyanides are concentrated in the roots and the shoots of seeds in germination as previously observed by Ikediobi and Olugboji (1988) and Dada and Dendy (1988). However, the reduction values we obtained are lower than those reported by these authors. Dada and Dendy (1988) showed that the removal of the roots and the shoots reduced cyanide content by more than 90% while, according to Ikediobi and Olugboji (1988), there is no difference between the cyanide content of raw seeds and that of degermed seeds. Traditional manual degerming did not allow the complete elimination of cyanide, but it lowered cyanide contents (96, 27 and 16 ppm, respectively in red sorghum, millet and maize) to a level which does not present any danger for human consumption. Thus, it is easy to detoxify germinated cereal seeds by the mechanical removal of the roots and shoots (Ikediobi & Olugboji, 1988). However, for red sorghum, the traditional technique of degerming will have to be improved to reach a final cyanide content closer to the initial cyanide content of raw seeds. Unfortunately, the reduction in cyanide content by degerming is accompanied by a decrease in α-amylasic activity of 25%, 28% and 15% respectively in red sorghum, millet and maize. This leads us to think that a great part of α-amylase is located in the shoots of germinating seeds.

4. Conclusion

This study showed that there are several alternatives to the traditional processes of cereal malting in Ouagadougou and that red sorghum is the main cereal processed. The malting of cereal induced, on the one hand, a reduction in ash and lipid contents and, on the other hand, a considerable increase in sugar contents which confers the sweet taste to the malt flours. The traditional process of cereal malting was effective in reducing phytate content and increasing α-amylase activity. It also induced a significant increase in cyanide content which, fortunately, can be eliminated by the manual degerming of germinated seeds. However, it is not necessary to include the maturation step (biochemical characteristics were not much affected by maturation) in the malting process, but necessary to systematically carry out degerming of the seeds after sun drying. Malt flours of red sorghum and millet (obtained without a maturation step and after degerming of the seeds) presented interesting characteristics that could be incorporated in infant flours produced in small production units or in the household to improve energy and nutrient densities of gruels intended for infants and young children. However, it is advisable to optimise the traditional process of malting with a view to maximizing effectiveness for the production of amylase.

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