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RESEARCH ARTICLE

Chemical and enzymatic characteristics of sorghum malt used for traditional sorghum beer production in Côte d'Ivoire

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Abstract

Malting is the first step in the manufacturing of traditional sorghum beer. The variability of the malting process causes variability of the enzymatic power and technological properties of the malt. At the traditional level, as the duration and conditions of each malting operation strongly depend on the know-how of producers, the malt quality is highly variable from one production to another. In order to give the sorghum beer producers sorghum malt with high and consistent qualities, we report technical knowledge for production of malt. The results showed that the malt produced under controlled conditions had statistically similar moisture content and values were significantly lower (7-9.3%) than those obtained for malt produced under uncontrolled conditions (10-24.8%). In addition, water-soluble and reducing sugar contents were higher in malt produced at laboratory and the optimum pH for amylase activities was detected at pH 6. During malt drying, undried malt alpha amylase specific activity felled to 0.90-3.20 U/mg of protein and the decrease was higher when grains were sun-dried than when they were dried at 45°C in an oven. Thus, to obtain the highest levels of sugars and amylases activities with the lowest moisture contents, malting conditions need to be controlled and optimized.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) plays a crucial role in food security in developing countries. It is involved in cooking of many foods such as breads, porridges, pastes and pancakes. It is also abundantly used to prepare traditional beers commonly named sorghum beers or opaque beers but known as *pito* or *burukutu* in Nigeria, *chibuki* in Zimbabwe, *dolo* in Mali and Burkina Faso, *bili bili* in Chad and *tchapalo* in Côte d'Ivoire (Moura et al., 2006; N'guessan et al., 2010). Despite its economic importance, the production of traditional sorghum beer remains more or less an empirical process, resulting in products without the same quality characteristics (Sanni, 1993). In order to give to consumers consistent and high-quality products, and rise producers gain, there is a need to investigate the traditional process of sorghum beers and to optimize the manufacturing conditions.

Basically, the manufacturing of sorghum beer involves malting, mashing, souring (lactic acid fermentation), boiling, alcoholic fermentation and straining (Haggblade and Holzpfel, 1989; Moura et al., 2006; Sawadogo et al., 2007), in which variations may occur depending on the regional location (Van der Aa Kühle et al., 2001). Malting is the first step in the manufacturing of traditional sorghum beer and involves the three main steps of steeping (soaking), germination and kilning (drying). The fundamental reason of soaking is to hydrate the grain and initiate metabolism of living tissues, which are habitually dormant when the grains are dry (Briggs, 1998). Germination is one of the

essential steps of sorghum processing into food because of the activation of enzymes, the decrease in antinutritional factors, the increase in bioavailability of minerals (iron, zinc, etc.), the increase in content of essential amino acids (especially lysine, tryptophan and methionine) and the increase in digestibility of macronutrients (Anglani, 1998). The principal objective of drying is to produce shelf-stable malt with a good level of amylase activity. The kilning (drying) temperature suitable for retention of high amylase activity and other endogenous hydrolytic enzymes is approximately 50°C (Hough et al., 1971). A moisture content of approximately 11% is considered safe and guarantees longer shelf life of malted sorghum. Drying at temperatures higher than 50°C may lower amylase activities particularly beta-amylase which is temperature labile (Agu and Palmer, 1996). In sum, malting procedure helps to mobilize endogenous hydrolytic enzymes (α- and β-amylases in the grain) to modify the structure of the grain (Briggs, 1998; Taylor and Belton, 2002). The variability of the malting process also causes variability of the enzymatic power and technological properties of the malt. In fact, it has been shown that steeping in alkaline liquor with air rest periods results in malt with high diastatic power. Moreover, amylase activities of sorghum grains increase with the duration of germination with an optimum after 55-60 h of germination before decreasing. At traditional level, as the duration and the conditions of each malting operation strongly depend on the know-how of producers, the malt quality is highly variable from one production to another and from one producer to another. This leads to traditional sorghum beers with variable quality, low nutritive value and inconsistent properties. In order to solve this problem, we have to give to the sorghum beer producers sorghum malt with high and consistent qualities usable for this traditional sorghum beer production.

In the present study, we report the technical knowledge for production of malt from sorghum with high technological quality usable for sorghum beer production. The quality of malt has been assessed by measuring its water-soluble and reducing sugars, pH, titratable acidity and specify enzyme activity.

Materials and methods

Production sites investigated and sampling

The traditional malting processes of sorghum grains were investigated at five randomly selected small scale *tchapalo* production sites at Adjamé-Williasmville (MA1, MA2, MA3, MA4 and MA5) and Cocody-Blokosso (MB1, MB2, MB3, MB4 and MB5) respectively in the district of Abidjan, the economic capital of Côte d'Ivoire. Red sorghum grains (*Sorghum bicolor*) were used by the producers from their usual suppliers in Abidjan. During malting, durations of the steeping (soaking), germinating and kilning (drying) processes were recorded and samples were taken for analyses. For each production site, the measuring processes were performed 3 times. Data obtained from brewers were used to establish a flow diagram with fixed durations for each operation (Figure 1). Once the diagram established, malting trials were conducted at the laboratory. The grains were purchased from local market. About 500 g of red sorghum grains was cleaned and freed from other materials and soaked in water for 8 h. The grains were spread on clean burlap in plastic trays and covered by another burlap sack and sprayed with water twice per day at temperature 28±2ºC for 48 h. Germinated grains left to dry in a forced-air oven at 45°C for 13 h then ground using an electric grinder, which was operated intermittently so as to avoid heating. The powders were kept in glass bottles for chemical analyses. Five trials were conducted at the laboratory and for each test, measurements were performed in triplicate.

Physico-chemical analysis

Moisture content

Moisture content was determined by finely milling 20.0 g of malted sorghum using an electric grinder. The sample was mixed thoroughly and 5.0 g was immediately placed in a clean, dry moisture dish, which had been tarred to 0.001 g. The dish was covered and weighed to 0.001 g. The lid was then removed and together with the dish (which contained the sample) was placed in an oven, which had been preheated to 105°C for 5 h. The dish was then covered with the lid and the set removed from the oven, placed in a desiccator and cooled to room temperature for 25 min. The dish and content were then reweighed on an analytical balance. The dish was re-placed in the oven and heated, cooled and weighed. This stage was repeated until constant weight was obtained. Triplicate determinations were carried out for each sample. The moisture content was calculated as a percentage of the initial weight of sample.

Determination of pH and titratable acidity

Ten (10) g of sorghum flour was mixed with 20 mL of distilled water prior to pH measurement. Value of pH was determined with pH-meter (pH-meter P 107 Consort, Bioblock, France). For titratable acidity determination, 20 mL

of liquid sample or suspension prepared as earlier described was centrifuged for 30 min at 4000 g. Of the supernatant, 10 mL was transferred to a 50 mL measuring flask and was titrated with 0.1 mol.L^{-1} NaOH using 1% phenolphthalein as indicator. The titratable acidity (%) was calculated according to Kimaryo et al. (2000). Two independent measurements were made for each sample.

Determination of sugars
Water-soluble carbohydrates were determined by the phenol sulphuric acid method according to Dubois et al. (1956) and total reducing sugars were quantified using the dinitrosalicilic acid method described by Bernfeld (1955). Sugars extraction was performed by the method described by Martinez-Herrera et al. (2006).

Effect of pH on the amylase activities
Enzymes extraction and quantification were performed as follows. Enzyme extracts were prepared by grinding 100 g of malted sorghum grains and mixing the flour with NaCl (0.9% w/v). The suspension was centrifuged (4000 × *g*, 4°C, 30 min) and the resulting supernatant was used as crude extract for all enzymes (alpha and beta-amylases). Effects of pH on amylase activities in crude extracts were tested at pH values ranging from 2.6 to 9 using the following buffers: 100 mM Tris-HCl (pH 7.0 to 9.0), 100 mM sodium phosphate (pH 5.6 to 7.6), 100 mM citrate phosphate (pH 2.6 to 7) and 100 mM sodium acetate (pH 3.6 to 5.6). Analyses were done in triplicate and the activities at optimal pH defined as 100%.

Determination of protein content and alpha amylase activity
Total protein was quantified by the method of Lowry et al. (1951) using Folin-phenol reagent. Bovine serum albumin was used as standard. Alpha amylase activity of the enzyme extract was measured by DNS method (1951). In brief the reaction mixture containing 1% soluble starch, 20 mM phosphate buffer (pH 7), and enzyme extract was taken and incubates at 37°C for 20 min followed by the addition of 3,5-dinitrosalicylic acid (DNS). The amount of the reducing sugar liberated during assay was estimated by measuring color development at 540 nm by UV-VIS spectrophotometer. 1 U of amylase activity is defined as the amount of enzyme that liberated micromole of maltose per minute under standard assay condition.
The specific activity is expressed as micromole of reducing sugars released per minute per milligram of protein (U / mg protein).

Statistical analysis
The results were statistically evaluated by one way analysis of variance (ANOVA) with the software Statistica, 99 Edition. Statistical differences with P-values under 0.05 were considered significant.

Results and discussion

1- Sorghum malt processing
The malting process comprised the stages of soaking, dripping, germination and drying. Steps such as maturation, sun pre-drying and degerming practiced by some malt producers in Burkina Faso and described as optional steps were not found here (Traoré et al., 2007). This could be due to the fact that our study concerned only two municipalities in Abidjan (Adjamé-Williasmville and Cocody-Blokosso) or due to the fact that maturation, sun pre-drying and degerming were abandoned by producers in order to supply high demand of the market.
The mean duration of each stage varied from one municipality to another and from one production site to another within a municipality. Thus, soaking varied from 8.07 h to 8.68 h at Adjamé-Williasmville and from 6.62 h to 10.13 h at Cocody-Blokosso (Table 1). These variations are not significantly different at Adjamé-Williasmville ($P > 0.05$) while there are at Cocody-Blokosso. According to Rooney and Waniska (2000), the optimal duration of soaking that enables sufficient sorghum grain water absorption depends on the vitrosity and the size of the grains. Traoré et al. (2007) reported a mean duration of 13±3 h. After soaking, sorghum grains were allowed to germinate on burlap sack and covered with another burlap sack at room temperature. The mean durations of germination stage recorded from traditional malt processors were 38.5-48.12 h at Adjamé-Williasmville and 47.37-59.79 h at Cocody-Blokosso. These findings support those of Dada and Dendy (1988) who reported 48 h for germination. On contrary, our values are lower than those of Traoré et al. (2007) who found 56-97 h and higher than those of Zangué et al. (2013) who noted 36 h of germination. Temperature and watering conditions may explain these differences. In fact, it was mentioned that the suitable germination temperature range is 20-30°C (Demuyakor and Ohta, 1992). During germination, the grains are watered at intervals and covered with shade cloth or sack to maintain high humidity.

Ogbonna (2007) reported that enzyme activity is highest during the early stages of germination. The traditional processors sun-dried germinated grains in order to stop the modification processes in the kernel and to produce a shelf-stable product. Traditional sorghum processors in this study used average times of 11.75 h to 15.65 h. Ballogou et al. (2011) reported 12 h for traditional processors in Benin and they suggested 6 h of drying with their shell drier. On contrary, literature most of the time mentioned 24 h, 48 h or 72 h (Dada and Dendy, 1988; Giamarchi and Trèche, 1994; Zangué et al. 2013).

2- Physico-chemical characteristics of sorghum malt

There were significant variations in moisture content of sorghum grains samples ($P < 0.05$). Values range from 8.1% to 12.2% for samples used at Adjamé-Williasmville, from 7.4% to 12.2% for samples used at Cocody-Blokosso and from 11.3% to 12.9% for samples used at laboratory (Table 2). This variability may be due either to the conditions of cultivation or storage of the seeds. Adequate hydration of seeds is needed for the enzymatic modifications of the substrate in the endosperm during germination (Agu and Palmer, 1998). It has been reported by Pelember et al. (2002) that increasing germination moisture improved sorghum, pearl millet and barley malt quality in terms of diastatic power, free amino nitrogen (FAN), hot water extract and reduced malting losses. Soaking is thus a very important stage in the malting process. After soaking, there were not significant ($P \geq 0.05$) variations in most of the samples moisture content. Values are around 35%. Drying at controlled conditions (45°C for 13 h) in the laboratory resulted in malts with no significant variations in moisture content. On contrary, malts obtained from traditional processors showed significant variations in their moisture content. Values range from 10% to 29.3% and are higher than that reported by Ogu et al. (2006). These authors reported moisture content of unmalted grains to be in the range rang 8.5- 10.5% and that of the malted between 5.2-5.7%. High moisture content encourages microbial growth and allows increase in metabolic rate, which depletes the extract content. According to Okon and Uwaifo (1985), the moisture content specification for sorghum malt is less or equal to 5.4% whiles that of barley malt is less or equal to 4.2%. But, according to Ballogou et al. (2011), for the manufacturing of traditional sorghum beer, moisture content of 9.04% is sufficient for malt conservation.

Water-soluble sugar and reducing sugar contents were higher in malt produced at laboratory (27.6-28.8 g/100g FM and 8.1-9.7 g/100g FM respectively) than malt produced by traditional processors (16.8-22.4 g/100g FM and 6.2-7.5 g/100g FM respectively). In addition, there were not significant ($P \geq 0.05$) variations in sugar contents when malting was conducted at laboratory. The significant ($p < 0.05$) difference in water-soluble sugars may have resulted from the proportionate decreases in the moisture. The high water-soluble sugar contents will yield high enough fermentable sugars. Furthermore, the fermentable sugars will be used as a carbon source by lactic acid bacteria to produce lactic acid and by yeasts to produce ethanol during the beer manufacturing. So, the higher are their contents, the better will be the beer manufacturing process.

In general, malt pH was not significantly affected by malting conditions (Table 2). Moreover, it was interesting to note that the malt pH of all the studied productions were within the range 5.05-6.1, which fall within the required mash pH (5.6±0.4). Similar results have earlier been reported by other workers. Indeed, Maoura et al. (2006) and Aka et al. (2008) observed that mash pH was 5,7 and 5,65 respectively. The results showed also that malt pH at laboratory is slightly lower than malt pH from traditional processors. According to Oyewole (1997), hydrolyzed starch of sorghum was converted to organic acids that reduced pH. So, Aka et al. (2008) found that organic acids in malted sorghum mash were oxalic, citric, malic, lactic, propionic and fumaric acids with a predominance of propionic acid (2.07 g/L). Lactic and propionic acids were reported to provide an acidic environment unfavourable for the growth of many pathogenic and spoilage microorganisms. The propionic acid, which has formed the basis for some biopreservative products, gives its antimicrobial action against microorganisms including yeast and moulds (Ross et al. 2002). Therefore, malt produced at laboratory scale in this study may have a better microbiological quality. In addition, these results may indicate that metabolic activities during malting were higher under controlled conditions than uncontrolled conditions. On contrary to pH, titratable acidity showed slight but significant ($p < 0.05$) variations in the laboratory and Adjamé-Williasmville malt samples while titratable acidity of malts produced at Cocody-Blokosso were statistically identical. Values range from 0.62% to 0.72% at Adjamé-Williasmville, from 0.77% to 0.80% at Cocody-Blokosso and from 0.60% to 0.77% at laboratory (Table 2). These values are lower than those reported by Makeri et al. (2013) for improved Nigerian barley malts. These authors found values ranged from 1.35% to 2.01%. This acidity will increase during the sorghum beer manufacturing up to 1.3% (Aka et al. 2008) or 12.69 g/L of lactic acid (Maoura et al. 2006) to give to the final product the souring taste which is important for the organoleptic properties of the beer.

3- Effect of pH on amylase activity

Amylases are produced by a wide spectrum of organisms, and each source produces biochemical phenotypes that significantly differ in parameters like pH and temperature optima as well as metal ion requirements (Rameshkumar and Sivasudha, 2011). Since alpha amylase activity is thought to be limited by the protonation of the nucleophile at low pH and by the deprotonation of the hydrogen donor at high pH (Fang and Ford, 1998), it is important to determine the optimum pH for amylases activities. The optimum pH for amylases (alpha and beta) activities in this study was determined with pH range from pH 2.6 to pH 9.0. As shown in Figure 2, amylases activities are strongly influenced by pH. Maximum activity was detected with pH 6 with sodium phosphate buffer. For citrate phosphate buffer 100 mM (pH 2.6 to 7), maximum activity was detected at pH 6 to 89.71% and the enzymes were not stable below pH 4. The amylase activities were highly decreased above pH 6.0. So, we can say undoubtedly that amylases from red sorghum malt prefer slightly acidic pH for optimal activity. The influence of optimum pH on these enzymes activities were, since their first detection in 1928, studied by several authors (Kumar et al, 2005; Egwin and Oloyede, 2006; Nour and Yagoub, 2010; Ba, 2013). Mehrahadi and Bandani (2009) determined that optimum pH value for alpha amylase isolated from the gut of the insect *Eurygaster maura* was 6.5-7. The optimum pH found in this study agree with pH 5.8 observed by Kumar et al. (2005) and with pH 5.5 reported by Ba (2013). Similar observations were also made by Mohamed et al. (2009) who reported that different amylases of wheat have a broad optimum pH range from 5.0 to 7.0. However, there are amylases with pH optimum in basic range as from *Spodoptera frugiperda* and *S. littoralis* (pH 9.6) (Mohamed, 2004).

4- Alpha amylase specific activity

A primary aim of malting is to develop and activate hydrolytic enzymes for the conversion of insoluble material. The development of alpha amylase during malting is of critical importance. According to Dewar et al. (2001), a number of factors are known to have an effect on the development of enzymes synthesised during germination and thus on the quality of the malt produced. Pelember et al. (2002) reported that increasing time of germination increase parameters such as diastatic power, β-amylase activity, free amino nitrogen, hot water extract and malting loss. Table 3 shows that specific activity of alpha amylase extracted from undried malt varied according to malting conditions. The highest values was obtained at Cocody-Blokosso (4.04 U/mg of protein) while the lowest values was obtained at Adjamé-Williasmville (2.78 U/mg of protein). The levels of undried malt alpha amylase activity found in the present study are in agreement with those of several varieties reported by Dicko et al. (2006). This activity decreased with drying. Values felled to 0.90-3.20 U/mg of protein and the decrease was higher when grains were sun-dried than when they were dried at 45°C in oven. Drying temperature effects on amylase activity were reported by several authors. Karababa et al. (1993) reported that low-temperature kilning schedules produce sorghum malts with greater diastatic power and α-amylase activity. According to Aisien and Muts (1987) kilning at 50°C seems appropriate and kilning at 80°C tends to encourage a better formation of aroma compounds.

Table 1 Steps duration (h) during malt production for traditional sorghum beer brewing

Production	Steeping			Germination			Kilning		
	Max.	Min.	Mean ±SD	Max.	Min.	Mean ±SD	Max.	Min.	Mean ±SD
MA1	8.75	8.28	8.51±0.33^{a}	48.00	29.00	38.5±13.43^{a}	13.70	13.60	13.69±0.00^{a}
MA2	8.75	8.63	8.68±0.08^{a}	48.00	47.50	47.75±0.35^{a}	13.81	13.31	13.56±0.35^{a}
MA3	8.16	8.00	8.07±0.11^{a}	48.00	48.00	48.00±0.00^{a}	13.06	13.00	13.02±0.04^{a}
MA4	8.45	8.00	8.22±0.31^{a}	47.92	47.75	47.83±0.12^{a}	14.70	13.06	13.88±1.15^{a}
MA5	8.66	8.40	8.52±0.18^{a}	48.25	48.00	48.12±0.17^{a}	13.50	13.00	13.25±0.35^{a}
MB1	12.00	8.26	10.13±2.64^{b}	72.00	47.58	59.79±17.26^{b}	21.50	7.50	14.5±9.89^{a}
MB2	8.31	7.60	7.95±0.50^{a}	48.00	47.16	47.58±0.59^{a}	12.00	11.50	11.75±0.35^{b}
MB3	8.25	5.00	6.62±2.29^{c}	47.75	47.00	47.37±0.53^{a}	15.56	12.00	13.77±2.51^{a}
MB4	8.50	5.00	8.25±0.35^{a}	63.50	43.00	53.25±14.49^{ab}	18.00	12.75	15.37±3.71^{a}
MB5	8.75	8.37	8.56±2.26^{a}	53.33	49.39	51.36±2.78^{ab}	16.50	14.81	15.65±1.19^{a}

MA1, MA2….MA5: productions at Adjamé-Williasmville; MB1, MB2……MB5: productions at Cocody-Blokosso. Max.: maximum value, Min.: minimum value; Mean ±SD: mean ± standard deviation; Mean values with same letter in a column are not significantly different ($P > 0.05$).

Table 2 Physico-chemical characteristics of sorghum malt

Production	Moisture content (%)			Reducing sugars (g/100g FM)	Water-soluble sugars (g/100g FM)	Malt pH	Titratable acidity (%)
	Before soaking	After soaking	After drying (malt)				
MA1	12.2±0.8^{a}	34.8±2.1^{a}	29.3±1.2^{a}	6.9± 0.04^{a}	17.3±0.10^{a}	6.00±0.1^{a}	0.66±0.01^{a}
MA2	9.0±0.6^{bc}	24.7±0.8^{b}	22.0±0.8^{b}	7.3±0.06^{b}	19.4±0.16^{ab}	6.10±0.1^{a}	0.62±0.0^{b}
MA3	8.4±0.3^{c}	35.1±6.4^{a}	14.5±0.8^{c}	7.5± 0.04^{b}	19.0±0.10^{b}	5.95±0.1^{a}	0.70±0.01^{c}
MA4	8.1±0.1^{c}	36.9±2.9^{a}	14.4±0.4^{c}	6.4± 0.02^{c}	16.8±0.13^{ac}	5.87±0.1^{a}	0.72±0.0^{c}
MA5	8.6±0.4^{bc}	37.4±0.2^{a}	24.8±3.4^{d}	7.5± 0.04^{b}	18.3±0.13^{ab}	6.00±0.1^{a}	0.66±0.01^{a}
MB1	12.2±0.5^{a}	33.6±0.4^{a}	12.4±0.1^{c}	7.2± 0.02^{b}	21.7±0.09^{a}	5.82±0.0^{a}	0.80±0.0^{d}
MB2	8.8±0.2^{bc}	35.1±0.2^{a}	19.1±0.6^{b}	6.8± 0.03^{ab}	20.2±0.08^{bc}	5.85±0.1^{a}	0.79±0.0^{d}
MB3	9.4±0.4^{b}	34.6±0.7^{a}	10.0±0.4^{f}	6.7±0.04^{ab}	21.8±0.18^{a}	5.90±0.1^{a}	0.78±0.01^{d}
MB4	7.6±0.2^{d}	37.2±0.2^{a}	22.9±2.1^{bd}	7.0±0.05^{b}	22.4±0.06^{a}	5.90±0.1^{a}	0.77±0.0^{d}
MB5	9.6±0.2^{b}	35.0±0.4^{a}	11.3±0.6^{fc}	6.2± 0.05^{c}	20.4±0.19^{c}	5.80±0.1^{a}	0.79±0.01^{d}
Lab1	11.3 ±0.1^{e}	34.5±0.2^{a}	7.8±0.1^{e}	8.4±0.01^{a}	28.0±0.03^{a}	5.44±0.0^{b}	0.74±0.02^{c}
Lab2	12.7±0.3$^{f\,a}$	34.3±0.3^{a}	8.9±0.8^{e}	8.1±0.02^{a}	28.6±0.12^{a}	5.55±0.1^{b}	0.70±0.02^{c}
Lab3	12.5±0.3^{fa}	35.1±0.1^{a}	7.0±0.7^{e}	8.0±0.05^{a}	28.3±0.03^{a}	6.05±0.1^{a}	0.60±0.01^{b}
Lab4	12.5± 0.4^{fa}	34.5±0.2^{a}	9.3±0.7^{e}	9.7±0.01^{b}	28.8±0.10^{a}	5.05±0.1^{d}	0.77±0.02^{d}
Lab5	12.9±0.1^{f}	34.4±0.6^{a}	8.3±0.4^{e}	8.3±0.02^{a}	27.6±0.03^{a}	5.75±0.1^{a}	0.63±0.02^{ab}

MA1, MA2….MA5: productions at Adjamé-Williasmville; MB1, MB2……MB5: productions at Cocody-Blokosso. Values are expressed as mean ± standard deviation (triplicate measurement). Mean values with same letter in a column are not significantly different (P > 0.05).

Table 3 Specific activity of alpha amylase extracted from sorghum malt (U/mg prot)

Production	**Undried malt**	**Malt**
MA1	3.47±0.02^{a}	0.96±0.01^{a}
MA2	2.78±0.01^{b}	1.40±0.1^{b}
MA3	2.79±0.01^{b}	1.72±0.01^{c}
MA4	3.43±0.01^{a}	0.90±0.01^{a}
MA5	3.11±0.01^{ab}	1.24±0.02^{d}
MB1	4.04±0.02^{c}	2.04±0.01^{e}
MB2	3.14±0.03^{ab}	0.87±0.01^{a}
MB3	3.10±0.02^{ab}	1.85±0.01^{e}
MB4	3.16±0.03^{ab}	1.94±0.01^{f}
MB5	3.36±0.02^{ac}	1.67±0.01^{g}
Lab1	3.99±0.02^{ac}	2.20±0.1^{h}
Lab2	3.63±0.63^{ac}	2.91±0.01^{i}
Lab3	3.70±1.20^{ac}	3.15±0.01^{k}
Lab4	3.55±0.17^{ac}	2.13±0.01^{l}
Lab5	3.53±0.03^{ac}	3.20±0.01^{k}

MA1, MA2….MA5: productions at Adjamé-Williasmville; MB1, MB2……MB5: productions at Cocody-Blokosso. Values are expressed as mean ± standard deviation (triplicate measurement). Mean values with same letter in a column are not significantly different (P > 0.05).

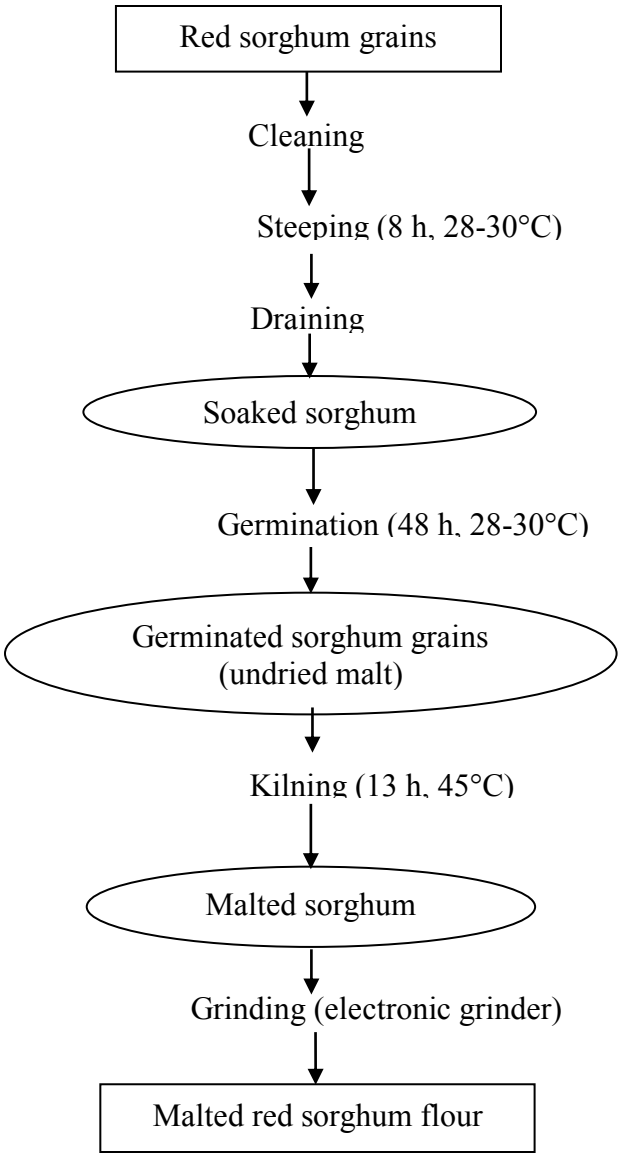

Figure 1 Flow diagram used for sorghum grains malting at laboratory scale

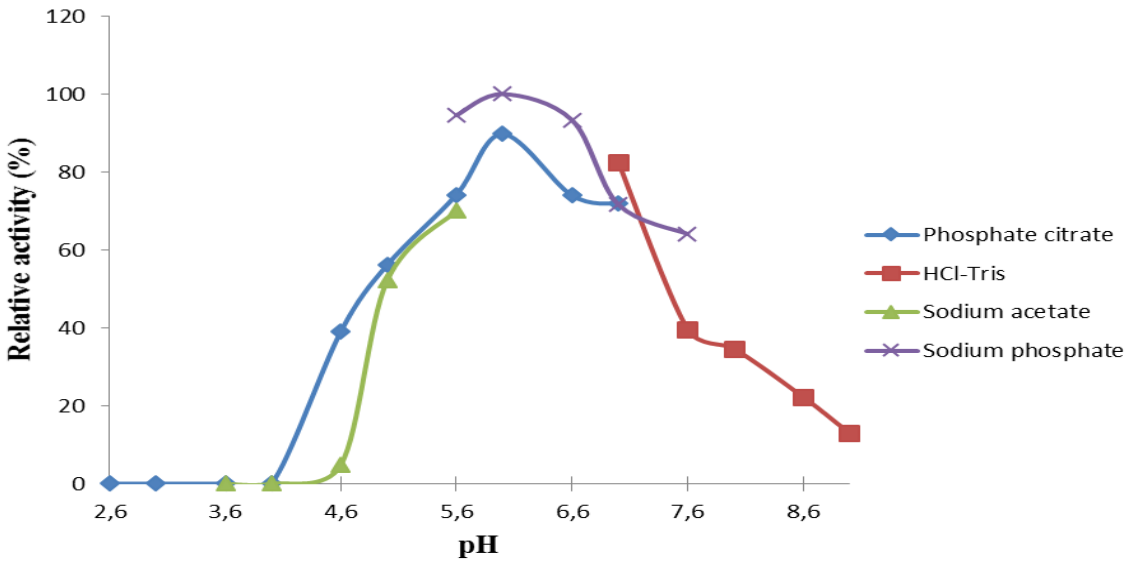

Figure 2 Effect of pH on amylase activity in crude extracts of sorghum malt

Conclusion

This study showed that for traditional sorghum beer brewing, processors produced malt based on their technological know-how. Thus, steeps duration varied from one production to another. This led to malted sorghum with significant differences in their moisture content, sugars contents, titratable acidity and amylase activity. But, malting at laboratory scale under controlled conditions gave malt with statistically similar values of moisture, total and reducing sugars. Moreover, under controlled conditions, malt quality was better than that produced by traditional processors. Therefore, it is advisable to control and optimize malting conditions with a view to maximizing malt quality need for beer brewing.

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