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Effect of Malting Time on Sugar Profile of Sorghum Flour

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Abstract

East African countries do not have sufficient local supply of cane sugar. The deficit is often bridged through sugar importation which negatively affects their economies. The malting process transforms the physical structure of grains, accompanied by synthesis and activation of a series of enzymes so that the final product is more readily used in food manufacturing. One of the changes that happen during the malting process is the hydrolysis of starch into simple sugars. Therefore, this process can be used to explore other sources of sugar apart from sugar cane in products made from cereals. In this study, red grain sorghum variety BJ 28, a dual-purpose variety suitable for grain and forage with a 7months maturity period and grows in an altitude range of 750-2300 MASL, was malted to evaluate changes in sugar profile for 9 days. The malted sorghum was analyzed for sugars, which were glucose, fructose, sucrose and maltose at 1-day intervals. The germination period showed a significant effect on the sugar profile of malted sorghum at $p \leq 0.05$. There was a significant increase in the sugar profile of sorghum malts from day one to nine. By the 9th day of malting, sucrose was the dominating sugar with a concentration of 2.952%, followed by glucose (0.518%), fructose (0.127%) and maltose (0.071%). This shows that malting can be used as an alternative to sugar cane in some products made from cereals.

Keywords: *Red sorghum, Malting, Sugar profile.*

Introduction

In East Africa like in some other parts of Africa, there is no self-sufficiency in sugar. As demand grows due to urbanization and rising incomes, imports of household sugar are increasing. Rwanda is among the least producers of refined sugar granules in Africa, has Kabuye Sugar Works (Kigali, Rwanda) as the unique sugar production industry with 17000 metric tonnes production capacity. Rwanda has deficient in sugar with 30% local production and 70% imported sugar [1]. In 2019 sugar production in Tanzania was estimated at 300,000 metric tonnes against a demand for 515,000 metric tonnes (a 40% gap) and the industrial sugar demand was 155,000 metric tonnes [2]. In Kenya 2019, sugar consumption in this country was approximately 1 million metric tonnes/year while the country imports between 350,000 metric tonnes and 400,000 metric tonnes [3].

The term malting is used to describe the process of preparation of raw materials for brewing and to a certain extent for use as an ingredient in foods preparation [4]. Malting process aims to convert and modify the physical structure of the grain which is accompanied by synthesis and activation of a series of enzymes so that the final product known as malt is more ready to be used in the subsequent stages of brewing, distilling and different food manufactures. Malts are obtained throughout a three-step process that involves steeping, germinating and kilning cereals under controlled conditions [5]. The modifications produced during the malting process include the partial degradation of the endosperm starch granules, protein bodies and protein matrix, increasing free amino acids and sugars. However, it appears that malting has little effect on the endosperm non-starch polysaccharide-containing cell walls [6]. Historically, malting also known as sprouting is a widely applied traditional technology in Africa. Specifically, the malting of sorghum is practised throughout sub-Saharan Africa for the production of traditional African beer and to some extent for use as an ingredient in porridge making [7].

Food beverages from sorghum become more nutritious when either malted or fermented [8]. Apart from nutritious food, sorghum has also great potential to be used in the brewing industry as a raw material. Sorghum grains can provide α- and β-amylases and other glucanases that mediate starch hydrolysis during germination [9]. In sorghum, α-amylase is the most important enzyme among all the malting enzymes and it accounts for about 75% of the saccharifying activity. The β-amylase content of malted sorghum is however relatively low compared to that of barley malt. Some South African sorghum cultivars have been reported to possess β-amylase activity that constitutes 18.39% of starch saccharification. The production of amylases and other diastatic enzymes during sorghum malting is influenced by ambient factors such as temperature, moisture and humidity. Although the temperature and soaking conditions that are optimal for the development of diastatic power in sorghum have been established, different durations of steeping and germination have been used for sorghum malting [10]. The objective of this study was to evaluate the effect of malting time on the sugar profile of sorghum flour treated in the same conditions apart from the duration of germination.

Materials and Methods

Acquisition of sorghum grains

Red grain sorghum variety BJ 28 (30kg) was purchased from a local market in Nakuru County, Kenya. The sample was collected in sacks, kept at room temperature (21°C) in a clean and dry place before analysis.

Preparation of sorghum grains and malting

The sorghum grains were sterilised to avoid the growth of mould [11] where samples were steeped in 0.2% NaOH solution for 4 h and then rinsed using three cycles of clean water to remove residual NaOH.

Sorghum malting was carried out according to [12] method with some modifications. Grains were soaked for 2 days in potable tap water at room temperature (21°C) in a stainless-steel container with water at 50 mm above the grain. During steeping, the grains were removed from the water for 30 min every 12 h for airing. After 2 days, the steeping water was drained. The hydrated sorghum grains were then transferred to other stainless-steel containers to continue the germination stage of which the containers were covered and kept for 1 to 9 days. During germination, the sorghum grains were agitated for aeration every 12 h. The germination was performed at room temperature (21°C). Every day of germination, at the time of aeration, a sample of 3kg malted sorghum was drawn and its germination stopped by drying in an oven at 50°C for 14 h.

At the same time of aeration, a 10g sample of the grains was taken to evaluate the number of germinated grains and the size of the root. All samples were separately milled using a laboratory micro-milling machine FZ102 made in China (Beijing) and flour of ≤0.5mm particle size from each sample was kept in separate polythene bags, labelled, sealed and stored at room temperature (21°C) for subsequent analysis.

Analysis of sugar profile

Samples of sorghum malts from day one to nine were analysed for sugar profile according to the [13] method 80-04-01 using a high-performance liquid chromatography (HPLC). The sugars analysed were glucose, fructose, maltose and sucrose in malted sorghum flours. An unmalted sorghum flour sample was used as the control. HPLC equipment Knauer made in Germany, Berlin City, equipped with Refractive Index Detector and column of Eurospher NH_2, a mobile phase of 78% acetonitrile with the flow rate of 1ml/minute and operating at a temperature of 40°C.

Statistical analysis

Data were analysed using analysis of variance (ANOVA) table to identify significant differences among the different malting periods using SAS software, General Linear Model (GLM) of Statistical Analysis Systems (SAS, 2009) computer package. Means were separated using Tukey's honest significance test at $p \leq 0.05$.

Results and Discussion

Sorghum grain roots showed after the first 24 hours of germination but were very small and it was difficult to separate the germinated and ungerminated grains. From day two to nine, the germinated grains could be separated from the ungerminated ones and the germination percentage has been calculated for each day. The results showed an increase in several germinated grains as shown in the following Table 1.

Table 1: Germination of sorghum grains.

	Day0 (%)	Day1 (%)	Day2 (%)	Day3 (%)	Day4 (%)	Day5 (%)	Day6 (%)	Day7 (%)	Day8 (%)	Day9 (%)
Germinated grains	0	DS	67.43	79.09	84.62	90.54	92.46	92.15	91.98	92.66
Ungerminated grains	100	DS	32.57	20.91	15.38	9.46	7.54	7.85	8.02	7.34
DS: Difficult to Separate										

The average length of the roots on day 2 to day 5 could reach 1cm considering the longest observed and they were having a white colour. From day 6 to day 9, the roots and the shoots could be identified by colour, root with brown colour and shoots with white colour. At these germination days, the length of the roots and shoots could reach 1.5 cm. The following Image 1 illustrates the appearance of sorghum grains at different malting days. Some of the grains have not germinated and this might be due to their physical conditions [14].

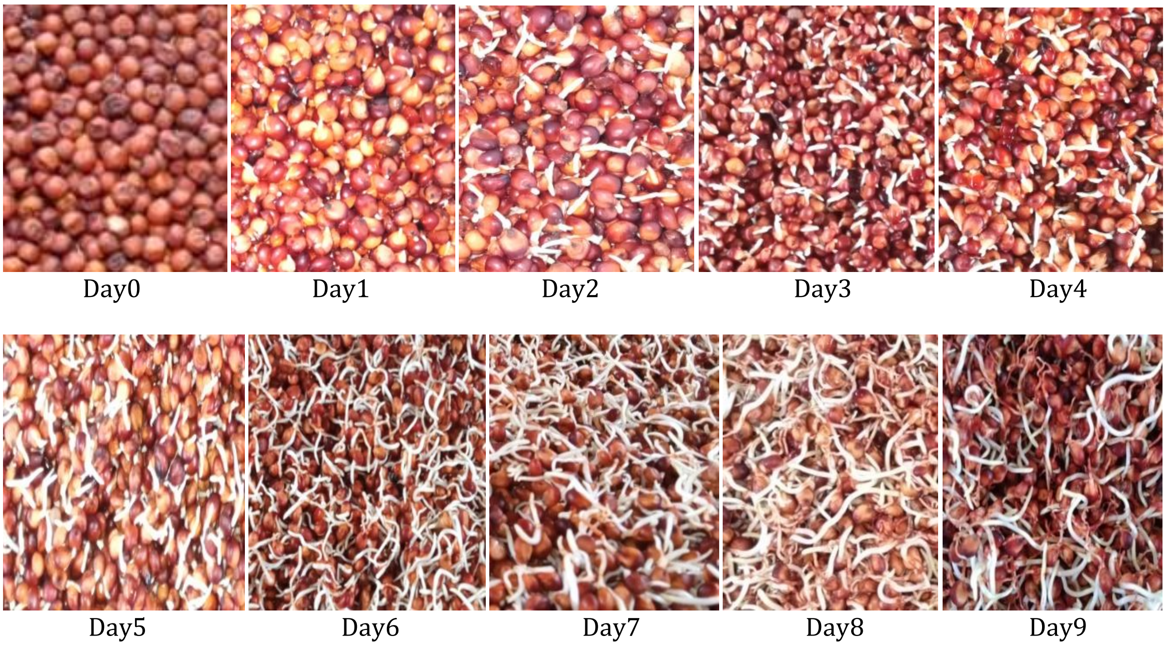

Image 1: Pictures of sorghum grains at different germination days.

The findings of the sugar profile analysis of malted flours for various times are shown in Table 2 for glucose, fructose, sucrose and maltose.

Table 2: Sugar profile of malted sorghum Flours.

Germination Days	**Sugar content**			
	Glucose % Dwb	**Fructose %Dwb**	**Sucrose %Dwb**	**Maltose %Dwb**
U S (DAY 0)	0.029±0.005^{c}	0.022±0.004^{b}	0.875±0.029^{d}	0.032±0.032^{b}
DAY 1	0.132±0.005^{bc}	0.105±0.001^{b}	0.947±0.032^{d}	0.031±0.006^{b}
DAY 2	0.3±0.04^{abc}	0.129±0.008^{b}	1.071±0.082^{cd}	0.071±0.026^{b}
DAY 3	0.344±0.011^{abc}	0.186±0.003^{b}	1.4±0.038^{cd}	0.361±0.04^{a}
DAY 4	0.502±0.08^{a}	0.541±0.024^{a}	1.551±0.019^{c}	0.122±0.07^{b}
DAY 5	0.145±0.028^{bc}	0.13±0.018^{b}	2.378±0.099^{b}	0.196±0.07^{ab}
DAY 6	0.404±0.03^{a}	0.113±0.001^{b}	2.268±0.004^{b}	0.089±0.002^{b}
DAY 7	0.47±0.057^{ab}	0.212±0.054^{b}	2.302±0.074^{b}	0.157±0.001^{ab}
DAY 8	0.468±0.069^{a}	0.196±0.047^{b}	2.537±0.09^{ab}	0.166±0.006^{ab}
DAY 9	0.518±0.013^{a}	0.127±0.029^{b}	2.952±0.026^{a}	0.071±0.016^{b}

Values are means ± standard deviation, n= 3. U S: unmalted sorghum, %DWB: percentage in Dry Weight Basis, values within the same column and having different superscripts letters are significantly different ($p \leq 0.05$).

The analysis shows that there is a significant difference in the sugar profile of sorghum flours malted for one day to nine days and for all sugars observed in the flours at $p \leq 0.05$, these sugars are maltose, sucrose, glucose and fructose. The increase is due to the enzymatic action in amylase and debranching of amylopectin [15]. Similar results have been observed by other researchers [16, 17]. The increase in glucose, fructose, sucrose and maltose concentrations may be seen clearly in Figure 1, which illustrates the above results on a chart diagram. The growth of mould by day nine, as shown in image 2, demonstrates that the sanitization performed at the start of the procedure was insufficient, and germination could not continue to avoid the production of mycotoxins-containing malt.

Image 2: Picture of sorghum grains at day ten, having some moulds(pointed by the arrow).

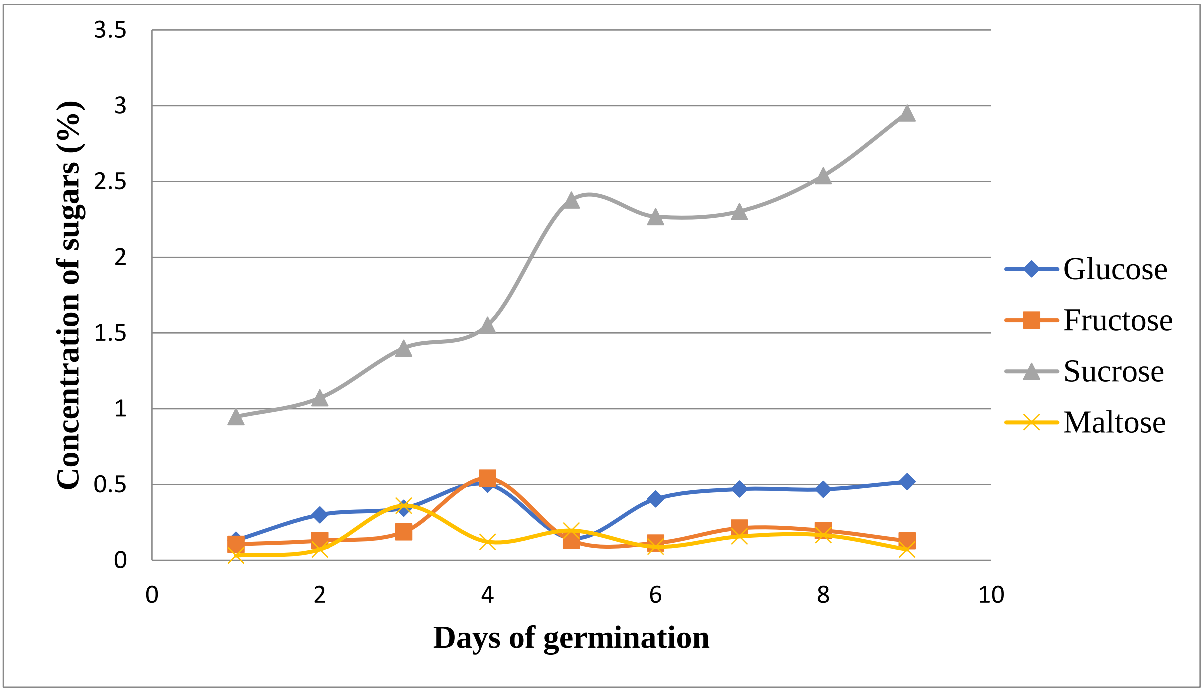

Figure 1: Concentration of sugars at different germination days.

Sucrose is the highest sugar observed in the experiment with a continuous increase in the amount from day one to nine, from 0.875% to 2.952%. According to studies [18], during germination, the actions of α- and β-amylase breakdown starch into primarily glucose and a small amount of other reducing sugar as well as non-reducing sugar, sucrose. And what makes more sucrose is the process by which glucose produced in the endosperm moves to the scutellum, where it is converted to sucrose. Sucrose is the form in which the carbohydrate is then transported to the growing sink tissues of the grains' roots and shoots. The concentration of glucose, fructose, and maltose is affected by metabolic reactions for the growth of roots and shoots, as well as the diastatic power of germinated sorghum, which reaches its maximum on day four and then decreases in subsequent days [10].

Conclusion

The sugar profile of malted red sorghum grains changes significantly with malting time. As days of malting increase, the sugar profile of the flour in terms of sucrose, glucose, fructose, and maltose contents increase. Sucrose is the dominant sugar in malted sorghum. Therefore, the malting of starch-rich cereal grains could be used to substitute for sugar cane, which has a high demand relative to production, particularly in developing nations.

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