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Physicochemical Characterization of Non-alcoholic Beverages Produced from Malted Roasted Varieties of Maize (*Zea mays*)

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Abstract Non-alcoholic malt beverages were produced with roasted malt from three maize varieties as *Local, Obatanpa* and *Yellow corn*. Chemical and physical properties of the beverages were determined by standard procedures for pH, titratable acidity (TTA), °Brix and colour. Acceptability test of the beverages was conducted using a trained laboratory-based panel of 20 members. The pH of beverage samples significantly differed ($p < 0.05$) among maize varieties and malting durations and ranged between 5.10 – 5.14 and 5.09 – 5.17 for the two treatments respectively. TTA was significantly different ($p < 0.05$) among the malting durations, with “96 hours malting” having the highest (0.19%). The TTA among the three varieties, however, was not significantly different. The °Brix increased as malting duration increased and colour were different ($p < 0.05$) among varieties and malting durations. Maillard and caramelization reactions, which occurred during roasting of the maize malts resulted in darkening of the non-alcoholic beverage and this was reflected in the low L* colour descriptor values. Sensory evaluation revealed significant differences between beverage samples malted over different periods. Chemical and visual properties of the non-alcoholic beverages from roasted maize-malt compared very well with those typical of other non-alcoholic malt beverage. Thus, roasting is a good unit operation to replace caramelization of sugar in the production of malt beverage from maize.

Keywords Non-alcoholic beverage, pH, Roasted maize malt, Titratable acidity, °Brix, Colour, Acceptability test

1. Introduction

Beverages are convenient and widely accepted for their thirst-quenching and refreshing properties as well as their ability to provide the needed energy for the body. They are produced from a wide variety of raw material of both plant and animal origin including fruits, vegetables as well as cereal grains, which provide proteins together with vitamins and minerals[1]. Beverages produced from cereal grains, both fermented alcoholic and non-alcoholic variants are consumed globally[2].

Cereals for use in beverage production are usually sprouted and dried in the process known as malting[2]. This modifies the grains physically, chemically and biologically[3. 4]. Desirable changes such as the hydrolysis of starch and protein into sugars and amino acids, respectively that occur in malted cereals used for the production of beverages and other cereal-based food have been widely studied[3-10]. Although the application of malted maize as a major source of hydrolytic enzymes for commercial brewing is not widely considered, its use in traditional non-alcoholic beverage production in Ghana is quite familiar. Customary non-alcoholic cereal beverage such as *ŋmadaa* (also *Ahei*, *Asana* or *Liha*) is processed from malted maize[11]. At the final stages of the production of these drinks, caramel is added to enhance flavour and give the dark brown colour characteristic of most malt beverages[11].

Roasting exposes food to dry heat for short periods and is known to impart desirable attributes. These pleasant qualities include texture[3], colour and flavour through the development of Maillard reaction products[12]. Other reported modification in roasted products include changes in amino acid profile in coffee[13], vitamins in barley malt[7], pasting, texture and thermal properties in barley[14]. Roasting of malt had been applied in brewing for colour and aroma development in beer[15]. A similar application to malted maize would subsequently improve the colour and enhance the flavour, aroma and other sensory characteristics of its non-alcoholic beverage. Adopting roasting would also eliminate the health risks associated with caramel usage and reduce the cost involved in producing the beverage. The objective of this study was to produce a non-alcoholic beverage from roasted maize malt without the addition of caramel, determine its physicochemical properties and assess its acceptability using a laboratory-based panel.

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2. Materials and Methods

2.1. Raw Materials and Initial Treatment

Three varieties of maize as *Local, Obaatanpa* and *Yellow corn* were procured from the Madina market in Accra, Ghana for the study. These varieties were selected based on availability, affordability and their application in the production of *ŋmadaa*: a traditional maize malt beverage. The grains were sorted and winnowed of all foreign materials; grain stalks debris and remaining cob parts. The different maize varieties (4.0 kg of each) were steeped at room temperature (28°C) in tap water (1:2 w/v). The setup was stirred once after 12 hours of steeping. After 24 hr of steeping, the steep water was drained off together with remaining chaff and other floating foreign material. After steeping, the weights of the maize varieties were 6.1, 5.8, 5.8 kg for *Local, Obaatanpa* and *Yellow corn*, respectively. Four units, each weighing 1.4 kg, from each variety of maize were germinated for 24, 48, 72 and 96 hr.

2.2. Malting and Roasting

Sprouting of the grains was done at room temperature (28°C). The units (1.4 kg/unit) from the three varieties of maize were malted on mica surface covered with moist towels. The towels were remoistened with 200 ml of water sprinkled twice daily at regular intervals to keep the grains moist and active and prevent mould growth. After germinating for stipulated time (24, 48, 72 and 96 hr) each unit of experimental setup was dried in a convective dryer (Apex B35E, London) at 50°C for 18 hr and the vegetative parts were removed by rubbing grains between the palms. The dried malted grains were then roasted in an electric oven at 225°C (General Electric, USA) for 10 min stirring it intermittently. The roasted grains were cooled, milled into grits (Cemotec, 1090 Sample Mill, Sweden) and packaged in high density polyethylene bags.

2.3. Mashing

Roasted malted samples from each variety were mashed in cold water (24.9°C) at 1:4 w/v and warmed at 65°C for 5 min. The mash was made to stand for 10 min to allow for sedimentation before it was filtered by gravity using a cheese cloth.

2.4. Formulation and Bottling

Using sucrose as sweetener, the Pearson-square method was used to adjust the °Brix of the final malt beverage to 10° for samples whose °Brix was lower than the desired °Brix of 10 – 12°. The formulated malt beverage was then pasteurized at 75°C for 10 min in batches, using stainless steel pans. Immediately after pasteurization, the beverages were bottled hot and the bottles laid on their side for rapid cooling.

2.5. Colour

Colour of the samples was determined using a Minolta Chromameter (CR-310, Japan). The colour values were expressed as L* (whiteness/darkness), a* (redness/greenness) and b* (yellowness/blueness). The variation of colours were characterised by the total colour difference (ΔE), which was calculated from the Hunter L*, a*, b* values using equation 1[16].

$$\Delta E = (\Delta L^2+\Delta a^2+\Delta b^2)^{1/2} \text{.................Equation 1}$$

2.6. pH, °Brix and Titratable Acidity

The pH of malted roasted beverage was measured using a pH meter (Jenway 3330, England) and °Brix was measured using a hand-held refractometer (HANNA RB 32, Germany). The titratable acidity was determined using titrimetry[17]. Malted roasted beverage sample was titrated against NaOH (0.1N) using phenolphthalein as indicator to a faint pink endpoint and total acidity expressed as percent of malic acid equivalent.

2.7. Sensory Analysis

Trained laboratory-based panel of 20 members with previous experience in sensory evaluation assessed beverages in an acceptance test[18]. Beverages were presented in identical containers labeled with a different 3-digit code, to panelists. They were asked to indicate their overall acceptability of samples in their preferred choice of order on a 7-point Hedonic scale that ranged from “Like very much” (7) to “Dislike very much” (1). Panelists were instructed to rinse their mouths with water before evaluating subsequent samples. A serene atmosphere of good lighting and ventilation, as well as quietness was provided for panelists to conduct the evaluation[19].

2.8. Statistical Analysis

The experiment was set up in a 2-way factorial analysis using three varieties of maize and four malting durations. ANOVA of the results was done using Statgraphics Centurion 16.1.11 (StatPoint Technologies Inc, USA, 2010) to compare means. Least Significant Difference (LSD) test was used to examine multiple comparisons between means at 5% significance level. All determinations were done in triplicates and data reported as Means ± Standard Error.

3. Results and Discussion

3.1. pH, °Brix and Titratable Acidity

Non-alcoholic beverages from malted roasted *Obatanpa* variety generally had significantly higher ($p < 0.01$) pH, followed by *Local* and *Yellow corn* (Table 1). There was also a significant effect of the duration of malting on pH of the beverages ($p < 0.01$). *Post hoc* test (LSD) revealed that malting for 72 hr lowered the pH more than malting for 24, 48 and 96 hr. Interestingly, malting for 24 and 48 hr had the same effect on the pH of the beverages, while malting for 96 hr reduced the pH of the beverages the least. Furthermore, the interactive effect of malting time and maize variety had a significant effect on the pH of malt beverage samples ($p < 0.01$).

Table 1. Means for pH, °Brix and titratable acidity of non-alcoholic beverages produced from malted roasted varieties of maize

		Mean		
Variety	Duration of malting (hr)	pH	°Brix	Titratable acidity (%)
Obaatanpa				
	24	5.21±0.00^{a}	3.2±0.2^{a}	0.07±0.00^{a}
	48	5.11±0.00^{b}	4.0±0.2^{ab}	0.10±0.00^{a}
	72	5.19±0.00^{b}	5.0±0.6^{b}	0.22±0.02^{b}
	96	5.16±0.00^{c}	8.0±0.0^{c}	0.18±0.08^{b}
Local				
	24	5.18±0.00^{a}	4.2±0.0^{a}	0.08±0.02^{a}
	48	5.13±0.00^{b}	5.0±0.2^{ab}	0.08±0.02^{a}
	72	5.05±0.00^{b}	5.2±0.2^{b}	0.10±0.00^{b}
	96	5.10±0.02^{c}	9.2±0.0^{c}	0.20±0.04^{b}
Yellow Corn				
	24	5.01±0.00^{a}	4.8±0.4^{a}	0.08±0.02^{a}
	48	5.14±0.00^{b}	4.2±0.0^{ab}	0.08±0.02^{a}
	72	5.05±0.01^{b}	6.0±0.2^{b}	0.13±0.00^{b}
	96	5.16±0.00^{c}	12.4±0.2^{c}	0.17±0.00^{b}

Mean ± standard error within each column followed by different superscripts is significantly different at *($p < 0.05$)*

All the beverages showed pH values of low acid foods (less than 4.5) similarly to that reported by Karel and Lund[20]. The pH of the malted roasted beverages was generally higher than that obtained by Hosseini *et al.*,[21] for malt beverages from barley and oats (pH 4.01) and Obuzor and Ajaezi[22] for some commercial carbonated non-alcoholic malt beverages (pH 4.4 – 4.6). However, the pH of the malted roasted beverages compares pretty well to the general pH range of 3.5 - 5.0 suggested for malt beverages by Jaganathan and Dugar[23]. The pH of the beverages was not lower because the beverages were not carbonated.

Titratable acidity for the roasted malt beverages for the different malting durations varied from 0.07% to 0.22 % ($p < 0.00$), indicating a significant increase in TA with an increasing duration of malting. Among the varieties of maize used, titratable acidity did not significantly differ ($p < 0.37$). The combined effect of malting duration and variety did not significantly affect the °Brix ($p < 0.31$).

Beverage from *Obaatanpa* malted for 96 hr did not follow the trend of increasing titratable acidity observed in the other varieties over the four different malting durations although the TTA for 72 hr was not significantly different from TTA for 96 hr (Table 1). This is probably due to different malts of different maize varieties having different organic acid composition/content. Further, roasting may have affected the formation of organic acids and could therefore have influence on the TTA of the final malt beverage. Even though slight roasting has been demonstrated to favor the formation of certain organic acids[24] and decrease pH, extensive roasting has been found to increase pH as a result of the breakdown of organic acids, especially the volatile ones[25]. The relationship between beverage pH and TTA, albeit not clearly predictable was inconsistent with the positively correlated one that exists between these two indices for other products.

Generally, samples from *Yellow corn* had the highest °Brix, while *Obatanpa* had the lowest. A general trend of increasing °Brix was observed as the malting duration increased from 24 - 96 hr ($p < 0.00$), however, there was no significant difference between malting for 24 hr and 48 hr. Also malting duration and variety when combined was found to significantly affect the °Brix of the resulting malt drink. Apart from malting for 48 hr, where Y*ellow corn* had the highest °Brix, *Local* showed a gradual increase in °Brix from 24 – 96 hr of malting

The increase in °Brix for malting from 24 – 96 hr, which is related to an increase in amount of maltose, is an indication of the extent of partial breakdown of endosperm starches as sprouting progresses because of increasing enzyme development[8]. The mean °Brix of 5.4 for the malt drink from 72 hr malting compared flavouably with Hosseini *et al.*,[21], but 96 hr of malting resulted in higher °Brix. However, °Brix results were lower than a contemporary non-alcoholic beverage[26]. The °Brix of beverage samples from 96 hr malting had a mean °Brix of 9.9 and so did not mandatorily need an upward adjustment with a sweetener, since it was greater than the °Brix requirement (not less than 8°) for non-alcoholic beverages, assigned by the Ghana Standards Authority[27].

3.2. Colour

Colour is an essential quality attribute that influences consumer judgment and preference of food. Colour indices (L*, a*, b* and ΔE) showed significant differences among varieties as well as the various malting periods, as shown in Table 2. The interaction term (malting duration and variety) of ANOVA for colour parameters also showed significant differences ($p < 0.00$). Variations in the colour of the beverages reflect the extent of colour development that occurred in their respective malts during roasting.

Table 2. Colour of non-alcoholic maize-malt beverages

Variety	Duration of malting (hr)	Mean				
		L*	a*	b*	ΔE	Preference
Obatanpa						
	24	49.29±0.89^{a}	5.03±0.18^{a}	11.87±0.18^{a}	50.61±0.83^{a}	3.8±0.4^{bc}
	48	46.62±0.12^{b}	7.76±0.09^{b}	9.62±0.23^{b}	52.60±0.14^{b}	5.1±0.3^{c}
	72	42.75±0.04^{c}	6.92±0.09^{c}	12.26±0.16^{c}	55.08±0.05^{c}	2.3±0.6^{a}
	96	50.07±0.20^{d}	4.71±0.15^{c}	13.91±0.21^{a}	50.54±0.22^{d}	3.1±0.5^{b}
Local						
	24	49.72±0.03^{a}	5.79±0.05^{a}	12.56±0.04^{a}	49.69±0.25^{a}	4.1±0.3^{bc}
	48	47.24±0.62^{b}	9.42±0.72^{b}	12.33±1.40^{b}	51.81±0.23^{b}	5.4±0.5^{c}
	72	43.04±0.11^{c}	5.52±0.07^{c}	12.38±0.10^{c}	53.92±0.13^{c}	1.5±0.3^{a}
	96	46.28±0.42^{d}	7.39±0.30^{c}	10.17±0.53^{a}	50.39±0.31^{d}	3.0±0.6^{b}
Yellow corn						
	24	51.78±0.29^{a}	5.28±0.39^{a}	13.46±1.85^{a}	50.42±0.02^{a}	4.3±0.3^{bc}
	48	48.02±0.38^{b}	8.79±0.90^{b}	10.43±1.12^{b}	52.31±0.19^{b}	2.7±0.5^{c}
	72	44.50±0.13^{c}	6.64±0.86^{c}	13.59±1.86^{c}	54.79±0.11^{c}	1.6±0.3^{a}
	96	51.26±0.75^{d}	6.22±1.19^{c}	13.49±2.75^{a}	53.06±0.44^{d}	4.4±0.5^{b}

L*(whiteness/darkness), a*(redness/greenness), b*(yellowness/blueness), ΔE (mean colour difference)
Mean ± standard error within each column followed by different superscripts is significantly different at ($p < 0.05$)

The L* values for the malt beverage, which is indicative of lightness or darkness of the product ranged between 42.75 (72 hr *Obatanpa*) and 51.78 (24 hr *Yellow corn*) with significant differences among the varieties ($p < 0.00$) and malting durations ($p < 0.00$). A decreasing trend of L* values runs along all the varieties from 24 hours to 72 hr of malting (Table 2). This is due to the extent of Maillard and or caramelisation that might have taken place during roasting[28] which ultimately affected colour development. Higher concentration of reducing sugars greatly favours brown colour formation in the Maillard reaction[29 - 31] and therefore higher °Brix resulted in greater colour development. However, beverage samples from 96 hr malting did not conform to this trend although the samples had higher °Brix and were expected to manifested in a darker roast and hence the least L* values. Factors such as moisture and water activity may have affected the Maillard reaction and color formation subsequently in the malts of this group of beverage samples.

The brown colour of the samples also had hues of yellow and red, which are exhibited in the positive (+) a* and b* values. In all cases +a* values were less than +b* values indicating a drift towards a yellow hue in beverage samples (Table 2). Beverage samples from *Yellow corn* generally showed much yellow hue because they had higher mean +b* values compared to the other two varieties, because of the intrinsic yellow colour of that maize variety.

Total Colour Difference (ΔE) showed significant differences between varieties ($p < 0.00$), between malting durations ($p < 0.00$) and a combination of variety and malting duration (interactive term) ($p < 0.00$). As shown in Table 2, it ranged from 49.69 to 55.08. The samples were different in visual appearance as a result of the variations in ΔE among them. The variation in ΔE shows the different extents to which Maillard and or caramalization reactions occurred in maize malts during roasting and caused darkening or malts and hence drink samples. The extent of browning reactions is affected by factors such as temperature, pH and amino nitrogen-reducing sugar ratio[29, 32].

3.3. Sensory Evaluation

Results of the acceptability test showed similarities between the three varieties of maize used as no significant differences existed between them ($p < 0.72$), an indication that any of the three varieties could be successfully applied in producing non-alcoholic malt beverage. However, on the Hedonic scale *Local* and *Obatanpa* had a mean score of 3.5 and 3.6, respectively suggesting that they were liked slightly, while *Yellow corn* was neither liked nor disliked as it retained a mean score of 3.3. This variety of maize has been shown to contain high levels of polyphenols and other compounds[33] and these may have imparted some bitterness and influenced some sensory attributes negatively hence beverages from this variety being the least acceptable by the 20-member panel.

The test rather showed differences ($p < 0.00$) among samples malted to different extents. Malting beyond 48 hr did not contribute positively to acceptability of the beverages since those from 48 hr malting, averagely had higher acceptability rating than 24 hr malting, 96 hr malting and 72 hr malting notwithstanding the fact that 96 hr malting resulted in the highest Brix (Table 2; Figs 1, 2). This shows that the acceptability of the beverages is not based on its Brix alone but a combined effect of several attributes.

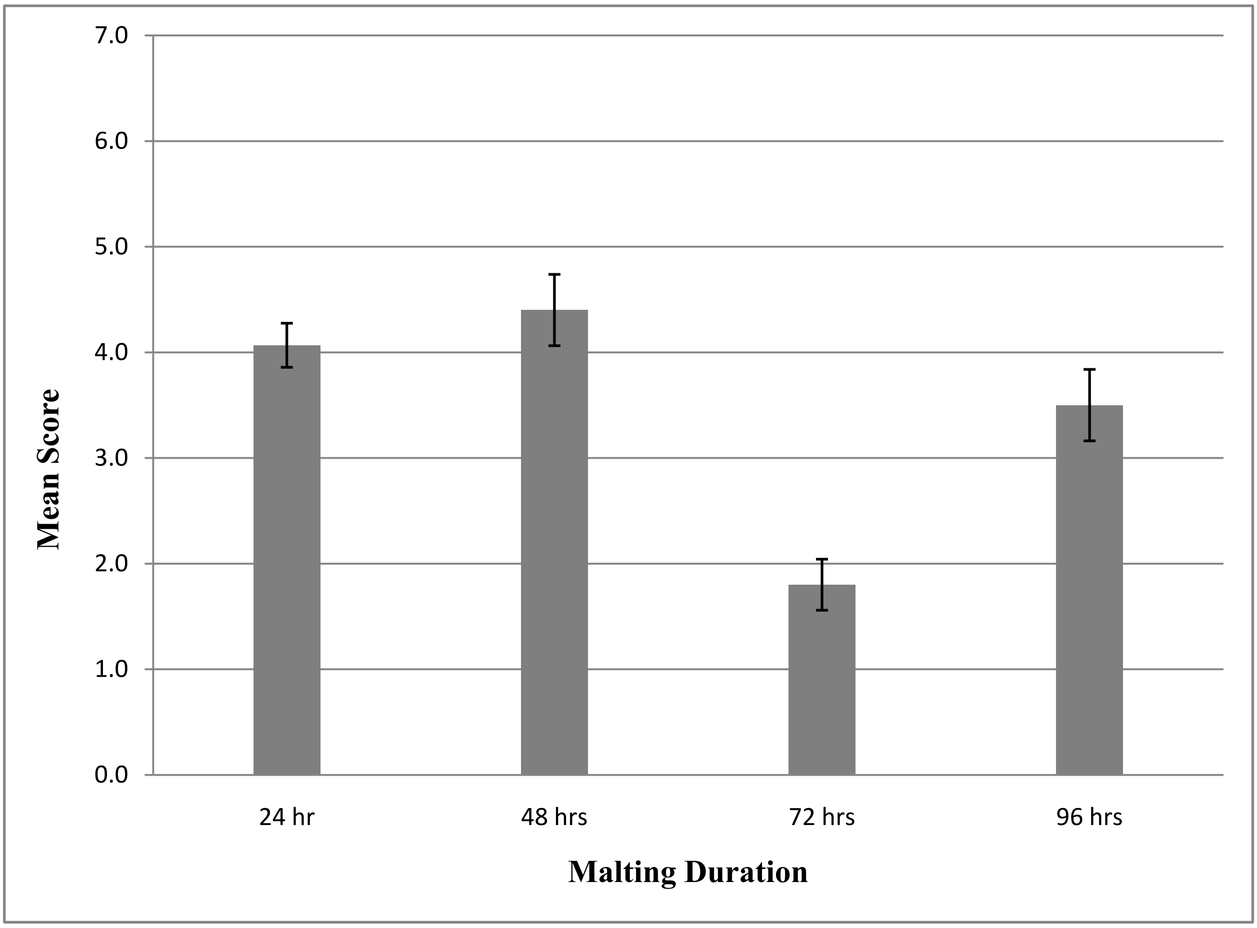

Figure 1. Mean Score of beverage samples from different malting duration

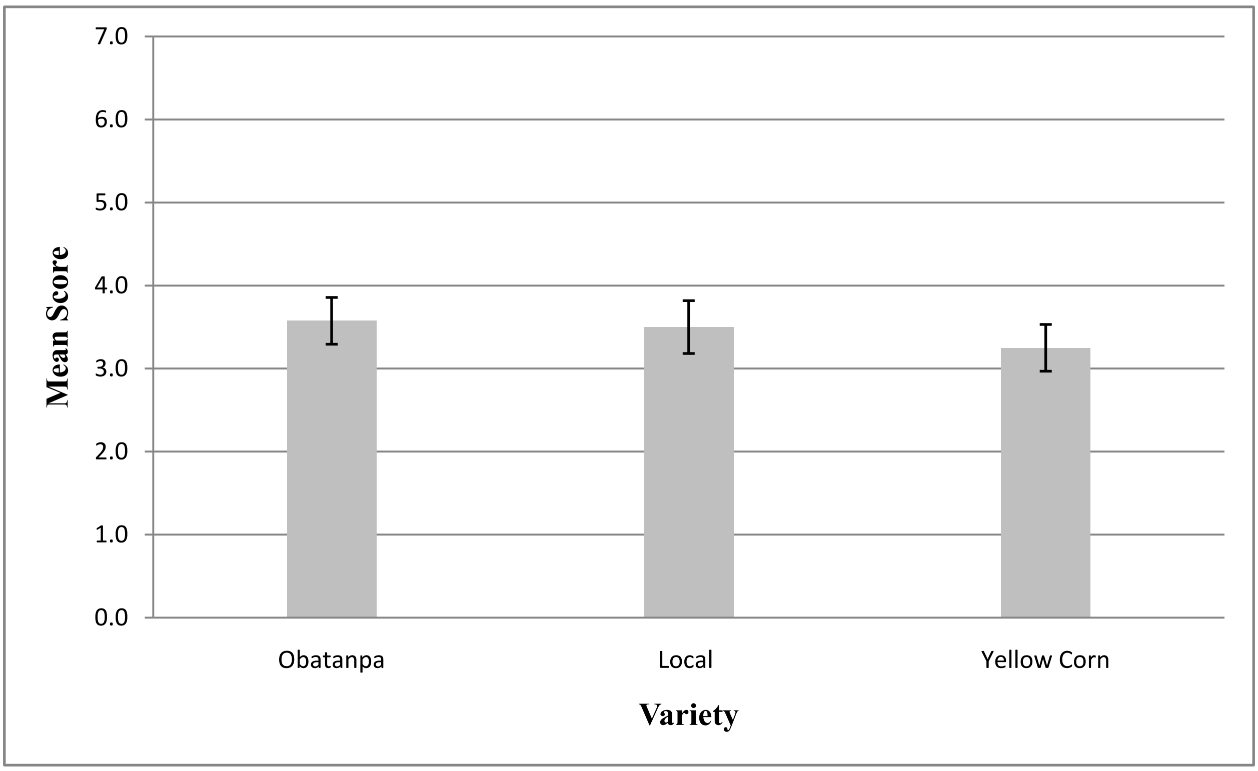

Figure 2. ANOVA Score by variety of the maize

4. Conclusions

This study has shown that roasting can be applied to give malted beverages its characteristic color, rather than relying on commercial caramel. The beverages had the dark brown colour that characterizes malt beverages because of the Maillard and/or caramelization reactions that occurred as a result of roasting of the maize malt. The beverages pH, which were significantly ($p < 0.05$) influenced by the duration of malting ranged from 5.01 to 5.21. The °Brix and TTA of the beverages ranged between 3.2 – 12.4 and 0.07 – 0.22 %, respectively. These two indices were found to increase with an increase in malting duration. Colour parameters of the beverages also differed significantly ($p < 0.05$) according to variety and malting duration. Beverages from *yellow corn* were the least preferred among the three maize varieties and beverages from 48 hr malting were the most acceptable by the sensory panel.

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