Malt quality characteristics of selected maize varieties

Abstract

In tropical and sub-tropical regions, the cultivation of barley is generally very limited and far less viable for brewing. This study was intended to investigate the potential of released maize varieties for malt purpose. Seventeen released maize varieties were collected from Bako, Ambo and Melkassa Agricultural Research Centers. The varieties were investigated for the most critical chemical compositions, germination test and malt quality. AMH-851 variety had the highest crude protein and ash contents. The highest moisture absorption (49.2%) and germination energy (82%) was noticed in MK-1 maize variety. Insignificant variation and less malting loss (0.7g) was noticed for MK-141 and BH-661 varieties. A significant increment in protein content was observed in maize malt compared to the un-malted grain. AMH-851had the highest (13.8%) and MK-2 showed the lowest (11.2%) malt protein content and the highest kolbach index. In its coarse and fine extract contents, BH-661 (69.93%) and BH-540 (69.29%) varieties had the highest and did not show a significant variation. A range of 6.8 to 29.07 wk enzymatic activity was observed among the selected maize malt with the highest for AMH-851 followed by BH-547 and the lowest for Limu variety. It was noticed that maize grains grown in intermediate agro-ecology could be used as potential malt for brewing purpose.

Key words: Extract; Maize; Malt quality; Variety**;** Wort.

Introduction

Brewing began in the Middle East 10,000 years ago (Fox, 2020). Beer is the third most popular drink in the world and probably the oldest most commonly consumed low alcoholic beverage next to water and tea (Habschied et al., 2020; Humia et al., 2019; Rošul et al., 2019). Since ancient times, malt produced from barely has been considered as the best and major raw material for alcoholic beverage production. In the tropical regions, however, the cultivation of barley is generally limited. Compared to maize, rice and sorghum, it is less viable (Sots & Bnyiak, 2018).

The increase in beer production, the limited production of malt barley and advancements in brewing technology has led brewers to use unconventional malted grains. This resulted in the increment of lager beer brewing using high proportions of other cereals (Taylor et al., 2013). For instance, rice in Asia, maize in America, and millet and sorghum in Africa are used (Chaves-López et al., 2020; Zhang & Xu, 2019). Chaves-López et al. (2020) revealed that government policies to replace imports and support local producers, consumer demand for unique and high quality, distinctive taste and aroma, reduced processing cost, the development of gluten-free beer, and demand for functional beer are identified as factors that have been contributing to other grains utilization. This shift is due to some restrictions and bans imposed by the government. For example, in Nigeria, a temporary ban on barley and barley malt imports from the mid-1980s to 1999 has resulted in the continuing general use of sorghum and maize in lager beer brewing (Taylor et al., 2013). Besides, consumers always look for new products with a novel brand, an original taste, eye-catching packaging, innovative technology, health benefits, and quality improvements (Betancur et al., 2020; Chetrariu & Dabija, 2020; Donadini et al., 2016).

Today, there are several totally non-barley lager beers being brewed across the world, such as Eagle in Africa, and Red bridge and Bard's Tale in the USA (Dufour et al., 1992; Taylor et al., 2013). Malts from wheat, sorghum and finger millet have been tested for their malting efficiency and as adjuncts in brewing (Odo *et al*., 2016). Sorghum and maize are usually used adjuvants in Europe as alternatives for malt (Bogdan & Kordialik-Bogacka, 2017; Hernández-Becerra et al., 2020; Rocha Dos Santos Mathias et al., 2019). Malted maize and sorghum along with the barley malt are in use in the production of some brands of beer (Muñoz-Insa et al., 2013a). Malt is the product of germination under controlled conditions. Malt syrup or malt extract is the viscous concentrate of the water extract of the malt which contains varying amounts of amylolytic enzymes that is subsequently used in the production of malt beverage (Oyewole and Agboola, 2011). The relatively high nutritional value of malt is based on its easily digestible carbohydrate, low sucrose content, enzymatically hydrolyzed proteins, vitamins and highly distinctive flavour and aroma compounds (Eneje et al., 2004).

In malting, the major process are steeping, germination and kilning of the grains; and the prime objective is to stimulate the development of hydrolytic enzymes that are inactive in the raw seeds (Ayernor and Ocloo, 2007; Oyewole and Agboola, 2011). During malting, the seeds undergo various changes such as increase in the quantities of amylase enzyme present in the grain and partial degradation of the cell wall, gums, protein, and starch (Ayernor and Ocloo, 2007; Oyewole and Agboola, 2011). Nonetheless, there are some limitations in the use of these cereals. Comparatively, amylase production during germination of cereals is lower than that of barley (Muñoz-Insa et al., 2013b). In addition, maize has no husk which acts as filter aid. Researches revealed that malting losses were very high in these tropical grains (Oyewole and Agboola, 2011). Eneje et al. (2004) and Oyewole and Agboola (2011) studied the relative malting qualities of rice, sorghum, millet and maize and reported that the malts from maize, which has some similarity to barley in some compositional traits could be used as a malt substitute for brewing.

In Ethiopia, the number breweries are increasing. Currently, a total of twelve brewery plants are found in the country. However, the production of malt barley is limited to Arsi, Bale, Central Highlands and North Western part of the country and still could not fulfill the demand of these breweries. Because of this, beverage industries particularly the beer industries are facing a problem of significant amount of malt barley in their stock. As a result, the country which is endowed with good weather for production of malt barley is forced to spend its hard currency for importing malt barley. In order to end the import and help the farmers to earn better income, the government along with the breweries has been promoting the local production of malt barley. However, still Ethiopia did not end the import of malt barley. Replacing malt barley with other grains like maize has a significant contribution particularly in the tropical regions and could encourage the use of cheap and locally available materials. Thus, looking for other starch source grains to replace partially or completely malt barley to produce beer is essential. Hence, this study was aimed to investigate the malting potential and malt quality attributes of released maize varieties grown in different agro-ecologies of Ethiopia.

Materials and Methods

Sample collection and preparation

A total of seventeen released maize varieties grown in 2020/21 growing season were used in this study and the samples of maize were collected from Bako, Ambo and Melkassa Agricultural Research Centers. Samples were packed in polyethylene plastic bag and transported to the Food Science and Nutrition Research. There was no visible damage to the grain and the samples were freshly harvested grains. The samples were cleaned by hand to remove any foreign matters that come along with the maize and visually inspected in order to remove any physically damaged maize, damaged seed coat; fade color and rinsing with tap and distilled water, the grains were spread on a clean surface layered with soft absorbent paper and allow drying at room temperature overnight. For each variety, a random sample of 1 kg cleaned maize sample was taken for the study.

Research design

There were seventeen treatments in this study. Varieties were considered as experimental treatments. A completely randomized design was used.

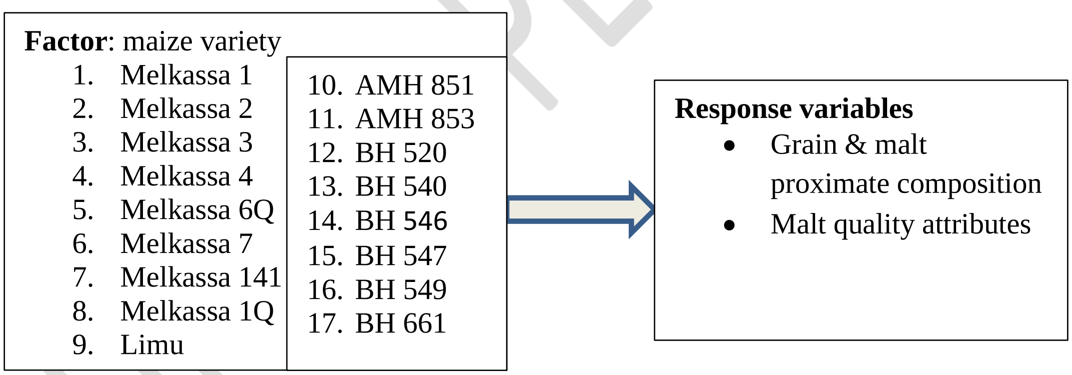

Image 1 : completely randomized design

Maize grain quality analysis

Grain moisture content determination

The moisture content of maize grain was determined by drying 2 g of sample in a hot air oven at a temperature of 105±2 °C till constant weight was obtained (AOAC, 1995). The moisture content was calculated as follows:

$$\text{Moisture content (\%)} = \frac{(\text{Weight before} - \text{Weight after})}{\text{Total weight}} x100$$

Grain protein content determination

Grain crude protein content (%) was determined by micro-Kjeldahl method of nitrogen analysis as described by AOAC (1995). In brief, 1 g ground sample was measured and transferred into completely dry Kjeldhal flask and 7 g of catalyst (KSO_4 & $CuSO_4$) was added to the sample inside the flask. And then, 10 mL of concentrated sulphuric acid was added and mixed with the sample and the digestion goes on until the solution was become clear. Then, the mixture was cooled and 100 mL of distilled water and 70 mL of sodium hydroxide (45%) were added and then distilled into 25 mL of excess boric acid containing 3 mL of mixed indicator. The distillate was titrated with 0.1 N hydrochloric acid to the red end point.

Crude Protein was calculated by multiplying percentage nitrogen in the flour sample by 6.25.

$$\text{Total Nitrogen (\%)} = \frac{(V_t - V_b) * 14}{W}$$

Where: W is weight of the sample taken for analysis, V_t is volume of HCl used for titration

V_b volume used for titrating blank

Maize malting method

All the maize malting procedure was performed according to the recommended methods of the Institute of Brewing (1989).

Grain steeping and germination

About 50 g of maize grains were steeped in 100 mL distilled water to bring a grain–water mixture ratio of 1:2. The steeping process was carried out for 24 h at room temperature. The steeping water was changed at 6 h intervals to minimize microbial contamination. After steeping, the steeped grains were forced for germination for 3 days using petri dish in a laboratory. During germination, the grains were regularly sprinkled with water, mixed and turned in order to achieve uniform temperature and moisture levels.

Kilning

The germination stage was terminated by drying (kilning) the seedlings in a thermostatically controlled hot-air oven, preset at 50 °C until the moisture content of the malt reached to the maximum recommended range (5.8%). Kilning was done for 72 h, after which both the radicle and plumule was manually removed.

Maize malt quality analysis

Degree of steeping

The degree of steeping (DS) of the grain varieties was estimated according to the modified Bernreuther apparatus method reported by Kunze (2004). Grain sample of known moisture content was weighed into the apparatus and steeped along with it for ease of draining excess water. At the end of the steeping process, the weight of water absorbed, X in g was calculated from the equations below:

$$\text{DS (g)} = \frac{w1(w0(w2 - w1)}{w2}$$

Where: w1= weight of grain before steeping in g,

w2= weight of grain at the end of steeping in g, w0= initial weight of water in grain before steeping in g calculated as follows:

$$\text{w0} = \frac{moisture\ content\ of\ sample\ in\ \%}{100}$$

Thereafter, the degree of steeping/attained moisture level, Y in % was calculated as follows:

$$\text{Y (\%)} = \frac{X}{W1} * 100$$

Where: X = weight of water absorbed at the end of steeping in g, w1= weight of grain sample before steeping in g.

Germination energy

Fifty grains were distributed evenly on the whole surface of germination plate. The plate was moistened with distilled water and then the non-germinated grain was removed and counted after 72 h of germination period.

The germination energy was calculated as follows:

$$\text{Germination energy (\%)} = 100 - \text{n}$$

Where; n is the number of non-germinated grain during germination.

Malt moisture content determination

Accurately 2 g of well-mixed sample was weighed in dried aluminum can. The contents were dried 1 h in oven provided with opening for ventilation and maintained at 130 ± 2 ^{0}C. The dish covered while still in oven, transferred to desiccators and weighed soon after reaching room temperature. The moisture content was calculated from loss in weight.

$$\text{Moisture content (\%)} = \frac{(\text{Weight before} - \text{Weight after})}{\text{Total weight}} * 100$$

Malt protein content

AOAC (1990) method was used for protein analysis. In brief, 1 g ground sample was measured and transferred into dry Kjeldhal flask and 7 g of catalyst (KSO_4 and $CuSO_4$) was added to the sample inside the flask. Then, 10 mL concentrated sulphuric acid was mixed with the sample and the digestion goes on until the solution was become clear or white. Cooled and 100 mL distilled water, 70 mL sodium hydroxide (45%) were added and distilled into 25 mL boric acid containing 3 mL mixed indicator. The distillate was titrated with 0.1 N hydrochloric acid to the end point.

$$\text{Total Nitrogen (N \%)} = \frac{(V_t - V_b) * 14}{W}$$

Where: W is weight of the sample taken for analysis, V_t is volume of HCl used for titration

V_b volume used for titrating blank

Crude protein (%) = N*6.25

Soluble protein

Soluble protein was measured by taking 20 mL of wort into Kjeldal flask and digested. The wort was heated to evaporate the excess moisture and then dried. Then, digestion was started by adding 3 mL of concentrated sulphuric acid, and 10 g of catalyst and anti-foam. The digestion, distillation and titration process was conducted according to EBC method 3.3.1

$$\text{Total (N\%)} = \frac{\text{T} * 14 * 100}{V}$$

V is volume of wort taken and T volume of HCl taken during titration.

Kolbach index

Kolbach index was calculated according to ASBC (2008) by using the following formula.

$$\text{Kolbach index } = \frac{\%soluble\ protien}{\%malt\ protien} \times 100$$

Mashing of ground malted maize

Mashing procedure

Malt samples (50 g) with 2 mm particle size was mashed and extracted with 360 mL of distilled water in a 500 mL Erlenmeyer flask. The content was mashed for 30 minutes at 45 °C and raised the mashing temperature up to 70 °C (rate 1 °C/min) for 25 min to activate the enzymes, and then 100 mL of 70 ^{o}C distilled water was added to each sample and held at 70 ^{o}C for 1 h. At 10 min and 15 min, saccharification test EBC (1998) was performed with 0.02 N iodine solutions. At the completion of mashing, the sample was cooled to room temperature and then distilled water was added to adjust the weight of the content in mash vessel to 450 g. It was mixed and allowed to settle for 20 min and it was decanted into a fluted filter (Whatman No. 1). The percentage sugar content of the clarified wort was read with an abbe refractometer and the percentage extract was calculated by using the following equation:

$$Extract\ (\%) = P(M + 1000)/(100 - M)$$

Where; P is the percentage sugar by refractometer reading, M is the moisture content of malt.

Wort color

The color of diluted sample wort was estimated by a serious of standards comprising colored glass discs.

Wort pH

The pH of wort was measured 30 minutes after the start of filtration with a glass electrode pH meter.

Diastatic power

Malted grain samples were ground and passed through a 0.5 mm screen. Diastatic power was measured using ASBC (2011) malt method No. 6. Reducing sugar was measured by the ferricyanide method and diastatic power was expressed as diastatic power degrees (DP^{o}) on dry matter basis.

Statistical analysis

A duplicate data was collected and analyzed by analysis of variance using Stata17 statistical software package. Results were expressed as mean ± standard deviation and p-value (<0.05).

Results and Discussion

Grain proximate composition

Table 1 shows important proximate composition of un-malted maize grains. The grain moisture content was in a range of 8.95 to 10.29% which is ideal for long storage of the grains. The protein contents of the intermediate and highlands maize varieties were higher than the lowland ones. Varieties, *AMH-851*, *BH-540* and *BH-520* insignificantly varied and showed the highest protein content. The measure of inorganic matters called total minerals of the grains insignificantly varied and ranged from 1.12 to 1.58%, which is in a good agreement with the result reported by Tsegay et al. (2019). Another study conducted on the variation in the chemical composition and physical characteristics of cereal grains also reported a mean of 9.3% crude protein content for maize genotypes (Rodehutscord et al., 2016).

Table 1. Released maize varieties grain proximate composition and germination potential

Maize variety	Selected grain proximate composition and germination characteristics					
	MC, %	CP, %	Ash, %	DS	GE, %	ML, g
BH-520	10.04±0.06^{a-d}	11.06±0.34^{ab}	1.29±0.03^{ab}	44.80±0.7^{b-d}	73±1.41^{bc}	0.78±0.02^{efg}
BH-540	9.53±0.03^{cde}	11.10±0.21^{ab}	1.34± 0.03^{ab}	45.45±1.1^{b}	62±1.41^{fgh}	0.72±0.02^{g}
BH-546	9.55±0.12^{b-e}	10.44±0.45^{ab}	1.26± 0^{ab}	45.35±0.35^{b}	76±1.41^{ab}	1.69±0.03^{a}
BH-547	9.41±0.07^{de}	10.72±0.23^{ab}	1.20± 0.0^{ab}	44.7±0.28^{bcd}	69±0.0^{cde}	1.74±0.06^{a}
BH-549	9.93±0.05^{bcd}	10.50±0.14^{ab}	1.24±0.04^{ab}	46.40±0.28^{b}	59±1.41^{h}	1.45±0.07^{b}
BH-661	10.45±0.21^{ab}	11.00±0.13^{ab}	1.18± 0.14^{ab}	42.15±0.63^{e}	61±0.0^{gh}	0.70±0.14^{g}
AMH-851	9.87±0.17^{bcd}	11.20±0.3^{a}	1.58±0.02^{a}	42.80±0.28^{de}	61±1.41^{gh}	1.85±0.07^{a}
AMH-853	8.95±0.36^{e}	11.06± 0.04^{ab}	1.40±0.0^{ab}	46.20±0.42^{b}	66±0.0^{def}	1.30±0.0^{bc}
MK-1	10.1±0.14^{a-d}	10.89± 0.08^{ab}	1.15±0.08^{ab}	49.2±0.84^{a}	82±0.0^{a}	1.36±0.06^{b}
MK-2	10.42±0.6^{abc}	10.28± 0.31^{ab}	1.16± 0.03^{ab}	42.95±0.5^{cde}	70±1.41^{cd}	1.0±0.0^{de}
MK-3	10.02±0.2^{a-d}	10.61±0.22^{ab}	1.48±0.44^{ab}	41.50±0.7^{e}	65±1.41^{efg}	1.45±0.08^{b}
MK-4	10.1±0.12^{a-d}	10.25±0.2^{b}	1.15± 0.06^{ab}	45.0±0.0^{bc}	69±0.0^{cde}	1.1±0.0^{cd}
MK-6Q	10.17±0.3^{a-d}	10.45± 0.21^{ab}	1.12± 0.03^{ab}	49.2±0.0^{a}	61±1.41^{gh}	1.0±0.0^{de}
MK-7	9.72±0.22^{b-e}	9.78±0.07^{ab}	1.25±0.07^{ab}	41.9±0.42^{e}	71±0.0^{c}	1.0±0.0^{de}
MK-141	10.3±0.23^{a-d}	11.21± 0.3^{a}	1.27± 0.04^{ab}	38.3±0.85^{f}	72±0.0^{bc}	0.71±0.02^{g}
MK-1Q	10.18±0.1^{a-d}	10.99±0.16^{ab}	1.14± 0.05^{ab}	36.55±0.63^{f}	59±1.41^{h}	0.95±0.07^{def}
Limu	10.29±0,17^{a}	10.25±0.21^{b}	1.09± 0.0^{b}	41.6±0.28^{e}	76±0.0^{ab}	0.75±0.07^{fg}

MC, moisture content; DS, degree of steeping; GC, germination capacity; GE, germination energy; ML, malting loss

Degree of steeping and germination test

Degree of steeping is described as the percentage increase in the weight of the grains after steeping due to increase in the moisture content of the grains. It is widely acknowledged as the most critical stage of the malting process. Relatively, a lower degree of steeping was observed in all maize varieties (Table 1). The highest degree of steeping (49.2%) was recorded for *MK-6* after steeping of the grains for 24 h. This would be due to its dependence on the steeping temperature and grains skin thickness compared to other cereals.

A maximum of 72% germination energy was noticed for the maize varieties at the third day of germination period. High germination energy is important for cereals to be malted as the results help to indicate dormancy in grains. The lowest germination ability was observed for BH-549 and *MK-1Q*. The germination potential of cereals during the malting process is important in terms of proteolysis and the release of β-amylase enzymes measured as diastatic power (Agu and Palmer, 1998). Large variations in protein will influence the ability of the proteolytic enzymes to hydrolyse the proteins embedding the starch, hence limiting the amylolytic enzyme attack on the starch (Ndubisi et al., 2016). When grains do not germinate during the malting process, such un-germinated grains will not contribute to the malted cereal enzymes. Un-germinated grains could also lead to processing problems as trouble shooting substrates such as β-glucan breakdown might be limited. The most important observation during the germination test worth mentioning is the presence of a single rootlet in germinating maize. This is contrary to 3 to 4 rootlets usually found in germinating barley during the germination test.

Maize malt characteristics

The maize malt quality attributes are presented in Table 2 and Table 3. Table 2 provides information on different maize varieties and their respective malt proximate compositions and malt quality attributes. The moisture, total and soluble protein contents and kolbach index (the ratio of soluble protein to total protein) of maize malt are shown in Table 2. The moisture content of maize malt ranged from 6.7% for *MK-1Q* to 7.97% for *AMH-851*. Except for *MK-4* and *MK-1Q*, all maize varieties did not significantly differed in their moisture content. The total and soluble protein contents of maize malt ranged from 11.2 to 13.8% and 3.45 to 4.2%, respectively. *AMH-851* had the highest and MK-2 had the lowest crude protein content. Bera et al. (2018) reported similar result for malt barley soluble protein content in a range of 4.26 t0 4.86%. A range of 11.95 to 13.50% for highland, 11.4 to 13.8% for intermediate and 11.2 to 13.1% for lowland maize varieties was noticed for total protein content of maize malt. A significant increase in protein content of malted maize was noticed compared to the un-malted maize. This could be as a result of storage nitrogen mobilization in maize grains during germination. A study revealed that malt protein content was inversely correlated to malt extract yield (Molina-Cano et al., 2000).

Table 2. Released maize varieties malt proximate composition and kolbach index

Maize variety	Malt proximate composition			
	Moisture content (%)	Total protein (%)	Soluble protein (%)	Kolbach index (ratio)
BH-520	7.52±0.25^{abc}	13.45±0.35^{ab}	3.90±0.14^{a-d}	29.02±1.81^{e}
BH-540	7.43±0.24^{abc}	13.50±0.42^{ab}	4.05±0.07^{ab}	30.01±0.42^{cde}
BH-546	7.15±0.21^{abc}	12.95±0.07^{a-d}	3.95±0.07^{a-d}	30.50±0.38^{b-e}
BH-547	7.83±0.23^{ab}	12.20±0.28^{b-e}	3.70±0.00^{b-e}	30.34±0.70^{b-e}
BH-549	7.05±0.07^{abc}	11.95±0.35^{cde}	3.65±0.07^{cde}	30.55±0.31^{b-e}
BH-661	7.86±0.19^{a}	13.20±0.42^{abc}	3.85±0.07^{a-d}	29.17±0.40^{e}
AMH-851	7.95±0.49^{a}	13.80±0.14^{a}	4.00±0.14^{abc}	28.98±0.73^{e}
AMH-853	7.40±0.14^{abc}	13.05±0.35^{abc}	4.05±0.07^{ab}	31.04±0.29^{b-e}
MK-1	7.25±0.21^{abc}	12.90±0.14^{a-d}	4.20±0.00^{a}	32.56±0.36^{abc}
MK-2	7.30±0.28^{abc}	11.20±0.28^{e}	3.80±0.14^{b-e}	33.92±0.41^{a}
MK-3	7.30±0.14^{abc}	11.50±0.56^{de}	3.70±0.14^{b-e}	32.18±0.35^{a-d}
MK-4	6.93±0.09^{bc}	11.75±0.35^{cde}	3.45±0.07^{e}	29.37±0.28^{e}
MK-6Q	7.56±0.19^{abc}	11.80±0.28^{cde}	3.65±0.07^{cde}	30.93±0.14^{b-e}
MK-7	7.20±0.28^{abc}	12.30±0.42^{b-e}	4.05±0.07^{ab}	32.94±0.56^{ab}
MK-141	7.65±0.21^{ab}	13.10±0.42^{abc}	3.45±0.07^{e}	26.34±0.31^{f}
MK-1Q	6.70±0.14^{c}	12.10±0.42^{b-e}	3.60±0.00^{de}	29.77±1.04^{de}
Limu	7.88±0.16^{a}	11.40±0.57^{e}	3.90±0.14^{a-d}	34.22±0.45^{a}

BH-Bako hybrid; AMH, Ambo hybrid; MK, Melkassa

In general, lowland maize varieties had the lowest and the intermediate agro-ecology maize varieties had the highest total protein content. The total soluble protein content of lowland maize malt ranged from 3.45 to 4.2%, the highest for *MK-1*, and the lowest for *MK-4* and *MK-141* with non-significant variation among them. *BH-520*, *BH-540*, *BH-546*, *AMH-851*, *AMH-853*, *Limu* and *MK-7* showed insignificant variation in total soluble protein content.

Malting increased the protein content of maize malt. Warle et al. (2015) reported similar changes in protein content of barley grain during germination. Kindiki et al. (2015) found that protein content of pearl millet increased significantly during germination followed by 24 h fermentation up to period of 5 days at different temperatures. This increase in protein content in germinated grain may be due to protein synthesis (Fasasi, 2009). In contrast, researchers observed that after germination there was slight decrease in crude protein content in germinated grains due to transfer of nitrogenous material in growing embryo. Agu (2003) revealed that roots and shoots developed in malted barley reportedly contain hydrolyzed protein, which can be directly correlated with malting loss.

Maize malt quality attributes are present in Table 3. The highest fine and course malt extract was observed for *BH-661* with non-significant difference with *BH-540*.

Table 3. Extracts content and wort color of maize malt.

Maize varieties	**Malt extract contents (g/100g)**		
	Course extract	Fine extract	Extract difference
BH-520	66.14±0.34^{b}	68.15±0.35^{c}	2.01±0.00^{def}
BH-540	69.29±0.55^{a}	71.15±0.35^{ab}	1.61±0.16^{g}
BH-546	63.96±0.64^{c}	65.90±0.57^{d}	1.94±0.08^{efg}
BH-547	63.65±0.49^{c}	65.90±0.28^{d}	2.25±0.21$^{b\text{-}e}$
BH-549	57.50±0.71^{d}	59.85±0.78^{e}	2.35±0.07^{bcd}
BH-661	69.93±0.32^{a}	71.55±0.49^{a}	1.62±0.17^{fg}
AMH-851	53.80±0.71^{e}	55.80±0.71^{g}	2.00±0.00$^{d\text{-}g}$
AMH-853	62.95±0.35^{c}	65.00±0.42^{d}	2.05±0.07^{cde}
MK-1	52.39±0.41^{e}	54.85±0.35^{gh}	2.46±0.06^{b}
MK-2	53.42±0.31^{e}	55.85±0.21^{g}	2.43±0.11^{bc}
MK-3	55.75±0.49^{d}	57.90±0.42^{f}	2.15±0.07$^{b\text{-}e}$
MK-4	52.85±0.21^{e}	55.20±0.28^{g}	2.35±0.07^{bcd}
MK-6Q	50.35±0.49^{f}	53.30±0.56^{h}	2.95±0.07^{a}
MK-7	41.25±0.35^{h}	43.25±0.35^{j}	2.00±0.00$^{d\text{-}g}$
MK-141	46.36±0.20^{g}	48.80±0.28^{i}	2.44±0.08^{bc}
MK-1Q	41.81±0.44^{h}	44.76±0.36^{j}	2.94±0.08^{a}
Limu	67.20±0.28^{b}	69.45±0.35^{bc}	2.25±0.07$^{b\text{-}e}$

BH-Bako hybrid; AMH, Ambo hybrid; MK, Melkassa

MK-7 and *MK-141* insignificantly differed and had the lowest malt extract (course and fine) contents. A significant variation was noticed within highland, intermediate and lowland maize varieties for their malt extract content. However, highland maize varieties showed the highest malt extracts than the intermediate and lowland ones. Among the intermediate agro-ecology varieties, *Limu* had the highest course (67.2%) and fine (69.45%) malt extracts than *AMH-853* which had 62.95% and 65% for course and fine malt extracts, respectively. *MK-3* and *MK-1Q* exhibited the highest and the lowest course extract percentage and significantly varied within the lowland varieties. Conversely, MK-7 had the lowest fine extract content. The lowland maize varieties, *MK-1*, *MK-2* and *MK-4* did not show a significant variation in their fine and course extract contents. Similarly, BH-546 and BH-547 insignificantly differed for its extract contents.

A range of 1.61 to 2.95% for extract difference and 3.75 to 14.75 EBC wort color were noticed between the highland, intermediate and lowland maize varieties grown in Ethiopia. Lowland maize varieties showed the highest, whereas the lowest malt extract difference was observed in highland maize varieties. However, the intermediate maize varieties did not exhibit a significant difference compared to that of highland maize varieties. *MK-6* and *MK-1Q* had the highest, and *BH-540* and *BH-661* the lowest maize malt extract difference. In terms of its wort color, highland maize varieties had the highest EBC than the lowland one. *MK-3* and *MK-6* respectively exhibited the highest (11.03 EBC) and the lowest (3.75 EBC) among the lowland maize varieties. Similarly, the highest and the lowest wort color was noticed with BH-549 (14.75 EBC) and BH-547 (5.46 EBC) within the highland ones, respectively. *AMH-853* and *Limu* varieties did not show a significant difference in their color of wort. Wort pH was ranged from 3.02 to 3.92 with the highest for *MK-2* and lowest for *AMH-851* maize malt.

Figure 1 shows the sugar extract contents of maize malt. In all maize varieties, the fine extract content was higher than the course extract content. A large variability was noticed among the varieties in their wort color with the highest for *BH-549* and the lowest for *BH-540* and *MK-6*. This large variation in wort color might be attributed to the level of pigmented testa of the maize grains.

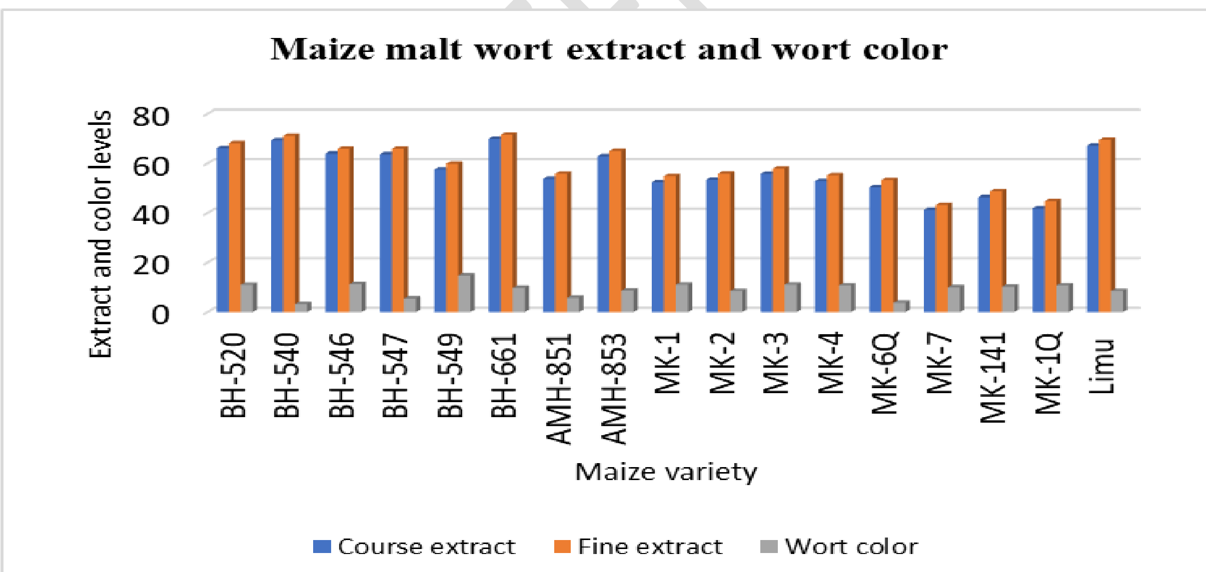

Fig 1. Maize malt wort extract and wort color

The diastatic power measured for malted grain is presented in Figure 2. Low enzymatic power (diastatic power) was noticed in maize malt compared to malt barley. Diastatic power is described as the activity of total starch converting enzymes presents in the grains (Georg-Kraemer et al., 2001).

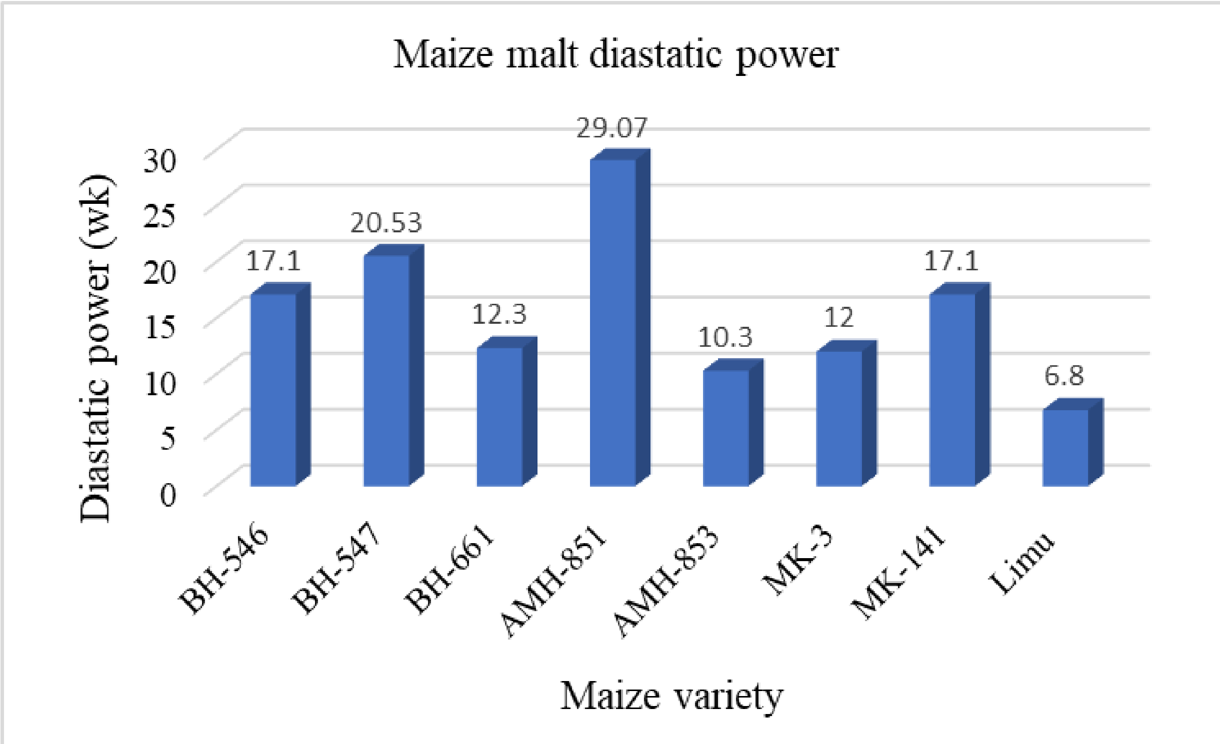

Fig 2. Maize malt diastatic power

AMH-851 showed the highest diastatic power (DP) whereas Limu had the lowest DP. The varieties, MK-3 and BH-661 and AMH-853 did show a significant variation. A huge variability was observed among the varieties. Variation in DP of malt is affected by complex interaction of genetic variation and environmental factors (Arends et al., 1995). β-amylase is considered as the most important enzyme responsible for diastatic power (Arends et al., 1995). α-amylase enzyme is synthesized during germination by mature aleurone layers of barley and typically, its level increases after third day germination. However, its importance in diastatic power of the grain is less than that of β-amylase (Georg-Kraemer et al., 2001). β-amylase activity can be used as a screening criterion to select the barley variety that is suitable for malting (Gibson et al., 1995).

Conclusion

The current study demonstrated the potential of maize malt in the brewing process. Total and soluble protein contents increased significantly after malting in all varieties. Highland and intermediate maize varieties showed better course and fine extract contents, and enzyme activity.

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