Production and Characterization of Malt and Beer Produced From Wheat Varieties

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Data Article

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Abstract

The objective of this research was to produce beer using local wheat to substitute or minimize imported barley malt. The physicochemical properties of malt beer were studied and the results revealed the alcoholic content in all malt samples ranged between 3.53-6.92 European Brewery Convention (EBC), pH (5.88-6.24), moisture content (6.77-7.35%), total protein (11.39-13.9%) and total nitrogen (1.50-2.44%). Besides, the physicochemical properties of finished beer were also determined and the values of apparent extract, real extract and original extract were found in the range of 1.67-2.86 °p, 3.17-4.0 °p and 8.04-9.53 °p, respectively. The apparent degree of fermentation, color, pH, alcoholic content, bitterness and haziness of wheat beer were found to have 66.68-82.55%, 7.16-9.40 EBC, 4.32-4.61, 3.90-5.40 (% v/v), 11.8-15.1 and 0.98-1.2, respectively. The results of this study indicates that wheat malt can serve as an alternative raw material for breweries in addition to barley malt.

Introduction

Beer is the third most popular drink next to water and tea in the world and probably the oldest alcoholic beverage. It consists of carbohydrates, amino acids, minerals, vitamins, and phenolic compounds mainly obtained from malt and hop which contribute the flavour and aroma of beer. Malt, water, hop and yeast are the raw materials required for beer production (Cheiran et al, 2019; Rygielska et al, 2019; Singh et al., 2016). Beer is flavored with hops, which adds bitterness and acts as a natural preservative, though other flavorings such as herbs or fruits may occasionally be included (Pai et al, 2015). There are numerous styles of beer in the market, where lagers, ales, stouts and wheat beers are some of the most consumed ones (Ruvalcaba et al, 2019). Their qualities are strongly influenced by the qualities of the raw materials (Humia, et al., 2019). The rising of alcoholic consumers as a result of personal income, international travels, and behavioral changes linked to urbanization that are seen in Ethiopia, the demand for the beer market are growing rapidly. Barley malt is the major raw material for beer production which is mainly produced only in the southeastern part of Ethiopia in Arsi and north part of Ethiopia in Gondar. Because of the shortage of raw barley and barley malt, most breweries import foreign malt from Belgium, China, and Spain. Therefore, it is essential to find other starch source grains to replace partially or completely barley to produce beer (Ditrych et al, 2015).

Wheat (*Triticum aestivum* L.) is the basis of a diverse range of staple foods globally, which includes bread and bakery items in addition to other products such as alcoholic beverages and food additives (Jouanin et al, 2018, Mastanjevic et al, 2018). Wheat beer popularity has varied over the years, but in the last few years, the expansion of craft and home brewing has added to the demand for wheat beers. In addition, wheat beers produced by international breweries have gained more attention. For instance, in Germany 50–80% beers are brewed with malted wheat and its adjuncts. United States Department of Agriculture Economic Research Service report suggested that between 5% and 10% of all malt used by USA brewers may be wheat, which is associated with the growing craft beer and craft malting industries, as well as, with the popularity of several wheat beers produced by larger international brewers (Jin et al. 2018). This

has increased the demand for suitable brewing wheat cultivars and gained market share (Faltermaier et al. 2014; Jouanin et al, 2018).

The use of wheat malt in addition to barley malt for beer production minimizes foreign currency; and increases the income of farmers and in general contribute to the growth of the country's economy. Currently, in Ethiopia there are more than eight beer producing breweries. According to Central Statistics Agency of Ethiopia (CSA), the exponential increase of beer demand put a pressure on the supply of barley. Malt processing factories in the country which supply malt to local breweries are limited and do not supply enough malt to all breweries according to their demand. Owing to this, breweries imported foreign malt from Europe to satisfy their demand. Thus, it is essential to find other grains locally as an alternative for beer production.

To the best of our knowledge, there have not been any published studies examining the physico-chemical properties of malt beers produced from wheat in Ethiopia. Therefore, this study aimed to produce malt from local wheat and characterize the physicochemical properties of the wheat malt beer.

Materials And Methods

Apparatus and Chemicals

The instruments and apparatus used in this study were analytical balance, mash apparatus with full accessory, Lg-automaltic aps, disk mill, Buhler Universal, stainless steel dish, destkit, protein digester Kieltec distilling unit, Foss tecator, measuring cylinder, Eterna boro, Anton paar, alcoholizer beer DMA 4500, What man filter paper, centrifuges, bitterness shaker, Lg-aumatic, pH meter, distillation apparatus, UV-spectrophotometer thermo scientific model Evolution 201, density meter Anton paar, White furze and plastic barrel.

Chemicals used in the study were iso-octane, O-phenylenediamine (OPD), N,N-diethyl-p-phenylenediamine (DPD), hydrochloric acid, sodium hydroxide, sulfuric acid, potassium sulphate, copper sulphate, protein tablet, tashiro indicator, iodine solution, filter aid, and distilled water. All reagents and chemicals were of analytical grade.

Sample Collection

Wheat samples were collected commercially from eight study areas (kebeles) where by wheat is the most widely grown: Kinno (W1) and Mikara (W2) (Debark woreda, North Gondar administrative zone), Chilla (W3) and Abitera (W4) (Dabat woreda, North Gondar administrative zone), Megendi Giworgis (W5) (Farta woreda, South Gondar administrative zone), Akenakuancha (W6) (Banja Shekudad Woreda, Awi administrative zone), Dengordiba (W7) and Gedebiye (W8) (Wogera woreda, Central Gondar administrative zone) of Amhara Regional State. The wheat was selected from the study areas by making a preliminary assessments with the woreda's agricultural offices and the community which used to brew local beer (Tella in Amharic) at their villages. In each market place, 5.0 kg representative wheat samples were collected from five sampling areas of each study area.

Study Design

The study design was an experimental based lab scale type where it was conducted by producing malt at Gondar malt factory laboratory and brewing beer at Gondar Dashen brewery plant. The qualities of the produced beer were evaluated based on different physico-chemical parameters.

Malting process was carried out by precleaning of wheat followed by steeping, germinating and killing process of the malt grains. The malt grain impurities like soil, stone and dust were removed during precleaning procedure.

The Physicochemical Properties of Malt

The moisture content, extract dry matter, scarification (iodine test), odor, speed of filtration, appearance, color, pH, total nitrogen and protein were performed according to European Brewery Convention (EBC) method (EBC, 2004).

Moisture Content. The moisture content was determined by using EBC method, where 20 g of each malted wheat sample was milled finely with a setting of 0.2 mm disk mill. After mixed thoroughly, 5.0 g of each ground sample in a clean dry stainless steel dish was placed in an oven at 105⁰c for 3 h. Finally, the samples cooled to room temperature for 20 min.

Mashing Process. In this study, 70 g of each malted wheat was milled with a lab disk mill set at 0.2 mm for fine adjustment and mixed with 200 mL of distilled water into a mash beaker at a temperature of 45⁰C and allowed to stand for 30 min with intermittent stirring to avoid the formation of precipitate.

Automatically, the temperature of the mash was then raised by 1⁰C per min until it reached to 70⁰C and after it was allowed to rest for 25 min and 100 mL of distilled water was added. The temperature of the mash was further raised to 65⁰C and the time it took was recorded. This was done by transferring a drop of the mash into a spot on a white porcelain plate and a drop of iodine solution was added for an hour with 5 min interval. Complete scarification (starch conversion) was indicated by a clear yellow spot after 15–20 min or 3rd – 4th alarm. After maintained the temperature of 80⁰c, the mash cooled to room temperature for 15 min. Finally, the mash was filtered and the filtrate stirred thoroughly with a glass rod (EBC, 2004).

Color. Beer color is generally affected by the hops and malt components. The germination and kilning process of malting determine the extent of color formation from Maillard browning reaction products and in some cases caramelization and pyrolysis reactions (Jaskula, et al, 2008). The beer samples were degassed by gently stirring with a magnetic stirrer at low speed and the samples were filtered with a 0.45 nm membrane filter and then absorbance reading was performed at 430 nm with the use of a 10 mm glass cuvette against a water blank. The color of the sample was then expressed in units of EBC (EBC, 2004).

Total Nitrogen and Protein Contents. Nitrogenous compounds are essential in determining the flavor, foam stability, haze formation, color, yeast nutrition and biological stability of beer (Zhang et al, 2019). The

growth of yeast involves the uptake of nitrogen, mainly in the form of amino acids for the synthesis of cellular proteins and other cell compounds (Lekkas et al, 2005). If the level of nitrogen is very high, amino acids inhibit further synthesis, increasing yeast growth and promoting higher alcohol formation (Donkelaar et al., 2016).

Proteins contained in beer are derived from water soluble proteins contained in the grains used in the malting and brewing process. These proteins play an important roles in determining beer quality such as foam stability, haze formation, and shelf life of the final products (Pai et al, 2015).

Total nitrogen values were obtained from the sum of all nitrogenous compounds including amino acids, peptides, proteins, nucleic acids and their degradation products present in wort (Steiner et al, 2010). For determining the total nitrogen content of wheat malt on the Kjeldahl principle was applied (EBC, 2004). In determining total nitrogen, 2.5 mL of conc. H_2SO_4 was added to 250 mL Kjeldahl digestion flask containing 20 mL wort and digested for 1 h at 180°C until dry. The digest was allowed to cool. Furthermore, 1.0 g of finely ground sample was added to the Kjeldahl digestion flask and then 12 mL conc. H_2SO_4 and a mixture of 7 g K_2SO_4 + 0.8 g $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ were added to the previously dried samples and to 250 mL Kjeldahl digestion flask as blank. Shacked gently to the wet sample. The solution was digested for 1 h at 400°C by gently controlled evaporation. Then after, the digest was allowed to cool at room temperature and five drops of tashiro indicator was added to the flask into which 25 mL of 0.1 N HCl had been pipetted. The flask was connected to the distillation apparatus such that the outlet tube of the condenser dipped beneath the H_2SO_4 in the receiving Erlenmeyer flask. The content had been cooled to room temperature and 75 mL of distilled water and 50 mL of 40% NaOH were added. The flask was heated smoothly for 5 min until the liquid began to distill. Finally, the excess H_2SO_4 in the receiving flask was titrated with standardized 0.1N NaOH till the color changed from blue to bright green.

Bitterness Analysis. Bitterness is due to the presence iso-alpha acid, produced from isomerization of hop alpha acid during boiling of the extract (Jaskula et al, 2008). It was determined according to EBC, where by 10 mL of each decarbonated and foam-freed beer sample previously acidified with the help of 1 mL of 0.1 N HCl was mixed with 20 mL iso-octane (2, 2, 4-trimethylpentane) and shacked vigorously for 15 min. Finally, bitterness was measured against the blank (iso-octane) by UV-Vis spectrophotometer at a wavelength of 275 nm with a 10 mm quartz cuvette and the results were expressed in Bitterness Units (BU).

Vicinal diketone (VDK) analysis. Two vicinal diketones (VDKs) namely 2, 3-butanedione (diacetyl) and 2,3-pentanedione are produced by yeast during fermentation with flavour threshold value around 0.1–0.2 ppm in lager and 0.1–0.4 ppm in ales, although flavour thresholds as low as 17 ppb and 14–61 ppb (Krogerus and Gibson, 2013). However, VDK can cause a buttery off-flavour above its threshold and it is one of the most important by-products in alcoholic fermentation as it decreases the sensory properties of the final product (Cyr et al, 2017).

In this study, VDK of beer samples had been done at the age of 5 days based on EBC method where by 100 mL each beer sample was centrifuged at 3000 rpm for 10 min and transferred into the distillation flask for distillation. Then, 0.5 mL of 1 % O-phenylenediamine (OPD) was added to each sample and blank and placed in the dark for 20 min. Finally, 2 mL of 4 M HCl was added to the samples and blank. After 20 min, the absorbance was measured at 335 nm against the blank (EBC, 2004).

Sensory analysis. The beer samples at the age of 16 days maturation were tasted by 7 trained analytical chemist panelists at Dashen Brewery sensory analysis laboratory room. The panelists are on average 8 years' experience and familiar with beer flavor. A 50 mL of beer samples were filled into eight clean and odorless testing glasses, so that panel members were evaluated the appearance, color, smell or odor, mouth feel, sour and sweet taste. Panelists were instructed to rinse their mouths with water before starting and between sample tastes. Each sample was evaluated by using a grading system like poor, good, very good and excellent.

Analysis of Matured Beer. Beer is matured/ lagered at temperatures of 0 °C to clarify for 2 weeks. During this process its filterability and colloidal stability of beers were improved. In this research, the original extract (OE), apparent extract (AE), real extract (RE), alcohol content (v/v), apparent degree of fermentation (ADF), color, haze and pH of matured wheat beers were determined.

Results And Discussion

Physico-chemical Parameters of Malt

Moisture and Dry Matter Content. The moisture content of wheat malt varieties was ranged between 6.83% and 7.94% (Table 1). The moisture content increased in the order of: W6 < W1 < W8 < W4 < W3 < W2 < W5 < W7. The increment observed in moisture content depicts water uptake by the viable wheat variety grains during steeping. The percentage of moisture content of all wheat samples were found to be higher than the values given by EBC (3-4.5%). This might be attributed to the difference in killing condition, grain type, and grain growing geographical factors. High moisture content encourages microbial growth and allows an increase in metabolic rate, which depletes the extract content. The moisture content of the wheat malts in this study were found to be comparable with the values reported by Jin et al. with moisture content ranging from 6.3–7.3% (Jin et al. 2008).

As shown in Table 1, the dry matter extracts (%E2, m/m) of W2 (77.88%), W5 (78.11%), W8 (79.61%) were comparable with the values described by EBC (78.5–80%). However, W1 (83.23%), W3 (83.14%) and W4 (83.28%) contained higher dry matter extract (% m/m) than given by EBC. Wheat samples W6 (76.04) and W7 (76.92) were contained slightly lower dry matter extract than provided by EBC.

Total nitrogen and protein content. As can be seen in Table 1, the protein content of all wheat malt varieties were found in the order of: W5(13.9%) > W6>(13.45%) > W8(13.1%) > W2(13.05%) > W7(12.65%) > W4(12.59%) > W1(12.51%) > W3(12.4%).

The quantity of protein contents analyzed in this study were slightly higher than the values given by EBC. High protein content in wheat malt is not desirable because it leads to a reduction of malt extract caused by proportionally lower carbohydrate and makes the beer cloudy (Depraetere et al, 2004; Ore et al, 2008). However, a low level of protein lowers enzymatic activity because it limits the nutrients required for yeast growth during the brewing process (Poreda, et al, 2014).

The nitrogen content of the wheat beers increased with the increase of the total protein content of wheat. This value depends on wheat variety, harvest and growing area as well as on the agronomic conditions like nitrogen fertilization. The levels of total nitrogen were slightly higher than that of the EBC value. The total nitrogen contained were found in the range of 2.18 to 2.44%, which are higher than the recommended values provided by EBC (1.6–1.8%). The lowest and highest values were investigated in W3 and W5, respectively.

The pH is considered as important criteria by the brewing industries which strongly influences sanitation and color, odour, taste, biological and chemical stability (Pai et al, 2015). As can be seen in Table 1, the pH of the malt samples were ranged from 5.88 to 6.24. The highest pH value was recorded in W3 with a pH of 6.24, while the least pH was observed in W7 with a pH of 5.88. The pH values are more or less comparable with EBC values (EBC, 2004).

In general, slight differences in physico-chemical parameters were observed for wheat malt due to various factors such as quality of grain, cropping, malting process, instrumental, human factor or geographical location.

Table 1
Physico-chemical analysis of various wheat malts (mean $\pm$ SD, n = 3)

Sample	pH	Color (EBC)	E ₂ fine grind (% m/m)	Moisture (%)	Total Protein (%)	Total Nitrogen (%)
W1	6.06 $\pm$ 0.036	4.54 $\pm$ 0.04	83.23 $\pm$ 0.305	6.88 $\pm$ 0.02	12.51 $\pm$ 0.03	2.19 $\pm$ 0.035
W2	6.19 $\pm$ 0.02	6.20 $\pm$ 0.02	77.88 $\pm$ 0.026	7.28 $\pm$ 0.056	13.05 $\pm$ 0.04	2.29 $\pm$ 0.05
W3	6.24 $\pm$ 0.055	4.21 $\pm$ 0.10	83.14 $\pm$ 0.136	7.27 $\pm$ 0.03	12.4 $\pm$ 0.02	2.18 $\pm$ 0.025
W4	6.22 $\pm$ 0.043	5.56 $\pm$ 0.04	83.28 $\pm$ 0.102	7.01 $\pm$ 0.035	12.59 $\pm$ 0.05	2.21 $\pm$ 0.03
W5	6.23 $\pm$ 0.08	3.53 $\pm$ 0.06	78.11 $\pm$ 0.07	7.35 $\pm$ 0.065	13.9 $\pm$ 0.045	2.44 $\pm$ 0.04
W6	6.2 $\pm$ 0.035	6.92 $\pm$ 0.03	76.04 $\pm$ 0.055	6.83 $\pm$ 0.056	13.45 $\pm$ 0.02	2.36 $\pm$ 0.015
W7	5.88 $\pm$ 0.015	5.98 $\pm$ 0.02	76.92 $\pm$ 0.068	7.94 $\pm$ 0.025	12.65 $\pm$ 0.05	2.24 $\pm$ 0.025
W8	6.22 $\pm$ 0.03	4.24 $\pm$ 0.06	79.61 $\pm$ 0.05	6.92 $\pm$ 0.03	13.1 $\pm$ 0.03	2.30 $\pm$ 0.01
EBC	5.6–5.8	3–5	78.5–80	3-5.8	9-11.5	1.6–1.8

Vicinal Diketone Analysis

The VDK was used as a parameter to assess the fermentability and quality of the beer. As the results shown in Table 2, the VDK values were found in the range of 0.12–0.28 ppm at the age of 5 days, which indicates that the yeast cells utilized sugars which were converted to ethyl alcohol and carbon dioxide, i.e., fermented well.

When comparing VDK values among the varieties of wheat samples W1, W3 and W4 contained low VDK. The highest value was observed at W6. This variation might be because of the fermentation temperature and malt type, wort extract. VDK with a flavour threshold was usually reported as around 0.1–0.2 ppm in lager and 0.1–0.4 ppm in ales, although flavour thresholds as low as 0.017 ppm and 0.014–0.061 ppm have been reported. The presence of VDKs above their flavour threshold in beer is generally regarded as a defect, since their flavour is undesirable in many beer styles and it can also indicate microbial contamination (Krogerus and Gibson, 2013).

Table 2
VDK analysis (mean ± SD, n = 3)

Varieties	Age (day)	VDK (ppm)
W1	5	0.17 ± 0.003
W2	5	0.22 ± 0.011
W3	5	0.19 ± 0.003
W4	5	0.12 ± 0.003
W5	5	0.27 + 0.003
W6	5	0.28 ± 0.004
W7	5	0.23 ± 0.005
W8	5	0.20 ± 0.018

Physico-chemical Properties of Matured Beer

In this study, physico-chemical parameters such as original extract (OE), apparent extract (AE), real extract (RE), alcohol content (v/v), apparent degree of fermentation (ADF), color, haze and pH of beer were measured at the age of two weeks. These parameters have a great influence on the sensory quality and microbiological stability of beers. Higher content of alcohol and lower pH values increase the microbial stability, while the fullness of taste is mainly depending on the content of extract. The content of alcohol and pH value are connected with the sharpness, freshness and sourness of beer (Tozetto et al, 2019; Veljovic et al, 2015).

The RE ($^{\circ}\text{p}$) and AE ($^{\circ}\text{p}$) of the beer can be calculated from the specific gravity of the distillation residue and the beer, respectively. However, OE ($^{\circ}\text{p}$) is calculated from the specific gravity of the distillation residue and the beer distillate. The AE expresses the non-fermentable sugars which are supposed to decrease during fermentation (Diakabana, et al, 2013). As shown in Table 3, among all samples analyzed AE and RE values of W8 were found to be the highest and W1 contained the least. The value of OE was highest in W4 (9.53 $^{\circ}\text{p}$) and the lowest for W6 (8.04 $^{\circ}\text{p}$). The fluctuations of AE, OE and RE may be caused by different conditions under which the fermentation of hopped wort occurs. Higher original extracts masked the bitterness of the beer, which revealed that W4 possessed the least bitterness of 11.8 BU (Eblinger, 2009). The bitterness of this study are consistent with lager beers typically values in the range from 6–30 BU, although much more bitter beers are also widely available commercially (Oladokun, et al, 2016).

The highest apparent degree of fermentation (ADF) and alcohol content v/v %) were obtained in W1 wheat malt, while the least observed in W6 wheat malt.

When the results of this study (Table 3) were compared with Ethiopian standard agency (ESA), the color, Alc(% v/v), bitterness, haze, pH and apparent degree of fermentation (ADF) of wheat varieties of W1, W2, W3 and W4 were tolerated except AE. Higher AE caused for low alc (v/v%) production during fermentation, which could be overcome by keeping good fermentation condition, use healthy yeast and enzymes in the brewing process.

The colors of the wheat beers were in the range of 7.16–9.40 EBC, which is found in the range color value (6–18 EBC) described in European 100% malt Pilsner (Jurado, 2005). The alcoholic contents were obtained in the range of 2.80–4.26(v/v %), in which some wheat malt samples collected from W1 (4.26%), W4 (4.03%) and W3 (3.63%) produced better alcohol than the rest wheat malts. This variation might be due to geographical difference, grain quality and type, cropping process and fermentable capacity of wort.

Our findings were very close to that of Depraetere et al. (2004) report. However, the OE and ADF values were found to be below the reported value of Depraetere et al. OE (12.2–12.4 $^{\circ}\text{p}$) and ADF (87.1–93.3%). It was also noted that the haziness of the wheat samples (0.98–1.2) were comparable with the values given by ESA (1.0). The haze content for beers should not be over 1.0 EBC. However, the haziness of beers above 2 EBC are unacceptable for commercial purposes (Lewis and Bamforth, 2006). This haze formation might be due to residual starch, pentosans from wheat, oxalate from calcium deficient worts, carbohydrate and protein from autolysed yeast, lubricants from lids, and dead bacteria from malt (Steiner, 2010).

Table 3
Physico-chemical analysis of wheat beer (mean $\pm$ SD, n = 3)

Sample	AE (°p)	RE (°p)	OE (°p)	ADF (%)	Color (EBC)	pH	Alc (%v/v)	Bitterness (IBU)	Haze
W1	1.67 $\pm$ 0.04	3.17 $\pm$ 0.02	9.52 $\pm$ 0.01	82.55 $\pm$ 0.04	7.75 $\pm$ 0.02	4.42 $\pm$ 0.02	5.40 $\pm$ 0.02	13.5 $\pm$ 0.01	0.96 $\pm$ 0.03
W2	2.54 $\pm$ 0.03	3.79 $\pm$ 0.00	9.12 $\pm$ 0.01	72.55 $\pm$ 0.03	9.32 $\pm$ 0.03	4.55 $\pm$ 0.02	4.37 $\pm$ 0.02	14.02 $\pm$ 0.02	0.90 $\pm$ 0.05
W3	1.92 $\pm$ 0.03	3.29 $\pm$ 0.05	8.89 $\pm$ 0.01	78.12 $\pm$ 0.02	8.12 $\pm$ 0.02	4.32 $\pm$ 0.02	4.54 $\pm$ 0.01	15.1 $\pm$ 0.02	0.91 $\pm$ 0.02
W4	1.97 $\pm$ 0.03	3.33 $\pm$ 0.04	9.53 $\pm$ 0.07	80.33 $\pm$ 0.02	8.82 $\pm$ 0.02	4.43 $\pm$ 0.01	5.03 $\pm$ 0.06	11.8 $\pm$ 0.06	0.97 $\pm$ 0.03
W5	2.67 $\pm$ 0.02	3.86 $\pm$ 0.02	8.83 $\pm$ 0.01	69.60 $\pm$ 0.01	7.16 $\pm$ 0.03	4.41 $\pm$ 0.01	4.02 $\pm$ 0.02	12.5 $\pm$ 0.03	0.91 $\pm$ 0.02
W6	2.68 $\pm$ 0.01	3.71 $\pm$ 0.01	8.04 $\pm$ 0.05	66.68 $\pm$ 0.02	9.40 $\pm$ 0.05	4.55 $\pm$ 0.05	3.90 $\pm$ 0.01	13.5 $\pm$ 0.05	1.0 $\pm$ 0.03
W7	2.54 $\pm$ 0.04	3.65 $\pm$ 0.02	8.27 $\pm$ 0.02	69.36 $\pm$ 0.01	8.71 $\pm$ 0.04	4.61 $\pm$ 0.02	3.83 $\pm$ 0.01	11.9 $\pm$ 0.03	1.0 $\pm$ 0.06
W8	2.86 $\pm$ 0.01	4.0 $\pm$ 0.02	8.65 $\pm$ 0.01	66.82 $\pm$ 0.02	8.01 $\pm$ 0.03	4.37 $\pm$ 0.02	3.80 $\pm$ 0.03	14.3 $\pm$ 0.04	0.95 $\pm$ 0.03
ESA	1.5– 2.1	3.2– 3.9	10.51– 12.5	80–87	6–10	3.6– 4.8	4.61– 5.1	-	≤ 1.0
Where AE = apparent Extract, RE = real Extract, OE = original Extract, ADF = apparent degree of fermentation, BU = bitterness and ESA = Ethiopian standard agency.									

Sensory Analysis

The results of sensory analysis were based on overall acceptability parameters and was found to be 42.85% very good, 28.57% good and 28.57% poor. Among flavors less mouth fullness and carbonation were graded as good, while foamed, colored, bitter and sour graded as very good. Moreover, mouth fullness and carbonation graded as very good may be a matter of the amount CO₂ injected while filling of the beer. Color and foam of the beer is the first eye appeal of the consumer was scoring very well in all beers, hopefully the result is acceptable (EBC, 2004).

Conclusion

Quality specifications for brewing malt grain are the most important specifications in comparison to other cereals in the brewing industry to produce quality beer. The physico-chemical parameters such as protein content, moisture, color, Alc (v/v %), Alc (v/v), ADF, VDK, pH, BU and color of beers produced from wheat malt were studied. Results were comparable with that of the standard set by Ethiopian standard Agency

(ESA) and European Brewery Convention (EBC). Over 85% of our population engage in farming crops like wheat and are consumed locally and underutilized in the brewing technology wheat. Therefore, incorporating wheat as a brewing malt would give an advantage to the breweries, malters and the country by increasing farmers' income and profit margin of the brewery and save our foreign currency to substitute foreign malt with local wheat malt. From the study, it was realized the utilization of wheat malt in addition to barley malt is effective and can produce quality beer.

Declarations

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Availability of data and materials

The data sets used and analysed during the study are available to readers as in the manuscript. All the data are included in the manuscript.

Authors' contributions

MT and MA involved in the conception of the research idea and design of the experiments. MA involved in the sampling, sample preparation and data analysis and also drafted the paper. MT provided guidance, corrections and supervision to the entire research, critically reviewed and amended the manuscript. All authors read and approved the final manuscript

Competing interests

The authors have no conflicts of interest.

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