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Full Length Research Paper

Malt quality of 4 barley (*Hordeum vulgare* L.) grain varieties grown under low severity of net blotch at Holetta, west Shewa, Ethiopia

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Four malt barley varieties (Beka, HB 120, HB 52 and Holker) and 3 fungicide (propiconazole) spray intervals (7, 14, 21 day) and no spray control were arranged in a RCBD in 4 replications to assess net blotch (*Pyrenophora teres*) effect on malt quality. The varieties were grown at Holetta agricultural research center in 2005, on 12 m^2 plot. Grain flour starch pasting and malt qualities were analyzed. Mash odour and colour were evaluated qualitatively. Significant differences (P < 0.05) in malt qualities were observed among varieties and also due to spray intervals in hot water extract (HWE, mean range = 76.6 to 79.7%). The varieties had a pasting- time and -temperature (Ti) of 4.7 to 5.0 min and 64.7 to 66.3°C, respectively. Peak, hot paste, cold paste, breakdown and setback viscosities were ranged 276.5 to 314.9, 176.3 to 218.3, 294.1 to 333.2, 86.3 to 99.6 and 102.4 to 116.4 BU, respectively. The pasting curves indicate no amylo- or -waxy starches with evidence of no damage by sprout- induced α-amylase activity and spray intervals. The varieties Ti matches mashing temperature (64 to 65°C) used in malt barley brewing. Malts from these grain varieties were prepared under controlled conditions. Malt aroma and flavor was similar with industry malt of sugary sweet taste. Thousand-kernel malting weight loss (TKMWL) was 11 to 13% and is in the range for desirably modified barley grain on malting. The varieties had a malt protein 6.4 to 7.4% and free amino nitrogen (FAN) 124.4 to 140.0 mg/100 g malt (db). The diastatic tendency assessed using malted barley flour as sources of enzymes and refined wheat flour starch as a substrate (1:29) showed a reduction in peak viscosities (mean) of the substrate starch paste from 678.0 to 168.0 BU. The varieties did not show consistent quality requirements in all parameters. Beka and HB 120 were better than HB 52 and Holker in HWE and diastatic tendency. The FAN level was high among HB 120, HB 52 and Holker. The findings indicate that net blotch incidence and severity influenced HWE and filtration time.

Key words: Diastatic tendency, malt extract, FAN, malt barley qualities, net blotch, propiconazole, starch flour pasting.

INTRODUCTION

Ethiopia has a shortage of malt barley to meet the demand of the local breweries (Mohammed and Getachew, 2003). Limited tests on grain qualities of malt barley have been carried out since 1982 at Holetta barley quality laboratory (HBQL) (Fekadu et al., 1996). Yield and quality of malt barley are influenced by many factors. Net blotch caused by *Pyrenophora teres* Drechsl. is one of the major constraints to barley production in Ethiopia (Yitbarek et al., 1996; Bekele et al., 2001; Asenakech, 2002). The disease affects the foliage of barley and under severe infection the diseases can severely reduce the photosynthetic capacity, resulting in yield losses and an excessive grain protein of reduced kernel weight (Horsley and Hochhalter, 2004). Under natural infection of the disease, a significant difference (P < 0.05) among

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spray intervals and the varieties were reported (Galano et al., 2008). These authors reported differences in disease incidence and percentage severity index at 107 days after planting and for the area under the disease progress curve with relative yield losses of 7.7 to 11.5% in Beka and 15.3 to 21.2% in HB 120 varieties. The hectoliter weight (HLW) of the varieties (63.5 to 66.8 kg) and for fungicide spray intervals (64.6 to 65.7 kg) was significantly different ($P < 0.05$) and similar difference was observed in grain dimension (length, width and thickness) and germination energy. However, for other grain quality factors like sieve grain size grading and grain protein content, significant variations were observed only among the varieties.

In addition to the yield losses by the disease, undesirable result arising from the net blotch-attacked barley may extend its corresponding effect on the malt. As the disease reduces carbohydrate content of the kernel (Horsley and Hochhalter, 2004), kernel protein may proportionally become higher even-though significant variations were not observed among fungicide spray levels but are among the varieties. Excess grain protein is undesirable for malting as it leads to delay in germination, excessive growth on germination which in turn increases malting loss, little extract and poor beer quality (Edney, 1996).

Since the quality of malt barley cannot be concluded from measurements of grain quality factors alone, malt qualities of four barely varieties that were grown at Holetta agricultural research center, Ethiopia, in 2005 under the natural infection of the net blotch (Galano et al., 2008) are reported in this paper.

MATERIALS AND METHODS

Samples

Four malt barley varieties (Beka, HB 52, HB 120 and Holker) and 3 fungicides (propiconazole) spray intervals (7, 14 and 21 day interval) and no spray controls were used in a factorial randomized complete block design with four replications. The fungicide was applied at the rate of 1 L in 210 L of water/ha. To prevent drift during spraying, each treatment was sheltered with polythene sheet supported by four wooden poles. The entire experimental plot was sprayed bayleton at the rate of 0.5 kg in 500 L of water/ha to protect barley scald and rusts infection.

The varieties were planted at the rate of 75 kg/ha in the experimental field with a plot size of 12 m^2, spacing of 0.2 m between rows, 1 m between plots and 2 m between replications. The planting was carried out on 24 June 2005. Diammonium phosphate was applied at the rate of 100 kg/ha (blanket recommendation). Weeds were removed 40 days after planting (DAP) and the second weeding was 35 days after the first weeding.

In this study, grain samples (Galano et al., 2008) from the harvested crop from the plots of 4 varieties and 4 fungicide spray levels were used for grain flour starch pasting, malt preparations and its quality analysis. Barley grain was milled to whole flour of particle size less than 0.75 mm (Cyclone sample mill, Tecator, Inc., Boulder, Colorado, USA). This sample was used for the pasting properties analysis.

Barley grain flour starch pasting

The pasting property was analyzed on 11% dry matter basis (db) by using Micro Visco-Amylograph® (Micro Visco-Amylograph®, Brabender Measurement and Control Systems, Germany). The amylograph was heated from 30 to 90°C at heating rate of 7.5°C/min and held at 90°C for 5 min and then cooled from 90 to 50°C at the rate of -7.5°C/min. The stirring rate was 250 rev/min. From the resulting pasting curves, the time (ti) and temperature (Ti) at initial viscosity increase, peak viscosity (PV), hot paste viscosity (HPV), breakdown viscosity (BDV), cold paste viscosity (CPV) and setback viscosity (SBV) were computed by the Brabender Visco-Amylograph software version 72300, Germany.

Malt preparations

Each barley grain sample was cleaned manually and by sieving to remove impurities and dockages. Malt was prepared under controlled steeping, germination and kilning conditions as described in Weston et al. (1993) with slight modifications. From each sample, kernels (100 g) were steeped in 223 mL of tap water at room temperature (*ca.* 23°C) for a total of 48 h (12 h s-2 h a; 8 h s-2 h a; 12 h s-2 h a and finally 10 h s; h = hour, s = steeping and a = aeration) to raise the moisture in the grain to about 42 to 44%. At the end of the steeping duration, samples were spread in nylon bags and placed on plastic sheet-lined aluminum shelves and were allowed to germinate in a relative humidity chamber (89.6% rh of 16°C) (Termaks chamber KBP 6395F, Bergen, Norway). Each sample was sprayed with 25.4 mL/day with distilled water for three days using hand sprayer to avoid the decrease in the relative humidity. On the fourth day (~ 84^{th} h) (when the length of the acrospire was three-fourth of the length of the kernel), the germinated samples were transferred to a time- and temperature-controlled drying oven (SANYO OMT, Japan) for kilning. The kilning was done at 49°C (10 h), a 30 min ramp to 54°C (4 h), a 30 min ramp to 60°C (3 h), a 30 min ramp to 68°C (2 h), a 40 min ramp and finally cured at 85°C for 2 h. On kilning, the malt aroma and flavor perceived was similar as the malt prepared industrially with sweet sugary taste. The cured sample was then polished to remove the dried rootlets and acrospire and packed in an airtight polythene bags and stored in a cool place (*ca.* 5°C) until the analysis.

Malting loss thousand-kernel weight

This was estimated (db) by weighing the counted (Numigral II Chopin seed counter, France) 1000 kernel mass of the prepared malt and subtracting it from the 1000 kernel mass of the intact grain.

Barely malt sample milling

The kilined barley sample was fine-ground (Bühler Miag Disc Mill, DLFU, Germany) (AOAC, 1990 method 935.30) until 4.5 - 5.5 g (9 to 11%) had remained on standard sieve No. 30 (0.5 mm). This malt flour was used for the malt quality analysis.

Malt moisture content

This was determined by taking *ca.* 2 g malt barley flour sample after oven drying at 103°C for 3 h (AOAC, 1990 method 935.29).

Malt protein content

This was estimated by the micro-*Kjeldahl* method of nitrogen

Table 1. Pasting properties of four malting barely varieties grain flour starches and the effect of three fungicide (propiconazole) spray intervals (7-, 14-, 21-day) and no spray to control net blotch (*P. teres*).

Treatment	ti (min)	Ti (°C)	PV (BU)	HPV (BU)	CPV (BU)	BDV (BU)	SBV (BU)
Variety							
Beka	5.0 ± 0.0[a]	66.3 ± 0.5[a]	277.4 ± 11.1[c]	191.3 ± 18.3[b]	305.4 ± 8.3[b]	86.3 ± 17.6[b]	113.1 ± 13.0[a]
HB 120	4.7 ± 0.1[c]	64.9 ± 0.5[c]	299.1 ± 17.9[b]	210.4 ± 12.4[a]	316.1 ± 16.2[b]	87.6 ± 8.9[b]	102.4 ± 10.8[b]
HB 52	4.8 ± 0.1[b]	65.5 ± 0.5[b]	276.5 ± 24.8[c]	176.3 ± 26.3[c]	294.1 ± 21.2[c]	99.6 ± 8.7[a]	116.4 ± 11.2[a]
Holker	4.7 ± 0.1[bc]	64.7 ± 0.5[c]	314.9 ± 14.9[a]	218.3 ± 10.0[a]	333.2 ± 11.2[a]	95.9 ± 7.2[a]	112.1 ± 7.2[a]
Spray Interval (days)							
7	4.8 ± 0.1[a]	65.4 ± 0.9[a]	289.9 ± 17.9[a]	198.6 ± 18.2[a]	312.4 ± 13.1[a]	91.1 ± 8.3[a]	111.1 ± 12.0[a]
14	4.8 ± 0.1[a]	65.5 ± 0.9[a]	291.4 ± 26.5[a]	199.4 ± 24.0[a]	314.4 ± 20.6[a]	91.3 ±10.0[a]	112.3 ± 11.0[a]
21	4.8 ± 0.1[a]	65.3 ± 0.9[a]	293.1 ± 29.6[a]	196.5 ± 30.8[a]	310.3 ± 28.1[a]	95.5 ±15.1[a]	111.4 ± 10.6[a]
No spray	4.8 ± 0.1[a]	65.7 ± 0.6[a]	293.6 ± 21.5[a]	201.8 ± 23.8[a]	311.7 ± 19.7[a]	91.6 ±15.5[a]	109.2 ± 14.0[a]

Values within the same column with different letters are significantly (P< 0.05) different.
ti = Beginning of gelatinization time, Ti = pasting temperature, PV = peak viscosity, HPV = hot paste viscosity, CPV = cold paste viscosity, BDV = breakdown viscosity, SBV = setback viscosity and BU = Brabender Units

analysis taking *ca.* 0.3 g malt flour (AACC, 2000 method No 46-11) using urea as a control. Malt protein content (%) = % N x 6.25.

Diastatic tendency (a joint α-amylase and β-amylase activity)

This was analyzed as described in the AACC (2000) method 22 - 10 by micro Visco-Amylograph® using 15% db (0.5 g malt flour as an enzyme + 14.5 g refined bread wheat flour as a base) in a buffered solution (disodium phosphate-citric acid) of pH 5.30 to 5.35. The amylograph for analysis was programmed as described above (section 2.2). A reduction in the peak viscosity (malt index) in the pasting curve was computed (Brabender Visco-Amylograph software version 72300, Germany) as a diastatic tendency.

Fine-grind hot water extract

This was done as described in the AOAC (1990) method 935.30. Malt (20 g) was mashed (LB 116 mashing apparatus, 4 beaker grist, mass 32 kg, water bath capacity 5.5 L, revolution speed capacity 200 rpm, agitator speed 100 rpm, VLB-Berlin, Germany) with 80 mL water at 45°C for 30 min (the mash odour was found aromatic for all the samples). Then the temperature was raised (1°C/min) to 70°C and 40 mL water was added further and saccharification was complete at this temperature marked by 2% iodine solution test. Brewery quality water (Harar Brewery Share Company, Ethiopia) was used in the mashing. The sample was cooled and adjusted to total mass of 180 g by addition of distilled water. The sample was filtered through filter paper of diameter 320 mm (Qual. 15 to 65 g/m^2) and the time elapsed by each sample to filter fully into a flask was recorded as filtration time. The malt extract was determined by specific gravity method (DMA density meter) expressed in degrees Plato (P) and converted to % dry matter basis as follows:

$$\text{Extract as is basis} = \frac{P(800+M)}{100-P}$$

where P = g extract in 100 g wort (AOAC, 1990, Plato, 970.90) and M = % H_2O in the malt.

$$\text{Ext dry basis} = \frac{(E \times 100)}{(100-M)}$$

Where E = extract as is basis and M = % H_2O in the malt.

Free amino nitrogen (FAN)

This was analyzed by micro-*Kjeldahl* method using 25 mL wort as described in the AOAC (1990) method 950.10.

$$\text{FAN (dry basis, mg/gmalt)} = \frac{\text{V in L of 0.087NHCL} \times \text{malt extract (dry basis)}}{\text{°Plato of wort} \times \text{specific gravity of wort}}$$

Data analysis

Analysis of variance (ANOVA) for malt quality parameters of the varieties subjected to net blotch protection spray durations were analyzed using SAS (statistical analysis system) version 8.2, 1999 to 2000, SAS Institute inc., Cary, NC, USA. Means were compared by DMRT at a probability level of 5%.

RESULTS AND DISCUSSION

Barley grain flour starch pasting

The pasting parameters (ti, Ti, PV, HPV, CPV, BDV and SBV) were significantly different (P < 0.05) only among the varieties (Table 1). Because of this the pasting curves were given only for no spray (Figure 1a) and more frequently sprayed (7 days interval) (Figure 1b) samples. The result indicated that the varieties were not as such different in their starch types they contain with no *waxy-* (Yanagisawa et al., 2006) or *amylo-* (Yoshimoto et al., 2000) traits. Also no evidence was found of sprout- induced damages to the starches by α-amylase activity. The

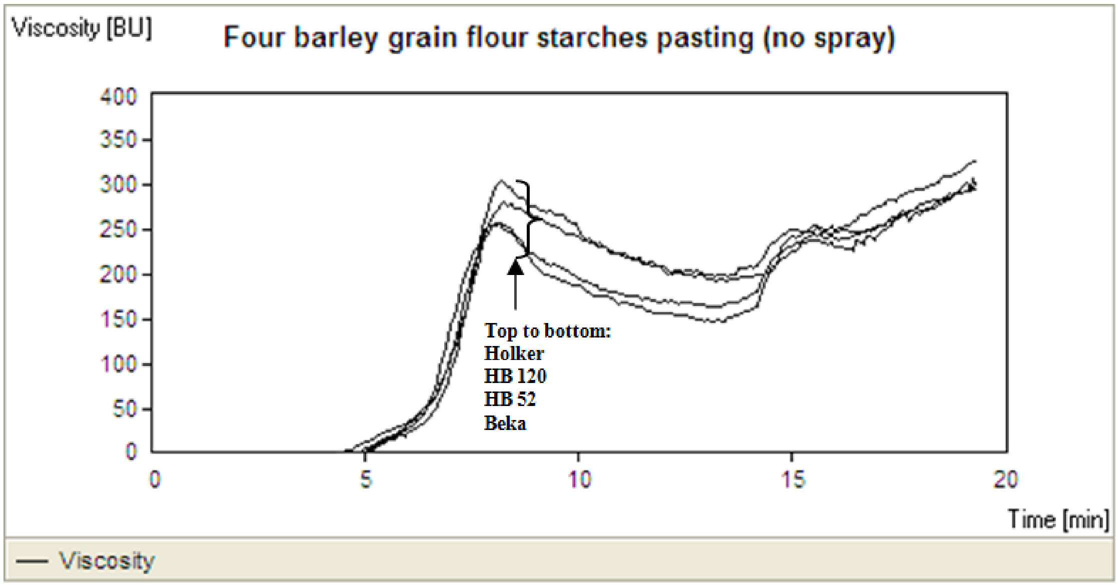

Figure 1a. Pasting curves of 4 barley (Holker, HB 120, HB 52 and Beka) grain flour starch (11.0% db) varieties (no spray).

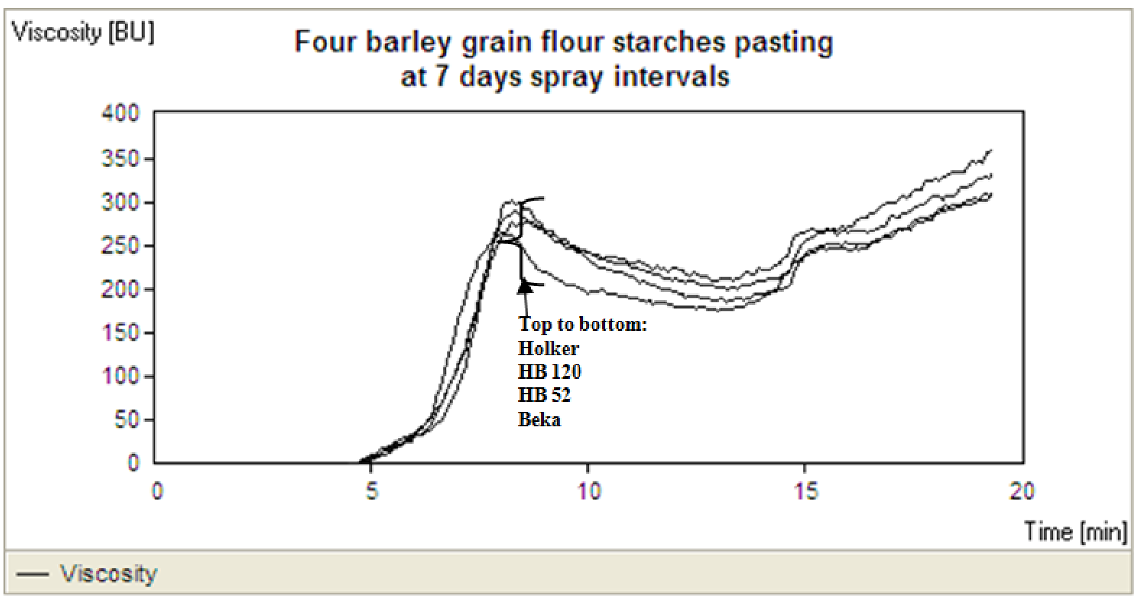

Figure 1b. Pasting curves of 4 barley (Holker, HB 120, HB 52 and Beka) grain flour starch (11.0 % db) varieties at 7 days spray intervals.

starches of the varieties began (ti) to gelatinize in less than 5 min (4.7 to 5.0 min). Significant difference in ti (min) existed between Beka and HB 52, Beka and Holker, Beka and HB 120 and HB 52 and HB 120. Significant difference in the pasting temperature (Ti, °C) was recorded among the malt barley varieties except between HB 120 and Holker. The pasting temperatures (approx. gelatinization temperature) for barley grain flour starches were ranged from 64.7 (Holker) to 66.3°C (Beka) and are similar to the peak starch gelatinization temperature (60 to 65°C) obtained on differential scanning calorimetry (DSC) for normal barely grain grown at 20°C (Tester 1997), but are lower than the tropical grain starches pasting temperatures: *tef* = 68 to 76°C (10.0%, db) (Bultosa, 2007), maize (8% db) = 75 to 80°C (Johnson, 2000) and sorghum 68 to 70°C (10.3% db) (Beta et al. 2000). This short duration of ti and low Ti of starch gelatinization has important contribution because it helps

Table 2. Malt qualities of four barely varieties and the effect of three fungicide (propiconazole) spray intervals (7-, 14-, 21-day) and no spray to control net blotch (*P. teres*).

Treatment	MMC (%)	TKMWL (g)	MP (%)	FAN (mg/100 g malt)	HWE (%)	FT (min.)
Variety						
Beka	6.7 ± 1.0[a]	3.4 ± 1.1[c]	6.4 ± 0.4[b]	124.4 ± 8.1[b]	79.2 ± 3.2[a]	33.8 ± 17.5[a]
HB 120	6.4 ± 1.4[a]	5.5 ± 2.0[ba]	7.3 ± 0.6[a]	139.4 ± 11.2[a]	78.2 ± 2.4[ba]	42.0 ± 14.7[a]
HB 52	6.7 ± 1.1[a]	6.1 ± 2.1[a]	7.3 ± 1.0[a]	140.0 ± 18.6[a]	76.8 ± 2.4[b]	39.9 ± 13.2[a]
Holker	6.9 ± 1.2[a]	4.7 ± 1.2[b]	7.4 ± 0.9[a]	137.5 ± 14.8[a]	78.0 ± 3.0[ba]	35.3 ± 13.4[a]
Spray Interval (days)						
7	6.7 ± 1.2[a]	5.5 ± 2.9[a]	7.1 ± 0.9[a]	135.0 ± 17.5[a]	76.6 ± 2.9[b]	43.6 ± 19.1[a]
14	6.7 ± 1.0[a]	4.4 ± 1.6[a]	7.2 ± 0.9[a]	135.6 ± 14.1[a]	77.5 ± 2.5[b]	38.8 ± 12.5[ba]
21	7.1 ± 1.3[a]	5.4 ± 1.2[a]	7.2 ± 0.8[a]	136.9 ± 14.0[a]	79.7 ± 2.6[a]	31.9 ± 9.3[b]
No spray	6.4 ± 1.2[a]	4.4 ± 1.1[a]	6.9 ± 0.9[a]	133.8 ± 15.0[a]	78.3 ± 2.6[ba]	36.8 ± 15.4[ba]

Values with different letters in a column are significantly ($P < 0.05$) different.
MMC = Dried malt moisture content; TKMWL = thousand kernel malting weight loss; MP = malt protein; FAN = free amino nitrogen; HWE = hot water extract and FT = filtration time

quick hydrolysis of the carbohydrates to fermentable sugars at low energy since the pasting temperature for the barley varieties matches the mashing temperature (64 to 65°C) normally used in beer brewing (Hoseney, 1998). The result also indicated that the starch of the varieties was not damaged due to moisture or sprout induced α-amylase activity in which case the ti and Ti would have been shorter than this.

The peak viscosity (PV, BU) had ranged between 276.5 (HB 52) and 314.9 (Holker) and significant difference ($p < 0.05$) was observed among any of the varieties except between Beka and HB 52. The PV in the varieties is considerably higher than the *amylo*-barley starch varieties reported in Yoshimoto et al. (2000). Batey et al. (2001) have found PV of 288 to 379 RVU (1 RVU ≈ 4.41 BU) for malt barley variety WB 185, 317 to 569 RVU for WB 136, 291 to 558 RVU for Schooner and 325 to 330 RVU for Kaputar. The result suggests that the starches of the varieties are intact with virtually no evidence of starch granules damage by the net blotch disease (Galano et al., 2008). However, the slight difference among the varieties in the peak viscosity is in part attributed to the slight genetic make up difference of the varieties. Holker variety with the longest kernel showed the highest PV (314. 9 BU) even at no spray (Figure 1a) and similar was exhibited in the 7 day (more frequent spray) (Figure 1b) interval. The lowest PV was observed in HB 52. Frequent spraying did not show significant impact on PV (Table 1 and Figures 1a and b) and similar was observed in varieties HB 120, HB 52 and Beka.

The hot paste viscosity (HPV) ranged from 176.3 BU (HB 52) to 218.3 BU (Holker). Significant difference ($P < 0.05$) was observed among all the varieties except between Holker and HB 120. The cold paste viscosity (CPV) ranged between 294.1 BU (HB 52) and 333.2 BU (Holker) and was significantly different ($P < 0.05$) among all the varieties except between HB 120 and Beka.

Breakdown viscosity (BDV) had ranged between 86.3 BU (Beka) and 99.6 BU (HB 52). The BDV for the varieties are considerably lower than for *waxy*-starches of barely grain reported in Yanagisawa et al. (2006) indicating the starches in the barley types studied are not *waxy* types. Because breakdown viscosity is the difference between peak viscosity and hot paste viscosity, the significant difference obtained among the varieties was due to differences in peak viscosity and hot paste viscosity inherent in by the varieties. Even though the PV of Holker appeared highest, with shear thinning during high temperature holding, the breakdown of its viscosity was not highest as experienced in some highly swollen starch pastes. The differences between HB 52 and HB 120, HB 52 and Beka, Holker and HB 120 and Holker and Beka in BDV were significant. The setback viscosity (SBV) had ranged between 102.4 BU (HB 120) and 116.4 BU (HB 52). The SBV indicates the pasted gel tendency toward gelation, which is normally high for varieties with high amylose content (Sasaki et al., 2000). In this observation the varieties had no significant gelation tendency difference except for HB 120. The gelation tendency observed are of normal barley starch types and are different from the *waxy*-(Yanagisawa et al., 2006) or *amylo*- (Yoshimoto et al., 2000) types.

Malt quality

Malt moisture content (MMC)

The malt moisture content difference was not significant among the varieties and among the spray intervals (Table 2). The malt moisture content for long shelf stable storage is recommended 4 to 5% (AOAC, 1990).

Representative analysis of North American malts for Klages (2-rowed) is 3.9%, Proline (2-rowed) 3.9%, Karl (6-rowed) 4.0%, Midwestern Larker (6-rowed) 4.1% and

Canadian 6-rowed and 2-rowed 3.8% (Briggs et al.,1996). In this study, malt moisture content that ranges 6.4 to 7.1% was found. Kilning apparatus (conventional air draught oven) influences moisture removal from the green malt. Inadequate moisture removal on kilning might have resulted in malt moisture content to be slightly greater than 4.8%. But at this moisture level the malt can be stored as shelf stable for reasonable duration since moisture 6.4 to 7.1% is still regarded low to invite pest infestations (Fleurat-Lessard, 2004).

Thousand kernels malting weight loss (TKMWL)

The TKMWL was significant ($P < 0.05$) only among the varieties but not among the spray intervals. Significant difference occurred between HB 52 and Holker, HB 120 and Beka, Holker and Beka and HB 52 and Beka (Table 2). This indicated difference among the varieties in terms of the rate at which modification took place on malting. The thousand kernel weight (TKW) of the un-malted barely grain was ranged 32.5 to 46.4 g. A reduction in the TKW that had ranged 3.4 to 6.1 g was obtained after malting and the reduction was high among the varieties with high TKW (that is, HB 52 followed by HB 120) (Galano et al., 2008). The loss associated to malting increases with germination time and temperature. Dewar et al. (1997) have found an increase in malting loss in sorghum with increasing germination time from 2 to 6 days and temperature from 18 to 25℃. On malting a weight loss of 10.0 to 20.0% is anticipated for the industrially prepared desirable barley malt (Hoseney, 1998) and the weight loss (10.5 to 13.0%) for the varieties are in this range.

Malt protein (MP)

The MP showed no significant difference ($P > 0.05$) among the spray intervals but is among the varieties (that is, MP in Beka is different from the rest) (Table 2). The malt protein had ranged between 6.4 to 7.4%. A reduce-tion in protein content has been found in all varieties when compared to the protein level in the grain 8 to 10% (Galano et al., 2008) and this protein level is suitable for pale ale and lager type malts (9 to 10% proteins) (Fix, 1999). This has happened because on malting large molecules like proteins and carbohydrates will be broken down into simpler molecules that are utilized by the developing shoots (acrospires) and roots (Fix, 1999). The reduction of protein is a normal phenomenon in malting.

Free amino nitrogen (FAN)

The FAN result was also not significantly different ($P < 0.05$) among the spray intervals, but was among the varieties (that is, FAN in Beka is different from the rest) (Table 2). The FAN showed the same trend of difference among the varieties as observed in the grain protein (Galano et al., 2008) and malt protein. Adequate amount of FAN is essential for yeast growth. The EBC (1998) standard requires a FAN of 120 to 160 mg/100 g malt on dry matter basis. In this study, the FAN of the varieties and the spray intervals had ranged from 124.4 to 140.0 mg/100 g malt on dry matter basis. The FAN level potentially would meet the minimum requirements for yeast growth. Therefore, the low incidence of net blotch disease did not as such affect FAN level of the varieties.

Hot water extracts (HWE)

The result showed the existence of significant difference ($P < 0.05$) among the varieties and the spray intervals (Table 2). Significant difference in HWE was only observed between Beka (highest HWE and lowest in TKMWL, MP and FAN) and HB 52 (lowest in HWE and highest in TKMWL, MP and FAN). With an increase in the proteins, a reduction in the starch level in the kernel and a reduction in the HWE is the likely (Weston et al., 1993). In this study, with the spray interval variations, somehow the extract level was influenced. For 21 and 14 day spray intervals and 21 and 7 day spray intervals, the difference between means was significant. The highest HWE was measured for 21 day spray interval and the lowest was for 7 day spray interval. This trend was expected to be increasing with frequent spray intervals. It appears the low disease intensity recorded during the growing season from the most frequently sprayed plots had less effect on the HWE. Factors other than the disease like nature of the varieties and degree of the endosperm cells modification (particularly β-glucans and protein matrices that encapsulates starch granules) by the malt enzymes on malting and mashing might have interactively influenced the HWE (Bamforth, 2006). Extract yield is one important factor in malt barley quality evaluation, because it is directly correlated to the volume of beer processed (Fix, 1999). The minimum fine grind extract yield of Canadian 2-row malt barleys is 80.0%. In the Czech republic, malt extract specification is 80.7% for the Budvar malt and 82.8% for the well grain modified barley malt. For 4 barley varieties fine grind extract of 73.3 to 80.6% were reported by Weston (1993). In the EBC (1998) standard a minimum of 79 to 82% and AOAC (1990) 74.0 to 77.0% fine grind extract were described. In this study, the fine grind extract had ranged from 77 to 80% for both the varieties and spray intervals meeting the standards described above. Starch level in the kernels of malt barley, which is directly correlated with the HWE can be affected by many factors. One such factor is the genetic make up of the barley variety and environment also influences the starch content (Tester, 1997; Savin et al., 1996). Since the varieties were grown under one location, the slight variations observed among the

Table 3. Malt index (14. 5 g wheat flour starches substrate + 0.5 g malt barley enzyme, db) and the effect of 3 fungicide (propiconazole) spray intervals (7, 14, 21 day) and no spray to control net blotch (*P. teres*).

Treatment	PV (BU)
Variety	
Wheat flour starch + Beka malt	145.0 ± 30.7[b]
Wheat flour starch + HB 120 malt	154.9 ± 29.2[b]
Wheat flour starch + HB 52 malt	170.9 ± 40.7[b]
Wheat flour starch + Holker malt	200.4 ± 35.5[a]
Mean	167.8
Wheat flour starch	678.0
Spray Interval (days)(wheat flour + malt)	
7	169.1 ± 40.4[a]
14	164.8 ± 48.2[a]
21	166.8 ± 30.5[a]
No spray	170.4 ± 40.9[a]
Mean	167.8

Values with different letters in a column are significantly (P < 0.05) different. Where PV = peak viscosity and BU = Brabender Units.

varieties would be a manifestation of the slight genetic difference among them and the spray intervals applied to control the diseases.

Filtration time (FT)

Significant difference in FT was observed among the spray intervals but not for varieties (Table 2). The FT for 7 day spray interval (44 min) was significantly different from the 21 day spray interval (32 min). Filtration time is influenced by the levels of β-glucans and heteroxylans (Stone, 2006) and their modifications on malting and mashing. Higher amount of these hot water soluble high molecular weight materials would result in viscous mash that lowers the speed of filtration, which is manifested by longer period of filtration time. This probably in part had contributed to the lower HWE measured for 7-day as compared to the 21 day spray intervals. Longer filtration time (greater than 60 min) delays the brewing time by lowering the speed with which the fermentable extract is obtained and thus lagging the beer production. In this study, no influence of net blotch at low incidence has been manifested on the varieties in terms of extending the filtration time beyond the EBC (1998) limit, which is less than 60 min.

Mash odour and colour

The mash odour of the malt was found normal for the varieties and the spray intervals. However, the wort colour appeared slightly greater than the EBC (1998) requirement. The colour was slightly amber brown (caramel color) for all samples which are probably more suitable for dark beer (less pale) making. Acceptable mash color is pale yellow (2.5 to 4.0 EBC units). Color and flavors that are imparted to beer are a result of Maillard reactions (reactions between free amino nitrogen and reducing sugars of the malt) basically developed on kilning and then further modified on mashing (Fix, 1999). This variation has brought the color slightly more brown than the one normally used in the Harar brewery employed for the making of pale lager type beer.

Malt diastatic tendency

The diastatic tendency of the barley malt enzymes was assessed through the evaluation of the malt index (peak viscosity) (AACC, 2000; Raschke et al., 1995). The peak viscosity (PV) of the refined wheat flour starch used as substrate was 678.0 BU. This PV was reduced significantly under the influence of the barley malt flour diastatic enzymes (hydrolytic enzymes that hydrolyzed pasted wheat flour starches into fermentable sugars and dextrins of low molecular weights of low paste viscosity) to 167.8 BU (Table 3) when the malt enzyme and refined wheat flour was supplied at the ratio of 1:29. The PV (malt index) is inversely related to the diastatic tendency (AACC, 2000; Raschke et al., 1995). The diastatic tendency of the malt enzymes was significant (P < 0.05) among the varieties but not among the spray intervals. Because of this, the pasting curves were only shown for no spray and frequently sprayed (7 days interval) samples (Figures 2a and b). The diastatic tendency of the

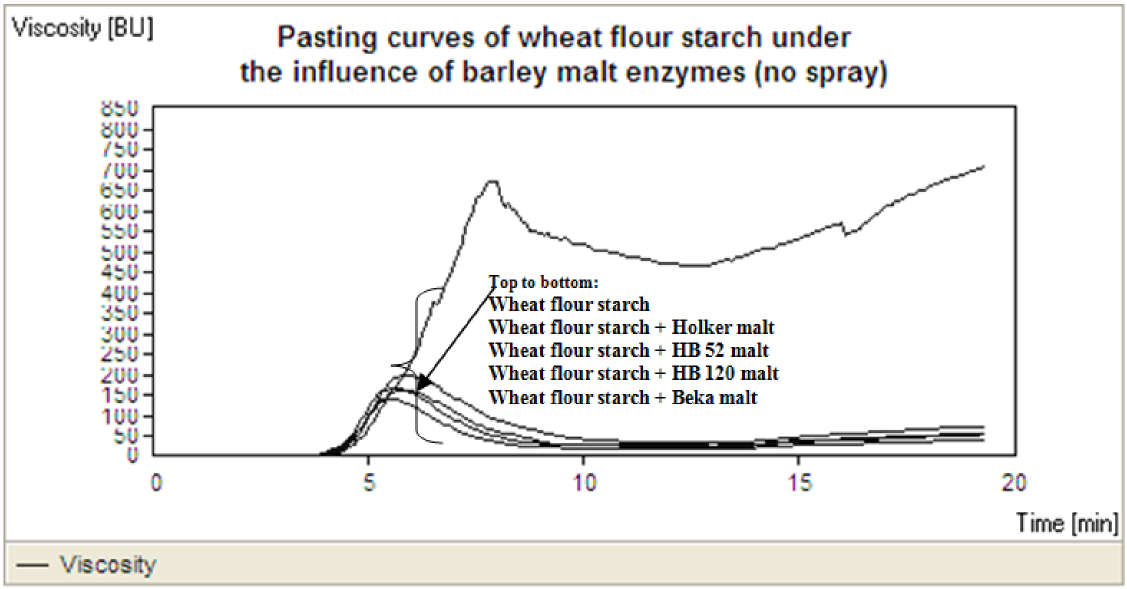

Figure 2a. Pasting curves of refined wheat flour starches (14.5 g, db) under the influence of 4 barley varieties (Holker, HB 52, HB 120 and Beka) malt enzymes (0.5 g, db) with no spray by propiconazole.

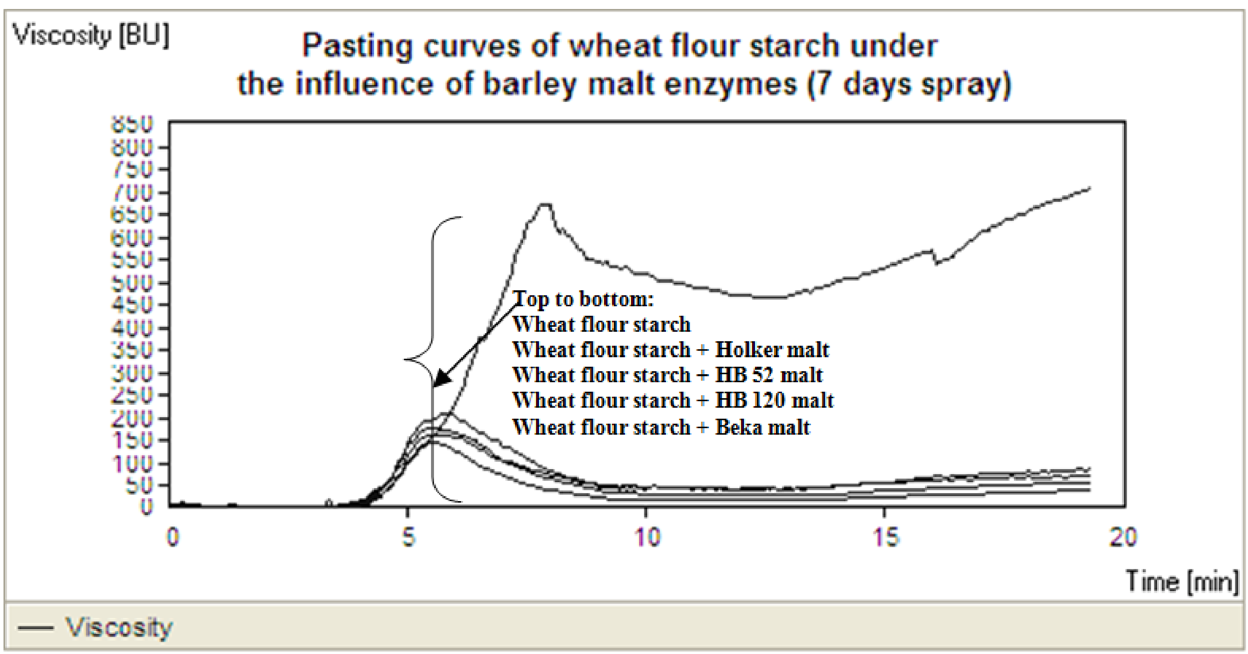

Figure 2b. Pasting curves of refined wheat flour starches (14.5 g, db) under the influence of four barley varieties (Holker, HB 52, HB 120 and Beka) malt enzymes (0.5 g, db) with 7 days spray interval by propiconazole.

malt from Holker was poor and was significantly different from Beka, HB 120 and HB52 (Table 3). The malt is required to have sufficient diastatic tendency because the higher the diastatic tendency, the more the fermentable sugars and the more the hot water extract and the more the beer volume thus made (Fix, 1999). In this study, Beka malt was highest in its diastatic tendency followed by HB 120 and HB 52. From the spray intervals, the malt from Beka also appeared highest in its diastatic tendency (result not shown) and presumably the hot water extract from the Beka variety was also highest (Table 2). The result showed that net blotch at low incidence as such did not affect these enzymes.

Conclusions

Most malt qualities evaluated showed differences only among the varieties and the values found were within the acceptable limit of breweries even though a single variety may not fulfill all the quality requirements. Only hot water extract and filtration time showed significant differences among the spray intervals. The hot water extract fell slightly below the minimum EBC requirement for both spray intervals and varieties with the exception in the Beka variety. Thousand malting weight loss, malt protein and FAN differences were among the varieties. A FAN of 120.4 to 140.0 mg/100 g malt indicated adequate level for yeast growth. The diastatic power was not affected by varying the spray intervals. The highest diastatic tendency exhibited by Beka makes this variety excel others and the least is for Holker. The normal filtration time (less than 60 min) obtained shows the sufficient modifications of β-glucans and heteroxylans on malting with variations among spray intervals. Net blotch disease infection can reduce the kernel carbohydrate content. However, under low severity, the result showed that the malt protein, diastatic tendency and FAN remain unaffected. To some extent the hot water extract and filtration time was found influenced with the spray interval used to control the disease. It seems that the production of malt barley is not frustrating under very low net blotch disease severity, provided that other factors are not limiting.

Future research direction on malt barley production in Ethiopia should address hot spot areas, studies using artificial inoculation, economic importance of the diseases, development of malt barley varieties for Ethiopian potential areas (improvement of grain and malt qualities) that boost the production, pertinent agronomic practice studies (appropriate malt barley production package for Ethiopian farmers) and strengthening micro-malting laboratory and expert capacity are recommended to overcome the limitations of malt barely production in the country.

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