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Potential of Triticale (X *Triticosecale* Wittmack) Malts for Beer Wort Production

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ABSTRACT

Triticale grain, a wheat-rye hybrid mostly used for animal feed, has been recently reported to exhibit different trends when used as unmalted or malted grain in the brewing industry. The aim of this study was to evaluate the potential of four different triticale lines to evaluate their potential for malt production. The four studied triticale malts PM-1, PM-3, PM-6, and PM-8 lines yielded an extract content higher than 100% and a diastatic power similar to some barley malts (86.19–190.19°L). The produced worts showed a higher percentage of soluble protein, between 4.56% and 5.66%, with a large viscosity value (~2.055 cP) reported for this raw material. Two triticale malts were selected based on their performance, PM-1 and PM-3, and fermented at different percentage combinations with barley malt (0, 30, 50, 70, and 100%). The results revealed that the use of 100% triticale malt yielded an acceptable fermentation, with an Apparent Attenuation Limit (AAL) of 72%. The optimal triticale-barley malt ratio was 30/70, where supplementing triticale malt enriched the extract, enhancing the fermentation. These results support the suitability and possible establishment of triticale grain as a brewing crop.

KEYWORDS

Extract; fermentation; lines; malts; triticale; worts

Introduction

Triticale (X *Triticosecale* Wittmack) is a small-seeded cereal grain, a product of the hybridization of wheat (*Triticum*) with rye (Secale). The crop was bred to be highly adaptable and cultivated worldwide. Under optimal conditions, this grain shows a competitive yield compared with either of its parents.[1] In the case of nutritional value, this cereal grain exhibits greater lysine content, with favorable protein digestibility, as well as mineral balance when compared to wheat.[2] These characteristics explain its use for animal feed but also opens the possible use for human consumption, whether as a complement or as a substitute for certain grains.[3]

For years, barley has been one of the most used crops for beer production. After malting, the germinated barley grain exhibits high protein and sugar levels, due to the degradation of the kernel endosperm, making this raw material an excellent brewing ingredient. However, despite the advancement in technology and characterization of the malting procedures, the yield of fermentable carbohydrates per kg of biomass requires a raw material with high diastatic power, which only barley malt can provide. As a solution, the industry has turned to the use of starchy adjuncts in order to manage an efficient and profitable brewing process.[4] These supplements or brewing adjuncts are un-malted grains such as maize and rice grits, starch, and in recent studies un-malted triticale has been also proposed.[5] They play the role of an extra source of fermentable sugars, and depending on the brewer, are added to produce additional features in the end product but have no contribution to enzyme activity or to the soluble nitrogen present in the wort.

Most non-malt adjuncts contribute neither enzyme activity nor soluble nitrogen to the wort; however, this is not the case with triticale. As this grain has high levels of α-amylase activity in its unmalted form, it performs well in malting and brewing. Furthermore, the relatively low starch gelatinization temperature of triticale (59–65 °C) brings an advantage in achieving efficiency of starch degradation, similar to barley malt.[6] However, triticale malt produces worts with excessive protein degradation and, therefore, a high soluble nitrogen content, both of which promote haziness, instability, and a dark color in the beer.[7,8] In general, triticale has larger malt losses but higher malt extracts, higher diastatic power, a shorter steeping period (about four times shorter) and higher α- and β-amylase activities compared to barley. Pomeranz et al.[8] found that triticale beers were generally darker in color and had higher pH values than beers made from barley. The average real extract of triticale beers was higher than that of barley beers. On the other hand, the average degree of fermentation in barley beers was higher compared to triticale beers. Therefore, triticale beers contained less alcohol and more nitrogenous compounds than barley beers. Another study conducted by Grujic et al.[9] showed that the substitution of 70% of the barley malt with triticale malt yielded worts with good analytical quality parameters. The authors reported that with an increasing content of malt triticale in the grist, wort viscosity increased, mainly due to the poor activity of cytolytic enzymes,

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especially the β-glucanases in the triticale malt.[5] Glatthar et al.[10] showed that the addition of 30% adjunct, in the form of unmalted triticale, during brewing increased the wort viscosity by 10%, compared with 100% malt, but did not significantly affect filtration or lautering rates.[10] In this context, the application of gibberellic acid and potassium bromate during malting usefully reduced wort viscosity. However, the increase in levels of wort-soluble nitrogen caused by this treatment would make it unacceptable in the manufacture of traditional British brewing malts.[11] Although there is malting quality variability in triticale, Holmes[12] indicated that it would be difficult to breed for this trait because there is no methodology available for rapid and simultaneous screening for both protein solubilization and carbohydrate modification. Therefore, the aim of this study was to evaluate the potential of four different modern triticale malts lines for their use in the production of beer worts.

Experimental

Materials

Four triticale modern lines were used: PM-1, PM-3, PM-6, and PM-8. These were harvested in 2013 and grown in Polotitlan, Mexico (International Maize and Wheat Improvement Center-CIMMyT). A commercial barley base malt from Briess® was used, which was produced in the U.S.A. from AMBA/BMBRI with 2-row malting varieties.

Methods

Triticale characterization

Proximal characterization. The American Society of Brewing Chemists (ASBC) methods 5-A, 7-A,[13] and Association of Official Agricultural Chemists (AOAC)[6] methods 923.09, 920.39, and 962.09 for moisture, protein, ash, ether extract, and crude fiber contents, respectively, were used to characterize the four triticale samples. The digestible carbohydrates were reported as the difference between the dry matter minus the addition of the ether extract + protein + ash + crude fiber. All samples were assayed in triplicate.

Viscosity profile. The methodology of Jane et al.[14] was followed to obtain the viscoamylograph profile using a rapid viscoanalyzer (RVA) 3 C (Newport Scientific PTY LTD, Sydney, Australia). The standard heating sequence was used and the data from maximum viscosity, final viscosity, and pasting temperature were extracted from the resulting curves.

Malting

Steeping. Samples (300 g, db) of triticale grain, previously washed with neutral liquid soap, were immersed in a solution of $Ca(ClO)_2$ g/L for 2 h. After that time, cleaned kernels were placed in a beaker with 250 mL of tap water at 18 °C in the germinating chamber (Electrolux, Mod. ERWW084MSKBM, China) for 18 h. After this period, the excess water was eliminated and the resulting kernels, containing around 45% grain moisture, were placed for 4 h for respiration at room temperature.

Germination. The samples were placed into trays into the same germinating chamber, at 18 °C and 90% relative humidity, in darkness for 3 days, until the acrospires reached a size of three-fourths of the grain.[15,16] During this step, three manual agitations were performed to avoid and to separate roots.[17]

Kilning. After germination, the triticale was dried using a 35 °C oven (Felisa, Mexico) for 19 h. Next, the temperature was increased to 45 °C for 24 h and then to 65 °C for an additional 25 h. Finally, the oven temperature was decreased to 30 °C for 14 h.[18,19]

Malt processing efficiency and grinding

The rootlets (culms) generated during germination were eliminated from the malts by deculming, and the clean malt was weighed.[20] Samples were ground according to AOAC method 935.30[6] and the method suggested by Figueroa.[21]

Malt quality

The moisture content of the malts was quantified following ASBC barley method 5-A[13] and specific gravities were determined using the ASBC method wort-2.[13] To quantify the malt extract content, the samples were finely ground and assayed following European Brewery Convention (EBC) Method 4.5.1.[20] The viscosity of the wort was measured using an Ostwald viscometer and ASBC method wort-13.[13] Diastatic power was determined using ASBC method malt-6.[13] Soluble protein was conducted with EBC method 4.3.1 and 4.9.1.[20] Apparent attenuations from the four triticale lines were selected to be replaced with 20%, 30%, 50%, 70%, and 100% barley malt. All of the mixes were fermented according to EBC method 4.11.2.[20]

Statistical analysis

The data were analyzed with statistical software JMP,[22] using one-way ANOVA, and means comparison was performed using Tukey's test with a significance level of $\alpha = 0.05$.

Results and discussion

Triticale characterization

Proximal characterization

Table 1 summarizes the proximal characterization of the four different triticale lines. The PM-8 line had the maximum moisture value and it was not significantly different compared with the PM-3 line. The PM-1 and PM-6 lines had no significant moisture differences, with moistures of 11.47% and 11.57%. These reported values were lower compared with the recommended values in the literature (around 13% as optimum storage moisture).[23] However, although the moisture results obtained in this work were low, Glatthar et al.[10] also reported moisture values of 11.0% and 11.3% for the triticale lines that they used, suggesting that values lower than 13% are typical in triticale seeds. Protein levels were around 11.97% and 13.25%, but

Table 1. Proximal characterization of the four different triticale lines.

Sample	Moisture (%)	Protein (%)	Ash (%)	Ether extract (%)	Crude fiber (%)	Nitrogen-free extract (%)
PM-1	11.47 ± 0.20b	13.25 ± 0.99a	1.86 ± 0.07bc	1.34 ± 0.25d	2.83 ± 0.07b	75.77 ± 6.4a
PM-3	11.71 ± 0.07ab	11.97 ± 1.30a	1.59 ± 0.05c	2.10 ± 0.26bcd	1.49 ± 0.13b	82.87 ± 1.24a
PM-6	11.54 ± 0.17b	12.87 ± 0.30a	1.72 ± 0.12bc	2.39 ± 0.11bc	1.93 ± 0.49b	81.03 ± 0.01a
PM-8	12.02 ± 0.22a	12.81 ± 0.01a	1.77 ± 0.16bc	1.08 ± 0.06d	2.63 ± 0.36b	82.26 ± 0.31a

Mean values ± standard deviations. Means shown with same letters within a column were not significantly different (p-value $\leq$ 0.05).

Table 2. Viscosity properties of the four different triticale lines.*

Sample	Maximum Viscosity (RVU)	Final Viscosity (RVU)	Pasting Temperature (°C)
PM-1	104.33 ± 5.51a	26.67 ± 3.06a	65.25 ± 0.01a
PM-3	101.50 ± 2.12a	24.50 ± 2.12a	64.70 ± 0.28a
PM-6	47.00 ± 0.01dc	14.50 ± 0.71b	62.65 ± 0.01a
PM-8	49.00 ± 0.01de	15.5 ± 0.71b	62.83 ± 0.25a

*Mean value ± standard deviation. Means shown with same letters within a column were not significantly different (p-value $\leq$ 0.05) from each other.

no statistical differences were observed amongst the four triticale lines. The protein contents of the four triticale lines were 4% higher when compared with barley samples analyzed by Lowe et al.[4] and the ash and crude fiber content were within reported values. However, the ether extract and nitrogen free extract results surpassed the values reported in the literature.[24] The low crude protein levels and low ash content were expected since the major concentration of minerals is located in the kernel pericarp.

Viscosity profile

The RVA profiles of the four different triticale lines are reported in Table 2. In terms of maximum viscosity, samples PM-1 and PM-3 had the maximum values and did not show statistically significant differences (above 100 RVU). However, lines PM-6 and PM-8 had around 54% lower values compared with the other two lines. The results of maximum viscosity were similar those reported by Zihua and Jane,[25] with values between 105 RVU-123 RVU. The triticale endosperm contains two different starch granules: large type A and small type B granules. Granules of type A contain a higher amount of amylose and larger amylose chains compared with the granules of type B. It is possible that lines PM-1 and PM-3 contained more type A granules compared with the other two lines, thereby developing this viscosity behavior. Another important factor that affects the viscosity is the high activity of α-amylase shown by the new varieties of triticale. Dennett et al.[15] analyzed different modern triticale cultivars, and all exhibited high α-amylase activities. Despite the significant differences amongst the viscosity analyses, the results show the relationship between the high intrinsic enzyme activity displayed by modern strains and their low viscosities. For the mashing step, low viscosity profiles are ideal to reduce mixing costs and to enhance the enzymatic hydrolysis yield. The same viscosity behavior could be observed with the final viscosity, where the lines PM-1 and PM-3 had similar final viscosities (∼27 RVU) and the triticale lines PM-6 and PM-8 had lower final viscosities (∼15 RVU). These results were similar with those obtained by Zihua and Jane,[25] who had maximum viscosities around 105 RVU-123 RVU and 34 RVU-62 RVU for final viscosity. For the pasting temperature, the four lines had similar values, varying from 62.8 °C to 65.25 °C, with no statistical difference. These pasting temperatures were lower than the results reported by others[25,26] for barley samples (from 86 °C to 94 °C). These low pasting temperatures are profitable. Enzymes such as α- and β-amylases show their optimum enzymatic activity at similar temperature ranges (64 °C – 70 °C) and, from an energy standpoint, lower heat input will be required to gelatinize the starch granules.

Malt quality

Barley malt has traditionally been the grain of choice in the brewing industry. Barley malt is preferred because, among other reasons, it has a high potential for extract development for yeast growth and fermentation. Malt quality is the most important factor to yield high extract worts of good quality, which upon fermentation produce high quality beers.[27] The specific gravity (SG) obtained from the different triticale malts is shown in Table 3. This parameter is closely related to the sugar content, short chain proteins, and solubles in the wort, which are substrates for yeast fermentation. All triticale lines' SG values were statistically different ($p \leq 0.05$). These samples had values around 1.04 g/mL, very similar compared to the barley malt used in this research. The line PM-1 had the highest SG, followed by lines PM-6, PM-3, and PM-8. Other works reported SG values for barley malts of 1.02 g/mL and for wheat malt values ranging from 1.03 g/mL to 1.05 g/mL.[12]

The extract content of the four triticale lines was more than 100% (Table 3) (103.85%–118.38%) and all were statistically different ($\rho \leq 0.05$). The PM-1 malt had the highest value even surpassing the barley malt extract. Barley malts extract values varied around 75–82%, depending on the kind of barley, and on the kind of malt.[19] The triticale malts yielded a better extract content compared with the barley malt. Extract content is an important factor in the brewing industry, because is related to the soluble fermentable sugars (mostly glucose and maltose) in the wort and is correlated with high concentrations of ethanol.[19,28]

Regarding the viscosity parameter, the triticale malts had values from 2.050 cP to 2.060 cP (Table 3) and all samples were statistically different ($\rho \leq 0.05$). Compared with the barley malt control, the sample PM-1 had a similar value. All viscosity values obtained in this research were high compared with other research.[2] Arguably, filtration of the wort is one of the most difficult steps in beer production; controlling the wort viscosity is crucial to a successful process. The viscosity of the wort is greatly affected by the hydrolysis of β-glucans during mashing. The relatively high viscosity of triticale worts was affected by the higher molecular weight of the triticale arabinoxylans associated with the

Table 3. Parameters of malt quality of the four different triticale malts compared to the barley malt.*

Sample	Specific gravity (g/mL)	Extract content (%) DB	**Viscosity (cP)**	Soluble protein (%) DB	Diastatic power (°L)
PM-1	1.048 ± 0.001a	118.38 ± 0.86a	2.060 ± 0.001a	5.66 ± 0.16b	190.19 ± 13.69a
PM-3	1.044 ± 0.001c	108.69 ± 0.19c	2.053 ± 0.001c	5.60 ± 0.07b	168.99 ± 16.56a
PM-6	1.045 ± 0.001b	110.71 ± 0.27b	2.054 ± 0.001b	4.56 ± 0.02d	86.19 ± 16.49b
PM-8	1.043 ± 0.001d	103.85 ± 0.07d	2.050 ± 0.001d	4.91 ± 0.01c	145.97 ± 14.12ab
Barley malt	1.048 ± 0.003a	77.87 ± 0.67e	2.062 ± 0.007a	11.50 ± 0.01a	140.00 ± 0.01b

*Mean values ± standard deviations. Means shown with same letters within a column were not significantly different (p-value $\leq$ 0.05) from each other.
DB, Dry basis; °L, Lintner degrees.

Table 4. Effects of two different triticale malts and combinations with barley malt on the Apparent Attenuation Limit (AAL).*

Triticale malt (%)	Barley malt (%)	AAL (%) PM-1	AAL (%) PM-3	Barley malt
100	0	72.23 ± 0.15b	72.63 ± 1.14b	77.07 ± 0.15ab
80	20	76.61 ± 9.37ab	73.84 ± 1.02b	
70	30	78.00 ± 2.12ab	78.95 ± 1.08ab	
50	50	79.90 ± 1.77ab	79.61 ± 0.49ab	
30	70	81.28 ± 2.17ab	83.79 ± 1.74a	

*Mean value ± standard deviation. Means shown with same letters within a column were not significantly different (p-value $\leq$ 0.05) from each other.
AAL, Apparent Attenuation Limit.

pericarp.[10,29] In previous studies on unmalted triticale, high viscosity values were obtained (2.14–2.38 cP), and the use of added enzymes on the unmalted triticale worts achieved 1.50–1.75 cP.[30] The values in this research were similar to those obtained by Blanchflower and Briggs[11] in their triticale micromashings. Comparing the results in Table 3, the high specific gravity and extract content in the triticale malts changed with the high viscosity obtained in the worts, meaning that high SG and extract values could be attributed to the higher presence of other molecules such as β-glucans and arabinoxylans, which dilute the amounts of fermentable sugars in the worts. On the other hand, the soluble protein generated in the triticale worts was 4.56% to 5.66% (Table 3); these values were significantly different. The triticale malts with more soluble protein were PM-1 and PM-3. These two triticale worts only contained half of the amount compared with the soluble protein observed in the barley malt wort. The reported values in the barley malt worts ranged from 3.90% to 4.70%.[9] Interestingly, the triticale malt worts contained slightly higher soluble protein compared with other previous reports. During the germination process, some of the proteins are hydrolyzed into soluble proteins or peptides. In the mash, part of the high molecular weight proteins, which were not hydrolyzed during malting, are modified by proteolytic enzymes producing polypeptides and amino acids.[16] In this case, the soluble protein in worts produced with triticale malts were not statistically different between PM-1 and PM-3 lines, but reached half the amount produced from barley malt. An important parameter influencing fermentation capacity and beer characteristics is the amounts and types of amino acids present in the sweet wort, since free amino acids represent the major nitrogen source for brewing yeasts.[31–33] Diastatic power represents the activity of amylolytic enzymes, such as α-amylase and β-amylase, and it is desirable that malts have high diastatic power (125–170°L). A deficiency in diastatic enzymes, particularly β-amylase, hinders starch conversion into fermentable sugars.[16] The triticale malts showed similar diastatic power between lines PM-1, PM-3 and PM-8 and showed no statistical difference (Table 3). The PM-1 malt achieved the highest value (190.19°L). Lines PM-3 and PM-8 had similar values compared to the barley malt, and the line PM-1 showed better diastatic power, suggesting that the triticale malts had good potential as sources of amylolytic enzymes.

According to the results obtained herein, the lines PM-1 and PM-3 were selected to continue with the fermentation studies, as these lines contained high diastatic power, good extract content, and a SG with enough amylolytic enzymes to yield adequate amounts of fermentable sugars.

Fermentation

Different percentages of triticale malts were evaluated to replace the barley malt (Table 4). The fermentation was measured as the percent of the Limit Attenuation of Fermentable Carbohydrates (AAL). The AAL is the ratio of effectively metabolized fermentable carbohydrates during fermentation in relation to the total fermentable carbohydrate content of the sweet worts. The AAL in the different mixes was 72.23–83.79%. Statistical differences were observed in both triticale lines when high malt values were used against the barley malt in the mixes. The AAL with 100% triticale malt, with both lines, was slightly lower compared with the all-barley malt value, producing good quality worts for fermentation. The use of 80% to 50% of triticale malt had similar AAL values compared with the control barley malt. The use of 30% PM-3 malt showed the best results but was not statistically different when compared to the 50 and 70% PM-3 malt treatments. The use of the PM-1 malt at different levels was not significantly different among the mixes. The synergy between barley and triticale malts resulted in high AAL, while the lower amounts of triticale increased the fermentation rate. Usually barley malts generate more fermentable sugars and soluble proteins due to their high enzymatic activity. The combination with triticale malt increased the starch content in the mix and improved hydrolysis. Similar results were found by Glatthar et al.,[10] who used unmalted triticale as an adjunct. The use of 70% unmalted triticale yielded higher AAL compared to the all-barley malt counterpart.

Conclusions

From the parameters studied in this research, the triticale malts showed a high potential to be used as a substitute for barley malt for the production of European beers. The triticale lines PM-1 and PM-3 generated similar results

compared with the barley malt. The high viscosity observed in the triticale containing worts, for large industries, could pose problems during lautering or filtration. However, this cereal could be used for homebrewing using all-malt from triticale or using 30% triticale malts to produce worts with a higher concentration of fermentable sugars. The use of triticale could be a successful alternative to reduce the cost of using a barley malt, by increasing the amount of starch in formulations, while keeping the enzymatic activity to produce worts of the same quality as a barley malt wort.

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