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Unmalted triticale cultivars as brewing adjuncts: effects of enzyme activities and composition on beer wort quality

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Abstract: The applicability of three selected triticale cultivars (Trinidad, Lamberto, Fidelio) for use as brewing adjuncts was investigated in comparison with wheat adjunct and barley malt. Fermentable substance, crude protein and arabinoxylan levels of starchy materials were determined as well as their native potencies (amylolytic, proteolytic, pentosolytic) to solubilise and degrade grain components during mashing. Laboratory-scale experiments were performed to evaluate the influence of the adjuncts (composition, enzyme potency) on beer wort quality by mashing mixed (1:1) grists of malt and adjunct. Barley malt was rated as the superior raw material, possessing considerably higher enzyme activities and yielding the lowest wort viscosity. Among the triticale cultivars cv Trinidad was identified as the most suitable to serve as a brewing adjunct due to its improved starch solubilisation properties and its ability to generate low wort viscosities. Compared with the potent malt enzymes, the enzyme activities of unmalted triticale (such as amylases, pentosanases and proteases) had little affect on the composition of the sweet worts. In contrast, the contents of crude protein and fermentable substance of the triticale varieties greatly affected wort quality. Furthermore, the adjunct moiety determined the level of wort viscosity when mashing a combination of malt and triticale. In general, the brewing properties of triticale cv Trinidad were comparable with those of wheat.
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Keywords: amylolysis; proteolysis; viscosity; adjunct; wheat; triticale

INTRODUCTION

Due to ever increasing competition, the brewing industry is forced to evaluate different grists on a cost quality basis. Thus, improved sources of starch designed for brewing purposes are of growing importance as until now primarily barley varieties have been investigated in detail with regard to the malting process. Canales[1] pointed out that demographic growth, scarcity of cereals and economic factors will undoubtedly lead to a substantial increase in the use of brewing adjuncts. In this respect, one can assume that the brewing industry will favour those adjuncts which are less expensive but still give a high quality beer. This implies that a proper technology and the scientific basis for their utilisation need to be provided.

Triticale (*Triticosecale* spp Wittmack)—a cross between wheat (*Triticum* spp) and rye (*Secale* spp)—complies very well with the requirements for modern brewing adjuncts. Previous studies conducted in our laboratory projected substantial savings in costs of raw materials by employing triticale instead of the currently utilized brewing adjuncts, like brewer's rice, maize grits or barley.[2] These studies also favoured the use of triticale rather than other adjunct materials for the maintenance of beer quality (eg foam stability, beer flavour characteristics).[2,3]

Common brewing adjuncts are usually considered non-malt sources of extractable carbohydrate,[4] which typically do not contribute substantial enzyme activity or soluble nitrogen.[5,6] Triticale is superior in this respect since it displays some brewing properties similar to those of malt; source varieties have significant levels of amylolytic activity in their unmalted form, even in the absence of visual sprouting.[7–11] In combination with a low gelatinization range of 59–65 °C,[8] triticale starch solubilisation and amylolysis could be completed during mashing by applying temperature regimes similar to those used for malt.[2,3,12–14] Moreover, triticale has native proteolytic activity,[15] which contributes both soluble protein and assimilable nitrogen to the wort.[2,3] Besides amylolysis and proteolysis, the degradation of non-starch polysaccharides during mashing is considered another essential parameter in brewing. Arabinoxylan and mixed linkage β-glucan

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have been recognised as factors that contribute to wort viscosity, decrease wort and beer filtration rates and cause subsequent problems such as haze formation or reduced extraction efficiency.[16–18] When using triticale, mixed-linkage β-glucans are negligible as a result of their minor content in the grains.[19] In contrast, the solubilisation of triticale arabinoxylans slightly increases wort viscosity and may affect beer filtration rates.[2,3]

The objectives of the present work were (1) to evaluate the enzymatic pattern and functional key characteristics of three selected triticale cultivars for use in brewing in comparison with those of unmalted wheat and barley malt, (2) to investigate the influence of determined adjunct characteristics and cultivar differences on wort quality when replacing half of the enzyme-potent malt in the grist with triticale or wheat, and (3) to determine critical parameters for the prediction of the quality of triticale for brewing.

MATERIALS AND METHODS

Cereal-based raw materials

The following raw materials were used in this study: winter triticale samples of cultivars Trinidad (five samples), Lamberto (three samples) and Fidelio (three samples) from crop years 1999, 2000 and 2001, as well as two winter wheat samples (2001 crops, cv Batis and cv Flair) and a commercial pale malt produced from two-rowed summer barley (Weyermann Specialty Malting Co, Bamberg, Germany). Triticale and wheat samples were supplied by German crop breeders (Hege Saatzucht, Waldenburg, Germany and Kruse Saatzucht, Enger, Germany).

All cereal-based materials were milled in a Retsch Rotor Beater Mill SR 2 (Haan, Germany) to pass through a 0.5-mm sieve. In each case, the extraction rate of the grist flour fraction ($<125\,\mu$m) exceeded $90\,g\,hg^{-1}$.

Analysis of cereal-based raw materials

Grist samples were analysed for fermentable substance (FS), crude protein, arabinoxylan and moisture content according to described procedures:[14] the Kjeldahl EBC (European Brewery Convention) method,[20] a colorimetric method described by Delcour *et al*[21] and a moisture analyser (Sartorius MA 51 Göttingen, Germany), respectively.

To evaluate enzyme activities and functional key characteristics of raw materials relevant to brewing practice, the conventional EBC analytical mash method[20] was employed. Amylolytic potency (amylolytic activity of raw materials combined with their starch solubilisation property) was estimated by the wort content of fermentable carbohydrates (glucose, fructose, maltose and maltotriose) as a proportion of grist FS. All saccharides were calculated as starch equivalents. Further calculations were performed in a manner analogous to the Kolbach index[20] and the outcome was designated as 'conversion index' (CI). The amylosaccharide composition of wort was analysed by a HPLC method described in a previous publication.[3] Furthermore, the proteolytic potency (proteolytic activity combined with protein solubilisation property) of raw materials was evaluated by using the Kolbach index (wort-soluble nitrogen from conventional EBC analytical mash given as a proportion of total grist nitrogen), commonly utilised for malt analysis according to the recommended method of the EBC.[20] Wort-soluble nitrogen was determined by the Kjeldahl method.[20] Pentosanase potency was derived from the extent of solubilisation arabinoxylan. Thus, analogous to the CI and Kolbach indices, we determined the 'arabinoxylan solubilisation index' (ASI). Soluble arabinoxylan was analysed using the method described by Delcour *et al*.[20] Finally, wort viscosity was determined by Ubbelohde capillary viscometer (Schott-Geräte GmbH, Hofheim, Germany) according to the recommended method of the EBC.[20] The increase in viscosity caused by high-molecular-weight dextrin[22] was eliminated by adding 0.5 ml of a bacterial α-amylase (Spirizym BA; Erbslöh Geisenheim, Geisenheim, Germany), at a mash temperature of 70 °C during the conventional EBC analytical mash. In each case, the adequately of degradation of wort amylosaccharides was recorded applying the iodine test.[20] Thus, we evaluated the influence of high-molecular-weight non-starch polysaccharides on wort viscosity mainly by this procedure.[22,23] All analyses described above were performed at least in duplicate.

Beer wort preparation

Laboratory scale experiments were performed with an adjunct ratio (triticale or wheat) of 1:1 calculated as FS. Mashes were prepared in mechanically stirred metal beakers in a mash bath with grist containing 42 g of FS and 300 ml of water (residual alkalinity: $1.59\,mval\,l^{-1}$). According to our previous work, the conversion regime employed was the most suitable one to process triticale.[3] It uses a modest pre-liquefaction stage (64 °C, 10 min, pH 5.9) with an adjunct: malt ratio of 9:1. After adding the remaining malt and water, the mash pH was adjusted to 5.5 followed by a rest of 40 min at 50 °C, a second rest of 60 min at 63 °C, a third 35 min rest at 70 °C and a final 10 min rest at 77 °C. The mash pH was adjusted using sulphuric acid. After conversion, the mash was cooled to 20 °C and adjusted by adding water (residual alkalinity: $1.59\,mval\,l^{-1}$) to the final weight of 450 g. The filtered wort (Machery-Nagel 614 one-quarter folded filter; Düren, Germany) was heated for 1 h in the mash bath at 98 °C with 200 mg of concentrated hop pellets (Hallertau magnum, type 45; HVG Hallertau, Wolnzach, Germany), added as a finely ground powder. Again, the precipitate was separated by filtration. All worts were prepared in triplicate.

Analysis of beer worts

Sweet worts were analysed for amylosaccharide content, soluble nitrogen and viscosity by the methods described above. Specific gravity, free amino nitrogen (FAN), colour and pH of worts were determined by a densimeter, the ninhydrin reaction, spectrophotometric and electrometric methods, respectively, according to the recommended methods of the European Brewery Convention.[20,24] Analyses of worts described above were performed in duplicate at least.

Statistical analysis

Groups of data (triticale cv Trinidad, cv Lamberto, cv Fidelio and wheat) were analysed with statistical software (SigmaStat; Jandel Scientific, Erkrath, Germany), using one-way ANOVA. To isolate the group or groups that differed from others, all pairwise multiple comparison procedures (Student–Newman–Keuls method) were performed at the ($p < 0.05$) significance level.[25] Linear regression analyses were used to establish relationships between two or more quantitative variables.

RESULTS AND DISCUSSION

Characteristics of cereal-based raw material

From the technological point of view, an adjunct is primarily employed in brewing to provide carbohydrates that can ultimately be broken down into fermentable sugars, and a maximum starch content is clearly desired in the use of a brewing adjunct. Adjuncts are also utilised to reduce the soluble nitrogen content in wort, which results in beers of better physical stability,[5,6] although it has disadvantages for yeast nutrition and beer foam stability.[26,27] Concerning this discrepancy, similar to the requirements of barley for malting, the brewer aims at a low protein content, particularly in triticale because triticale proteins are highly susceptible to malt protease. Therefore, malt triticale adjunct worts generally contain sufficient soluble nitrogen (yeast-assimilable as well as foam-enhancing N) as a result of enzymatic protein degradation during mashing.[2,3] Similar data were also reported for triticale malt.[19,28] However, there is an inverse relationship between protein and starch levels in cereal grains. Consequently, a high protein content always reduces the amount of wort-fermentable sugars. In this context, we determined FS and crude protein of starch-rich raw materials (Table 1). In accordance with previous reports on other varieties used as unmalted adjuncts,[11] triticale contained FS contents similar to wheat, and clearly exceeded those of barley malt. Mean values for the different triticale cultivars and wheat did not vary sufficiently to exclude the possibility that they could be attributed to random sampling variability. In addition, crude protein levels of wheat, barley malt and various triticale cultivars were in a similar range. Minor variations between individual samples can be attributed to agricultural and environmental conditions,[11] which were beyond our control. Our data indicate however, that triticale complies with the basic requirements to serve as a brewing adjunct. Since the observed protein content is influenced significantly by agricultural practices,[11] and most triticale production is currently targeted at the feed industry,[29] we recommend a stringent adjustment of the production process to reach an excellent brewing quality of triticale.

The arabinoxylan content of the raw materials was evaluated as another important quality parameter (Table 1). Again, no significant differences were determined among the triticale cultivars examined in this work. Similar arabinoxylan contents of triticale have also been previously documented.[30] Significantly

Table 1. Chemical key characteristics of cereal-based raw materials used in this study

Raw material (crop, cultivar, year)	FS[a] (mg g^{-1} dry basis)	Crude protein (mg g^{-1} dry basis)	Arabinoxylan (mg g^{-1} dry basis)
Triticale, Trinidad, 1999	694	135	62
Triticale, Trinidad, 2000	720	129	67
Triticale, Trinidad, 2001	708	123	73
Triticale, Trinidad, 2001	716	128	66
Triticale, Trinidad, 2001	727	116	72
Triticale, Lamberto, 1999	706	131	71
Triticale, Lamberto, 2001	716	116	64
Triticale, Lamberto, 2001	710	113	70
Triticale, Fidelio, 2000	729	88	96
Triticale, Fidelio, 2001	717	113	53
Triticale, Fidelio, 2001	710	122	65
Wheat, Batis, 2001	728	121	35
Wheat, Flair, 2001	722	117	35
Barley malt, Pilsner, 2000	673	115	66
Mean values[b]			
Triticale, Trinidad	713 ± 13a	126 ± 7a	68 ± 4a
Triticale, Lamberto	711 ± 5a	120 ± 10a	68 ± 4a
Triticale, Fidelio	718 ± 10a	108 ± 18a	72 ± 22a
Wheat, over-all	725 ± 4a	119 ± 3a	35 ± 1b

[a] FS = fermentable substance, calculated as starch equivalents.

[b] Mean value ± standard deviation. Means shown with same letters within a column were not significantly different ($p < 0.05$) from each other.

lower arabinoxylan levels were found in wheat (35 mg g^{-1}), whereas malt contained only slightly lower amounts (66 mg g^{-1}) than those found in triticale.

Table 2 summarises the native enzymatic potency of raw materials used in brewing. Amylolytic potencies (CIs) of the adjunct groups compared here did not differ statistically. This may be attributed, at least in part, to the cultivar-independent influence of the various cultivation conditions on pre-harvest sprouting and the formation of α-amylase.[29,31] Nevertheless, compared with wheat, mean conversion indices of all triticale cultivars were higher (approximately 1.09 times for cv Trinidad, 1.50 times for cv Lamberto and 1.37 times for cv Fidelio). We assume that the increased amylolytic potencies of triticale are caused by higher amylolytic enzyme activities, since triticale starch has been found to be similar to that of wheat in relation to morphology, granule size and distribution, in amylose content, iodine affinity, gelatinisation temperature and solubility during pasting.[9,32–35] The mean amylolytic potency of triticale was closer to that of wheat than to that of barley malt. In addition, triticale showed a significantly higher proteolytic potency than wheat. Thus, triticale Kolbach indices were approximately 1.44 (cv Trinidad) 1.66 (cv Lamberto) and 1.55 (cv Fidelio) times those of wheat. Presumably these values were caused by both higher water- and NaCl-soluble protein contents (albumins plus globulins)[36] and increased proteolytic enzyme activity[31] in triticale. Yet unmalted triticale performed worse than a commercial barley malt in this respect.

Varying pentosanase potencies were also observed for the raw materials tested. Whereas the mean ASI contents of triticale cultivars ranked within those of malt, those of wheat cultivars broadly exceeded this level. Since only low contents of arabinoxylan-degrading enzyme activities can be measured in unmalted wheat,[37] we assume that higher proportions of wheat arabinoxylans are more susceptible to solubilisation during mashing than those in triticale. Although triticale contained approximately twice as much arabinoxylan as wheat (Table 1), the soluble arabinoxylan contents of worts did not change correspondingly. Hence, they only reached approximately 1.04 (cv Trinidad), 1.29 (cv Lamberto) and 1.22 (cv Fidelio) times those of wheat. Owing to considerable variations between individual ASI values, no significant statistical differences could be established between the tested cultivars of triticale. Moreover, a high pentosanase potency of unmalted adjuncts appeared to affect adversely the viscosity of worts from conventional EBC analytical mashes. Significant distinctions in wort viscosities were noted among the triticale cultivars (Table 2). The use of cv Trinidad resulted in the lowest viscosities whereas cv Lamberto performed worst. Yet triticale cv Trinidad produced poorer results than wheat or malt. Differences between the latter two are in accordance with the results of Cleemput *et al*[38] who reported higher molecular weights of water-soluble arabinoxylan of unmalted wheat than in barley malt. Correspondingly, we assume that the viscosities of triticale worts resulted mainly from high contents of long-chain arabinoxylan. Finally, data for mean enzyme potencies indicated that amylolytic, proteolytic and pentosanase activities possibly interfere in triticale. However, a statistical relationship ($R^2 = 0.84$) could only be established between the conversion index and the Kolbach index of triticale (Fig 1).

In summary, analysis of cereal based raw materials characterised triticale as a brewing adjunct containing similar FS and crude protein to, but broadly higher arabinoxylan levels than, wheat. Furthermore, triticale had higher levels of desired amylolytic and proteolytic potencies, accompanied by minor pentosanase potency. A high ASI (pentosanase potency) seemed to be a detrimental brewing property shared by triticale and wheat, which merely effected solubilisation of long-chain arabinoxylan, whilst the degradation of high-molecular-weight soluble arabinoxylan remained insufficient. Statistical differences among the employed triticale cultivars were found in their viscosity-increasing properties, where cv Trinidad appeared to be most suitable to serve as a brewing adjunct. As expected, barley malt performed as the superior raw material having considerably higher amylolytic and proteolytic potencies and produced the lowest wort viscosities. This is mainly a result of

Table 2. Enzyme activities and functional properties of cereal-based raw materials analysed in relevance to brewing practice

Raw material (crop, cultivar)	CI[a] (%)	Kolbach index (%)	ASI[b] (%)	Viscosity, 8.6% Plato (mPa s)
Barley malt, Pilsner	84.5	39.7	29.4	1.46
Mean values[c,d]				
Triticale, Trinidad ($n = 5$)	46.5 ± 17.4a	24.4 ± 2.6a	26.8 ± 3.0a	2.14 ± 0.13a
Triticale, Lamberto ($n = 3$)	64.0 ± 6.5a	28.2 ± 0.6a	34.2 ± 12.6a,b	2.38 ± 0.10b
Triticale, Fidelio ($n = 3$)	58.2 ± 14.4a	26.4 ± 1.7a	31.9 ± 9.6a,b	2.29 ± 0.04a,b
Wheat, over-all ($n = 2$)	42.6 ± 7.6a	17.0 ± 0.3b	49.4 ± 0.6b	1.78 ± 0.04c

[a] CI = Conversion index (fermentable carbohydrates of wort from conventional EBC analytical mash as a proportion grist FS; all saccharides were calculated as starch equivalents).
[b] ASI = arabinoxylan solubilisation index (soluble arabinoxylan of wort from conventional EBC analytical mash as a proportion of grist arabinoxylan).
[c] Mean value ± standard deviation. Means shown with same letters within a column were not significantly different ($p < 0.05$) from each other.
[d] Individual samples belonging to compared groups are shown in Table 1.

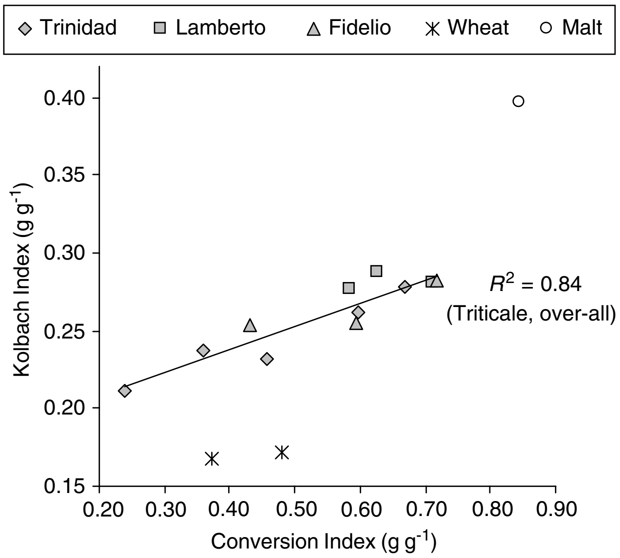

Figure 1. Relationship between amylolytic and proteolytic potencies of raw materials analysed for relevance to the brewing process.

degradation processes of non-starch polysaccharides during malting.

Influence of adjunct characteristics on beer wort quality

The effect of amylolytic potency and cultivar differences of the adjuncts on starch solubilisation and amylolysis during mashing mixed (1:1) grists of malt and adjunct are presented in Fig 2. Compared with triticale cv Lamberto, cv Fidelio and wheat, the use of triticale cv Trinidad significantly increased the amylosaccharide contents of sweet worts (Fig 2a, to an average of 1.022 times) those of the other raw materials tested. These unexpected findings could be explained by a higher susceptibility to solubilisation of cv Trinidad starch granules. However, it could not be determined whether the higher solubility was caused by a modified starch composition or by improved release of starch granules from the endosperm. Furthermore, we noted a minor favourable effect of high amylolytic potency (CI) of the adjuncts on the wort amylosaccharide levels in the case of cv Trinidad ($R^2 = 0.89$) and, to a lesser degree when using cv Lamberto. For the latter, however, the low number of samples ($n = 3$) provided only a low statistical significance. These data indicate that the amylolytic potency of triticale may support malt amylases to improve starch solubilisation. The ratios of fermentable carbohydrates to total wort amylosaccharides remained largely similar among all the triticale malt worts (Fig 2b). We assume that the high amylolytic activity of the predominant malt enzymes outbalanced possible effects of cultivar affiliation or amylolytic potency of triticale on amylolysis of wort amylosaccharides. It should be noted that fermentable sugar ratios of worts were slightly decreased by using triticale rather than wheat. However, the higher amylosaccharide levels of cv Trinidad malt worts compensated this deficiency resulting in concentrations of wort fermentable sugars similar to those of wheat.

Figure 3 shows the effect of adjuncts on the soluble nitrogen contents of sweet worts. The proteolytic potency (Kolbach index) and the cultivar affiliation of adjuncts (triticale and wheat) had no detectable influence on these levels (Fig 3a). In contrast, the wort soluble nitrogen correlated with the nitrogen contents of the grists (Fig 3b). This could be firmly established for triticale (correlation value $R^2 = 0.86$). These data indicate largely consistent protein solubilisation properties among the adjuncts in the presence of considerable proteolytic enzyme activities (adjunct: malt ratio of 1:1). This proteolysis was predominantly due to the enzymes present in the malt, rather than the adjunct material.

Figure 4a depicts the effects of pentosanase potency (ASI) and cultivar differences of the adjuncts on

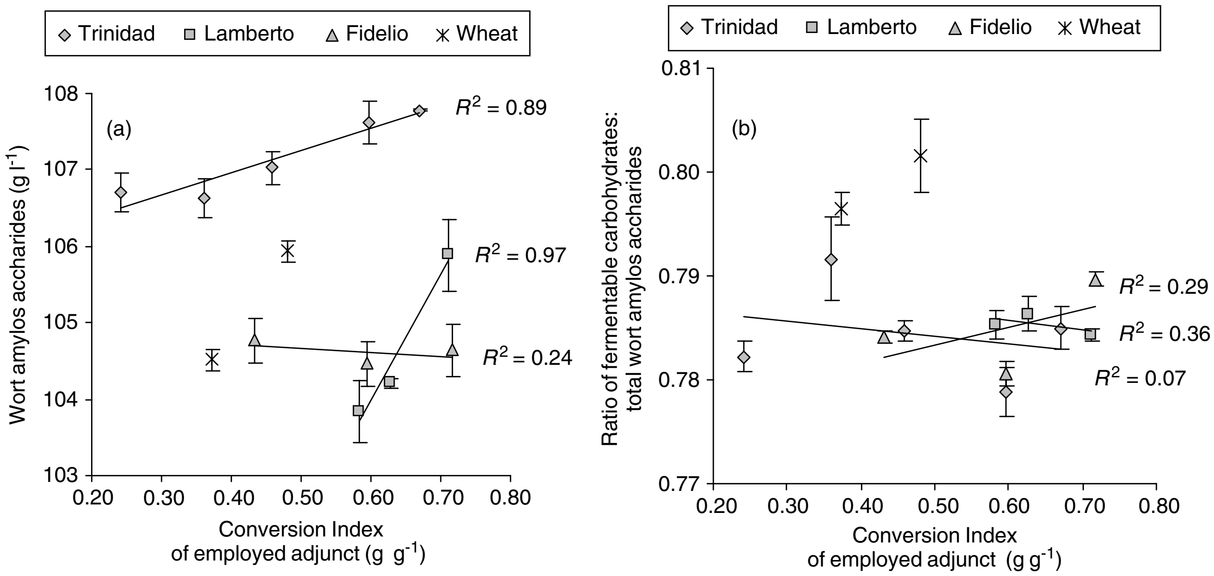

Figure 2. Influences of amylolytic potency and cultivar affiliation of adjuncts on (a) amylosaccharide content and (b) amylosaccharide conversion rate of sweet worts ($n = 3$) prepared from mixed (1:1) grists of malt and adjunct.

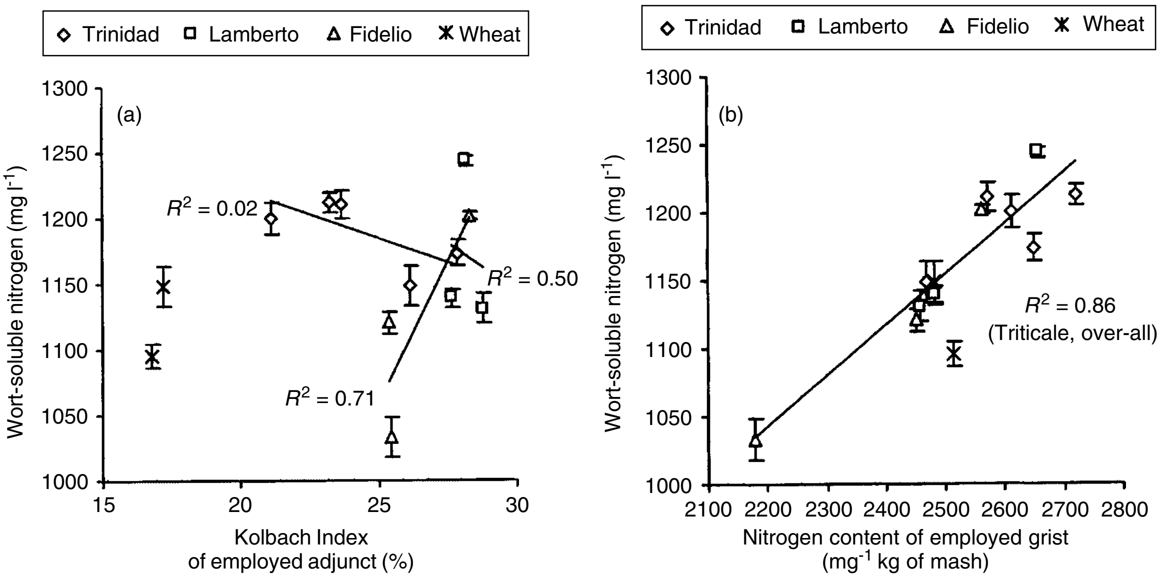

Figure 3. Influences of (a) proteolytic potency and cultivar affiliation of adjuncts as well as (b) grist nitrogen sources on the soluble nitrogen levels of sweet worts (n = 3) prepared from mixed (1:1) grists of malt and adjunct. These determinations were made on mashes prepared according to the EBC analytical mash method,[20] using grists containing 42 g of fermentable solids.

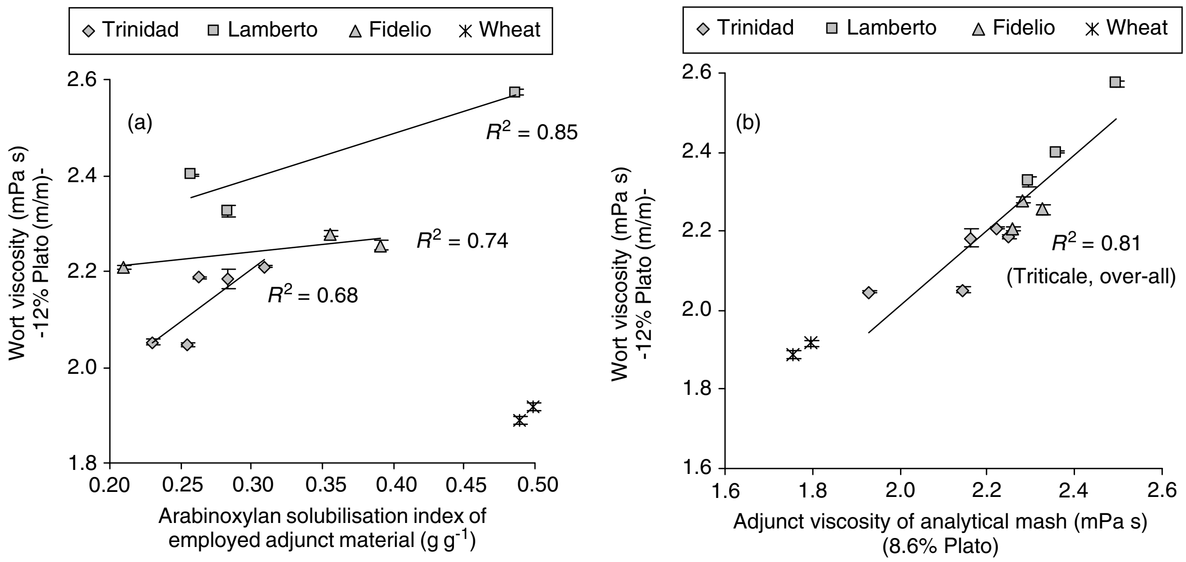

Figure 4. Influence of (a) pentosanase potency and cultivar affiliation as well as (b) wort viscosity from conventional EBC analytical mash of adjuncts on the viscosity of sweet worts (n = 3) prepared from mixed (1:1) grists of malt and adjunct.

the viscosity of sweet worts prepared from mixed (1:1) grists of malt and adjunct. Irrespective of the various adjunct pentosanase potencies, the raw material groups (triticale cv Trinidad, cv Lamberto, cv Fidelio and wheat) were statistically different in the generation of wort viscosities, except for the distinction between cv Trinidad and cv Fidelio. In comparison with wheat, the use of triticale generally increased wort viscosity. Considerable differences were also observed among different triticale cultivars. Thus, the mean viscosities of triticale malt worts were, respectively, approximately 1.12 (cv Trinidad), 1.28 (cv Lamberto) and 1.18 (cv Fidelio) times, those of wheat malt worts. In addition, the high pentosanase potencies (ASI) of triticale probably adversely affected the viscosity of sweet worts. Because of the low number of group samples, however, these correlations should be interpreted with caution. In general, the viscosities of the sweet worts were largely as expected from the results of the raw material analyses (Fig 4b). A statistical relationship (R^2 = 0.81) could be established between the determined triticale viscosities of the conventional EBC analytical mash and the viscosity of beer worts prepared from them. These findings indicate that malt endoxylanases degrade the long chain arabinoxylan of triticale to only a negligible extent during mashing. Thus, the adjunct properties were mainly responsible for the wort viscosities in mashing mixed grists of malt and triticale.

We also determined FAN supply, colour and pH of sweet worts of various grists (Table 3). Although the

Table 3. Free amino nitrogen (FAN), FAN ratio of soluble nitrogen (N), colour and pH of sweet worts ($n = 3$) prepared from mixed (1:1) grists of malt and adjunct

Adjunct material (crop, cultivar, year)	FAN (mg l^{-1})	FAN ratio of soluble N (mg g^{-1})	Colour (EBC units)	pH
Triticale, Trinidad, 1999	152	125	5.9	5.62
Triticale, Trinidad, 2000	150	128	6.0	5.58
Triticale, Trinidad, 2001	152	126	5.9	5.56
Triticale, Trinidad, 2001	144	120	5.8	5.61
Triticale, Trinidad, 2001	147	128	5.9	5.59
Triticale, Lamberto, 1999	169	136	6.6	5.55
Triticale, Lamberto, 2001	151	133	5.9	5.64
Triticale, Lamberto, 2001	151	133	6.0	5.63
Triticale, Fidelio, 2000	140	136	6.3	5.54
Triticale, Fidelio, 2001	147	131	5.9	5.54
Triticale, Fidelio, 2001	166	138	6.5	5.62
Wheat, Batis, 2001	134	122	5.5	5.49
Wheat, Flair, 2001	143	125	5.9	5.50
Experimental error	<2.1%	<1.7%	<3.4%	<0.6%
Mean values[a]				
Triticale, Trinidad	149 ± 3.5a	125 ± 3a	5.9 ± 0.1a	5.59 ± 0.02a
Triticale, Lamberto	157 ± 10.4a	134 ± 2b	6.2 ± 0.4a	5.61 ± 0.05a
Triticale, Fidelio	151 ± 13.5a	135 ± 4b	6.2 ± 0.3a	5.57 ± 0.05a,b
Wheat (over-all)	139 ± 6.4a	124 ± 2a	5.7 ± 0.3a	5.50 ± 0.01b

[a] Mean value ± standard deviation. Means shown with same letters within a column were not significantly different ($p < 0.05$) from each other.

FAN levels in triticale malt worts were approximately 1.09 times those in wheat malt worts, the means of the compared adjunct groups were not significantly different due to the relatively high standard deviation inherent in FAN level determinations (~9%). Still, these findings constitute an economic advantage of triticale over wheat, since free amino acids represent the major nitrogen source for brewing yeasts.[6,39] Furthermore, the degree of degradation of soluble wort peptides fluctuated amongst the adjunct materials tested (Table 3). Thus, FAN ratios of soluble nitrogen of cv Lamberto and cv Fidelio worts were 1.07–1.09 times those of wheat and cv Trinidad worts. We assume that besides a moderate effect of the proteolytic potency of the adjuncts, the bulk of grist crude protein being derived from the malt moiety led to these findings. Therefore, the proteolytic potency of triticale (and the differences between its varieties) in terms of FAN supply can be neglected. Finally, the various adjunct materials exercised no decisive influence on the colour and pH of sweet worts; as compared with triticale, the use of wheat merely generating a slightly lower pH.

In summary, the use of triticale cv Trinidad increased the amylosaccharide levels of sweet wort prepared from mixed (1:1) grists of malt and adjunct as compared with other adjunct materials tested. Furthermore, a high amylolytic adjunct potency provides a theoretical advantage in starch solubilisation but amylolysis (supply of fermentable sugars) of soluble wort amylosaccharides was not affected. In addition, grist nitrogen sources clearly generated the amounts of wort-soluble nitrogen. In contrast, the proteolytic potency of the adjuncts had no influence in this respect. Comparing triticale varieties, cv Trinidad led to the lowest wort viscosities, although it was slightly worse than wheat. In terms of viscosities, the conventional EBC analytical mash procedure was found to be highly suitable to assess triticale quality for use in brewing. In addition, slightly increased wort FAN levels were noted for triticale as compared with wheat. The colour and pH of sweet worts remained largely unaffected by the adjuncts employed.

CONCLUSIONS

Among the three triticale cultivars examined for the use as brewing adjuncts in this work, cv Trinidad was identified as the most suitable, a major advantage compared with cv Lamberto and cv Fidelio being the higher yield of wort amylosaccharides during mashing, due to the good solubilisation properties of its starch granules. Furthermore, we could show that cv Trinidad clearly generates malt triticale worts of the lowest viscosity, which aids wort and beer filtration. The various enzyme activities of similar triticale cultivars were, in contrast, of little importance for sweet wort properties in mashing the mixed grists, as a result of the overwhelming potential of the malt enzymes. Thus, triticale composition is of particular importance for wort quality, and we recommend that triticale cultivation schemes be adjusted to achieve a high starch content and a lower concentration of crude protein. The adjunct property also clearly affected the level of wort viscosity when mashing malt in combination with triticale because of the marginal ability of malt endoxylanases to degrade triticale arabinoxylans. Thus, the method described here to determine adjunct viscosities is highly suitable as a screening tool for triticale varieties to be used for brewing purposes. The use of triticale cv Trinidad, compared with wheat, provided similar amounts of fermentable sugar and a 6% increase of total soluble nitrogen to sweet beer worts. In addition, cv Trinidad utilisation increased the viscosity in relation to wheat–malt worts by 12% and the FAN content by 7%. These data demonstrate that wheat and a currently used triticale cultivar (cv Trinidad) share similar properties in their effects on final beer quality. The potential of triticale as a brewing adjunct could be further enhanced by breeding specifically aimed at its use in brewing industry.

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