Japan. Jour. Crop. Sci. 60(2) : 291--297 (1991)

Malting Quality of Hexaploid Triticale in Comparison with That of Barley, Wheat and Rye

Rewat LERSRUTAIYOTIN, Shoji SHIGENAGA and Naoki UTSUNOMIYA
(*Faculty of Agriculture, Kyoto University, Kyoto 606*)
Received May 16, 1990

Abstract : Malting quality of hexaploid triticale (× *Triticosecale* Wittmack) was analysed in comparison with that of barley as a standard, and wheat and rye as parental species, by using the micro-malting method. Triticale malt had higher diastatic power than rye and wheat, and was particularly higher than barley. Malt extract and extract yield of triticale were almost as high as the levels for rye, while those of barley were rather low. An average value of total malting loss obtained from 11 cultivars of triticale was lower than that of hexaploid wheat and malting loss from shoot and root was lower than that of barley and hexaploid wheat. Total and soluble nitrogen were high in triticale. Steeping period of triticale was shorter than that of barley by about four-fold. The high diastatic power, high malt extract, and short steeping period in triticale malt seemed to be advantageous industrial brewing characteristics, while high total nitrogen and low germination capacity appeared to be disadvantageous.
Key words : Diastatic power, Extract yield, Genome, Malting quality, Micro-malting, Triticale.

六倍体ライコムギの麦芽製造品質，とくにオオムギ，コムギ及びライムギとの比較について：
LERSRUTAIYOTIN R.・重永昌二・宇都宮直樹（京都大学農学部）
要　旨：六倍体ライコムギ（× *Triticosecale* Wittmack）の麦芽製造品質を，麦芽標準作物としてのオオムギ，並びにライコムギの親作物としてのコムギ及びライムギと比較して検討を加えた．ライコムギ麦芽はライムギやコムギの麦芽よりもジアスターゼ力が高く，とくにオオムギの麦芽に比して著しく高かった．麦芽エキス及びエキス収量については，ライコムギとライムギはオオムギよりも高い値を示した．麦芽収量率はライコムギの方がオオムギより高かった．ライコムギの浸麦時間は平均18.5時間で，オオムギの平均76.0時間に比して著しく短かった．以上の点でライコムギは醸造原料としてすぐれた品質を備えていることが明らかになったが，全窒素含量がオオムギ，ライムギ，コムギより高く，また発芽力において劣る難点があり，更に検討を要する．
キーワード：エキス収量，ゲノム，小量麦芽製造，ジアスターゼ力，麦芽製造品質，ライコムギ．

Generally, barley is the main cereal for malt production. According to the high price of malt produced from barley, analysis of the malting quality of other cereals is desirable, especially for importing countries with unsuitable conditions for barley production.

Triticale (× *Triticosecale* Wittmack) is a man-made cereal crop derived from the amphidiploid between wheat (*Triticum*) and rye (*Secale*)[14]. Hence, triticale combines characteristics of wheat and rye. Yield of triticale has recently been improved to comparably high level. Under less favorable conditions, triticale sometimes shows higher yield than barley and wheat. Due to the favorable nutrition characteristics of triticale seed[10], such as high protein and lysin content, the main use of this crop is for animal feed. Pomeranz[14] suggested that triticale can be used for human consumption in breakfast cereals, by the distilling industry, and, also, as malting grain. Holmes et al[8]. have previously reported that triticale showed tolerance for malt processing conditions and exhibited extremely rapid water uptake, high malt extract, and extract yield, after studies with a single variety[16], and then in advanced lines[12,13].

In this study, malting quality of hexaploid triticale cultivars was analysed in comparison with that of barley as a standard, and wheat and rye as parental species.

Materials and Methods

Plant cultivation

Eleven cultivars of hexaploid triticale (× *Triticosecale* Wittmack ; AABBRR-genome : Lasko, Beagle, Yogui, Currency, Rosner, Bronco, Armadillo, Cinnamon, Koala, Welsh, and Camel/Pato), three cultivars of two-rowed barley (*Hordeum distichum* L. ; HH-genome : Ebisu, Satsuki Nijo, and New Golden), three cultivars of hexaploid wheat (*Triticum aestivum* L. ; AABBDD-genome : Sonalika, Saitama 26, and Norin 61), two cultivars of rye (*Secale cereale* L. ; RR-genome : Petkus and King II) and a cultivar of tetra-

Table 1. Winter/Spring growth habits, constitution of R-genome chromosomes, and cytoplasm of eleven hexaploid triticale cultivars used in this experiment

Cultivars	Winter/Spring growth habits	Constitution of R-genome chromosomes	Cytoplasm
Lasko	Winter	Complete	*T. aestivum*
Beagle	Spring	Complete	*T. turgidum*
Yogui	Spring	Complete	*T. aestivum*
Currency	Spring	Complete	*T. aestivum*
Rosner	Spring	2D/2R substitution[1)]	*T. turgidum*
Bronco	Spring	2D/2R substitution	*T. turgidum*
Armadillo	Spring	2D/2R substitution	*T. turgidum*
Cinnamon	Spring	2D/2R substitution	*T. aestivum*
Koala	Spring	2D/2R substitution	*T. aestivum*
Welsh	Spring	2D/2R, 4D/4R substitution[2)]	*T. aestivum*
Camel/Pato	Spring	2D/2R, 4D/4R, 5D/5R substitution[3)]	*T. aestivum*

1) 2R chromosome is substituted by 2D chromosome.
2) 2R and 4R chromosomes are substituted by 2D and 4D chromosomes, respectively.
3) 2R, 4R and 5R chromosomes are substituted by 2D, 4D and 5D chromosomes, respectively.

ploid wheat (*Triticum turgidum* L.: AABB-genome: Kyone Ni) were used in this experiment. Seeds were planted in mid-December 1988 at Experimental Farm of Kyoto University, Takatsuki, Osaka. The winter/spring growth habit, constitution of R genome chromosomes and cytoplasm of triticale cultivars tested in this experiment are shown in Table 1. Seeds were planted in two rows on 1.5 m-wide ridges, with 10 cm spacing between plants. Spacing between two rows on each ridge and between ridges was 1 m and 3 m, respectively. Fertilizers of N and K_2O were applied as a top dressing at a rate of 3 kg/10 a in mid-March 1989. Matured seeds were harvested in June 1989 and dried for about 1 month in a room under air circulation, before threshing by hand. Because triticale, rye and tetraploid wheat had rather high ratios of small-size seeds, seeds bigger than 2.2 mm in width in every crop were used for producing malts.

Micro-malting method

Four replications of fifteen grams of seeds were steeped by immersing seeds in 100 ml beakers filled with distilled water and placed in an incubator at 15°C. Steeping was completed when the moisture content in the seeds reached 43%. Water was changed daily during steeping. After steeping was completed, the film of water on the seedcoat was removed with a cotton cloth. Seeds were allowed to germinate in an incubator at 15°C for about 7 days in 100 ml beakers covered with vinyl wrappers to maintain the moisture content of seeds. After completion of germination, green malts were put into a mesh cup of 8 cm in diameter and oven-dried at 40°C, 60°C, and 85°C for 12h, 3h and 5h, respectively. The shoots and roots of malts were removed by rubbing malts with cotton cloth and mesh. Malts were then ground. Malt powder smaller than 150 μm was used for the analysis of malt quality.

Measurement of malting quality

Four replications of analysis were done in each malting quality characteristic. Malt extract was measured by using the modified version of the specific gravity gradient tube method modified from Atkin et al.[2)] and Nakagawa[11)]. Extract yield was calculated from the equation:

$$\text{extract yield } (\%) = \frac{\text{malt extract} \times \text{malt yield}}{100}$$

Malt yield was calculated from the equation:

$$\text{malt yield } (\%) = 100 - \text{total malting loss}$$

Total malting loss was calculated from the equation:

$$\text{total malting loss } (\%) = \frac{(DW_1 - DW_2)}{DW_1} \times 100$$

where DW_1 was dry weight of seed (g), and

DW_2 was the dry weight of malt (g) after the shoot and root were removed. Malting loss from the shoot and root was calculated from the equation :

$$\text{malting loss from shoot and root } (\%) = \frac{(DW_3 - DW_2)}{DW_1} \times 100$$

where DW_1 and DW_2 were the same as above equation, and DW_3 was the dry weight of malt before shoot and root were taken off.

Diastatic power was determined with the titration method by using sodium thiosulfate titrate with the iodine-starch compound[11]. Colorimetrical method using indophenol blue was used for measuring total nitrogen content[17]. Soluble nitrogen content was measured by mixing malt extract with 0.9% NaCl solution[7]. The Kolbach index was calculated from the equation :

$$\text{Kolbach index } (\%) = \frac{N_1 \times 100}{N_2}$$

where N_1 was soluble nitrogen (%) and N_2 was total nitrogen (%). To measure the steeping period moisture content of every sample was measured after steeping for 12, 18, 24, 36, 48, 60, 72, 84, and 96h. Due to the variation in water absorption rate of each sample, steeping was ceased when the moisture content attained 43%. Steeping period was calculated from the equation :

$$\text{steeping time (h)} = T_1 + \frac{(T_2 - T_1)\ (43 - M_1)}{(M_2 - M_1)}$$

where T_1 and T_2 were the consecutive times that moisture content of seed was lower and higher than 43%, respectively ; and M_1 and M_2 were the moisture contents of seed measured at T_1 and T_2, respectively. Due to the variation of the steeping period and only one kilning per day, the germination periods of each sample were not equal. However, the differences in germination period among the samples was less than 24 hours.

A germination test was conducted by allowing 100 seeds to germinate on two pieces of filter paper in 11 cm-diameter petri dish containing 6 ml of water, and placed in an incubator at 20°C. Germination capacity was calculated by counting the total number of germinated seeds in a dish, 5 days after the start of the test.

Results

Malting quality characteristics in each cultivar and crop are shown in Table 2. There was on significant difference in average values of malt extract between triticale, rye, and tetraploid wheat malts. Hexaploid wheat and barley malts had low malt extract. In extract yield, rye and triticale malts were significantly higher than the others. Malt in triticale, barley, and rye had low total malting loss. In malting loss from shoot and root, hexaploid wheat and barley were significantly higher than triticale, rye and tetraploid wheat.

Triticale malt showed the highest diastatic power followed in descending order by tetraploid wheat, rye, hexaploid wheat, and barley malts. There was no significant difference in diastatic power among tetraploid wheat, rye, and hexaploid wheat. High ratios of diastatic power to percentage of total nitrogen were obtained in triticale, tetraploid wheat, and rye. No significant difference was observed among these three crops. Germination capacity of rye, hexaploid wheat, and barley seeds were significantly higher than that of triticale and tetraploid wheat seeds. Tetraploid wheat showed the lowest germination capacity.

Malt in triticale and hexaploid wheat had high total nitrogen contents. No significant difference, however, was observed between them. Total nitrogen contents in the malt of rye and barley were low, while moderate in that of tetraploid wheat. Soluble nitrogen content of malt extract in triticale was as high as that in tetraploid wheat. The Kolbach index in tetraploid wheat, rye, and triticale was significantly higher than that in barley and hexaploid wheat. Steeping period of seeds in barley and hexaploid wheat was longer than that in rye, tetraploid wheat, and triticale by a little more than two-fold.

Discussion

As a fermentable material, malt extract, resulting from hydrolyzing seed compounds, is one of the most important characteristics of malt. High malt extract is one of the favorable characteristics in the brewing industry. In this experiment, the average value of malt extract in triticale was higher than that in barley even though one triticale cultivar, Bronco, was exceptionally as low as barley. Tombros and

Table 2. Malting quality characteristics of triticale, barley, hexaploid wheat, rye

Crops cultivars	Malt extract (%)	Extract yield (%)	Total malting loss (%)	Malting loss from shoot and root (%)	Diastatic power (°WK)
Triticale	**90.04 a**[2]	**78.28 a**	**13.00 b**	**2.42 b**	**673.7 a**
Lasko	96.95 a[3]	81.97 a	15.44 abc	5.27 ab	890.8 a
Beagle	93.26 b	78.78 bc	15.53 abc	2.16 efg	791.9 b
Yogui	93.22 b	81.34 ab	12.73 cdefg	1.67 fg	710.9 c
Currency	90.95 bc	77.29 cdef	15.05 abcd	2.03 fg	637.4 d
Rosner	88.19 cde	77.78 cde	11.81 efg	1.95 fg	679.3 c
Bronco	82.29 gh	74.20 ghij	9.82 g	1.09 g	699.0 c
Armadillo	88.69 cd	79.16 bc	10.69 fg	1.82 fg	590.2 d
Cinnamon	89.74 c	79.63 abc	11.28 efg	2.18 efg	686.8 c
Koala	89.18 c	78.30 cd	12.20 defg	2.74 defg	582.5 d
Welsh	90.11 c	76.88 cdefg	14.67 abcd	2.51 defg	605.0 d
Camel/Pato	87.93 cde	75.75 defg	13.85 abcde	3.19 cdef	537.6 de
Tetraploid wheat	**89.47 a**	**74.85 b**	**16.33 a**	**2.65 b**	**503.4 b**
Kyone Ni[4]	89.47 c	74.85 fghi	16.33 a	2.65 defg	503.4 ef
Rye	**90.32 a**	**80.25 a**	**11.13 b**	**2.63 b**	**445.8 b**
Petkus	89.54 c	79.15 bc	11.57 efg	2.52 defg	460.3 fg
King II	91.10 bc	81.36 ab	10.69 fg	2.75 defg	431.3 g
Hexaploid wheat	**85.66 b**	**72.04 b**	**15.91 a**	**4.87 a**	**418.0 b**
Sonalika	85.89 def	71.74 j	16.48 a	4.45 abc	505.4 ef
Saitama 26	85.81 def	72.13 ij	15.94 ab	4.72 abc	412.2 g
Norin 61	85.30 ef	72.25 ij	15.29 abc	5.45 a	336.5 h
Barley	**83.08 b**	**73.43 b**	**11.57 b**	**4.32 a**	**310.5 c**
Ebisu	83.92 fgh	72.92 hij	13.10 bcdef	5.24 ab	323.0 h
Satsuki Nijo	84.17 fg	75.51 efgh	10.19 fg	3.74 bcde	339.1 h
New Golden	81.17 h	71.87 j	11.42 efg	4.00 abcd	269.9 h

1) Diastatic power/% total nitrogen
2) Different letter within a column for comparing average values of each crop shows significant difference at 5% level.
3) Different letter within a column for comparing average values of each cultivar shows significant difference at 5% level.
4) Local cultivar in Myanma

Briggs[16] suggested that the lesser amount of aleurone layer in triticale[12] than in barley[4], accompanied by a larger proportion of starchy endosperm, may be one of the causes of higher malt extract in triticale. Malt extract in most triticale cultivars was also higher than that in hexaploid wheat. Tetraploid wheat showed low extract yield, while its malt extract was high. This is attributed to the high total malting loss in tetraploid wheat.

Malts with high extract yield in general have high malting loss. In this experiment, rye and triticale were higher in extract yield than tetraploid wheat, hexaploid wheat, and barley. However, their total malting loss and malting loss from shoot and root were comparatively low. It is suggested that some genetic factors of rye affect the productivity of high extract in cooperation with low respiration and embryo development.

Malt extract is composed of the hydrolyzed substances derived from enzyme activities. Owing to high percentage of starch in endosperm of cereals, malt extract seems closely related to diastatic power. High diastatic power is favorable not only for digestion of its

and tetraploid wheat shown as an average value for each crop and each cultivar

DP/TN[1)]	Germiantion capacity (%)	Total nitrogen (%)	Soluble introgen (%)	Kolbach index (%)	Steeping period (h)
264.9 a	**86.3 b**	**2.60 a**	**0.97 a**	**37.68 b**	**18.5 c**
362.1 a	96.0 abc	2.46 c	0.80 c	32.43 ef	23.9 e
332.1 ab	84.0 ef	2.41 cd	1.04 ab	43.31 bc	12.6 j
312.3 bc	87.3 def	2.30 cd	0.98 b	43.17 bc	27.5 de
264.3 de	77.3 f	2.41 cd	1.08 ab	44.77 abc	15.5 hij
231.8 defg	85.3 def	2.94 b	1.05 ab	35.84 de	14.9 ij
206.8 ghi	89.5 cdef	3.38 a	1.05 ab	31.01 ef	18.6 ghi
267.9 de	85.8 def	2.21 d	0.72 c	32.19 ef	17.5 ghij
215.8 fgh	89.5 cdef	3.19 a	1.17 a	36.87 cde	21.9 fg
256.4 def	75.0 f	2.27 cd	0.75 c	32.98 ef	20.2 fgh
275.6 cd	90.5 cde	2.20 de	1.01 ab	46.04 ab	16.9 hij
188.6 ghij	89.5 cdef	2.86 b	1.03 ab	35.82 de	13.8 ij
254.4 a	**68.8 c**	**1.99 b**	**1.01 a**	**50.71 a**	**28.7 b**
254.4 def	68.8 f	1.99 e	1.01 ab	50.71 a	28.7 d
271.5 a	**98.5 a**	**1.65 c**	**0.71 b**	**43.20 ab**	**30.5 b**
273.8 cde	99.5 a	1.68 fg	0.74 c	43.68 abc	29.8 d
269.1 de	97.5 ab	1.61 fg	0.69 c	42.72 bcd	31.1 d
170.3 b	**96.7 a**	**2.45 a**	**0.51 c**	**20.67 d**	**73.4 a**
203.4 ghij	91.8 bcd	2.49 c	0.74 c	29.68 ef	74.4 b
165.6 ijk	99.3 a	2.49 c	0.48 de	19.11 g	70.9 b
141.9 k	99.0 a	2.39 cd	0.32 e	13.22 g	74.9 b
191.7 b	**97.3 a**	**1.64 c**	**0.46 c**	**28.16 c**	**76.0 a**
186.1 hij	94.8 abc	1.74 f	0.48 de	27.75 f	71.8 b
229.1 efgh	97.3 ab	1.50 g	0.41 de	27.27 f	90.4 a
160.0 jk	99.8 a	1.69 fg	0.49 d	29.47 ef	65.7 c

own starch, but also for that of adjuncts. Diastatic power in triticale was the highest, and was much higher than that in barley. Pomeranz et al.[14)] found that diastatic power in triticale lines was as high as that in wheat, and higher than that in rye and barley. Even though triticale malt showed 1.5 fold higher diastatic power than rye, and 1.36 fold higher than tetraploid wheat in this experiment, the malts of these three crops were estimated to be the same level in malt extract. If starch granules are embedded in protein matrix[6)], a speculative explanation related to germination capacity may be possible. Stenvert and Kingswood[15)] suggested that a continuous protein matrix, which correlates with high protein content, physically entrapping the starch granules would result in difficulty in separating the starch granules from the protein in wheat. Low germination capacity in tetraploid wheat and triticale may indicate no hydrolyzing of nitrogen contained in large number of ungerminated seeds. Then, the hydrolysis of starch granules in the malt of triticale and tetraploid wheat is considered to be more difficult than that of rye.

Because of high glucan content in barley seeds, ungerminated and incompletely modified seeds cause low malt extract, slow filtration rate and high molecular nitrogen in extract, which result in low quality of beer[3)]. Anderson et al.[1)] reported that glucan content in triticale seeds is lower than that in barley. In this experiment, even when germination capacity was rather low, triticale had high malt extract and diastatic power. This suggests that ungerminated or incomplete modification of seeds may induce less problems in triticale than in barley.

The disadvantageous characteristics of

triticale malt are high total and soluble nitrogen contents. Too high soluble nitrogen content causes poor quality of beer, including instability and haziness[9]. Considering that hexaploid wheat also had high total nitrogen content, whereas that of tetraploid wheat was rather low, RR genomes in hexaploid triticale and DD genomes in hexaploid wheat presumably contribute to an increment of the total nitrogen content. Hopkins and Krause[9] suggested that a high total nitrogen content is usually accompanied by intense enzyme production. Such a relationship, however, could not be observed extensively throughout the malts of different crops used in the present experiment, even though both triticale and hexaploid wheat had high total nitrogen contents.

As a conclusion, it can be said that the advatageous characteristics of triticale in malting quality to barley are much higher diastatic power, higher malt extract and extract yield, and shorter steeping period. On the contrary, problems of triticale malt are high total and soluble nitrogen content, and rather low germination capacity. Breeding of triticale lines with low total nitrogen content and improved cultivation with less application of nitrogen fertilizer may solve this problem. On the other hand, due to the high diastatic power in triticale, adjuncts are possibly used in high percentages, which would result not only in reducing the cost of malt, but also lessen the soluble nitrogen content in malt extract when adjunct with low nitrogen content is used. Owing to no husk covering triticale seed, another problem of triticale is the low filtration rate. Using glumes from other cereals, especially rice, may solve this problem. In this experiment, the genetic component of rye was supposed to correlate with the favorable malting quality in triticale, high diastatic power, while the component also had the tendency to correlate with the unfavoravle malting quality, high nitrogen content. As a small amount of seed samples was employed, results obtained in this experiment may give only suggestive information of malting quality in triticale. However, this information may be useful to further study of malting quality in this crop at the level of industry.

Acknowledgments

The authors wish to express thanks to Dr. S. Taya, Chugoku Agricultural Experiment Station, Ministry of Agriculture, Forestry and Fisheries, for providing us with the malting quality testing methods. Thanks are extended to Mr. Y. Aida, Plant Bioengineering Research Laboratories of Sapporo Breweries LTD, and Mr. T. Honjo, Mr. J. Kawasaki and Mr. T. Nomura, Osaka Factory of Sapporo Breweries LTD, for their supply of barley malt as a test sample as well as their valuable suggestions. We are also grateful to Prof. Y. Tani and Prof. T. Tochikura, Faculty of Agriculture, Kyoto University, for their valuable advice.

References

1. Anderson, M.A., J. A. Cook and B. A. Stone 1978. Enzymatic determination of 1, 3 : 1, 4-β-glucans in barley grain and other cereals. J. Inst. Brew. 84 : 233—239.
2. Atkin, L., I. Stone and P. P. Gray 1948. Use of the specific gravity gradient tube for brewing control. Wallerstein Lab. Commun. 23 : 281—288.
3. Bathgate, G.N., G. H. Palmer and G. Wilson 1974. The action of endo-β-1, 3 glucanases on barley and malt β-glucans. J. Inst. Brew. 80 : 278—285.
4. Briggs, D.E. 1978. Barley. Chapman and Hall, London.
5. Chen, C.H. and W. Bushuk 1970. Nature of proteins in triticale and its parental species I. Solubility characteristics and amino acid composition of endosperm proteins. Can. J. Plant Sci. 50 : 9—24.
6. Forrest, I.S. and T. Wainwright 1977. The mode of binding of B-glucans and pentosans in barley endosperm cell walls. J. Inst. Brew. 83 : 279—286.
7. Franken-Luykx, J.M.M. 1967. Spectrophotometric determination of nitrogen in wort. J. Inst. Brew. 73 : 187—189.
8. Holmes, M.G., C. E. May and H. R. Taylor 1986. Malting triticale-new use for a new crop ?. In Proceedings of the Thirty-sixth Australian Cereal Chemistry Conference, Adelaide, Australia. 71—73.
9. Hopkins, R.H. and C. B. Krause 1937. Biochemistry Applied to Malting and Brewing. George Allen and Unwin Ltd, London.
10. Knipfel, J.E. 1969. Comparative protein quality of triticale, wheat and rye. Cereal Chem. 46 : 313—317.
11. Nakagawa, A. 1955. Test Methods for Brewing in

Beer Industry. Maki-Shoten, Tokyo, Japan*.
12. Pomeranz, Y. 1971. Functional characteristics of triticale, a man-made cereal. Wallerstein Lab. Commun. 34 : 175—186.
13. ———— 1974. Malting of triticale. In Triticale-First Man-made Cereal, (Ed.) C. C. Tsen, Minnesota. 261—270.
14. ———— , B. A. Burkhart and L. C. Moon 1970. Triticale malting and brewing. Proc. Am. Soc. Brew. Chem. 10 : 40—46.
15. Stenvert, N.L. and K. Kingswood 1977. The influence of the physical structure of the protein matrix on wheat hardness. J. Sci. Food. Agric. 28 : 11—29.
16. Tombros, S. and D. E. Briggs 1984. Micromalting triticale. J. Inst. Brew. 90 : 263 : 265.
17. Weatherburn, M.W. 1967. Phenol-hypochlorite reaction for determination of ammonia. Anal. Chem. 39 : 971—974.

* Translated from Japanese by the present authors.