Analysis of malting characteristics of grain in spring barley varieties and breeding lines

A. Leistrumaitė,
V. Paplauskienė

Lithuanian Institute of Agriculture
LT-5051 Akademija,
Kėdainiai distr., Lithuania
E-mail: alge@lzi.lt

During 1995–2000, grain and malt quality characteristics of spring barley varieties and breeding lines were investigated at the Lithuanian Institute of Agriculture. 45–50 samples were evaluated annually for 1000 kernel weight, hectoliter weight, extract content, protein content, starch content, grain grading. Most of the Lithuanian varieties and breeding lines tested meet the requirements for malting barley grain grading. However, protein content depended on the weeather conditions of the year. An extremely high protein content (14.2–19.2%) was accumulated in barley grain in the dry and warm year 1999. The increase in protein content tended to decrease malt extract content in spring barley varieties and breeding lines. The malt extract content of spring barley varieties and breeding lines did not exceed 80%. The spring barley breeding lines 6121-2, 6782-33, 7134-24 were distinguished for a high yield, 1000 kernel weight, and statisfactory malting quality.

Key words: spring barley, variety, breeding line, malting quality

INTRODUCTION

Barley is one of the most common crops in Lithuania, covering 66.3% of the total spring cereal sowing area. Barley is generally regarded as a feed crop but is also used for malt. With the development of malting and brewing industry interest in high quality malting barley has been in the increase. Yield and grain quality of spring barley depends greatly on the varietal characteristics [1, 2]. Cultivation of varieties with top malting quality helps us to achieve a high yield of quality malt with minimal labour and costs. Quality requirements for malting barley are far more complex than those for feed barley. More than 30 parameters are applied for characterization of malting quality of barley grains [3]. Beside evaluation of field characteristics (grain yield, heading and maturity time, lodging and disease resistance) and grain quality (colour, smell, shape, size, hectoliter weight (HLW), 1000 kernel weight (TKW), grading, germination, protein and starch content), the malt quality characteristics (extract content, viscosity, diastatic power, Kolbach index, soluble protein content, colour of wort) play a key role in the evaluation of the malting and brewing potential of barley varieties [1, 4]. Malting quality has been the subject of several studies which revealed it to be a complex trait influenced by a number of genes, environmental conditions and growing technology [4, 5].

Grains for malt must be yellow of various tints, with typical smell, without mould. Grains with ovate or ellipse shape are preferable for malt, as they absorb water more evenly during steeping and the biochemical processes in them are more even.

Grain grading is a very important quality characteristic. This index is strongly related to grain coarseness. The percentage of coarse grains on a $2.5 \times \times 20$ mm sieve for malt barley must be no less than 91%. Grain coarseness is a varietal feature, but depends on environmental conditions too [6]. Coarse grains accumulate more starch than protein [3]. To ensure a good and uniform malting process there is demand for big and uniform kernel size [7].

Grain protein content in barley is influenced to a high degree by the environment, and this may cause problems if barley is intended for malt. Barley used for malt should have a grain protein content not exceeding 11.5%. It is, therefore, important to breed for cultivars with low and less environmentally influenced grain protein content [8]. Surplus of protein reduces malt extract content, as the enzymic breakdown of grain endosperm becomes more difficult and results in heating up of germination and impeded fermentation process [3]. The pro-

tein has a value as food for yeast and its level should not be low [7].

Extract content shows the part of dry matter from ground malts affected by enzymes that moved to water solution. For brewing industry the highest possible extract content is demanded; in good malting barley it is well over 80%. All these characters can be influenced by breeding [7]. That is why the first step to success in the growing systems of malting barley is a choice of appropriate variety. Varietal effect accounts for 25–40% of malting varieties' performance *versus* growing conditions [9].

The objective of this study was to estimate malting grain characteristics of Lithuanian spring barley varieties and breeding lines.

MATERIALS AND METHODS

Agronomic assessment of spring barley varieties and breeding lines was conducted during 1995–2000. The Lithuanian spring barley malting variety 'Auksiniai 3' was used as a control. Annually 45–50 samples were evaluated. The spring barley varieties and breeding lines were planted in the competitive yield trials, in the 10 m^2 plots with 4 replications. The soil of the experimental site was Endocalcari-Epihypogleyic Cambisoil (CMg-p-w-can) light loam. The preceding crop was seed clover of the 1st year. $N_{60}P_{60}K_{60}$ fertilization was applied.

The period 1995–2000 was rather favourable for spring barley versatile evaluation because of variable weather conditions (1995 dry, 1996 wet, 1997 dry, 1998 cool and rainy, 1999 dry and hot, 2000 wet).

In the trails we evaluated grain yield (t ha^{-1}), 1000 kernel weight (TKW) (g), hectoliter weight (HLW) (g 1^{-1}), in grains we determined malt extract content (%), protein content (%), starch content (%), and grain grading. Protein content was determined by the Kjeldahl method and starch content by hydrochloric acid dissolution. Malt extract content was determined on the basis on EBC (Analytica-EBC, 1987).

The level of statistical significance of data was calculated by the method of dispersion analysis using the ANOVA software and the variability of traits using the STATENG software [10].

RESULTS AND DISCUSION

The coarse grain output in the study period was 71.9–99.4% (Table 1). In 1996 and 1999 this index varied in a wider range than in the other years. Both coarse grain output and fractional grain composition are equally important for the assessment of barley grain suitability for malting. Comparison of fractional grain composition of individual years suggests that grains of 1996 yield are uneven. Most of them (72.5–90.0%) remain on a 2.5 × 20 mm sieve, but the other part (1.0–10.7%) goes down through a 2.2 × 20 mm sieve. Because of low grain output, 42.5% of spring barley varieties and breeding lines do not meet the requirements for malting barley. In 1996 grain coarseness and uniformity were negatively affected by warm and dry spring weather and crop lodging in July. In the rest of the years of study small grain output did not exceed 3%, which is demanded in brewing industry. The spring barley varieties and breeding lines were divided into three groups according to coarse grain output: I – coarse grain output <85%, II – coarse grain output 85–91%, III – coarse grain output >91% to meet the requirements of brewing industry. The largest grains grew in the years 1995, 1997 and 2000. Most of spring barley varieties and breeding lines fell into group III and met the requirements for malting barley. However, only 12.8% of barley grains harvested in 1996 met the requirements for this index. The results show that the influence of weather conditions on grain coarseness is very significant, however, the impact of the genotype is also very important. Some spring barley varieties and breeding lines show a stable grain coarseness ('Aura', 'Alsa', 7134-24, 6700-28), while the others varied a little but met the requirements for malting barley in all years of study.

Table 1. **Grain grading and distribution of spring barley varieties and breeding lines according to grain coarseness**

Year	Grain grading (grains on a sieve %)			Groups by coarse grain output >2.5		
	>2.5 × 20 mm	2.2 × 20 mm	<2.2 × 20 mm	I <85%	II 85.0–91%	III >91%
1995	80.6–99.4	0.8–18.3	0.0–1.8	4.4	15.6	80.0
1996	72.5–99.0	9.3–18.7	1.0–10.7	47.6	39.6	12.8
1997	84.1–98.8	1.2–13.7	0.1–2.7	13.3	13.4	73.3
1998	81.5–97.1	2.6–22.6	0.0–1.0	12.5	38.6	48.9
1999	71.9–98.0	1.9–17.3	0.0–2.0	12.5	20.8	66.7
2000	78.0–99.4	0.4–20.2	0.1–1.8	4.2	22.9	72.9
Mean	78.1–98.6	2.7–18.5	0.2–3.3	15.8	25.2	59.1

The next important malting barley parameter is protein content. Protein content in barley grains ranged from 9.9 to 19.2% depending on the year (Table 2). The highest protein content was accumulated in 1999 (on the average 16.2%). Some authors have reported that climatic conditions (first of all a long drought) can be a reason of increasing crude protein content in barley caryopses [9]. In 1999 the weather conditions were extremely unfavorable for barley. There were severe frosts in May after sowing and drought during the whole vegetative growth period. Such weather conditions resulted in a high accumulation of proteins. The protein content in barley grains was influenced to a high degree by the climatic conditions in all experimental years. Only about half of the samples met the requirements for this index in 1998. In the other experimental years, excluding 1999, most of the breeding lines were attributed to group II, in which part of the samples slightly surpassed this requirement.

When the protein content increases, starch and malt extract levels decrease in barley grain [3]. An especially low extract content was accumulated in barley grains harvested in 1999 (Table 3). At a high grain protein content (14.2–19.2%), the extract content was 71.0–79.0%. Only the minority of samples were attributed to group III (medium extractivity). The extract content of the majority of breeding lines (77.1%) was very low and did not exceed 75.9%. According to averaged data, an increase in protein content by 3.6% decreases the extract content by 5.7%, 3.1% and 3.4%, respectively, in the stadard variety 'Auksiniai 3'. Mean differences of extract content among individual experimental years, except 1999, are moderate, suggesting that grains of most spring barley breeding lines could be suitable for malt production. Differences among individual spring barley breeding lines in extract content are much higher. That enables to make selection according to this characteristic.

The spring barley varieties and breeding lines studied were divided into 5 groups according to the extract content: I – very low (<75.9%), II – low (76.0–77.9%). III – medium (78.0–79.9%), IV – high (80.0–81.9%), V – very high (>81.9%). Experimental evidence suggests that in all experimental years there were breeding lines with high and very high extract content. Most of the lines (42.7–63.8%), except in 1999, were characterized by medium extract content.

The grain yield and malt quality parameters of Lithuanian spring barley varieties and breeding li-

Table 2. **Protein content in grains and distribution of spring barley varieties and breeding lines according to protein content**

Year	Mean	Variation range	Variation coefficient	Groups by protein content %		
				I 9.0–11.5	II 11.6–13.0	III >13.0
1995	13.5	11.4–14.8	5.5	2.8	63.9	33.3
1996	11.6	9.9–13.8	5.2	28.9	65.8	5.3
1997	13.0	11.7–14.9	5.0	0.0	31.7	68.3
1998	12.0	10.2–13.0	7.0	52.2	47.8	0.0
1999	16.2	14.2–19.2	7.9	0.0	0.0	100.0
2000	12.8	11.9–14.1	4.8	0.0	64.3	35.7
Mean	13.2	11.5–15.0	5.9	14.0	45.6	40.4

Table 3. **Extract content in grains and distribution of spring barley varieties and breeding lines according to extract content**

Year	Mean	Means of data		Variation coefficient	Extract content groups (%)				
		min	max		I <75.9	II 76.0–77.9	III 78.0–79.9	IV 80.0–81.9	V >81.9
1995	79.1	75.7	83.5	2.3	2.2	22.2	48.9	23.3	3.4
1996	78.8	76.6	81.4	1.0	6.4	17.0	63.8	12.8	0.0
1997	78.4	76.4	81.4	1.2	0.0	35.6	53.3	11.1	0.0
1998	79.0	75.9	82.2	1.3	0.0	20.4	53.1	24.5	2.0
1999	73.0	71.0	79.0	1.7	77.1	18.6	4.3	0.0	0.0
2000	78.1	76.5	80.5	2.1	2.1	43.7	42.7	12.5	0.0
Mean	77.7	75.3	81.3	1.6	14.6	26.2	44.4	14.0	0.9

nes were compared (Tables 4 and 5). The best grain yield was produced by the variety 'Aura', but it was affected by the growing conditions and varied within 2.88–7.42 t ha^{-1}. The yield of the standard variety 'Auksiniai 3' was lower, but more stable throughout the years. The average data of evaluation show that all spring barley varieties, except 'Aidas', met the requirements for malting barley grain coarseness. The coarse grain output for 'Alsa' and 'Aura' exceeded 90%, whereas for the German malting barley variety 'Alexis' varied within a wider range (86.6–97.7%). According to the mean protein content all varieties exceeded the permissible level for malting barley. This index was affected by the data of the year 1999 with exceptional climatic conditions. Starch content in grains is important for malting varieties, because two thirds of malt extract substances are produced from starch. The mean starch content in grains of the malting variety 'Alexis' was 61.1%, in the standard variety 'Auksiniai 3' 60.4%, and in the rest of varieties it varied within 57.4–58.7%. The variety 'Auksiniai 3' showed a high hectoliter weight and the variety 'Ūla' a high thousand kernel weight. In the varieties with starch content over 60%, the extract content was high (group IV). The extract content in Lithuanian varieties, except 'Aidas', was medium.

A high grain yield was produced by the lines 6121-2, 6782-33, 6791-35. The yield of line 7134-24 was low and varied from 3.00 to 5.26 t ha^{-1}. This line was evaluated only in 1998–2000 and the data were affected by the dry growing conditions of 1999. The average data of the study show that all spring barley lines, except 6121-2, met the requirements for malting barley grain coarseness. The coarse grain output of the line 7134-24 was 96.1% and varied within 94.1–98.0%. According to the mean protein content all evaluated lines exceeded the permissible level for malting barley. It was affected by climatic conditions of the year 1999. The

Table 4. **Grain yield and malt quality characteristics of Lithuanian spring barley varieties in competitive yield trials (1995–2000)**

Variety	Origin	Grain yield t ha^{-1}	Protein %	Starch %	HLW g l^{-1}	TKW g	Coarse grain output >2.5 mm	Extract content %
Auksiniai 3 – st.	Lithuania	4.86	12.8	60.4	721	47.3	92.5	80.3
Ūla	Lithuania	5.29	12.8	58.7	694	54.5	93.9	78.5
Alsa	Lithuania	5.27	13.6	57.4	685	50.0	93.2	78.3
Aura	Lithuania	5.47	13.6	57.8	684	50.5	94.4	78.3
Aidas	Lithuania	4.99	13.2	57.9	674	48.1	88.2	76.8
Alexis	Germany	5.05	12.0	61.1	681	49.2	90.5	80.7
LSD_{05}		0.468	0.74	1.86	13.0	1.88	3.34	1.47

Table 5. **Grain yield and malt quality characteristics of spring barley promising breeding lines (1995–2000)**

Line	Pedigree	Grain yield t ha^{-1}	Protein %	Starch %	HLW g l^{-1}	TKW g	Coarse grain output >2.5 mm	Extract content %
Auksiniai 3	standard	4.86	12.8	60.4	721	47.3	92.5	80.3
6121-2	Krinichnij × [(KM1192 × × Ofir) × (Deba × KM1192)]	5.34	13.3	59.2	700	47.6	86.0	79.3
6700-28	[(Vega × (Sv73608 × WW6405)] × [HVS929/77 × × (Chellas × Mirena)]	5.20	12.8	57.8	700	52.7	92.5	79.2
6706-20	[(Vega × (Sv73608 × × WW6405)] × Vista	5.26	12.9	58.2	709	51.4	91.9	78.7
6782-33	[(Vega × (Ofir × × Berenice)] × Liisa	5.43	12.8	59.9	700	48.8	90.7	79.8
6791-35	[(Vega × (Ofir × Berenice)] × × Flare	5.54	12.2	58.1	689	51.0	94.0	77.3
7134-24*	Prima × Yavelin	4.44	13.0	59.2	682	51.4	96.1	79.1
LSD_{05}		0.432	0.79	1.10	13.0	2.26	4.40	1.25

* 1998–2000.

mean of the starch content and hectoliter weight in grains of the breeding lines varied between 57.8–59.9% and 682–709 g l^{-1}, respectively, and did not exceed the standard variety 'Auksiniai 3' (60.4% and 721 g l^{-1}). The lines 6700-28, 6706-20, 7134-24 and 6791-35 showed a high thousand kernel weight. The extract content of promising breeding lines, except 6791-35, was medium (group III). The best extract content was shown by the line 6782-33 (79.8%). It varied from 77.3% in the dry year 1999 to 82.1% in 1995, which was favourable for malting characteristics. Analysis showed that strong annual effects occurred over the study in malting grain characteristics of Lithuanian spring barley varieties and breeding lines. However, there are rather prominent differences among separate spring barley breeding lines, allowing us to expect that selection in early generations according to this characteristic is possible.

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A. Leistrumaitė, V. Paplauskienė

VASARINIŲ MIEŽIŲ VEISLIŲ IR SELEKCINIŲ LINIJŲ GRŪDŲ SALYKLINIŲ SAVYBIŲ TYRIMAS

S a n t r a u k a

1995–2000 metais Lietuvos žemdirbystės institute tirti vasarinių miežių salyklines savybes apibūdinantys rodikliai: 1000 grūdų masė, saiko svoris, grūdų stambumas, baltymų, krakmolo kiekis grūduose, salyklo ekstraktingumas ir kt. Kasmet buvo tiriama 45–50 veislių ir linijų. Daugumos tirtų lietuviškų vasarinių miežių veislių grūdų stambumas atitinka salykliniams miežiams keliamus reikalavimus, tačiau baltymų kiekis grūduose priklausė nuo metų meteorologinių sąlygų. Ypač didelį baltymų kiekį vasariniai miežiai sukaupė sausringais 1999 metais – 14,2–19,2%. Padidėjęs baltymų kiekis miežių grūduose mažino salyklo ekstraktingumą. Tirtų miežių veislių ir linijų vidutinis salyklo ekstraktingumas neviršijo 80%. Tarp tirtų linijų derlingumu ir tinkamomis salyklinėmis savybėmis pasižymėjo selekcinės linijos 6121-2, 6782-33, 7134-24.