50 Years of Progress in Quality of Malting Barley Grown in the Czech Republic

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ABSTRACT

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This paper summarizes the results of study of malting and agronomic characteristics of barley varieties grown in the territory of the Czech Republic over the period 1955–2005. Mean year-on-year increase in the grain yield was 53 kg/ha. Mean increase in TGW was 0.177 g/year over the studied period. Accumulation of protein in the studied varieties declined ca by 12%. Varieties from the beginning of the 21st century displayed a 4% higher extract content than those grown in the second half of the 1950s. Mean year-on-year increase in extract (d.m.) was a 0.0641 percentage point. By the end of the 1970s most of the varieties achieved values of diastatic power higher than 300°WK. In the 1970s to 1980s, diastatic power declined to under the level of 300°WK. In the 2nd half of the 1990s and at the beginning of this century, activity of amylolytic enzymes increased considerably in some modern varieties and values of diastatic power frequently moved over 350°WK. Activity of proteolytic enzymes increased by 6%. Mean year-on-year increase in Kolbach index was a 0.1456 percentage point. Value of relative extract at 45°C increased by 3%. Mean year-on-year increase in relative extract at 45°C was a 0.0645 percentage point over the studied period. Value of the apparent final attenuation, a trait characterizing quality of wort composition, increased by 3%. Mean inter-year increase in apparent final attenuation was a 0.0756 percentage point.

Key words: Barley, breeding progress, malting quality, yield components.

INTRODUCTION

In the 1970s barley breeding in the territory of the today's Czech Republic, which was historically a part of the Austrian-Hungarian Monarchy, was limited to a primitive selection of seed from better stands and exchanging such selections among farmers. Landraces were thus created in more or less closed areas. The old landraces were populations. They were highly undemanding, drought-resistant, early maturing and extensive in their cultivation[28]. Varieties according to our modern concept did not exist and the barley grown was highly heterogeneous. Selection was mainly based on the grain appearance. Plump, well filled grains with a fine husk were popular. Level of mealiness or steeliness was assessed by biting or chewing the grain[49,50]. The original two-rowed barley had a nodding lax ear (var. *nutans*).

Some areas became famous for their barley quality. In central Europe, the principal malting barley regions producing grain with excellent malting quality were Bohemia (first of all in the Elbe Plain) and Moravia (especially the Haná district, a fertile area along the rivers Morava and Haná)[23]. Both these regions are part of the Czech Republic.

The collection of regional varieties, as important genetic resources for breeding of spring barley, started in the current territory of the Czech Republic in the 1870s. Proskowetz[40] was the first to point out the significance of the regional varieties in 1890. In 1872 he gathered 20 regional barley varieties from the whole of Haná and tested them in Kvasice and Židlochovice in 1873 and 1874. The best varieties were achieved by the landrace he obtained from a farmer from Holešov. It exceeded the others in earliness, quality and yield and became a starting material for further breeding. Initially Proskowetz used the plant progeny method to select plants with the best developed ears and best grains[26]. In 1884 breeding based on individual selection was completed and a new variety was established. Proskowetz named it after the breeding method used, i.e., Proskowetz Hanna Pedigrée (the original name was "Kvassitzer Original Hanna Pedigree Gerste"). In autumn 1904, Proskowetz began to collaborate with Prof. E. von Tschermak-Seysenegg on the cultivation of Hanna barley[26]. They used individual selection and pedigree testing to find early and high-yielding lines of malting barley[52,60,64].

In 1886, F. Kneifel started barley breeding in Opava, Silesia. In 1926 the variety Opavský (also referred to as Kneifel, Kneifel barley, Kneifel barley – Opavský, Opavský Kneifel) was bred. The variety Opavský was the first representative of so-called fullcorn barley. It had short plump filled grain and a finely wrinkled gold-yellow husk, high extract content and short post-harvest maturation. In other countries it was denoted as Kneifels Vollkorn, Vollkorn, or Vollkorngerste[26,28].

Both the varieties, Proskowetz Hana Pedigree and Opavský (Kneifel), were used in the breeding programs in

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various parts of Europe and got into the pedigrees of many well known varieties[17,23,27,28]. The variety Hannchen (Svalövs Hannchen) was selected from the variety Proskowetz Hana Pedigree. For example the French variety Beka (Bethge XIII x Kneifel) was bred from the variety Kneifel and the variety Bethge was formed from the Old-Bohemian barley[28].

The first experiments with intercrossing of two varieties were carried out in the territory of the today's Czech Republic as early as 1900[22]. This method only began to be used more widely around 1920. However, even earlier varieties formed by the crossing of barley Hana were grown here. They were bred by Prof. E. von Tschermak-Seysenegg in Groß-Enzersdorf near Vienna. For example, it was the variety Hanna X Hannchen (1910) with a typical big grain, low protein content and a firmer stem which led the way. In 1919, Tschermak-Seysenegg used combination crossing between a long-ear variety Proskowetz Hana Pedigree and barleys from Asia Minor which were taken to Vienna in 1902 by Prof. Zederbauer and the varieties Hanna Kargyn (Hanna X Turkish landrace from Kargy) were created, a world champion in the London Exhibition of 1927, and Hanna Kaisarie (Hanna X Turkish landrace from the district of Kaisarie, today's Kayseri). The Asia Minor barley Kargyn from Kaisarie was an early short-stem variety[17,53]. In 1928, crossing was used for breeding the first Czech variety Židlochovická Alfa[28]. It was an early variety of exceeding quality, resistant to drought, with low protein content. It was excluded from further breeding as it lodged considerably.

In 1912 the Institute of Plant Breeding was established in Lednice in Moravia. The original name of the Institute was "Fürst Johann von Liechtenstein-Pflanzenzüchtung-Institut", but was later renamed the Mendel-Institute. Today it is a part of the Mendel University of Agriculture and Forestry, Brno (The Mendeleum – Institute of Genetics and Plant Breeding, Faculty of Horticulture). The first director of the Institute was Prof. E. von Tschermak-Seysenegg, followed by his assistant Prof. F. Frimmel in this function. Barley breeding started here with the selection from the barley landrace grown in Valtice. In 1929 the variety Valtický B was bred. Crossing of this variety with the variety Starnovský Kneifel produced the variety Valtický C in 1938. The variety had a well filled grain, a fine husk, and its earliness and quick development determined it for growing in arid areas. In 1941–1945, it was commandeered as a German variety named Feldsberger Braugerste. However, the original breeding material was nearly destroyed at the end of the war in 1945. Continuity of the variety was secured by further selections. In 1950, the variety was again released under the name Valtický. Valtický proved its quality and from malting and brewing aspects it secured a place among the best varieties. Over the period 1958–1960, the variety Valtický was sown in half of the barley production area of the Czechoslovak Republic. Valtický is in the pedigree of many successful Czech varieties (Ekonom, Jantar, Sladár, Topas) of the 1960s[53] and by the middle of the 20th century, the varieties of the Haná origin were considered the best malting varieties in the world[8].

In 1956, dry seeds of the variety Valtický were given a single dose of X-ray irradiation and subsequently sown. A 10 kiloroentgen variant contained a plant with increased tillering and a shorter stem. After further selections, this plant became the basis for a later variety Diamant, which was released in 1965. The variety Diamant meant a breach into the construction of plant habit, both morphologically (stem shortening) and physiologically (different rhythm of plant development). Substantial enhancement of resistance to lodging is a pronounced trait stabilizing not only grain yield, but also its malting quality[34]. Soon the variety Diamant was used for further breeding in the former Czechoslovakia and also abroad. In the former German Democratic Republic, the variety Trumpf (or also Triumpf, Triumph, Trumph) was bred from this variety and then on its basis many new varieties were formed. The varieties Diamant and Trumpf appear in the pedigree of about 150 new varieties bred during the last 25 years[25]. All the varieties bred in the former Czechoslovakia, on the basis of Diamant, are denoted as "Diamant type varieties"[53]. The variety Diamant is found in the pedigree of many successful Czech varieties (Ametyst, Hana, Favorit, Rapid, Spartan, Korál, Safír) of the 1970s[28]. The varieties Rubín and Akcent, bred in the late 1980s and 1990s, were the most widespread varieties in the Czech Republic and were also "Diamant types".

Originally, the varietal composition of spring barley in Czechoslovakia and then in the Czech Republic was restricted to the varieties bred in this territory. Only exceptionally were some varieties included in the category "Foreign Variety Permitted for Import". In 1993, the Czech varieties occupied nearly 70% of all reproduction areas in the Czech Republic, the rest were the varieties of Slovak provenience. In 1996, the German variety Krona was registered in the Czech Republic[44]. Since that year, the number of foreign varieties has increased in the assortment of the Czech Republic and in 2004 Czech varieties occupied 30% of the reproduction areas, Slovak varieties 5% and foreign varieties 65%[45].

At the end of the 19th century and the first half of the 20th century, considerable attention was paid to the assessment of malting barley in the territory of today's Czech Republic. Many classification systems were designed and further improved[7,14,15,62]. These systems were confined to external grain characters or content of nitrogenous substances and starch[61]. The authors of these studies also suggested introducing a malting test for quality assessment. Laboratory malting became a tool for the evaluation of lines formed in breeding programs. Besides the malting quality, breeders have always had further targets such as yield, sieving fractions over 2.5 mm, ear length, resistance to diseases, etc.

On 4 August 1920, the Institute of the Fermentation Industry in Brno was established. Within this institute, the Malt Industry Section was set up with support of the Czechoslovak malting industry. It was equipped with a pilot malt house for 600 kg grain samples and this equipment was used till 1950. Today this section (Malting Institute) is a part of the Research Institute of Brewing and Malting (RIBM). Since its origin, it has been focused on the evaluation of quality of malting barley varieties.

On 1 January 1951, the Central Institute for Supervising and Testing in Agriculture (CISTA) was set up. It is engaged in the registration of new varieties of barley and also other crops. Experimental locations of the CISTA are placed all over the territory of the Czech Republic. Varieties in all locations are grown using the same husbandry. Subsequently, the results (yield, TGW, resistance to diseases, etc) are collected and evaluated.

Collaboration of the RIBM and CISTA, which has lasted for nearly 60 years, ensures the objectivity of the evaluation of malting barley varieties. Each year, samples of the malting barley varieties are taken from several of CISTA's experimental locations. The barley samples are micromalted and the malts are analysed. New barley varieties are registered according to their yield, resistance to diseases and also on the basis of the results of the micromalting tests.

This paper summarizes data from the RIBM reports evaluating the malting barley varieties developed during the last 50 years. It documents that the breeders have managed to change the nature of the barley plant and thereby increase its yield and malting quality significantly. Contribution of the breeding effort for farmers and brewers is considerable, as a variety is the cheapest intensification factor for both growers and maltsters.

MATERIALS AND METHODS

Varieties

The studied data were obtained from research reports of the Research Institute of Brewing and Malting in

Table I. List of varieties.

Serial number	Variety	Country of origin[a]	Year of registration	Beginning of testing	Accession number[b]
1	Proskovcuv hanacky	CSK	1919	1955	03C0600015
2	Hanacky Kargyn	CSK	1919	1955	03C0600013
3	Ratborsky	CSK	1925	1955	03C0600017
4	Stupicky Hanacky	CSK	1926	1957	03C0600010
5	Opavsky Kneifel	CSK	1926	1955	03C0600005
6	Kasticky	CSK	1932	1955	03C0600132
7	Novodvorsky Hanacky	CSK	1933	1955	03C0600004
8	Stupicky Plnozrnny	CSK	1937	1955	03C0600007
9	Triumf	CSK	1938	1955	03C0600011
10	Valticky	CSK	1938	1955	03C0600019
11	Slovensky 802	CSK	1946	1962	03C0600006
12	Slovensky Dunajsky Trh	CSK	1946	1956	03C0600008
13	Bohatyr	CSK	1948	1955	03C0600012
14	Celechovicky Hanacky	CSK	1956	1956	03C0600057
15	Semcicky hospodarsky	CSK	1956	1956	03C0600054
16	Branisovicky C	CSK	1959	1959	03C0600070
17	Ekonom	CSK	1960	1960	03C0600075
18	Plena	GDR	1960	1965	03C0600680
19	Vynosny	CSK	1960	1960	03C0600072
20	Merkur	CSK	1964	1964	03C0600147
21	Diamant	CSK	1965	1965	03C0600166
22	Dvoran	CSK	1965	1965	03C0600154
23	Jantar	CSK	1966	1966	03C0600158
24	Sladar	CSK	1967	1967	03C0600197
25	Denar	CSK	1969	1969	03C0601303
26	Dukat	CSK	1971	1971	03C0600152
27	Topas	CSK	1971	1971	03C0601301
28	Ametyst	CSK	1972	1973	03C0601200
29	Favorit	CSK	1973	1974	03C0600091
30	Hana	CSK	1973	1974	03C0600090
31	Atlas	CSK	1976	1976	03C0600094
32	Elgina	GDR	1976	1972	03C0600349
33	Rapid	CSK	1976	1976	03C0600095
34	Trumpf	GDR	1973	1976	03C0601019
35	Diabas	CSK	1977	1977	03C0600064
36	Spartan	CSK	1977	1977	03C0600055
37	Koral	CSK	1978	1978	03C0600089
38	Safir	CSK	1978	1978	03C0600096
39	Fatran	CSK	1980	1980	03C0600099
40	Opal	CSK	1980	1980	03C0600101
41	Krystal	CSK	1981	1981	03C0600104
42	Zefir	CSK	1981	1981	03C0600103
43	Rubin	CSK	1982	1982	03C0600059
44	Mars	CSK	1983	1983	03C0600058
45	Bonus	CSK	1984	1984	03C0600061
46	Zenit	CSK	1985	1985	03C0600062
47	Jaspis	CSK	1986	1986	03C0600066
48	Orbit	CSK	1986	1986	03C0600067

(continued on next page)

[a] CSK – Czechoslovakia, CZE – Czech Republic, DEU – Germany, DNK – Denmark, FRA – France, GBR – Great Britain, GDR – German Democratic Republic, SVK – Slovak Republic.
[b] Plant Genetic Resources Documentation in the Czech Republic (http://www.vurv.cz/index.php?key=section&id=108).

Brno[20,48,55–59]. A list of the varieties presented in the reports is given in Table I. In the Table each variety has an accession number under which it was registered in the Plant Genetic Resources Documentation in the Czech Republic[39].

From 1955–1990, the final reports of the RIBM in Brno provided information on the results of analyses of samples from all testing stations apart from the content of nitrogenous substances (proteins) in the grain. Since 1991, the RIBM final reports include only four selected testing stations, where the control malting barley varieties attained optimal or close to optimal value of average content of nitrogenous substances (proteins) in grain (10.7–11.2%) in the given year. Therefore, to provide an objective comparison of the data for the whole period studied, the testing stations where the average content of nitrogenous substances (proteins) in barley grain was farthest away from the optimal values in 1955–1990 were excluded from further evaluation.

Only the registered varieties were included in the studied set and the assortment of the monitored varieties differed slightly each year. Obsolete varieties, or those that did not become established, were excluded from the set and the next year they were replaced by new varieties.

In the text below, the name of the variety is followed by its serial number. The same serial numbers are also given in Table I and in the figures.

Micromalting and barley and malt analysis

In the 1950s, many technological parameters were followed, but only some of them were studied for the whole

Table I. List of varieties. *(Continued from previous page)*

Serial number	Variety	Country of origin[a]	Year of registration	Beginning of testing	Accession number[b]
49	Jarek	CSK	1987	1994	03C0600068
50	Perun	CSK	1987	1987	03C0600069
51	Novum	CSK	1988	1988	03C0600074
52	Malvaz	CSK	1989	1989	03C0600077
53	Galan	CSK	1990	1990	03C0602267
54	Jubilant	CSK	1991	1991	03C0602268
55	Terno	CSK	1991	1991	03C0602181
56	Akcent	CSK	1992	1992	03C0602182
57	Heran	CSK	1992	1993	03C0602184
58	Ladik	CSK	1992	1993	03C0602487
59	Profit	CSK	1988	1988	03C0600073
60	Sladko	CSK	1992	1992	03C0602187
61	Svit	CSK	1992	1993	03C0602186
62	Donum	SVK	1993	1993	03C0602368
63	Forum	CZE	1993	1992	03C0602369
64	Stabil	SVK	1993	1992	03C0602370
65	Pax	SVK	1994	1994	03C0602371
66	Viktor	CZE	1994	1994	03C0602248
67	Amulet	CZE	1995	1995	03C0602342
68	Kompakt	SVK	1995	1995	03C0602423
69	Lumar	CZE	1995	1995	03C0602340
70	Atribut	CZE	1996	1996	03C0602343
71	Ditta	DEU	1996	1999	03C0602435
72	Famin	CZE	1996	1996	03C0602484
73	Krona	DEU	1996	1996	03C0602366
74	Olbram	CZE	1996	1996	03C0602420
75	Pejas	CZE	1996	1998	03C0602459
76	Scarlett	DEU	1997	1998	03C0602426
77	Tolar	CZE	1997	1998	03C0602486
78	Heris	CZE	1998	1999	03C0602572
79	Madonna	DEU	1998	1998	03C0602521
80	Nordus	DEU	1998	1998	03C0602571
81	Sabel	GBR	2001	2001	03C0602577
82	Madeira	DEU	1999	1999	03C0602555
83	Maridol	CZE	1999	1999	03C0602573
84	Jersey	NLD	2000	2000	03C0602597
85	Saloon	GBR	2002	2002	03C0602659
86	Annabell	GBR	2001	2001	03C0602566
87	Diplom	DEU	2002	2002	03C0602661
88	Malz	CZE	2002	2002	03C0602668
89	Philadelphia	DEU	2002	2002	03C0602662
90	Prestige	GBR	2002	2002	03C0602634
91	Biatlon	GBR	2003	2003	03C0602694
92	Calgary	FRA	2003	2003	03C0602693
93	Faustina	DEU	2003	2003	03C0602704
94	Respekt	CZE	2003	2003	03C0602695
95	Nitran	SVK	2004	2004	03C0602712
96	Bojos	CZE	2005	2005	03C0602742
97	Class	FRA	2005	2005	03C0602721
98	Radegast	CZE	2005	2005	03C0602744
99	Sebastian	DNK	2005	2005	03C0602773

period. For this project, the parameters followed for a few decades were chosen. Data on yield, TGW and sieving fractions over 2.5 mm were obtained from CISTA.

Many changes that could influence the results occurred during the period studied. The valid MEBAK and EBC methods were used for the malt analyses[9–12,31–33]. Procedures for the determination of particular studied traits were standardized and automated. The range of analyses varied according to the requirements of the malting industry. In 1975, the original floor malting was replaced by malting in a pneumatic micromalting plant. Since that year, essentially the same malting system as the one described in the MEBAK method[31] has been used.

Statistical evaluation of the results

Basic parameters of spring barley and malt, analysed in the Malting Institute of the RIBM Brno from 1955 to 2005, comprised information on 99 varieties tested in 51 experimental locations. A total of 3954 assessments of the given parameters were used for the evaluation of variety × location × year. Initially, for the individual parameters, the residual maximum likelihood method and 3-way ANOVA without interaction were used to determine the effects of years, locations and varieties.

$$y_{ijk}^{p} = \mu_p + \alpha_{p,i} + \beta_{p,j} + \gamma_{p,j} + e_{p,ijk}$$

Where:

y_{ijk}^{p} represents the value of the p-th parameter relating to the i-th variety tested at the j-th experimental location in the k-th year,

μ_p the total mean of the experimental series of the p-th parameter,

$\alpha_{p,i}$ the effect of the i-th variety of the p-th parameter,

$\beta_{p,j}$ the effect of the j-th experimental location of the p-th parameter,

$\gamma_{p,j}$ the effect of the k-th year of the p-th parameter, and

$e_{p,ijk}$ the independent random error with $N(0,\sigma^2)$.

Subsequently, the original values were adjusted and the effects of environment, years and experimental locations reduced using the factor

$$z_{p,i} = y_{ijk}^{p} - \beta_{p,k} - \gamma_{p,l}$$

and after that assessed using the linear and polynomic correlation and regression analysis where a variable, regressor, was the year in which the variety was analysed for the first time in the RIBM ($x_{p,i}$) using the factors

$$z_{p,i} = a_p + b_p x_{p,i}$$

or $z_{p,i} = a_p + b_p x_{p,i} + c_p x_{p,i}^2$

The polynomial analysis was used for the evaluation of diastatic power. The adjusted varietal means of the evaluated parameters are given in Figs. 1–9.

Biometrical evaluation was performed in the statistical system Statistica.

The x-axis indicates years in which the varieties were analysed in the RIBM for the first time. In some older varieties, the data do not correspond to the year of their release into practice.

RESULTS

Agronomic characters

During the studied period, yield of barley grain gradually increased. In the mid-1960s, the variety Diamant (21) achieved 4.4 t/ha, in the 1970s the variety Trumpf (34) achieved 5.1 t/ha, in the 1980s the varieties Orbit (48) and Novum (51) yielded 5.7 and 5.8 t/ha, respectively, and in the middle of the 1990s the varieties Viktor (66) and Lumar (69) provided 5.9 t/ha. During the last decade, the highest yields were achieved by varieties of a foreign origin: Sebastian (99) 6.9 t/ha, Saloon (85) 6.5 t/ha, Biatlon (91) 6.4 t/ha, and Philadelphia (89) 6.3 t/ha. The Czech variety Bojos (96) 6.3 t/ha and Slovak Nitran (95) 6.3 t/ha

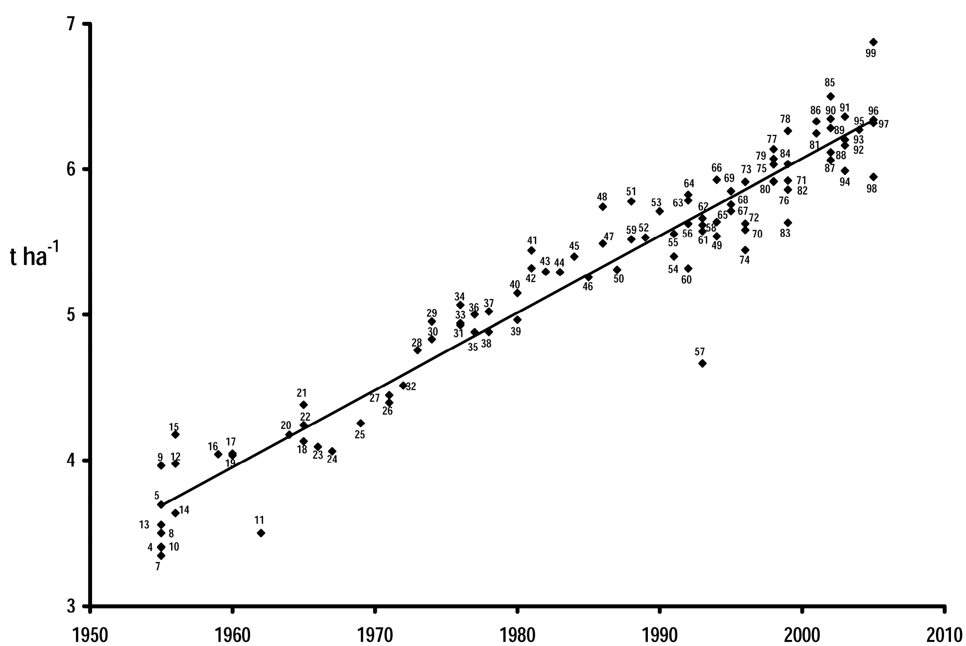

Fig. 1. Yield of grain (1955–2005).

Table II. Correlation and regression analysis of selected parameters, 1955–2005.

	Intercept	b_1	b_2	Correl. coeff.	Prob. level	Significant level[a]
Yield of grain [kg ha^{-1}]	–99.9344	0.0530		0.9658	0.0000	***
Thousand grain weight [g]	–313.7680	0.1770		0.8587	0.0000	***
Grading > 2.5 mm [%]	–1026.2600	0.5538		0.8620	0.0000	***
Protein content [%]	59.5416	–0.0244		–0.7604	0.0000	***
Extract content [%]	–45.8466	0.0641		0.8802	0.0000	***
Diastatic power [°WK]	292139.3	–295.05	0.07456	0.4193	0.0001	***
Kolbach index [%]	–245.918	0.1456		0.7469	0.0000	***
Relative extract at 45°C [%]	–88.2096	0.0645		0.3236	0.0198	*
Apparent final attenuation [%]	–69.8631	0.0756		0.6077	0.0000	***

[a] *, p-level = 0.05. ***, p-level = 0.001.

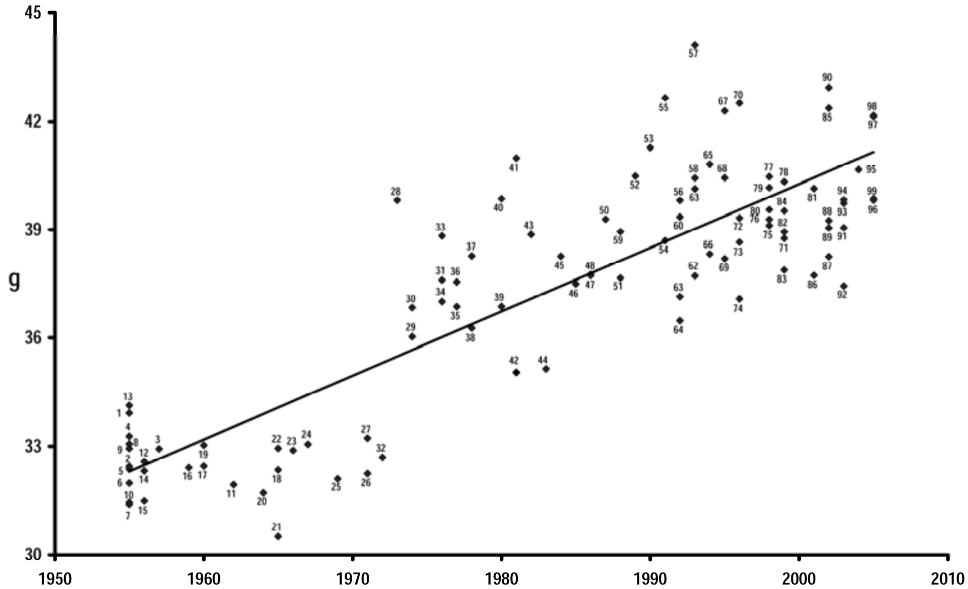

Fig. 2. Thousand grain weight (1955–2005).

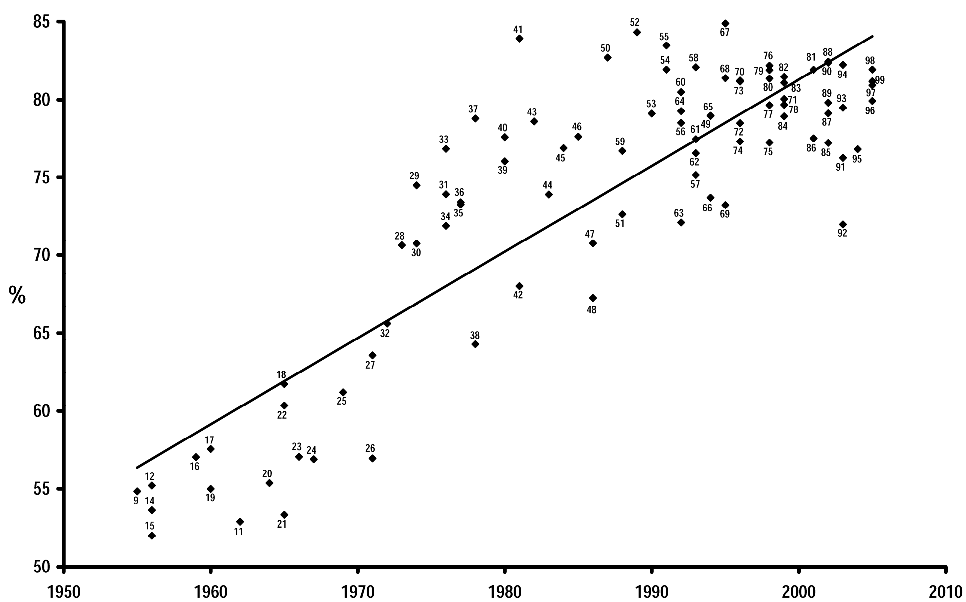

Fig. 3. Grading > 2.5 mm (1955–2005).

also had the same yield potential as the variety Philadelphia (Fig. 1).

Yield of the oldest varieties was even less than 3.5 t/ha in the experimental locations, whereas yield of the modern recent varieties in experiments carried out by CISTA was 6.0–6.5 t/ha and in some cases even as high as 7 t/ha. Average yield in 1955–1959 was 3.7 t/ha and in 2001–2005 it was 6.3 t/ha. Varieties grown in the latter half of the 1950s achieved ca 59% of the current varieties yield. Average annual year increase in grain yield was 0.053 t/ha (Table II).

Thousand grain weight is an important factor affecting extract yield. In the Diamante Type varieties (the 1970s) and later modern varieties, morphological and physiological changes resulted in an increase in TGW and thus also grain yield (Fig. 2). The improved TGW values were recorded in the varieties Bohatyr (13) 34.1 g, Ametyst (28) 39.8 g, Krystal (41) 41.0 g, Terno (55) 42.7 g, and Heran (57) 44.1 g. The oldest varieties had a TGW of around 30–34 g, while the modern ones achieved 38 g and more. Average TGW of the varieties grown in 1955–1959 was 32.5 g and in 2001–2005, it was 40 g. Genetic gain in this parameter was nearly 19%. In the studied period, the average year-on-year increase in TGW was 0.177 g (Table II).

Sieving fractions of grain over 2.5 mm is another important factor. In the old varieties, such as Diamant (21) and Trumf (9), values of this parameter varied between 50–60%. In the latter half of the 1970s and 1980s, sieving fractions over 2.5 mm increased significantly, especially in the varieties Krystal (41) 83.9%, Koral (37) 78.8%, and Rubín (43) 78.6% (Fig. 3). Genetic gain in this parameter was 25.2%, since the average value of sieving fractions of grain over 2.5 mm in the varieties grown in 1955–1959 was only 54.2%, but by 2001–2005 it was 79.4%. Average year-on-year increase in sieving fractions over 2.5 mm was a 0.55 percentage point over the followed period (Table II).

Malting characters

A tendency to gradually reduce the accumulation of nitrogenous substances can be observed in newer varieties (Fig. 4). Significant progress was recorded in the variety Diamant (21) 10.6%. In the mid fifties content of nitrogen substances in grain of the studied varieties varied on the level of 12%, but at the end of the given period it was lower by one percent. The year-on-year decrease was a 0.0244 percentage point (Table II).

Starch modification

Extract content indicates the degree of starch modification during malting and mashing. This important technological and economic parameter was monitored for the whole fifty-year period and reflects the result of breeding efforts. Progress in extract was recorded in the varieties Diamant (21) with 81.5%, Sladar (24) 81.5%, Rubín (43) 82.3%, Perun (50) 82.3%, Donum (62) 82.8%, Olbram (74) 82.9%, Malz (88) 83.4%, and Biatlon (91) 83.7%. While in the second half of the 1950s, values below 80% of extract were quite common, e.g. in the variety Stupicky Hanacky (4), at the end of the 1970s, extracts moved up to the level of 81% and at the end of the following decade values around 82% were quite frequent (Fig. 5). Genetic gain in this parameter was affected by lower nitrogen accumulation in grain and higher activity of the caryopsis enzymatic apparatus during malting in the modern varieties. Varieties from the beginning of the 21st century exhibited a 4% higher extract content than those grown in the second half of the 1950s. Average year-on-year increase in extract yield (d.m.) of malt was a 0.0641 percentage point (Table II).

Amylolytic modification

Another technological parameter followed for the whole fifty-year period was diastatic power. Breeding progress in diastatic power, i.e., activity of amylolytic en-

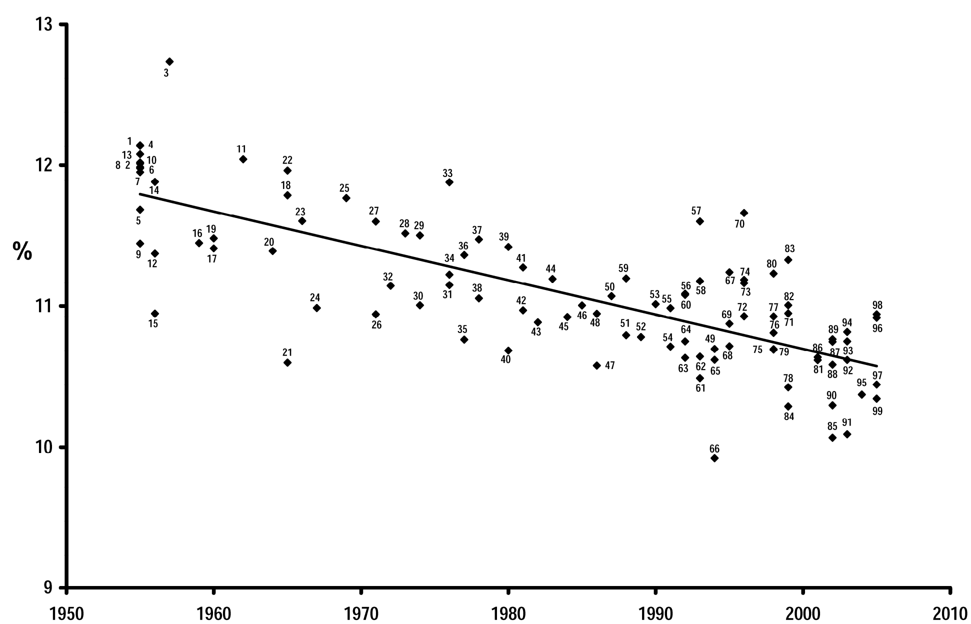

Fig. 4. Protein content (1955–2005).

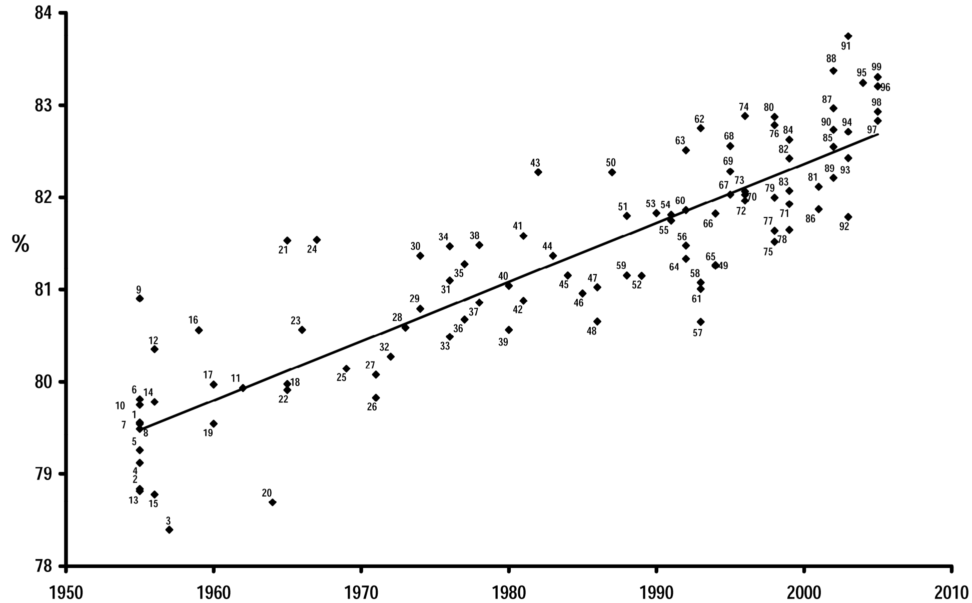

Fig. 5. Extract content (1955–2005).

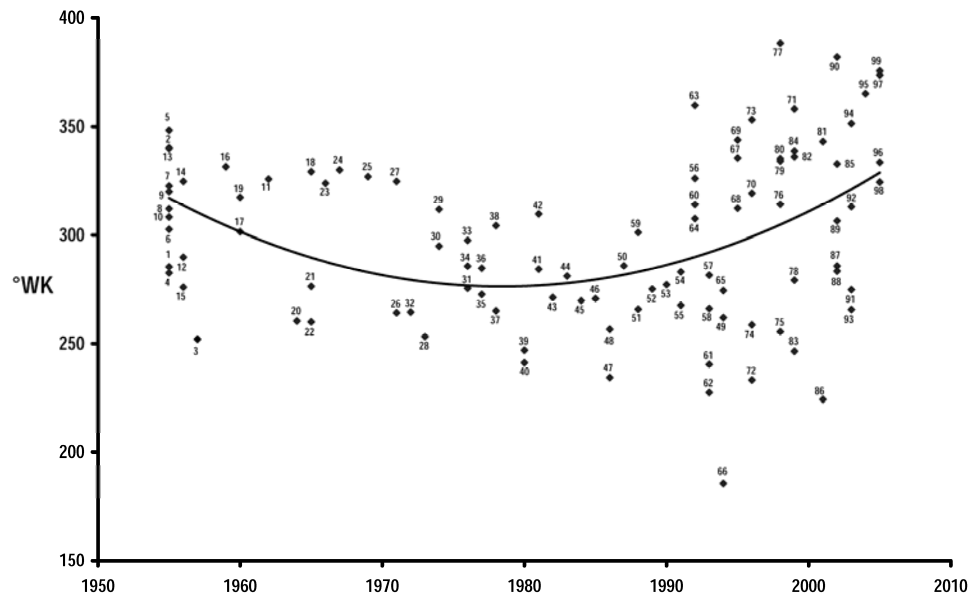

Fig. 6. Diastatic power (1955–2005).

zymes (first in β-amylases) is very interesting. While at the end of the 1970s, most varieties achieved values of diastatic power higher than 300°WK (e.g., the variety Bohatyr (13)), during the 1970–80s, diastatic power decreased; for example, in the varieties Ametyst (28) and Koral (37) to levels even below 300°WK. In the second half of the 1990s and at the beginning of this century, in some modern varieties such as in Tolar (77), Prestige (90), and Sebastian (99), a pronounced increase in the activity of amylolytic enzymes occurred and values of diastatic power moved frequently above 350°WK (Fig. 6).

Proteolytic modification

Proteolytic modification expressed by the value of the Kolbach index has been followed in the RIBM since 1956. Significant breeding progress was also recorded in this trait i.e. gradual improvement in protein modification. In the first half of the 1960s, activity of proteolytic enzymes in the studied set of varieties was significantly low; for example, in the variety Merkur (20), it was only 35.8%. Since the second half of the 1960s, proteolytic modification gradually improved in the studied varieties (Fig. 7). At the end of the studied period, average values of proteolytic modification were around 43%. In some samples such as in the variety Biatlon (91), values of Kolbach index as high as 50% were recorded. The varieties Sladko (60), Nordus (80), Jersey (84), and Biatlon (91) showed the highest tendency to proteolytic overmodification.

Genetic gain in this parameter was ca 7%, as the average value of the Kolbach index of the varieties registered

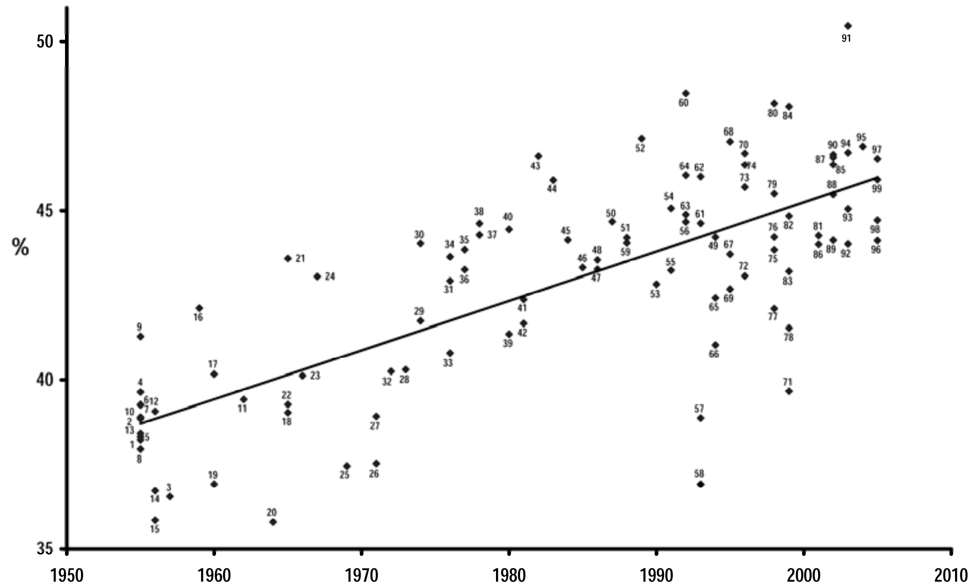

Fig. 7. Kolbach index (1955–2005).

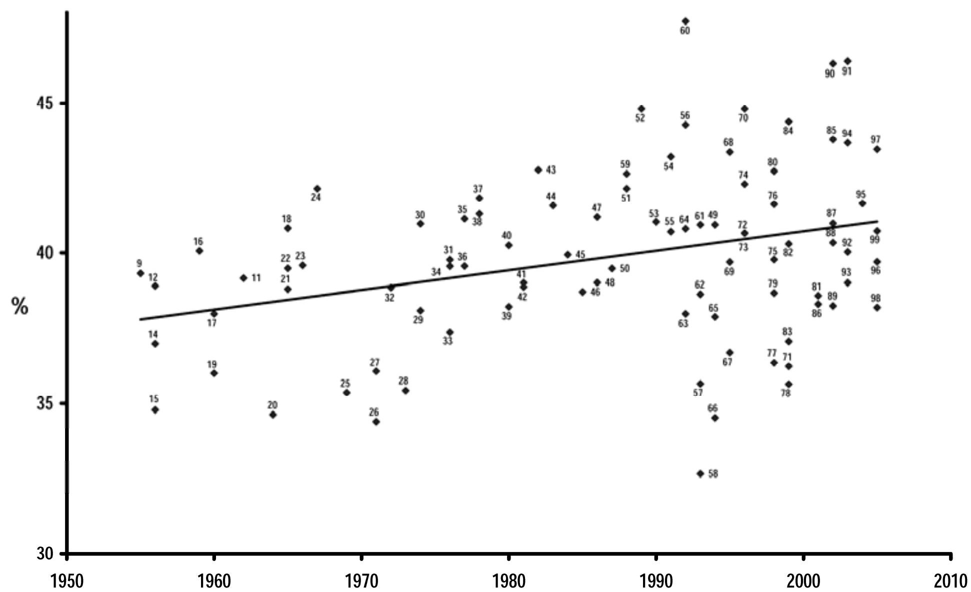

Fig. 8. Relative extract at 45°C (1963–2005).

in 1955–1959 was 38.7% and in 2001–2005, it was 45.8%. The average year-on-year increase in Kolbach index was 0.1456 percentage point for the studied period (Table II).

Relative extract at 45°C

Relative extract at 45°C in the tested varieties has been followed in the RIBM since 1963. This parameter expresses activity of proteolytic enzymes and α-amylolysis and to a certain extent it correlates with the value of the Kolbach index. Activity of enzymes affecting the value of relative extract at 45°C increased gradually. The value of relative extract at 45°C was affected both by the varietal composition and the weather in a given year. Progress in relative extract at 45°C was subsequently recorded in the varieties Valtický (10) 39.3%, Sladár (24) 42.1%, Rubín (43) 42.8%, Malvaz (52) 44.8%, and Sladko (60) 47.7% (Fig. 8).

Relative extract at 45°C of the varieties registered from 1955 to 1959 was about 38.2%. In the varieties registered at the end of the period studied (2001 to 2005), the value of this parameter was about 41.2%. Genetic gain in this parameter moved up by a level of 3%. Mean year-on-year increase in relative extract at 45°C was a 0.0645 percentage point over the studied period (Table II).

Wort quality composition

Since 1968, the method based on fermentation of laboratory wort has provided information on the expected course of the fermentation in practice. Figure 9 demonstrates considerable breeding improvement. Progress in wort quality composition was brought about by the varie-

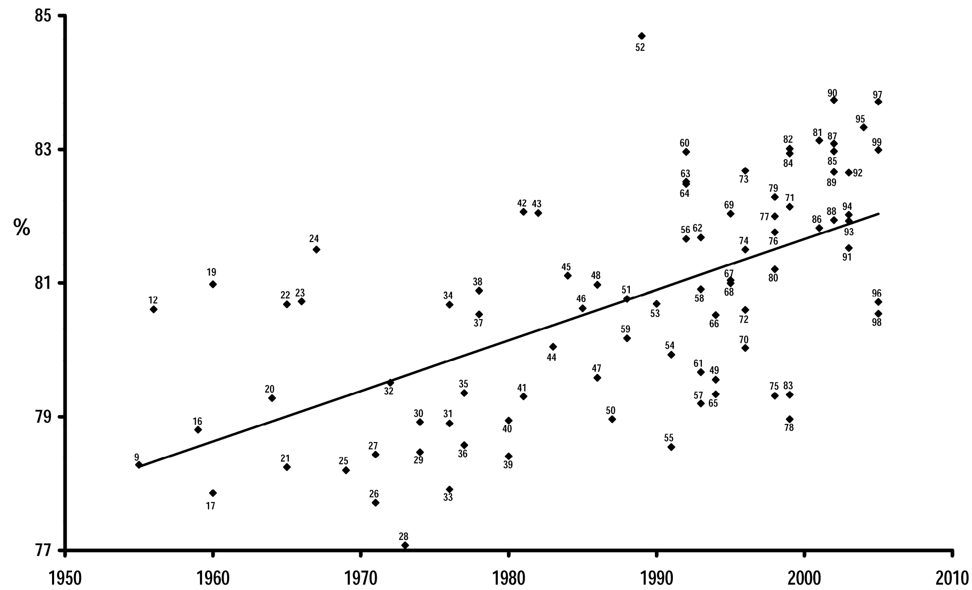

Fig. 9. Apparent final attenuation (1968–2005).

ties Slovenský dunajský trh (12) 80.6%, Vynosny (19) 81.0%, Sladar (24) 81.5%, Zefir (42) 82.1%, Sladko (60) 83.0%, and Prestige (90) 83.7%. However, the highest value was achieved by the Czech variety Malvaz (52) 84.7% registered in 1989 (Fig. 9). Initially, breeding was not aimed at wort quality and wort quality improvement was connected with progress in the other technological parameters. It was only after the introduction of this parameter that selection and breeding for wort quality started.

The average value of apparent final attenuation of the varieties registered in 1955–1959 was 79.2%, and 82.3% in the varieties registered in 2001–2005; genetic gain was thus 3%. Average year-on-year increase in apparent final attenuation was a 0.0756 percentage point (Table II).

DISCUSSION

In the 1950s, both the varieties created by selection from landraces at the end of the 19th century and the varieties formed by crossing at the beginning of the 20th century were grown on Czechoslovak farms. This collection of varieties was included in the testing performed by the newly established Central Institute for Supervising and Testing in Agriculture.

Introduction of micromalting tests led to changes in the evaluation system of barley malting quality. Originally, the samples of tested barley were placed into nylon sacks and malted on floors. Later, automatic laboratory micromalting plants were developed and constructed. Originally, the RIBM used a micromalting plant from the company Seeger for testing barley varieties. In 1995, this equipment was replaced by a micromalting plant from the company KVM, constructed on the basis of the RIBM's experiences and needs.

Studies showing breeding progress are always very interesting. A lot of studies describing morphological, fenological and agronomic characters of barley have been published[1,30,36,41,66], but only a few papers have dealt with the progress of malting quality[4,37,38,63].

Yields of barley grain and other cereals have risen dramatically during the past century. This was caused by two factors: optimization of crop management and the breeding of new varieties reacting appropriately to intensive management of growing[16].

Variety, location, year and their interactions are principal factors affecting yield and quality of the harvested product[6]. Variety is the cheapest intensifying factor for a barley grower and the barley processing industry. Comparison of the qualities of varieties over a longer period demonstrates the benefits that breeding has brought to barley growers and malt houses and breweries. Determination of average year-on-year increase can help find prospective parameters for further breeding.

Figure 1 shows that newer spring barley varieties achieved higher yields. This trend has also been confirmed by other studies[1,17,30,36,41]. Yield of the oldest varieties barely achieved 3.5 t/ha at experimental locations, whereas yield of modern varieties in the CISTA tests was 6.0–6.5 t/ha and in some cases even 7 t/ha. This was also confirmed by results obtained when these varieties were grown together in 2006 and 2007[29]. Chloupek and Hrstková[6] presented an average year increase in yield by 46 kg/ha in the EU 15 and by 32 kg/ha in the USA over 1961–2003. A study by the American Malting Barley Association (AMBA) demonstrated progress in yield in the western part of the USA during the period of 1960–2000 on the level of +0.15 bu/acre (11 kg/ha) in the six-rowed varieties and +0.33 bu/acre (23 kg/ha) in the two-rowed ones, summarily +0.27 (19 kg/ha)[2].

According to Ekman[13], Riggs et al.[51] and Wych and Rasmusson[65], the annual increase in grain yield before targeted breeding was 0.39–0.9%. The year-on-year increase was 0.84–2%, after introduction of the varieties created by deliberate crossing, in the last 50–60 years. In Austria, annual progress of 0.11% during a hundred-year period before 1948 and 1% in the period of 1948–1982[19] was recorded. Yield in the production (agricultural) areas of the Czech Republic increased by 42 kg/ha/year in 1961–2003[5,6]. However, yield potential was higher and the annual increase was 53 kg/ha in the 1955–2005 varietal experiments, as demonstrated in this study (Table II). Increase in spring barley grain yield is generally connected with higher production of dry matter, lowered plant height and increased lodging resistance. This resulted in an increase in the yield potential of new varieties[17]. The decline in lodging of the two-rowed varieties in the US West (1960–2000) was 0.87% per year and it stopped on values below 25%. In the six-rowed varieties, the decline in lodging was 0.41% per year and currently it is between 25–30%[2].

Values for agronomic yield are closely connected with thousand grain weight and sieving fractions over 2.5 mm. These parameters therefore exhibited the same trend as yield. Malting barley breeding programs preferentially select for plump caryopses, which automatically results in higher TGW, lower protein content and higher extract content in modern cultivars. This fact is supported by the determined increase in volume weight in the US West, annually by 0.06 lb/bu (0.079 kg/hl) in the six-rowed and 0.01 lb/bu (0.013 kg/hl) in the two-rowed varieties. Increase in sieving fractions over 6/64" (2.4 mm) increased on average by 0.4% in the six-rowed varieties and by 0.21% in the two-rowed ones. Currently it is around 85% in both types[2].

Žáková and Benková[66] found an increase in TGW of 0.03 g/year in the assortment of varieties grown under the current conditions. Other authors observed either a consistent[13,18,65] increase in grain weight or only moderate or slight increases[24,51]. The present study, however, determined significantly higher average year-on-year increases in TGW in the period studied.

Malting parameters

Progress in the breeding of spring barley malting varieties has not been restricted only to yield. At the same time, progress in improving malting quality has been achieved. However, minor attention has been devoted to this issue. Malting quality is closely connected with the activity of the hydrolytic enzymes. In addition, sensory or colloidal stability of the final product can be affected by malt oxidoreductases such as lipoxygenase or superoxide dismutase. Although enzymes participate in the regulation of biochemical and physiological processes during malting, there is still only a limited amount of information on their activity in old and in modern varieties.

Increased growth of plump grains contributed significantly to the reduction of protein content, increased values of extract level, diastatic power, Kolbach index and improved α-amylase activity[4,17,54,65].

Determination of extract is probably the oldest analytical method used for malt evaluation. This method was introduced in the 2nd half of the 19th century and was standardized in the course of time. The last significant amendment was the acceptance of the methods for preparation of laboratory wort at the EBC congress in 1975. In addition, other older methods were standardized (diastatic power, Kolbach index, etc.). In this 50-year period, some new methods were introduced. In the 1960s apparent final attenuation and relative extract at 45°C were introduced for testing new varieties in the RIBM.

Friability and determination of β-glucan in wort belong to the newest frequently applied methods. The RIBM only began to use these methods for the evaluation of varieties at the beginning of the 1990s and therefore they were not included in this study.

Results of nitrogenous content in grain indicate a change in nitrogen accumulation and distribution in the barley caryopsis. The finding that the content of nitrogenous substances in caryopses of new varieties declines was also confirmed by Walmsley and Sarx[63].

Increase in malt extract is in correlation with reduced protein content and increased starch content in caryopsis and increased activity of the hydrolytic enzymes[17]. Walmsley and Sarx[63] studied the change in quality of varieties over a thirty-year period and they also found increased extract content and apparent final attenuation values.

The 1960–2000 AMBA study[2] confirmed the tendency toward increased values of extract in the varieties grown in the US West (0.14% and 0.098% in the six-rowed and two-rowed varieties, respectively).

Diastatic power reflects the activity of hydrolytic enzymes, including α- and β-amylases, which are involved in the hydrolysis of starch to fermentable sugars. α-Amylase is synthesized only during malting, while β-amylase is already formed during caryopsis maturation.

The increase in the values of diastatic power detected in the present studies was also confirmed by the AMBA[2]. According to this study, the values of diastatic power in the US West increased by 1.63°L (5.04 WK) per year in the six-rowed and 0.64°L (4.75 WK) in the two-rowed varieties. On the other hand, in the US Midwest no increase in these values was found except for a period in the 1980s[3]. Similar trends were also determined for the values of α-amylase.

The Czech Republic wants to maintain the sensory character of beer as the Czech national drink[21,35,46,47]. Therefore the varieties[42,43] with values of relative extract at 45°C max. 38%, Kolbach index in the range of 39 ± 3%[21], and apparent final attenuation to 82%[35] have also been included in the recent varietal collection of the Czech Republic.

Use of physiological, biochemical and morphological characters as selection criteria makes progress in breeding malting barley even more rapid, as these characters are consequently affected and changed. Comparison of these characters in the old and modern varieties can help identify the indicators of breeding quality in genetic sources of barley used in breeding new varieties. Breeding for resistance to diseases, lodging, drought and yield also affects varietal characters specifying malting quality. Explicit identification of changes caused by breeding to diseases, etc and changes caused by breeding for malting quality can therefore contribute to further progress in malting barley breeding.

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