Study of Grain Quality from Viewpoint of Cereal Breeding for Proper Animal Nutrition

Untersuchung der Kornqualität vom Gesichtspunkt der Züchtung von Getreide für die richtige Tierernährung

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Abstract

Cereal grain for feeding is a main way of production use and the most important raw material for production of feed mixtures in the Czech Republic. The assortment of basic cereal cultivars registered for growing in the country is now very vast, neverless data on grain quality for feeding farm animals is neither provided in cultivar descriptions nor included in the system of grain quality evaluation when tested in state official trials.

Grain of the cultivars of the main cereal species (spring barley, winter barley, winter wheat and winter triticale), registered in the Czech Republic till 2003 and tested in the official trials for A List of Recommended Cultivars in 2002-2004 (at the locations of the Central Institute for Supervising and Testing in Agriculture) were selected for study of grain physical characteristic (hardness in PSI, %), chemical composition (N-substances, starch, fat, fibre, nonfibre carbohydrate, organic matter, ash, minerals - P, K, Ca, Mg, beta-glucans in barley- all in $g.kg^{-1}$, wet gluten in % and gluten index in wheat) and digestibility using „in vitro“ methods - on Daisy II incubator (Ankom firm) - as the decrease in grain dry matter after cultivation with amylase (after 1h and 6h - in %) and on Vitrogest instrument (RICB Rapotin) - as the volume of produced gases after sample cultivation at the defined volume of a cultivating medium (after 4h, 8h, 20 h and 24h - in $ml.g^{-1}$).

The study revealed differences due to environmental effects, differences among species and also among individual cultivars. The most affected nutrients were starch (all species differ statistically significantly), fibre (all barley cultivars had more fibre than wheat or triticale, but winter barley also differed from spring one by higher fibre content), N-substances (wheat exceeded all species) and hardness (with the most softest grain for triticale). This character belongs together with fibre to the parameters with the largest variability; we found also rather high variability among individual cultivars and species in mineral content, and particularly in calcium and potassium.

Grain nutritional quality, tested by „in vitro“ methods, revealed that the course of nutrient degradation using amylase and feed fermentation in the cultivating medium with rumen juice was not identical in the examined cereals. Reciprocal correlations between methods and times of testation were different at particular cereal species. As the results founded at Daisy II show, especially after 1h, there was hardly any correlation with the Vitrogest results for spring barley and winter wheat; in the winter barley and triticale the highly significant positive relationship was found. The LSD post hoc test results showed, that the variability in the „in vitro“ indicators of the particular cereal species was influenced by range of the represented genotypes and the size of the variability in the individual cultivars. We found the great differences between groups regarding morphological (2-rowed and 6-rowed winter barley cultivars) or qualitative criteria (breadmaking quality classes E, A, B and C in winter wheat).

Both „in vitro“ tests indicate the barley species as the „slower“ (in the case of Vitrogest the slowest was the spring barley cultivar Annabell) and the highest speed of degradability was found in winter wheat (in Vitrogest) and triticale (in Daisy II), when statistically significant differences were assesed particularly among wheat cultivars. Since various categories of farm animals require a different speed of the organic matter degradability (monogastric versus ruminants), it is possible to both „positive“ and „negative“ results to select suitable species and individual cultivars for feeding. As the aims of our work tend to specify basic requirements for nutritional quality of cereal grain and find and define the most important and appropriate criteria in order to classify present cereal genotypes, we studied also the interrelationships between „in vitro“ indicators and chemical and physical characters.

Our results showed that the measure of closeness and direction of interrelationships among chemical composition, grain hardness and „in vitro“ indicators of nutritional quality of grain was different by particular cereal species for N-substances, fat, organic matter, ash, and macronutrients.

Grain hardness did not show any important negative effect on „in vitro“ indicators in all cereal groups and a similar low effect was recorded in gluten in the set of wheats. The incerased fibre content showed unambiously negative correlation in all examined species. By contrast, significant and positive effects were found for starch content and total content of nonfibre carbohyddrate (except of group of spring barley cultivars). The results of our study will be further verified in „in vivo“ balance feeding tests.

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Der Inhalt

Getreidekorn für Futterzwecke ist die Hauptverwendung der Getreideproduktion und auch der Hauptrohstoff für die Kornmischungen in der Tschechischen Republik (CZ). Das Sortiment der zugelassenen Sorten in CZ ist sehr breit, trotzdem die Angaben der Futterqualität werden nicht zur Verfügung gestellt oder nicht im System der Kornqualitätsbestimmung im Rahmen der Wertprüfung im Zentralinstitut für die Kontrolle und Prüfung in der Landwirtschaft eingeschaltet.

Getreidekorn der Sorten der wichtigsten Getreidearten (Winterweizen, Sommergerste, Wintergerste und Wintertriticale), die in CZ bis 2003 für die empfehlende Sortenliste A 2002-2004 registriert worden sind, wurden für die Untersuchung der folgenden Parametern gewählt: physikalische Charakterisierung (Kornhärte in PSI, %), chemische Zusammensetzung (N-Substanzen, Stärke, Fett, Faserstoff, Stickstofffreie Extraktstoffe, Organischesubstanz, Asche, Mineralien - P, K, Ca, Mg, Betaglukanen bei Gerste - alles in $g.kg^{-1}$, nasse Gluten in % und Glutenindex bei Weizen), Verdaulichkeit durch „in vitro“, Methoden - der Bestimmung auf Daisy II Incubator (Ankom Firma) als Herabsetzung der Korntrockensubstanz nach dem Anbau mit der Amylase (nach 1 und 6 Uhr im %) und auf dem Vitrogest Apparat, vom Forschungsinstitut für Rinderzucht Rapotin - wie der Umfang der Gasproduktion während Musteranbau im definierten Umfang des Anbaumediums (nach 4, 8, 20 und 24 Stunden - in $ml.g^{-1}$).

Die Untersuchung hat die Unterschiede entdeckt, die durch Umwelteffekte, Getreideart und Getreidesorten verursacht wurden. Meist beeinflusst Nährstoffe waren Stärke (alle Getreidearten unterscheiden sich statistisch nachweisbar), Faserstoff (alle Gerstensorten hatten mehr Faserstoff als Weizen oder Triticale, aber die Wintergerste unterscheidet sich von Sommergerste durch höheren Faserstoffgehalt), N-Substanzen (Weizen erreicht einen höheren Gehalt als andere Getreidearten) und Kornhärte (Triticale hat das weichste Korn). Diese Eigenschaft gehört gemeinsam mit dem Faserstoff zum Parametern mit der höchsten Variabilität, wir haben also etwa erhöhte Variabilität unter den einzelnen Sorten und Arten im Mineralgehalt, besonders im Calcium und im Kalium festgestellt.

Ernährungskornqualität, geprüft durch „in vitro“ Methoden, hat entdeckt, dass der Verlauf der Nährstoffzerlegung bei der Anwendung der Amylase und Futtergärung im Anbaumediums mit Pansensaft war nicht identisch bei untersuchten Getreidearten. Gegenseitige Korrelationen zwischen Methoden und Zeit der Prüfung waren unterschiedlich bei einzelnen Getreidearten.

Während die festgestellten Resultate bei Daisy II zeigen, besonders nach eine Stunde, fast keine Korrelation mit Vitrogest Resultaten bei Sommergerste und Winterweizen; bei Wintergerste und Triticale wurden nachweisbare positive Beziehungen festgestellt. LSD post hoc Tests stellten dar, dass die Variabilität der „in vitro“ Indikatoren bei einzelnen Getreidearten durch Anzahl der Genotypen, Größe der Variabilität einzelnen Sorten beeinflusst wurde. Wir haben festgestellt, dass die Differenzen unter den Gruppen beziehungsweise den morphologischen Parametern (2-zeilige und 6-zeilige Wintergersten) oder qualitative Kriterien (Backqualität Klassen E, A, B und C bei Winterweizen) nicht nur für physikalische Charakterisierung und chemische Zusammensetzung, sondern auch mittels „in vitro“ Tests festgestellt gefunden könnten.

Sowohl „in vitro“ Testen zeigen, dass Gerstearten „langsamer“ (im Fall der Vitrogest - die langsamste war die Sommergerste Sorte Annabell) und die höchste Geschwindigkeit der Zerlegung wurde bei Winterweizen (im Vitrogest) und Triticale (im Daisy II) festgestellt, wenn statistisch nachweisbare Unterschiede bei Weizensorten evaluiert wurden. Weil die unterschiedliche Kategorie der landwirtschaftlichen Tieren unterschiedliche Geschwindigkeit der Zerlegung der organischen Stoffen (Monogastrische versus Wiederkäuer) fordern, es ist möglich durch „positive“ und „negative“ Resultate günstige Getreidearten und Getreide Sorten für Futterzwecken zu selektieren. Weil das Hauptziel unserer Untersuchung die Bestimmung der grundsätzlichen Ernährungsanforderungen bei der Getreidekornqualität und der Fund und die Definition der wichtigsten Kriterien für die Einstufung der Getreidegenotypen war, haben wir auch Interbeziehung zwischen „in vitro“ Indikatoren einerseits und chemischen und physikalischen Merkmalen untersucht.

Unsere Resultate dargestellt, dass der Maßstab der Dichte und die Richtung der Interbeziehungen zwischen chemischen Zusammensetzung, Kornhärte und „in vitro“ Indikatoren der Ernährungsqualität des Kornes differieren sich bei verschiedenen Getreidearten und Getreidesorten. Besonders es handelt sich um N-Substanzen, Fett, organische Substanz, die Asche und die Mikroelemente. Die Kornhärte hat keine wichtige negative Effekte auf „in vitro“ Indikatoren bei alle Getreidearten nachgewiesen und ähnlich niedrige Effekte wurden im Gluten beim Ensemble der Weizensorten festgestellt. Erhöhtes Gehalt der Faserstoff hat eindeutig die negative Korrelation bei allen geprüften Getreidearten nachgewiesen. Im Gegenteil, nachweisbare und positive Effekte wurden bei Stärkegehalt und gesamten Gehalt Stickstofffreie Extraktstoffe (mit der Ausnahme der Gruppe der Sommerbraugerstesorten). Die Resultate unserer Untersuchung werden weiter im „in vivo“ Balance Futtertest nachgeprüft.

Introduction

Cereal grain is the most important raw material for production of feed mixtures in the Czech Republic. In the marketing year 2003/2004, the mean consumption of grain for feed production was 3,452.500 t, which accounted for more than 60 % of the total cereal grain consumption. In 2004, for production of feed mixtures 2,053.213 t of grain were used, which was about 65.5 % of feed raw materials. This amount included 47.7 % of wheat, 31.1 % of barley, 2.8 % of oats, 3 % of rye and triticale, 15 % of maize, and 0.4 % of the other cereals. The development of feed production and consumption has tended to decline over the last years due to the decrease in livestock headage, nevertheless, grain for feeding is a main way of production use in the country (ZEMEDELSTVÍ 2004).

The assortment of basic cereal cultivars registered for growing in the Czech Republic is now very vast. Furthermore, after accession of the country to the EU, the European Catalogue of Cultivars has been valid since 2004. However, rapid replacement and short life of registered cultivars, which is typical for most European countries (ŠPUNAROVÁ et al. 2005), meet regional requirements of the processing industry only, and particularly of milling and baking, and brewing and malting industries. Data on grain quality for feeding farm animals is neither provided in cultivar descriptions nor included in the system of grain quality evaluation.

Greater interest in detailed knowledge of grain nutritional quality of the most widely grown species but as well as individual cultivars of feed cereals is based on increasing activities of both specialists from the fields of research, breeding and testing of cereal cultivars and from grain purchasing enterprises, and farmers.

The chief aims are to specify basic requirements for nutritional quality of cereal grain, find and define the most important and appropriate criteria in order to classify present cereal genotypes, and develop new cultivars for specific categories of farm animals.

Materials and Methods

The cereal cultivars tested in the Czech official trials (A List of Recommended Cultivars) conducted at the locations of the Central Institute for Supervising and Testing in Agriculture in 2002-2004 were selected for the study of grain physical characteristics, chemical composition, and digestibility using „in vitro“ methods. The study was carried out within the project financed by the Ministry of Agriculture of the Czech Republic which was aimed at „Research on grain nutritional quality of different cereal species and types for intensive feeding technologies of high-productive ruminants“. The examined cultivars are listed in *Table 1* in a descending order according to the applied multiplication area for the year 2004. A set of cereals included 25 cultivars of winter wheat, 13 cultivars of spring and winter barley, and 8 cultivars of winter triticale. In other part of the study, the cultivars are presented as individual sources of variability only in order to keep the results, particularly those associated with „in vitro“ testing, anonymous. The set of winter wheat cultivars was divided according to breadmaking quality into the classes: E = elite wheat, A = quality wheat, B = bread wheat, C = unacceptable for leavened dough. The set of winter barley was divided into the groups according to spike morphology, 6-rowed and 2-rowed.

To study nutritional quality, grain samples were taken each year from the locations exhibiting minimum variability in yield and quality parameters during the last 10 years. The locations were: winter wheat - Jaromerice, spring barley - Verovany, winter barley and triticale - Hradec nad Svitavou. The grain samples were taken from the trials conducted at an increased level of inputs (except of winter triticale), according to standard agronomic measures for the cereals, at the experimental stations of the Central Institute for Supervising and Testing in Agriculture (HORÁKOVÁ et al. 2005).

Chemical analyses

Seed samples used for chemical analyses were ground to pass through a 0.5-mm screen on a laboratory mill. Moisture content was measured following the air-oven method, all results were expressed on a dry weight basis. Nutrients were determined (Weenden method) according to the Czech State Standard 46 7092 „Methods for Feed Testing“ using a device Kjeltec-Auto Distillation 2200 for nitrogen determination and FIBERTEC-1020 for fibre determination at the Research Institute for Cattle Breeding Rapotín. Indicators of organic matter content and nonfibre carbohydrate (NFC) used in the methodology for feed assessment for ruminants were calculated. At the Institute in Kromeríz, starch content was assessed using a polarimet-

Table 1: **A list of selected cereal cultivars ordered according to the multiplication area in 2004**

Winter wheat	Symbols	Spring barley	Symbols	Winter barley	Symbols	Winter triticale	Symbols
Sulamit	WW4	Jersey	SB8	Luran	WB2	Modus	WT4
Ebi	WW11	Prestige	SB10	Nelly	WB4	Kitaro	WT7
Ilias	WW21	Malz	SB13	Merlot	WB6	Lamberto	WT8
Batis	WW18	Tolar	SB3	Carola	WB3	Kolor	WT2
Ludwig	WW5	Heris	SB5	Lomerit	WB7	Marko	WT6
Alana	WW12	Kompakt	SB2	Reni	WB13	Presto	WT1
Rheia	WW7	Orthega	SB7	Alissa	WB5	Disco	WR3
Mladka	WW8	Diplom	SB12	Vilna	WB11	Sekundo	WT5
Bill	WW19	Scarlett	SB4	Duet	WB10		
Clever	WW20	Amulet	SB1	Luxor	WB1		
Nela	WW3	Annabell	SB9	Jolante	WB9		
Rapsodia	WW25	Nordus	SB6	Tiffany	WB8		
Meritto	WW9	Philadelphia	SB11	Camera	WB12		
Globus	WW22						
Clarus	WW24						
Drifter	WW17						
Karolinum	WW10						
Šárka	WW2						
Corsaire	WW13						
Alibaba	WW23						
Complet	WW16						
Vlasta	WW14						
Samanta	WW1						
Svitava	WW6						
Rialto	WW15						

ric method according to Ewers, modified by DAVÍDEK et al. (1981). Nitrogen was measured on an instrument from the Leco firm (Dumas method), contents of macroelements by spectrophotometric method (P), AAS method (Ca, Mg), AES method (K - the samples were prepared by mineralisation according to Kjeldahl) and total ash was measured after sample combustion. Beta-glucan content (BG in samples of spring and winter barley) was determined according to McCLEARY (1985, Megazyme firm). Fat was assessed by a standard method (extraction) in the firm O.K. SERVIS BioPro, Ltd. The content of N-substances was assessed by conversion from N content using a factor 6.25 because of evaluation of grain for feeding purposes. All results were adjusted to g.kg^{-1}, i.e. to the values used by feed producers. For wheat grain, besides those parameters, wet gluten was measured (in %, according to the ICC method, standard 15 using our own gluten washer at the Agricultural Research Institute Kromeríz, Ltd.) and gluten-index was assessed (GI) on a device Glutomatic 2200. Grain hardness (in %, method AACC 55-30, using Particle size index for wheat hardness = PSI) was determined cooperatively with the Czech Agricultural University in Prague (Dr. O. FAMERA).

Testing the grain digestibility using „in vitro“ methods

The „in vitro“ methods that use a close relation between digestibility and other indirect indicators were employed. At the Institute in Rapotín, the samples of cereal grain were cultivated in an instrument Vitrogest (POZDÍŠEK 1996) that enables to cultivate samples at the defined volume of a cultivating medium which is composed of one portion of rumen juice and two portions of reagent solution („artificial saliva“, according to McDOUGALL 1948). A criterion of digestibility of feed fermentation simulation in the rumen was the volume of produced gases (in ml.g^{-1}) at experimentally verified times of 4, 8, 20, and 24 hours (Vitro-4h, Vitro-8h, Vitro-20h, and Vitro-24h).

Degradation of nutrients (particularly of starch) was determined in an instrument Daisy II incubator manufactured by the Ankom firm, where a rate of degradation is considered as a decrease in grain dry matter following the cultivation of cereal samples in amylase solution at two determined times (Daisy-1h and Daisy-6h).

Evaluation of results

The results were analysed by standard statistical methods using software Statistica 7.0. Variability was measured by coefficient of variation (CV, %). The graphs for publication are constructed using MS-Excel.

Results and Discussion

Grain chemical composition

Weather conditions of the cropping years 2002-2004 differed and thus affected both the development of the examined cereals and grain quality. Long-term rainfalls were recorded in 2002 that resulted in disastrous floods; strong frosts in the winter and extreme drought in the summer were in 2003. The year 2004 was the most favourable for the development of cereal stands and was considered as the year of high yields and good quality of most grown cereals. The results of analysis of variance (no table is presented) confirmed a significant effect of the year as a source of variability for all examined parameters and indicators, whereas the year 2004 considerably differed from the other two years.

The importance of detailed knowledge of proportion, composition and ratios of nutrients and other grain components is stressed by both foreign and home specialists in the field of animal nutrition (CAMPBELL 1996a and CAMPBELL 1996b, JEROCH and DÄNICKE 1995, ZEMAN and DOLEZAL 2002, and others). *Table 2* shows mean values and statistically significant differences among the examined cereals.

The experimental data documents that, despite of considerable year fluctuations, there were differences not only among different species (wheat-barley), but as well as within similar species (spring-winter barley).

All four groups of cereals statistically differed from each other above all in starch content that together with organic matter and nitrogen-free extract belonged to the indicators with the least variability. The starch content ranged from the average of 576.7 g.kg^{-1} for a cultivar of 6-rowed winter barley up to 693 g.kg^{-1} for the triticale cultivar Presto. In general, all triticale and wheat cultivars statistically significantly differed by higher starch content from all examined barley cultivars, either winter or spring and also some winter wheat cultivars.

The energetic value of grain can be markedly reduced by a higher proportion of indigestible compounds including detrimental substances exhibiting antinutri-

Table 2: **Mean values of grain chemical composition and hardness (2002-2004)**

	N-substances*		Fat		Fibre		Starch		NFC***		Organic matter	
Species	Mean	S_x	Mean	S_x	Mean	S_x	Mean	S_x	Mean	S_x	Mean	S_x
Spring barley	111.43a**	1.5	22.06d	0.4	53.45b	1.5	618.92b	2.0	786.23b	2.3	973.95a	0.3
Winter barley	116.66a	2.0	20.70c	0.3	60.24c	2.1	591.00a	2.7	775.42a	3.1	974.16a	0.4
Winter wheat	150.87b	1.8	17.92b	0.2	27.82a	0.4	657.27c	2.1	782.2ab	2.1	982.48c	0.2
Winter triticale	111.60a	2.5	15.91a	0.5	29.40a	2.1	679.46d	4.1	822.11c	4.0	980.44b	0.1

	Ash		P		K		Ca		Mg		Hardness	
Species	Mean	S_x	Mean	S_x	Mean	S_x	Mean	S_x	Mean	S_x	Mean	S_x
Spring barley	24.36c	0.2	3.69b	0.06	4.28b	0.05	0.68b	0.03	1.15a	0.01	18.35a	0.5
Winter barley	24.24c	0.3	3.92c	0.04	4.08b	0.08	0.80c	0.02	1.14a	0.02	16.22a	0.3
Winter wheat	16.60a	0.2	3.51a	0.03	3.41a	0.06	0.57a	0.02	1.11a	0.02	16.97a	0.6
Winter triticale	18.79b	0.1	3.90c	0.03	4.10b	0.09	0.6ab	0.01	1.17a	0.02	21.48b	0.5

* - all values in g.kg^{-1}, hardness in PSI units, %; ** - different letters in the column indicate statistically significant difference at P0.05; *** - nonfibre carbohydrate

tional effects (fibre, non-starch polysaccharides, polyphenols, phytates, enzyme activity inhibitors, etc.). The fibre content in grain of the examined cereals was unambiguously influenced by hulls.

While there were no significant differences between wheat and triticale, the known fact was confirmed in barley again - the fibre content was on average 6.8 g.kg^{-1} higher in winter barley vs. spring barley. Likewise, different spike morphology resulted in the difference in fibre content between 2-rowed and 6-rowed barley being 11.9 g.kg^{-1}. In wheat, the effect of classification into individual quality classes was apparent. Statistically significant differences in both starch (by 13.3 g.kg^{-1}) and fibre content (by 4.2 g.kg^{-1}) were found between classes E and C. Though winter barley had the highest fibre content, it did not exhibit the highest variation in this character. That was found in triticale (CV = 35.4 %) when selected cultivars contained up to 54.7 g.kg^{-1} fibre in 2002, whereas only the mean content of 16.6 g.kg^{-1} was measured for one cultivar in 2004. However, such a high variability influenced a level of significance among cultivars, so they did not statistically differ among each other even at the difference in fibre content of 11.9 g.kg^{-1}.

Grain as an energy source is stressed for all categories of farm animals, however, approaches to evaluation according to different animal categories are different. For ruminants, the ratio of roughages and concentrated feeds is related to effectiveness of energy use (VALDOVÁ 2002) and it is reported that concentrated feeds generally increase dry matter intake up to 60 % of total feed ration. For monogastric animals, requirements for proportions of individual saccharide groups differ in dependence on a category. While in poultry, an increased content of all fibre forms is a significant indicator of the decrease in growth performance and feed efficiency (BOROS et al. 2002, LAZARO et al. 2003, RAGAEE et al. 2001, and others), pigs, due to a higher proportion of cellulolytic enzymes, could be able to adapt to higher content of fibre (VAREN and YEN 1997).

Protein in cereal grain contributes to a total energetic value of grain, however, it plays its own role as a source of digestible N-substances and some important essential amino acids. The assessed differences in some parameters among individual species within the tested groups of cereals were very pronounced.

Especially in the content of N-substances, for instance, wheat statistically highly significantly differed from all other examined cereal species. Of course it is possible that these values were affected by different agronomic practices, however we took into account standard crop management practices that were applied to certain cereal species in the state trials. In contrast to fibre content, the cereal sets were rather balanced in the content of N-substances, which was also expressed in a level of coefficient of variation that accounted for about 10 % within tested cultivars and cropping years (*Table 3*).

Similarly to differences in fibre content, significant differences were found in the content of N-substances among subgroups within species and namely in winter barley and winter wheat. The 6-rowed winter barley cultivars exceeded the 2-rowed ones in the mean fibre content by 9.2 g.kg^{-1} and the winter wheat C cultivars (unacceptable for leavened dough) differed statistically significantly from elite wheat (E, by 11.6 g.kg^{-1}), and also from quality wheat (A, by 6.0 g.kg^{-1}).

In „in vivo“ experiments with laboratory rats and pigs, we found (VACULOVÁ et al. 1994, VACULOVÁ and HEGER 1998) that the cultivars of winter wheat, triticale and some materials of hulless oats differed not only in a level of true protein digestibility, but particularly in values of indicators of net protein utilisation and protein biological value, which confirms some cultivar distinctions in protein composition. To assess a biological value of N-substances was not part of our project, however research data published abroad over the last decades and as well as our own results confirm that different amino acid composition associated with the increased protein and fat content in grain unambi-

Table 3: **Variability in nutrient content and hardness in grain samples**

	N-substances*			Fat			Fibre			Starch		
Species	CV %**	min.	max.	CV %	min.	max.	CV %	min.	max.	CV %	min.	max.
Spring barley	8.7	97.4	131.0	11.5	17.9	29.5	17.6	36.8	75.7	2.0	596.0	652.0
Winter barley	10.8	93.9	141.0	8.8	16.8	26.7	22.0	30.2	82.8	2.9	563.0	632.0
Winter wheat	10.1	126.3	185.3	10.9	14.2	22.8	13.4	20.8	37.9	2.7	621.0	701.0
Winter triticale	10.9	89.9	126.7	14.8	11.9	19.8	35.4	16.6	54.7	3.0	644.0	719.0

	NFC*			Organic matter			Ash			P		
Species	CV %	min.	max.	CV %	min.	max.	CV %	min.	max.	CV %	min.	max.
Spring barley	1.8	756.6	812.0	0.2	970.8	978.1	5.5	21.3	27.1	9.7	3.1	4.4
Winter barley	2.5	743.4	824.6	0.2	967.3	978.6	6.6	21.1	29.1	6.5	3.3	4.3
Winter wheat	2.3	736.9	810.7	0.2	978.9	985.9	8.3	13.8	19.7	7.6	2.8	4.2
Winter triticale	2.4	787.8	855.9	0.1	979.0	981.5	2.9	17.6	19.9	4.3	3.5	4.3

	K			Ca			Mg			Hardness		
Species	CV %	min.	max.	CV %	min.	max.	CV %	min.	max.	CV %	min.	max.
Spring barley	6.9	3.7	4.9	25.7	0.1	1.1	6.1	1.0	1.3	16.0	13.6	25.5
Winter barley	11.6	3.2	5.0	16.5	0.6	1.2	9.0	0.9	1.3	12.3	12.3	20.3
Winter wheat	14.8	2.6	6.0	23.4	0.3	1.0	12.9	0.9	1.8	32.7	9.8	34.2
Winter triticale	10.8	3.2	4.8	9.6	0.5	0.7	9.1	1.0	1.4	11.8	17.4	26.4

* see *Table 2* ** CV=coefficient of variation in %

guously increases biological value of protein and net protein utilisation for monogastric animals (VACULOVÁ et al. 1994).

The increased content of N-substances and fibre obviously expressed also in grain hardness. The largest variability in this character was found in wheat with the values of PSI from 9.8 to 34.2 % and these differences were also confirmed in individual years. Grain hardness of wheat has been studied in the world for quite a long time on both biochemical and genetic level, so some practical results are available that can be applied in breeding programmes. On average of all years and tested cultivars, the lowest values of PSI were assessed for winter barley (PSI = 16.2 %) though it did not significantly differ from wheat (PSI = 16.97 %) or spring barley (PSI = 18.35 %). The hardest grain was found in some cultivars of winter wheat that are included in the quality class B. Statistically significantly softer grain than the whole group was assessed in triticale cultivars only.

Regardless that cereals are considered as a feed with the lowest content of minerals, except of phosphorus (WEISS et al. 1992), we found rather high variability among individual cultivars and species, and particularly in calcium and potassium. The highest phosphorus content was assessed in winter barley and triticale (3.9 $g.kg^{-1}$) that differed from spring barley and winter wheat. The latter had the lowest mean content of macroelements in grain and moreover, the lowest mean ash content as compared to spring and winter barley, and triticale. Since the content of macroelements in grain is related to not only soil fertility and fertilisation level, but it changes due to different soil and climatic conditions, it could be explained by the location where both species were grown.

Grain nutritional quality was tested using „in vitro" methods.

To define precisely nutritional quality of feed is not easy because the same feeds can have different effects on different categories of farm animals and animals of various age and production categories (BLACK 2001). Therefore, knowledge of digestibility (MÍKA 1997) and energy and protein utilisation in a living organism is often more important than information on a total content of these substances based on chemical analyses.

Our results from evaluation of grain samples using „in vitro" methods in 2002-2004 are illustrated in *Figure1*. It is apparent that the course of nutrient degradation using amylase and feed fermentation in the rumen was not identical in the examined cereals. Reciprocal correlations between methods and times of testation were different at particular cereal species. As the results founded at Daisy II show, especially after 1 h, there was hardly any correlation with the Vitrogest results for spring barley and winter wheat; in the winter barley and triticale the highly significant positive relationship was found (data not included). The LSD post hoc test results showed, that the variability in the „in vitro" indicators of the particular cereal species was influenced by the range of the represented genotypes and the size of the variability in the individual cultivars. The decrease in the mean grain dry matter after cultivation with amylase was first (Daisy-1h) the lowest in wheat, however, at the end two barley species showed to be „slower". In triticale, on the contrary, both the start (decrease in sample dry matter on a level of 41.2 %) and further course of degradation were fast, and at the end, the highest proportion of degraded dry matter was obtained (on average 67.3 %).

If the whole set of cereals was compared, most triticale cultivars differed from barleys (except of spring barley cultivars Prestige and winter barley cultivar Tiffany after 6h) at the beginning as well as at the end of testing; some significant differences were also found for winter wheat, the cultivars Rapsodia, Clarus and partly Alibaba. These differed from most spring and winter barleys, but as well as from some wheats, for instance, the cultivar Corsaire.

If the cereal samples were tested by Vitrogest, no significant differences at the starting time (4h) were found; the only exception was the spring barley cultivar Annabell that significantly differed by slower degradation and winter barley cultivar Jolante that significantly differed by faster degradation from the most spring and winter barleys even at the time of 8h. At further times (8h, 20h, and 24h incubation), the highest mean volume of produced gases was measured in wheat (142.8, 197.2 and 205.2 $ml.g^{-1}$, respec-

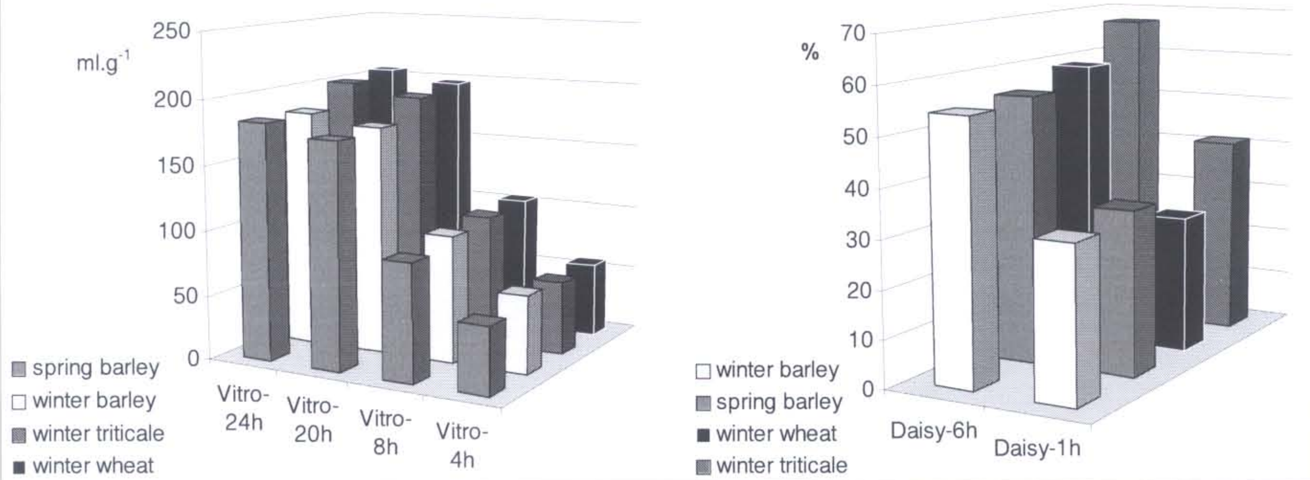

Figure 1: **Mean values of grain degradation indicators tested by „in vitro" methods in an instrument Vitrogest (according to the volume of gases, $ml.g^{-1}$) and Daisy II Incubator (%), 2002-2004**

tively) followed by triticale showing insignificant small difference. Similarly to testing in an instrument Daisy II, individual differences among cultivars and groups according to quality classification in wheat or spike morphology in winter barley were assessed. The two barley species did not significantly differ in the mean volume of produced gases; the differences were present rather in starting times of testing in contrast to wheat. Though triticale reached higher values than both barley species when tested by Vitrogest, the variability among individual cultivars was low and mostly insignificant. Data on the variability in „in vitro" indicators of nutritional quality are summarised in *Table 4*. In contrast to the results of chemical analyses, a level of variability in these indicators was higher, particularly at early times of testing. At the end of testing, the differences among materials were smoothed down and the proportion of degraded part of the sample decreased. The results of this part of our study correspond with data achieved by LEONARD (1997) or GIBB and McALLISTER (2003) who found faster grain degradation in wheat vs. barley.

As the aims of our work tend to specify basic requirements for nutritional quality of cereal grain and find and define the most important and appropriate criteria in order to classify present cereal genotypes, we studied also the interrelationships between „in vitro" indicators and chemical and physical characters. Measure of closeness and direction of interrelationships among chemical composition, grain hardness and indicators of „in vitro" nutritional quality of grain was assessed by correlation coefficients within the groups of individual cereal species (the table is part of the poster, it is not included in the text). The values and significance of correlations among evaluated data were different depending on a concrete cereal species. It was possible to state that the set of winter barleys exhibited the highest number of close, statistically significant relations and, on the contrary, most of assessed relations among the examined characters and indicators were weak and statistically insignificant for spring barley. In triticale, a close and negative relation was found between the content of N-substances and both „in vitro" values, and partial negative correlation coefficients were also measured for wheat and winter barley.

The incerased fibre content showed unambiguously negative correlation in all examined species. By contrast, significant and positive effects were found for starch content and total content of non-fibre carbohydrate (except of the group of spring barley cultivars), similarly to the converted indicator of organic matter amount.

Grain hardness did not show any important negative effect on „in vitro" indicators in all cereal groups and a similar low effect was recorded in gluten in the set of wheats.

Conclusions

The results of the study on chemical composition and „in vitro" digestibility of grain of cultivars of the most widely grown cereal species confirmed differences on the level of both species and cultivars, however for some characters and indicators only. Most of significant differences were found in winter wheat for fibre content and grain hardness, in spring barley for starch and beta-glucan contents, in winter barley for grain hardness, and in triticale for grain hardness and ash content.

In general, the largest variability was found in the set of wheat cultivars that also differed according to classification into different breadmaking quality classes and almost in all examined parameters and indicators. Significant differences were confirmed again in the set of winter barley between 2-rowed and 6-rowed cultivars according to spike morphology. These differences were apparent in both differences in chemical composition, particularly in the content of fibre, N-substances, ash, starch and some minerals (P and Ca), and results of grain testing by „in vitro" methods.

As reported by PARÍZEK and JURECKA (2001), breeding new cultivars of field crops is of increasing importance and is one of a few possibilities how to enhance grain quality, production intensity or to keep it and simultaneously limit loads of undesirable agents in the environment and food chain. This fact is also accepted by international organisations (IBFN, FAO, and other organisations and initiatives in the scientific community) because they admit that species and varietal differences in nutrient composition can be significant and that cultivar-specific food composition and consumption data will form the evidence base by which other activities related to nutrition and biodiversity can most effectively be undertaken (FAO 2005).

Table 4: **Variability in nutritional quality of cereal grain tested by „in vitro" methods**

Species	Daisy-1h*			Daisy-6h			Vitro-4h		
	CV %**	min.	max.	CV %	min.	max.	CV %	min.	max.
Spring barley	14.8	26.5	46.0	9.4	48.3	68.4	31.4	18.5	80.3
Winter barley	20.0	22.3	44.9	10.8	44.7	66.6	29.4	31.5	92.0
Winter wheat	18.5	19.4	42.3	11.2	45.4	77.6	24.6	23.5	89.0
Winter triticale	21.6	28.6	55.2	9.6	57.3	79.2	32.1	36.1	95.6

Species	Vitro-8h			Vitro-20h			Vitro-24h		
	CV %	min.	max.	CV %	min.	max.	CV %	min.	max.
Spring barley	19.7	50.4	122.0	16.0	107.6	229.7	15.6	113.6	235.8
Winter barley	16.8	67.7	131.4	14.6	127.9	223.0	15.2	131.7	235.2
Winter wheat	15.5	66.7	142.8	11.7	150.6	261.4	11.3	158.0	273.4
Winter triticale	15.1	84.1	138.2	9.9	162.5	235.7	10.0	170.6	251.8

* - indicators - in % (Daisy) or $ml.g^{-1}$ (Vitro) - see Materials and Methods, ** - see *Table 3*

The same conclusions are also applicable to utilisation of crops, and in particular cereals, considering differences in nutritional quality, for nutrition of farm animals. Since various categories of farm animals require a different speed of the organic matter degradability (monogastric versus ruminants), it is possible to both „positive" and „negative" results to select suitable species and individual cultivars for feeding. In order to make a full use of the determined „advantages" of suitable cereal species or cultivars, it is essential to have an indirect indicator or indicators, which would be easily determined, that are in close relation with values measured in „in vivo" experiments. Therefore, we will use the current results in another part of the project for selection of different materials for „in vivo" testing in balance feeding tests with heifers.

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