PREDICTION OF SUITABILITY OF DIFFERENT RAPID METHODS BASED PARAMETERS FOR TECHNOLOGICAL QUALITY EFFECTIVE WHEAT SEGREGATION

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Abstract: *Warehousing technology is permanently facing the problem of predicting of rheological properties of blends of wheat segregated in each silo bin on the basis of parameters determinable by rapid methods before the lots of wheat to be stored are segregated. The most frequently used criteria for segregation, reported also to be the most effective one, is the protein content which can be determined only if the expensive NIRS instruments are available. The aim of the research presented in this paper was to investigate and determine the correlations of the parameters determinable by different rapid methods obtained by segregation of wheat on the basis of different segregation criteria (test weight, protein content, gluten content, falling number, irremovable admixtures categories content) with the most widely used parameters of dough rheological properties (farinograph, extenzograph and amylograph). Additionally, the correlations obtained for wheat blends segregated on the protein content basis as the most frequently used and the most widely excepted segregation criteria were compared with those obtained by wheat segregation on the basis of other criteria, obtainable without expensive and, in most cases unavailable, NIRS instruments needed for rapid determination of protein content. Protein content is proved to be the most effective criteria, while the application of other criteria examined proved to be resulting only in partial effects.*

Key words: *wheat, segregation, rapid methods, dough rheology, correlation*

INTRODUCTION

Wheat quality can be defined as a set of properties that assure the possibility to obtain certain final product of desired quality. For different types of final products (bread, buns and rolls, puff pastry, biscuits etc.) different sets of quality parameters are required.

The values included in the set of parameters that define the end-use: property of wheat i.e. flour are usually the ones that define the rheological behavior of wheat dough based on widely applied farinograph, mixograph, mixolab, extensograph, alveograph and amylograph methods simulating mixing, molding and gelatinization processes of dough in the technological process of wheat based products production Rich evidence can be found concerning the relations of mentioned wheat quality parameters and the end-use properties of wheat.

The results obtained by Keiffer et. al, (1998) indicated that the rheological properties of

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dough and gluten as well as the gluten index are correlated with the bread quality properties obtained both with optimised micro-baking test and with the standard baking test. On the other side, Hubner (1999) emphasized that soft wheats used primarily to produce cookies, cakes, and biscuits, have quality requirements very different from those of bread wheats, stating that in general, soft wheats have been bred to have low protein content, and conventional wisdom has been that protein composition of soft wheat is relatively unimportant. Hubner (1999) states further that amounts of most individual fractions of soft wheat protein correlated poorly with quality descriptors revealing clearly that suitability of soft wheat cultivars for specific products can be rapidly determined by quantitative and qualitative analyses of protein composition

According to Anderssen et.al. (2004) the extension testing of wheat-flour dough has become one of the key cereal chemistry links to end product quality assessment, because of its perceived relevance to baking performance, and because of the various correlations that have been inferred and assumed since the extensibility of a dough started to be investigated. Kurtenjak et.al (2008) conducted the factor analysis and multivariate chemometric modelling for rapid assessment of baking quality of wheat cultivars in which quality properties were evaluated by 45 different chemical, physical and biochemical variables and the multivariate linear regression models based on minimal number of three principal factors were derived for simple and fast prediction of wheat properties defining total glutenins, total w-gliadins and the ratio of dough resistance/extensibility as the three main factors.

On the other side, rheological properties of wheat dough that are highly correlated to wheat dough processing properties and widely accepted as the determinants of end use quality of wheat and the predictors of the quality of final products are determined using number of applied rheology methods which require specific expensive equipment and which are all time consuming. For that reason the possibility to predetermine rheological properties of dough on the basis of the results obtained with rapid methods has for long time been inexhaustible topic of research, among which only some of the most recent ones are mentioned bellow.

Pasha et.al, (2007) investigated the correlation of wet and dry gluten content with other wheat quality parameters and found out positive correlations of these parameters with Zeleny value, sodium dodecyl sulfate sedimentation value and falling number. Bordes et.al (2008) computed the correlation coefficients to analyse the relationships between traits for grain characteristics and flour and dough properties finding that protein content correlated significantly with the most mixograph parameters indicating dough mixing properties and with some alveograoh parameter indicating dough extension properties. Advanced statistical techniques in correlating wheat quality parameters were used by Ramzi-rad et.al, (2007) showing the ability of artificial neural network (ANN) technology for predicting the correlation between farinographic properties of wheat flour dough and its chemical composition taking as the input parameters of the neural networks (NN) the four most important chemical parameters influencing farinographic properties, namely protein content, wet gluten, sedimentation value and falling number while the output parameters of the NN models were six farinographic properties including water absorption, dough development time, dough stability time, degree of dough softening after 10 and 20 min and valorimeteric value. Reigner et.al (2009) showed in his investigations that protein was a significant indicator of quality for six out of 10 flour/dough functionality traits: falling number, peak mixing time, absorption, extensibility and flour strength while single kernel hardness and the standard deviation of kernel diameter (i.e. the variation in kernel diameter across a 300-kernel sample) were indicators in at least five out of 10 flour and dough functionality traits: Single kernel hardness was a significant indicator of falling number, extraction rate, flour strength, peak mixing time, absorption, stability and dough tenacity. Variation in kernel diameter was shown to be a good indicator of dough stability, tenacity, extensibility and the tenacity/extensibility ratio.

In spite of rich evidence of effects of wheat segregation on the basis of protein content both in practice of most wheat producing countries and in the academic literature in the world (Baker et.al, 1999; Petersen and Fraser, 2000; Barbottin et.al, 2008) and in the country (Torbica et.al, 2004; Bodroža et.al, 2004) in the warehousing practice in Serbia, with exception of rare cases, wheat is still not segregated and all received lots of wheat are stored only on the basis of the chronological string of acceptance into the warehouse silo bins (Filipčev and Mastilović, 2004).

Most of the research published in the area of investigation of correlations of different wheat quality parameters has been performed on the basis of analysis of samples of wheat varieties or samples of wheat grown under certain conditions. The practical question with which the warehousing technology is faced is the problem of predicting of rheological properties of blends of wheat segregated in each silo beam on the basis of parameters determinable by rapid methods before the lots of wheat to be stored are segregated.

In order to answer this question the aim of the research presented in this paper was to investigate and determine the correlations of the parameters determinable by rapid methods (test weight, protein content, gluten content, falling number, irremovable admixtures categories content) with the most widely used parameters of dough rheological properties (farinograph, extenzograph and amylograph) for bland of wheat obtained by segregation of wheat on the basis of different segregation criteria. Additionally, the correlations obtained for wheat blends segregated on the basis protein content as the most frequently used and the most widely excepted segregation criteria were compared with those of blends obtained by segregation of wheat on the basis of other criteria based on parameters obtainable without expensive and in most cases unavailable NIRS instruments needed for rapid determination of protein content.

MATERIALS AND METHODS

At collecting points in three wheat silos in Serbia samples of all received wheat lots during one harvest were collected and analysed by the most frequently available rapid methods including: moisture content, test weight (GAC 2000, DickeyJOHN, USA), protein content (Infratec 1241, Foss Analytical, Denmark), falling number (ICC standard No. 107/1) and admixtures content (shrunken and broken kernels, organic and inorganic foreign material, weed seeds, other cereal grains, moisture content, kernels with moisture content germ, sprouted kernels and damaged kernels – ICC standard No. 102/1). Admixture content was determined on the basis of visual assessment of presence of different admixtures by the trained technicians while the shrun-ken and broken kernels were determined as the material passing through 2mm screen metal sieve. All together about 3500 samples were collected and analysed.

Using obtained data basis and formed sample collection, simulation of wheat segregation on the basis of different segregation criteria was performed. The 200g portions of 20 chronologically subsequent samples with parameters in defined segregation criteria ranges, as determined by used rapid methods, were aggregated. In this way 150 samples of wheat segregated on the basis of different segregation criteria were obtained. For each range and each set of segregation criteria multiple samples were prepared using different samples of wheat lots with the same segregation criteria applied. All obtained samples of wheat blends obtained under different segregation criteria were analysed concerning both, rapid methods based parameters and rheological properties of dough.

In all obtained samples the range of technological quality parameters was determined including: Brabender extensograph (ICC standard No.114/1) parameters including dough energy, extensibility and resistance, Brabender farinograph (ICC standard No. 115/1) parameters including water absorption, sum of dough development and dough stability time, degree of dough softening, and farinograph quality number, falling number

(ICC standard No. 107/1) and Brabender amylograph (ICC standard No. 126/1) maximal viscosity.

In order to predetermine effects of application of different segregation criteria the main set of samples of wheat blends was divided in two subsets: the first in which were included only the samples which were segregated on the basis of protein content as the most frequently and the most widely accepted parameter (SS1 - 70 samples) and the second in which were included samples obtained on the basis of all other applied segregation criteria obtainable without expensive equipment necessary for protein content determination (SS2 - 80 samples).

Each sample obtained in the described way can represents actually the wheat stored in one silo bin and the conclusions drown out on the basis of obtained sample sets can scaled up to the level of wheat stored by application of different segregation criteria.

Sample formation and analysis scheme is presented in table1.

Table 1.
Applied procedure for formation of the samples

Collecting of wheat subsamples at colleting points at two different locations
Location A – 2500 samples, Location B -800 samples, Location C – 200 samples

Analysis of collected wheat subsamples
(moisture, test weight, protein content, falling number, admixtures quantity and structure)

Segregation of wheat samples into wheat blends based on different segregation criteria

Segregation on the basis of protein content (solely and combined with other criteria like falling number, variety)	Segregation on the basis of other criteria except protein (falling number, irremovable admixtures content levels, variety, location)
Sample subset 1 (SS1)	**Sample subset 2 (SS2)**

Analysis of wheat blends samples
- Rapid tests (test weight, protein content, falling number, irremovable admixtures categories content)

Laboratory milling of wheat samples (MC1 mill, Chopin, France)

Analysis of flour samples
- Rheological properties (farinograph, extensograph, amilograph)

Statistical data processing (, descriptive statistics, correlation – Statistica 8.0)

The subsets of samples were characterized based on the range and mean values of determined quality parameters as well as the statistical determinants of variation of determined parameters among wheat blend samples in each subsample set including the range of values (minimum and maximum), standard deviation and coefficient of variation.

The correlation coefficient between parameters determined on the basis of rapid methods and rheological properties were calculated using statistical software package Statistica 8.0 separately for each of analysed subsets of wheat blend samples (SS1 and SS2).

RESULTS AND DISCUSSION

Correlation between rapid test parameters and rheological properties of wheat

The first aspect of possibility for prediction of end use purpose technological quality of wheat was examined on the basis of correlation of parameters determinable by rapid methods applied as the criteria for wheat segregation (test weight, content of different categories of irremovable admixtures, protein content and falling number) and rheological properties of wheat used as the base for defining of convenience of wheat for different end purposes.

Correlation coefficients between parameters determined by rapid methods and determined farinograph properties of wheat dough for two subsets of samples (SS1 and SS2) are presented in table 2, and for extensograph and amylograph properties in table 3.

Table 2.
Correlation coefficients between protein parameters determined by rapid methods and determined farinograph properties of wheat dough for two subsets of samples

	Water absorption (%)	Dough softening degree (BU)	Quality number	Peak time (min)	Departure time (min)	Sum of peak and departure time (min)
Test weight (kg/hl)						
• SS1[(a)]	0,21	0,17	-0,13	0,03	-0,08	-0,04
• SS2[(b)]	0,58*	-0,04	0,21	0,21	0,10	0,17
Protein content (% dmb)						
• SS1[(a)]	0,48*	-0,75*	0,83*	0,57*	0,60*	0,70*
• SS2[(b)]	0,28*	-0,22*	0,37*	0,32*	0,41*	0,44*
Falling number (s)						
• SS1[(a)]	0,01	-0,20	0,10	0,03	0,09	0,07
• SS2[(b)]	0,11	-0,51*	0,48*	0,26*	0,27*	0,31*
Fusarium infested kernels (%)						
• SS1[(a)]	0,04	-0,24*	0,18	0,10	0,23	0,20
• SS2[(b)]	-0,11	0,09	-0,08	0,02	0,05	0,04
Black germ kernels (%)						
• SS1[(a)]	-0,18	0,08	-0,02	-0,05	-0,12	-0,10
• SS2[(b)]	-0,13	0,11	-0,05	0,04	-0,02	0,01
Sprouted kernels (%)						
• SS1[(a)]	-0,01	-0,06	0,05	-0,10	0,20	0,07
• SS2[(b)]	0,09	0,09	-0,03	0,04	-0,04	-0,01

[(a)] samples segregated on the basis of criteria including protein content
[(b)] samples segregated on the basis of criteria not including protein content
* correlation coefficients significant at p=0,05

Regardless whether protein content or other criteria were used as the base for wheat segregation no significant correlations were determined with any of parameters of rheological quality of wheat in the case of content of kernels with discoloured germ and in the case of content of sprouted kernels in wheat samples indicating that application of these parameters as the base for wheat segregation cannot be expected to lead to obtaining of wheat lots differentiated by end use quality. This conclusion has to be taken in account with the awareness of the fact that all the samples originate from the same production year in which discoloured germ and sprouting were not major problems, and that the results in production years in which these problems were more expressed might be different.

Concerning the irremovable admixtures categories content it is interesting to notice that fusarium infested kernels content was proven to have low but significant correlation coefficient with several wheat rheological quality parameters including farinograph degree of softening and extensograph resistance and extensibility as well as the ratio of these parameters, but only in the case of sample subset in which protein content was applied as a segregation criteria.

Low but significant correlation coefficients were calculated also between test weight and extensograph resistance and resistance/extensibility ratio in the case of subset of samples segregated on the basis of protein content. Test weight correlated significantly also with water absorption in the case of subset of samples segregated on the basis of criteria other than protein.

Table 3.
Correlation coefficients between protein parameters determined by rapid methods and determined extensograph and amylograph properties of wheat dough for two subsets of samples

	Energy (cm^2)	Resistance (BU)	Extensibiity (mm)	Ratio R/E	Peak viscosity (BU)
Test weight (kg/hl)					
• SS1[(a)]	0,01	0,35*	-0,22	0,31*	-0,01
• SS2[(b)]	0,03	0,14	-0,06	0,10	0,00
Protein content (% dmb)					
• SS1[(a)]	0,67*	-0,65*	0,83*	-0,81*	0,13
• SS2[(b)]	0,33*	-0,50*	0,59*	-0,54*	-0,01
Falling number (s)					
• SS1[(a)]	0,19	0,19	0,02	0,10	0,50*
• SS2[(b)]	0,27*	0,15	-0,02	0,12	0,73*
Fusarium infested kernels (%)					
• SS1[(a)]	0,11	-0,28*	0,27*	-0,28*	0,11
• SS2[(b)]	-0,09	-0,18	0,03	-0,11	-0,11
Black germ kernels (%)					
• SS1[(a)]	-0,10	0,12	-0,15	0,16	-0,07
• SS2[(b)]	-0,04	0,09	-0,09	0,11	-0,02
Sprouted kernels (%)					
• SS1[(a)]	0,05	-0,08	0,07	-0,11	-0,08
• SS2[(b)]	-0,09	0,07	-0,16	0,01	0,05

[(a)] samples segregated on the basis of criteria including protein content
[(b)] samples segregated on the basis of criteria not including protein content
* correlation coefficients significant at p=0,05

The correlations between falling number and rheological wheat quality parameters appeared to be significant only for the subset of samples which were segregated on the basis of parameters other than protein including falling number as the base for segregation. Falling number correlated significantly with amylograph peak viscosity, proving once again its applicability as a rapid method for determination of amylase activity in wheat during its acceptance into warehouses. It is interesting to emphasize that falling number values expressed significant correlation also with all of the farinograph parameters except water absorption indicating relations between mixing properties of dough and the properties of starch component of wheat flour.

Finally, protein content was by the research presented in this paper confirmed to be the parameter determinable by rapid methods which has the most significant relation with wheat dough rheological properties. Protein content correlated significantly with all rheological properties of wheat except amylograph peak viscosity. However, correlation coefficients were higher for the subset of samples in which protein content was used as the base for segregation. The highest correlation coefficients were determined for extensograph extensibility and the ratio of dough resistance and extensibility, as well as for farinograph quality number, but high values of correlation coefficients were determined also for extensograph energy and resistance and farinograph water absorption, dough development time and stability.

Effects of application of different segregation criteria

Based on values and differences of correlation coefficients obtained it can be concluded that the application of different segregation criteria in practice will result in existence of lots of wheat stored in silo bins characterized with different levels of quality parameters of stored wheat expressing different levels of different end use quality convenience of wheat. Without any criteria applied for wheat segregation, representing current situation in the country, wheat will be segregated and stored based only on chronological string of reception of wheat into the silo bins. The lots of wheat blends will in this case be all of about the same average quality, and the homogeneity of stored wheat will be poor.

Application of different segregation criteria will result in obtaining of lots of wheat stored in silo bins for which the value of technological quality parameters will depend on their correlation with applied segregation criteria parameters. In this way obtained lots of stored wheat will more or less differ among each other concerning certain technological quality parameters and will thus represent the commodity suitable for different end use purposes.

Table 4.
Mean values and range of determined values for investigated subsets of samples of wheat blends

	average		minimum		maximum	
	SS1[(a)]	SS2[(b)]	SS1[(a)]	SS2[(b)]	SS1[(a)]	SS2[(b)]
Test weight (kg/hl)	79,50	79,50	77,20	74,20	81,80	82,70
Protein content (% dmb)	12,6	12,7	10,5	11,7	14,4	14,1
Falling number (s)	283	290	151	141	396	403
Fusarium infested kernels (%)	0,31	0,28	0,00	0,00	0,80	0,80
Black blight infested kernels (%)	1,04	0,98	0,00	0,00	2,70	2,70
Sprouted kernels (%)	0,09	0,12	0,00	0,00	0,50	0,80
FARINOGRAPH						
Water absortion (%)	51,1	51,1	48,3	48,4	53,3	55,1
Peak time (min)	2,00	1,75	1,00	1,00	8,00	6,00
Departure time (min)	1,50	1,50	0,50	0,50	7,50	5,50
Sum of peak and departure (min)	3,50	3,25	1,50	2,00	11,50	9,50
Dough softening degree (BU)	50	50	15	20	100	80
Quality number	66,4	66,8	43,5	54,4	96,9	81,3
EXTENSOGRAPH						
Energy (cm^2)	98,1	101,9	42,1	84,4	141,9	127,6
Resistance (BU)	555	560	350	410	750	740
Extensibility (mm)	119	121	80	98	163	144
Ratio R/E	4,90	4,72	2,27	2,84	8,18	7,55
AMYLOGRAPH						
Peak viscosity (BU)	350	366	60	60	900	1000

(a) samples segregated on the basis of criteria including protein content
(b) samples segregated on the basis of criteria not including protein content

In order to predict the ranges of technological quality that can be expected to be obtained on the basis of segregation of wheat either on the basis of protein content or on the basis of other criteria included in the examination presented in this paper the descriptive statistics data were calculated for both formed sub sets of wheat blend samples.

The descriptive statistics data for the for the subsets of samples including mean values and range of obtained values on one hand, and standard deviation and coefficient of variation as the measures of dispersion of obtained values on the other hand, is presented in table 4 and 5 respectively.

It is obvious, even without statistical analysis, that regardless of criteria used as the base for wheat segregation, the mean values of obtained wheat blends will be almost the same, depending predominantly on the characteristics of the production year. On the other hand the range inside which varies the quality of wheat differs for the most of relevant wheat end use quality parameters depending whether protein content or other criteria were used for segregation. The range of protein content in wheat samples in subset obtained by applying protein content as the segregation criteria (SS1) varies from 10,5% dmb representing wheat convenient for biscuits and cookies production to 14,4% representing premium quality wheat at international markets.

Table 5.
Standard deviation and coefficient of variation for investigated subsets of samples of wheat blends

	Standard deviation		Coefficient of variation, %	
	SS1[(a)]	SS2[(b)]	SS1[(a)]	SS2[(b)]
Test weight (kg/hl)	1,05	1,40	1,32	1,76
Protein content (% dmb)	1,22	0,39	9,69	3,05
Falling number (s)	63,64	51,19	22,85	17,64
Fusarium infested kernels (%)	0,19	0,19	62,66	71,18
Black blight infested kernels (%)	0,47	0,44	45,43	45,71
Sprouted kernels (%)	0,15	0,17	158,06	140,74
FARINOGRAPH				
Water absortion (%)	1,06	1,12	2,08	2,18
Peak time (min)	1,57	0,70	73,03	40,04
Departure time (min)	1,69	0,91	99,29	70,32
Sum of peak and departure (min)	2,72	1,36	70,45	44,80
Dough softening degree (BU)	21,27	12,41	41,53	26,43
Quality number	11,92	6,61	17,94	9,90
EXTENSOGRAPH				
Energy (cm^2)	19,80	10,01	20,18	9,82
Resistance (BU)	87,60	68,93	15,71	12,31
Extensibility (mm)	20,00	10,51	16,78	8,71
Ratio R/E	1,42	0,93	29,09	19,86
AMYLOGRAPH				
Peak viscosity (BU)	184,98	219,07	53,18	59,83

[(a)] samples segregated on the basis of criteria including protein content
[(b)] samples segregated on the basis of criteria not including protein content

However, the range in which varies protein content of wheat samples from the subset obtained by application of segregation criteria other than protein (SS2) is somewhat narrower ranging from 11,7% dmb to 14,1% dmb, excluding the possibility of obtaining the lots of wheat convenient for biscuits and cookies production. The confirmation of more convenient dispersion of quality of wheat lots obtained by segregation on the basis of protein content can be outdrawn also from the values of standard deviation and coefficient of variation, presented in table 3, which are in the case of protein content more than three times higher for SS1 compared to those of SS2.

Much wider ranges of quality parameters characterizing wheat samples obtained in SS1 (segregation on the basis of protein content) in comparison to SS2 (segregation on the basis of criteria other than protein content) are expressed in the cases of farinograph quality number, extensograph energy and extensibility.

In the case of subsample set obtained when protein content was applied as the segregation criterion (SS1) farinograph quality umber ranges from 43,5 repersenting wheat from C1 farinograph quality group to even 96,6 representing top class A1 farinograph quality group wheat. For sample subset 2 this range is narrower: from 54,4 to 81,3 still expressing the effectiveness of conducted segregation based on criteria other than protein content but in much narrower limits. Ranging of extensograph energy from 42,1 to 147,9 cm^2 and extensograph extensibility from 80 to 163 mm confirms the wide variability of end use purposes covered by wheat lots segregated on the basis of protein content. The range both emphasized extensograph parameters in the case of segregation based on criteria other than protein excludes extremely low and extremely high values for both paramaters, limiting end use purposes for which segregated wheat lots might be declared to be convenient.

Less expressed but still noticeable differrences in ranges of different levels of quality of obtained wheat samples in dependence of applied segregation criteria (protein or other) is obtained for other farinograph parameters (water absorption, peak time, departure time and their sum and softening degree) with more expressed differentiation in the range of maximum values of quality parameters expressing better technological quality.

Little or no differences in obtained ranges of quality in dependence of applied segregation criteria were registered for test weight, admixtures content, falling number and amylograph peak viscosity values.

All notices differences and similarities in ranges of obtained quality of segregated wheat lots in dependence of segregation criteria applied are confirmed by the differences and similarities of values of standard deviation and coefficient of variation as presented in table 5.

CONCLUSIONS

The research presented in this paper indicates that different wheat quality parameters determinable by rapid methods can with different efficacy be used as the base for segregation of wheat during its acceptance into warehouses in order to obtain lots of segregated wheat of different end use quality defined on the basis of wheat dough rheological properties.

The most effective segregation can be achieved when protein content is used as the base for segregation, and the utilization of falling number values can lead to better differentiation of end use quality of wheat lots concerning the parameters depending on amylase complex activity and starch properties.

The effects of segregation which is based on parameters determinable without expensive equipment like test weight and irremovable admixtures content will lead to little or no effects in differentiation of segregated wheat lots concerning its end use technological quality expressed on the basis of its rheological properties.

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