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PHD THESIS

STUDY OF THE RELATIONSHIP AMONG BAKING QUALITY ATTRIBUTES IN FLOURS OF WINTER WHEAT

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“The main aim
of human science is
the human himself.”
(F. Kölcsey)

“The science
and well-considered
works of breeders, researchers,
agronomists, millers and bakers keeping
the final results in view and their joy
experienced in work gives us our
everyday bread, serving
by this the human.

(Z.-né Fekete, Sütőipar, 1991. 4. p. 08.)

1. The aim of the research

Our basic food the bread and bakery products are made from ~60% of wheat flour and ~36% of water, so their quality is mainly determined by the quality of flours used their production. The ideal flour is the one from which can produce breads of big volume, desired form, elastic crumb, of pleasant taste and odour, bright and popped crust of the desired colour. The baking suitability of wheat flour is determined by its technological qualities i.e its capacity of water adsorption, the physical dough properties and the state of flour enzymes.

The baking value of flours can be judged most surely by baking test. The results of test are depends on the method as well, due to practical requirements, is different according to the country, the place and the product. In practice the methods of measuring the gluten, the dough and enzyme states are more welcome as they are much more uniform, precise and less material, device and time consuming.

The main aim of my research work was to establish whether it was possible to predict baking results with the flour and dough examination methods applied in industrial practice and if so, whether predictability was permanent or if it was not (as supposed) what influence of methodological, crop year and milling technological factors have to be considered and what is the relationship among the pieces of information of certain methods.

2. Literary aspects

The demands of baking industry are met with hard wheat. In hard wheat no or just small quantities of puroindoline-proteins are produced (BÉKÉS, 2001).

From the point of view of producing a gas retaining viscoelastic dough structure the quality and quantity of proteins capable of establishing coherent gluten-network are important (KOSUTÁNY, 1907). In one respect, the rheological behaviour of the dough is determined by genetically coded protein. Today it is possible to provoke the production of the required protein through genetic intervention (MACRITCHIE, 1992). In order to obtain good quality of varieties appropriate soil and climate are needed. The third requirement of obtaining good quality is the optimal nutrient-supply and suitable cultivation. Each factor of production - green crop, tillage operations, seed quality, sowing time, stem number, plant-protection, harvest - affects quality (POLLHAMERNÉ, 1973). For the sake of appropriate processing different quality wheat types have be stored separately and in a way that ensures preserving their health (MONDA et al., 1991). The preservation and exploitation of good end-using properties of wheat can be ensured by appropriate milling technology. The chemical composition of flours depends on the chemical composition of wheat to be milled and changes according to the types and extraction of flours (ATWELL, 2001).

The baking value of flours is determined by the gas production and gas retention of the dough. To evaluate the gas production capacity of the flour it is necessary to examine the amylolitical state. The water-binding capacity

of the flour depends on physical properties of the dough. The physical properties influence the processing condition, proving ability, shape-keeping and the shape and crumb structure of the finished product (AUERMAN, 1984).

To judge the baking value of flour it seems to be more informative to test the dough instead of gluten (LASZTITY, 1979). The dough kneading instruments like farinograph or valorigraph make it possible to determine the water-binding-capacity of the dough and to register the process of dough development and further changes occurring in the dough during kneading (development time, stability, elasticity, degree of softening, etc.) (HANKÓCZY, 1938). The instruments stretching the relaxed or fermented dough record force/time diagram, the characteristics of which (resistance, extensibility, curve configuration ratio, work input) describe the strength of flour and dough. The Chopin alveograph is particular because it deforms the sheet-piece of dough not only to one but all direction while inflates it to a bubble, so imitates the expansion of gas cells formed in the rising dough. With the Chopin rheofermentometer it is possible to test the gas-production and gas-retention and the dough volume-development at the same time.

The importance of baking test in the prediction of baking-value of flours is accepted by most researchers. In SZALAI's (1990) opinion it is the baking test process that may reveal the defects of the flours not discovered earlier or the negative effects of minor problems that may show remarkable influences on the end product. The quality control of the bread-probe involves measuring the volume, the shape-ratio, the crust, the crumb structure and the taste and odour. In standardized baking test all parameters are the same, so the differences among flours come out well. The optimised

tests are accommodated to the different water-binding and kneading demands of flours, which is nearer to practical consideration (POLLHAMERNÉ, 1981).

The combined character of wheat and flours, the great variety of possible methods require the investigation of the importance of certain quality attributes in the formation of baking quality and the search for the relationships and harmony among the results obtained with the given methods. The quality system can become efficient and economical only if the relationships among the quality attributes are well-known and understood.

The aim is to find and apply the simplest, fastest and most informative possible methods.

3. Materials and methods

The investigations were carried out in the years 2001 - 2003. The varieties of two crop-years (2001 and 2002) were analysed in the same way.

3.1. Wheat samples

I have been worked with flour samples of 24 bread-wheat varieties grown by the same cultivation in breeding gardens of Cereal Research Nonprofit Company in Szeged. The varieties assured the background of quality fluctuation. The varieties were the following (Table 1.):

Table 1. The varieties in experiments

Bánkúti 1201	GK Favorit	Jubilejnaja50	GK Miska	GK Sas
GK Cipó	GK Forrás	GK Kalász	GK Mura	GK Szálka
GK Csörnöc	GK Garaboly	GK Malmos	GK Öthalom	GK Szivárvány
GK Dávid	GK Góbé	GK Marcal	GK Pinka	GK Zugoly
GK Élet	GK Jászság	GK Mérő	GK Répce	

Wheat samples were ground on laboratory mill type Élgép LM and on Brabender Quadromat Senior mill in the case of 16 varieties in the year 2002 to test the influences of milling procedure (sample-group É16 and Q16).

3.2. Instruments, methods and characteristics

The characteristics summarized in Table 2 were determined. To examine the influences of methodological system baking tests were carried out not only by Hungarian Standard (HS) but also by baking small amounts of dough (68g) mixed optimally by Valorigraph (Modified test). The bounds of flour tests were enlarged i.e. beside the Hungarian standard methods other well-known international methods were applied. The wet and dry gluten content and gluten quality (gluten index) were determined by Glutomatic-Glutork system. The dough samples were tested by Chopin Alveograph and Rheofermentometer and by Kieffer Dough Extensibility Rig with the TAXT-2i (Stable Micro Systems) Analyser.

All determinations were made at least in duplicates or sometimes in replicates.

Table 2. Characteristics and methods

Characteristic and unit	Code	Method
Flour yield, %	Kiő	KARÁCSONYI, 1970
Flour moisture, % (m/m)	Nedv	HS 6369/4-1987
Flour ash content, % of dry basis	Hamu	HS 6369/3-1987
Falling number, sec	Eszám	HS 6369/9-1977
Wet gluten, % (m/m)*,	Nsikér	HS 6369/5-1987
Gluten spreading, mm/hour	Ter	
Glutomatic wet gluten, % (m/m)*,	Glns	ICC Standard 155
Gluten index	GI	
Dry gluten, % of dry basis	Szs	
Water adsorption,%	Vfk	HS 6369/6-1988
Valorigraph quality number	Értsz	
Development time, minute	Tki	
Development time ISO, minute,	TkiI	HS-ISO 5530-3:
Stability, minute	Stab	HS6369/6-1988
Curve width, VE	Nyújt	
Degree of softening, VE	Ellá	
Degree of softening ISO,VE,	ElláI	HS-ISO 5530-3:
Farinograph quality number	FQN	AACC-1983. 54.21
Maximum dough height, mm	Hm	Chopin
Time to reach the max. height, minute	T1	Rheofermentometer F2
Dough height at 3. hour, mm	h	Instrument
Loss in dough height at 3. hour , %	Tv%	Manual
Maximum of gas formation curve, mm	Hmg	
Time of max. gas formation, minute	T1g	
Total gas volume, ml	Ögáz	
Lost gas volume, ml	Egáz	
Gas retained in dough, %	Vt%	
Resistance to deformation, mm	P	AACC-1983. 54.30
Dogh extensibility, mm	L	
Curve configuration ratio	P/L	
Deformation energy, 10^{-4}J	W	
Resistance, g	Nyell	SMS TAXT-2i
Extensibility, mm	Nyú	Instrument
Work input, g·mm	Munka	Manual
Extension quality index	Nyért	
HS loaf volume, ml/100g liszt,	Tf	HS 6369/8-1988
HS loaf form ratio	AH	
Crumb softness, EE	D	HS 20501/3-1982
Crumb relative elasticity	R/D	
Elastigraph quality index, EE	EÉ	

Small loaf volume, ml /100g liszt	Kistf	Modified
Small loaf form ratio	KisAH	own method

3.3. Statistical methods

The describing statistics (mean, deviation, coefficient of variation (CV%), etc.) and the distribution were calculated, and the loose values were checked and procedures suitable to compare several databases were applied such as One- and Two-way Analysis of Variance, Correlation Analysis based on linear regression, Simple- and Multiple Stepwise Regression, Principal Components Analysis and Canonical Correlation (SVÁB, 1979., 1981). The significance level was chosen at $p<0,05$ probability. The statistical program packages of Microsoft Excel 7.0 and Statgraphics 6.0 were used.

4. Results and discussion

4.1. The average common quality of test groups

The flours of wheat varieties without dependence on the crop years, milling procedure and baking method represented weak-medium end-use value in their usual Hungarian quality attributes. Low wet gluten content (26,3-28,8%), very small gluten spreading (0,8-1,2mm), slightly weak amylolitical function (331-369sec), good-medium water adsorption (59,6-64,6%), medium valorigraph quality index (57,7-65,7), small loaf volume (332-386ml/100g flour) and wide spread loaf form (AH: 2,2-2,3) were typical. The baking achievement could be considered as definitely weak, so many of varieties have to be improved.

4.2. The variation of characteristics in test-group

In the variation of the characteristics of the test-groups (2001., 2002., É16, Q16) the first factor of determination was the range of value of each characteristics represented by the varieties. The change in crop year and milling procedure get the CV% in small or large degree to thin or wide. The CV% of the alveograph traits were well equalized independently of the test-groups (P- 28,8-32,6%, L- 22,2-24,3%, P/L- 44,9-47,4%, W- 27,8-31,6%). The water adsorption (3,9-7,0%), curve width (11,3-13,3%), gas-retention capacity (1,6-2,7), loaf form ratio (HS- 6,3-9,6%; Modified-10,3-14,5%) characteristics had a little CV% change too. The alveograph traits had standard error of the mean of <4%. Some properties in both year of measurement had errors bigger than 10% (gluten spreading, stability, dough height loss% and time of maximum gas formation in the rheofermentometer, all TAXT dough parameters and elastigraph quality index).

4.3. Simple correlation in the test groups

In the correlation matrix of examined quality parameters obtained for different test groups the complex and very varying character of relations between the characteristics could be observed. Significant ($p<0,05$) but only weak and medium linear correlation were prevailed. Very strong ($r>0,9$) and strong ($r=0,8$-$0,9$) correlation was formed only between parameters of similar content like gluten contents, and some dough traits. Even in the latter cases the standard errors of estimating linear equation were bigger than the standard error of the measurement.

The flour and dough parameters showing significant correlation with loaf characteristics are collected into Table 3.

Table 3. Effects of crop year, milling and baking method

		HS baking		Modified baking	
Effect	Correlation	Loaf	AH	Loaf	AH
2001	0,65-0,8	Nsikér,Glns, Szs,Vfk,TkiI, T1,FQN			
	0,5-0,65	Tki,W,Értsz, Tv%		Nsikér,Vfk	Eszám,Ter, GI,Stab,Ellá, ElláI,Nyújt
	<0,5		GI,Ter,Eszám, Stab,Kiő, Tv%,Ellá, ElláI,Nyújt	Nyújt	Kiőrl, Értsz
2002	0,65-0,8	Nsikér,Vfk, Nyújt,h	GI,Tv%		
	0,5-0,65	Glns,Szs,Tki, Hmg,T1,Tv%, Eszám,Ögáz	h, P, P/L, T1	Vfk,Nsikér, Nyújt,Tki, h,Hmg, Ögáz,W	Stab
	<0,5	Kiőr, P,	Stab, FQN, Hmg, Vt%	Glns,TkiI, Hm	Ellá,Értsz
É16	0,65-0,8	Vfk	Tv%	Ögáz	
	0,5-0,65	Nyújt,h,Ellá, ElláI,T1, Tv%,Hmg	GI,h, Hmg,Szs	Hmg	Értsz,Stab
Q16	0,8-0,9	h			
	0,65-0,8	Hm,T1		Hm, h	GI
	0,5-0,65	Eszám	Eszám	T1,Vfk	Eszám,Ter, Glns,P,W

It could be perceived that the kind of flour and dough properties showing correlation with the loaf characteristics and the level of the correlation varied strongly under all studied circumstances. In each tested group HS baking gave more and higher correlation with loaf volume parameters than

modified baking. In both years gluten content, water adsorption, time of dough development, time to reach maximum height and degree of loss of dough height in rheofermentometer and alveograph W indexes had importance beside loaf volume. Gluten content, water adsorption and valorigraph curve width correlated with the modified baking volume in both years too. Changing the milling procedures (Q16) and the number of varieties in test group (É16) caused decrease in the number of the correlating parameters and change in types of emphasized parameters.

The loaf form ratio correlated with gluten quality (gluten index, gluten spreading) and the different dough parameters expressing the dough resistance (stability, degree of softening, quality numbers, dough height at the end of measurement, coefficient of loosing dough height, P, P/L) and the falling number.

The equation of linear relationship determined on the base of simple correlation with the highest determination (r^2=56-59%) gave estimation for the HS loaf volume and with only 6,8-7,5% of standard error. The HS loaf form ratio could be estimated only with determination of 18-49%. Simple correlation analyse was not able to give the sure estimation for the baking performance.

4.4. Multiple regressions in the test groups

The linear equations estimating the loaf characteristics taking into account several flour and/or dough parameters at the same time changed with changing the crop-years, milling methods, number of varieties in the tested group and with the change of the baking method and baked loaf parameters. The results of estimation are placed into Table 4.

Table 4. Results of multiple regressions												
Hatás	2001			2002			É16			Q16		
	R^2 %	Error %	Vari.	R^2 %	Error %	Vari.	R^2 %	Error %	Vari..	R^2 %	Error %	Vari.
Tf	**84,8**	**4,7**	**Glns Vfk T1 TkiI**	**92,7**	**3,1**	**Ns Vfk h Hmg**	77,6	3,8	Vfk h Hmg	76	3,2	h
AH	55,6	4,5	Ellá, EllálI	76,8	4,8	GI,h Vt%	49,7	7,1	Tv%	25,4		Esz
D	28,7	5,8	Vfk	66	21	Vfk	67,6	22,3	Vfk h	75,1	12,8	Hm Ögáz
R/D	41,6	7,9	Esz	49,5	2,8	Esz T1g	64,3	2	Esz TkiI	39,9	2,2	Tv%
EÉ				61	28	Vfk	73,3	23,9	Esz Vfk	62,1	18,3	Hm
Tfkis	39,9	10,6	Vfk	69	8,2	Hm Hmg Vfk	46,5	7,6	Ögáz	61,7	5,7	h
AHkis	60,1	6,8	Kiő Nyújt	45	8,7	Stab Ellá	35,1	10,6	Stab	68,8	8,9	Esz GI

The best estimation was reached for the 2002 year test group when on the HS loaf volume the coefficient of determination was ~93% and the standard error of estimation was 3%. In the equation gluten content, water adsorption, rheofermentometer dough height at the end of the measurement and gas-curve height were chosen. In 2001 about 85% of determination and 5% of error of estimation were established and Glutomatic wet gluten, water adsorption, dough development time on ISO, time to reach the maximum dough height in rheofermentometer were chosen. For the test group with decreased number of varieties the coefficients of determination were worse. The level of the estimation for modified loaf volume with other quality traits was weaker in all cases (2001-R^2=40%; 2002-R^2=69%) and the errors of estimation were higher (10,6 and 8,2%).

The success of estimation on the base of multiple regressions for loaf volume means that it is possible to reach good estimation but only with much expenditure (time and cost), so the baking is more useful to apply.

The estimation for loaf form ratio give less exact results. The knowledge of dough parameters (stability, degree of softening, curve width) and gluten index could help in the selection the flours.

4.5. Analyses of the influences of independent variables in the 2002 year test group

After standardization of partial regression coefficients in the linear estimating equation it was possible to establish the relative weights of some independent variables. On the basis of these results the complex character of the relationships between quality attributes of flour, dough and baked

loaf and the uncertainty of the appearance of influences were numerically verified. So gluten content accounted 32% (21% own, 10,6% others-indirect and common), rheofermentometer dough end height 23% (10% own, 13% others), water adsorption 21% (7% own, 14% others) and rheofermentometer gas-curve height 18% (8% own, 10% others) of the variation in the HS loaf volume. Hmg accounted 26%, Vfk 24% and Hm 20% of the variation in the modified loaf volume and 30% of the variation was not identified.

Gluten index accounted 41%, h 22% and Vt% 14% of the variation in the HS loaf form ratio, and other unknown effect was 23%. Stability accounted 30%, Ellá 16% of the variation of Modified form ratio and 54% was the range of unknown effects.

4.6. Results of principal component analyses (PCA)

The principal component analyses verified in deepest details the complexity of quality and the uncertainty of the estimation. We have to agree with the opinion that the relation-system among quality parameters have to be analysed going to the root of the matter, so in the level of protein content and compound.

The number of principal component, the dimension and distribution of component weights depended on the type and number of varieties used to analyse and on cultivars and milling methods.

When the most common flour and dough and loaf characteristics (p=22) were drawn to analyses 5 principal components (PC) determined in 82%, when only flour– and dough characteristics were used (p=28; p=32) 7 PC

determined in 88% and with the flour-, dough and loaf characteristics altogether (p=26) again 7 PC were able to explain about 88-91% of all the variation. The loaf values appeared with the biggest weights in PC1, where water adsorption, P, P/L, W, rheofermentometer h and T1 characteristics had big weights too. The loaf volume had considerable weights in other PC, too. The variance of the loaf form ratio was distributed to a greater extent between the components. The type of variables and the distribution of their variance changed more when the milling method was changed.

The characteristics chosen into the same principal component were not entirely the same as it could be seen in multiple linear regressions. Gluten content had the biggest weights in the stepwise equation for HS loaf, but was absent from the PC1.

4.7. Multiple regressions with principal component variables

In Table 5 are collected the parameters of the equation calculated for the data of the 2002 test group.

Table 5. Results of stepwise regression analyses with original and component variables

	Original			PC p=32			PC p=28		
	n=23			n=22			n=22		
	R^2 %	Error %	Variable	R^2 %	Error %	Variable PC	R^2 %	Error %	Variable PC
Tf	**92,7**	**3,1**	**Ns,Vfk,h, Hmg**	**87,9**	**2,9**	**1,2,4,5,6,**	**80,3**	**3,3**	**1,2,4**
AH	76,8	4,8	GI,h,Vt%	59	6,3	1,3	68	5,7	1,2,3
Kis tf	69	8,2	Hm,Hmg, Vfk	42,1	8,2	1,8	66,9	6,2	4,8,1
Kis AH	45	8,7	Stab,Ellá	53,4	8,7	2,5,9	40,6	9,3	2,7

It can be stated that multiple regression with component variables to estimate loaf characteristics was not more successful than with original variables. At the same time the PCA is more complicated and time-consuming.

4.8. Results of canonical correlations

The possibility of analyses depended on the number of samples in the sample-group. In test group having only 16 elements the analyses were not possible. The important variables which were emphasized in the analyses are in Table 6.

It can be seen that there is strong methodological influence. Canonical equation with HS baking parameters had 82-87% of determination while with modified baking parameters only 55-73%. The differences could be caused by differences in baking method (HS- semi-optimised, Modified-fully optimised). Loaf volumes were emphasized with parameters like wet gluten, water adsorption and valorigraph quality index. This result could be caused by, the selection conception based on the importance of gluten content and valorigraph achievement.

Table 6. Results of canonical correlation

year	MSZ baking								Modified baking			
	R^2	p	2.group	1.group	R^2	p	2.group	1.group	R^2	p	2.group	1.group
2001	74	0,006	Tf 1,0 AH -	Glns 0,99 Kiő 0,58 GI 0,46	53	0,015	AH 0,96 Tf 0,19	Tki 1,1 Ellá Ért -	66	0,002	AH 0,77 Tf 0,57	Vfk 0,57 Esz - Ért -0,31
	82	**0,000**	**Tf 1,0** **AH**	**Vfk -** **Ert -0,51**	63	0,002	Tf 0,86 AH -	W 1,4 P -0,46 L -0,31	73	0,002	Tf 0,6 AH 0,74	Ellá Nyújt - Ért 0,41
	40	0,048	AH Tf 0,13	Esz -0,51 Ns 0,4 Ter 0,43	**87**	**0,000**	**TF 0,95** **AH -**	**Ögáz -** **Eltg** **T1**	69	0,023	Tf 0,97 AH 0,15	h 0,95 T1g T1 -0,65
	84	**0,000**	**Tf 0,99** **AH -**	**Ért 0,87** **Vfk 0,54**								
2002	**86**	**0,000**	**Tf 1,01** **AH**	**Ns 1,1** **Kiő 0,43** **Szs -0,3**	64	0,005	D -1,2 Tf 0,97 AH 0,62	Vfk - Ns Ter	64	0,09	Tf 1,0	Ns 1,7 Szs - Kiő 0,62 GI 0,48
	55	0,036	AH - Tf 0,21	GI 1,26 Gln 0,89 Szs -0,43	**87**	**0,000**	**Tf 0,65** **AH -**	**h 1,4** **T1 -** **Hm -** **Hmg -** **T1g**	55	0,014	Tf 1,0 AH 0,15	Vfk 0,89 Ns 0,66 Ter -0,4 Esz -
	85	**0,000**	**Tf 1,0** **AH**	**Ns 0,68** **Vfk 0,53**								

On the bases of this result the rheofermentometer can be proposed instead of baking test as objective instrument/method for the estimation of baking performance of wheat and flour. As it is material and time-consuming the rheofermentometer is not suitable for serial test, but in all other cases can give informative and useful results.

The research work has proved the importance and exclusivity of baking test in estimating the baking value of flours and the necessity of its methodological development.

5. New scientific results

1. I have concluded that alveographic testing is one of the best dough testing methods. The testing error is approximately 4 %. When testing with TAXT, valorigraph or rheofermentometer the testing error of certain characteristics exceeded 10%.

2. On the basis of simple correlation it can be concluded that it is the gluten content, the capacity of water adsorption, the valorigraph dough formation time and extensibility, the rheofermentometer dough height, loss in dough height, gas production and retention and the alveograph W parameter that showed persistent relationship with the volume (r=0,5-0,8).

3. The form attributes showed weaker correlation with the gluten quality (gluten index, gluten spreading), the valorigraph, rheofermentometer and alveograph dough characteristics and the falling number (r=0,4-0,7)

4. With multiple linear regression it is either impossible to estimate the baking properties or it can only be done through testing several flour and dough types so in order to give good estimation concerning the baking value of flours baking tests have to be done.

5. A new result has been achieved by the fact that I have determined the relative effect of the variables in the statistical estimation on the sample group and, by this, the concrete relations within the system.

6. I have concluded that the analysis and the regression of the principal components does not ensure better results in the estimation of baking value than the multiple linear regression.

7. The application of canonical correlation analysis in the examination of relationship among measurable properties on certain levels of quality tests is novel. In accordance with the breed selection orientation of the examined wheat variaties the canonical variables of the volume and form measured with standard baking methods gave close equations (determination of 82-87%) with the canonical variables calculated with flour and dough testing properties of which the wet gluten content, the capacity of water adsorption, the quality number and the rheofermentometer properties were significant.

8. I have come to the conclusion that the rheofermentometer is better fit for estimating the baking value than any other device used during the tests because its characteristics showed close correlation with the volume in both years. I would recommend its use as a substitute for baking tests.

9. I have concluded that equations giving close estimation of the volume can only be achieved accidentally even with multivariety statistics. The justified importance of baking tests draws the attention of the necessity of methodological development. Baking tests have to be based on objective grounds in every respect.

6. Practical utility of the results

1. On the basis of examinations, data analysis and evaluation it seems evident that in the estimation of the baking value of wheat and flours the gluten content and quality and the results of valorigraph examination and falling number have to be invariably relied on.

   In addition to the values of valorigraph water adsorption and quality number attention has to be paid on the dough formation time, with special respect of the value measured by HS-ISO.

   The curve width, the softening and gluten index determined in the Glutomatic system can be judged as useful in the estimation of loaf form.

2. Firm decision of the baking ability of flours can only be made after a direct baking test. Although it can be successful with an HS baking test, this does not exclude the necessity of method development, which would be necessary for the better accommodation to practical needs. Valorigraph kneading needs further examination. I suggest testing the bread making machines as possible devices of objective qualification in parallel experiments to see their applicability.

3. For lack of baking possibilities the reliability of estimation can be increased if flours are submitted to a fermentation test. For this the Chopin rheofermentometer can be used. Its price is much more favourable than that of the Brabender instrument. I recommend its use in the later phases of breed selection.
4. The alveograph is a good device for examination with slight measurement error. Its characteristics do not seem to be related to the loaf quality with absolute certainty. It appears to be suitable, however, for the technological comparison of flours in form of dough.
5. With the way of my sample preparation the TAXT method as technological quality estimation method cannot be suggested.

7. Publications written about this subject

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