Water Absorption Determination of Wheat Flours applying Centrifuge and its Relationship to Farinograph Water Absorption Determination

Ljiljana Unbehend[1], Günter Unbehend[2#] and Ivica Strelec[3]
[1]Staatliches Seminar für Didaktik und Lehrerbildung (Berufliche Schulen) Karlsruhe, D- 76135 Karlsruhe/ Germany
[2]Federal Research Center for Nutrition and Food, Schützenberg 12, D-32756 Detmold/Germany
[3]J. J. Strossmayer University, Faculty of Food Technology, Kuhaceva 18, HR-31000 Osijek/Croatia

Summary
The water absorption of flours from German wheat harvested in 2001 and 2002 was determined by standard method using Farinograph and centrifuge as an alternative possibility for the water absorption determination. Determination of centrifuge water absorption (CWA) was performed with 2 g (harvest 2001 and 2002) and 4 g (harvest 2002) of wheat flour applying preliminary determined "best centrifugation conditions". Obtained results of centrifuge water absorption (CWA) and farinograph water absorption (FWA) were compared by statistical analysis. The volume yield of statistically obtained extreme samples was carried out in Rapid-Mix-Test for rolls using both FWA and from CWA calculated predicted water absorption (PWA). The volume yields of rolls were compared. The variations between operators during water absorption determination using centrifuge were also investigated. High linear correlation was obtained between CWA and FWA results in all investigated groups. In extreme samples differences in volume yield influenced by differences of used water absorption were not found. Variation between operators did not show any significant differences in CWA determination.

Zusammenfassung
Die Wasseraufnahme von deutschen Weizenmehlen aus der Ernte 2001 und 2002 wurde nach der ICC-Standardmethode im Farinographen bestimmt. Alternativ zur Standardmethode wurde die Wasseraufnahme der Prüfmuster mittels Zentrifuge ermittelt. Zur Optimierung der alternativen Bestimmungsmethode wurde die Wasseraufnahme der Weizenmehle aus der Ernte 2001 und 2002 in der Zentrifuge mit 2 g Weizenmehl und bei den Weizenmehlen aus der Ernte 2002 zusätzlich mit 4 g Prüfmaterial durchgeführt. Die Untersuchungsergebnisse aus den beiden Methoden wurden mittels statistischer Analyse miteinander verglichen. Die Weizenmehle, die in der vergleichenden Untersuchung die größten Unterschiede auswiesen und die in der statistischen Analyse als Ausreißer gekennzeichnet wurden, wurden im Rapid-Mix-Backversuch für Weizenkleingebäcke verbacken. Dazu wurden einmal die im Farinographen ermittelte Wasseraufnahme und einmal die aus der Zentrifugenwasseraufnahme kalkulierte Wasseraufnahme im Backversuch verwendet. Die erzielten Volumenausbeuten der Kleingebäcke wurden miteinander verglichen. Des Weiteren wurden die Einflüsse des Bedienpersonals auf die mittels Zentrifuge ermittelte Wasseraufnahme untersucht. Zwischen den Untersuchungsergebnissen aus den beiden Prüfmethoden konnten hohe Korrelationen in der ermittelten Wasseraufnahme nachgewiesen werden. Die Gebäckvolumen der Weizenkleingebäcke aus dem Rapid-Mix-Test zeigten keine signifikanten Unterschiede. Die Einflüsse des Bedienpersonals auf die Messergebnisse sind als gering einzustufen.

Keywords: water absorption, wheat flours, farinograph, centrifuge / Wasseraufnahme, Weizenmehl, Farinograph, Zentrifuge

Introduction

The water absorption characteristic has been used to describe wheat variety quality as a part of standard protocols[1)]. In several countries since 1930, the Brabender Farinograph has been used to determine water absorption according to ICC-Standard 115/1[2)]. The amount of water added to flour with 14 % moisture, to produce a maximum consistency of 500 FU, is called farinograph water absorption[3)]. In the literature, this term is often misused for water addition to dough.

Ability of wheat flours to absorb water (water absorption) manly depends on the content of proteins, mechanically damaged starch and pentosans[3,4)]. Some studies[5,6)] have shown that the water absorption depends further on several factors such as variation in soil fertility and in the growing conditions. The water absorption can be used for quality prediction of baked products and therefore wheat breeders and processors have been using it as an important indirect quality characteristic of wheat flour[7)].

The exact determination of water absorption using Farinograph is time consuming requesting two and sometimes three analyses using at list 50 g of flour. Regarding the above mentioned, some authors[8)] have tried to find a new way to determine water absorption. *Rychener* and *Nemeth*[8)] investigated the possibility of water absorption determination preparing the dough in Farinograph by use of constant water amount and finally calculating water absorption from in Farinograph registrated dough consistency. An alternative new method for water absorption determination to farinograph water absorption has been developed by *Tripette* and *Renand*, using an adapted Alveograph. The ability of NIR to measure protein level, and/or starch damage, as well as positive relationship between these two contents and the water absorption have made it successful in modeling water absorption[9)].

G. Unbehend, E-Mail: G.Unbehend@bagkf.de

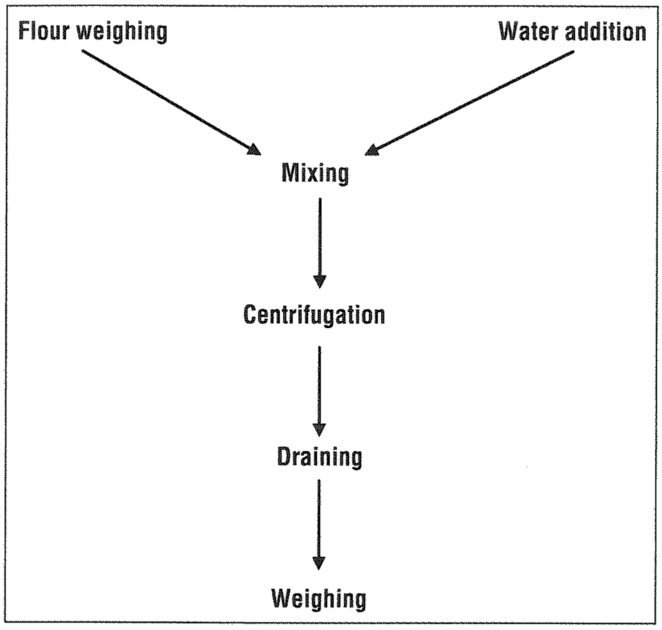

Fig 1 Schematic representation of water absorption determination using centrifuge

Table 1. Centrifugation conditions in preliminary investigations

Conditions	Centrifugal force [g]	Time [min]
Conditions I	5000	5
Conditions II	5000	10
Conditions III	5200	5
Conditions IV	5200	10

Table 2. Correlation coefficients and determination coefficients of CWA with FWA at different centrifugation conditions (n = 16)

Conditions	R	R^2
Conditions I	0.973	0.946
Conditions II	0.860	0.739
Conditions III	0.892	0.796
Conditions IV	0.772	0.596

One of the possible methods for determination of water binding capacity is centrifugation as an unmoistening method, where centrifugal force is used to separate the moisten particles of a sample from the excessive amount of water. *Anderson* et al.[10] used centrifuge to determine water-absorption index of maize starch measuring swelling power of starch. However, the wheat flour is complex system in which besides the starch the other components, such as proteins and pentosans, participate in water binding properties and influence the end result. Several other authors[11,12] have tried to relate an alkaline water retention ability of wheat flours to baking properties, also using centrifuge, for the purpose of evaluation and selection of wheats.

The aim of this paper was to develop a fast and simply method for determination of water absorption determination in wheat flours using centrifugal force to separate excessive water from dough formed during centrifugation, and compare this method with standard method[2].

Materials and methods

Materials

The determinations performed with German wheat flours T-550 (ash content 0.55 %) of different quality, 121 samples from harvest 2001 and 100 samples from harvest 2002.

Determination of farinograph water absorption

The water absorption (FWA) was determined during mixing and kneading using Brabender Farinograph (*Brabender*, Germany), according to ICC-standard method No. 115/1[2].

Determination of centrifuge water absorption

The procedure of water absorption determination using centrifuge is shown in Figure 1. Procedure was performed at room temperature with 2 or 4 g of wheat flour mixed with excess amount of water, in ratio 1:5. After the flour had been weighed in tarred centrifuge tube and distillated water had been added to the flour the suspension was gently manually mixed with thin stick and centrifuged. After centrifugation water was poured away and the dough samples were drained for 5 min at room temperature and finally weighed. The centrifuge water absorption (CWA) was calculated following the calculation of farinograph water absorption. This procedure was carried out with samples from both harvest years 2001 and 2002 using 2 g samples. For samples from harvest 2002 centrifuge water absorption was determined also using 4 g of flour and 20 ml water, applying the same procedure as described in the Figure 1.
The different centrifugation conditions were preliminary tested using 16 samples (Tab. 1). Centrifuge accelerations of 5000 g and 5200 g for the time of 5 min and 10 min centrifugation were used. Finally CWA were determined in all samples at the best centrifuge conditions.
In order to investigate deviations between operators, CWA of 16 samples was determined by two operators.

Statistical analysis

In order to verify the obtained results Statistical Analysis System (Statistica 6.0, *StatSoft Inc.*, Tulsa, USA) procedures and programs were used. The results of both methods, CWA and FWA, were related using multiple regressions. From the linear regression equation the predicted water absorption (PWA) was calculated. Deviation between the operators was investigated by ANOVA treating person as fixed factor. Multiple regression and ANOVA was conducted on the mean of two replicates.

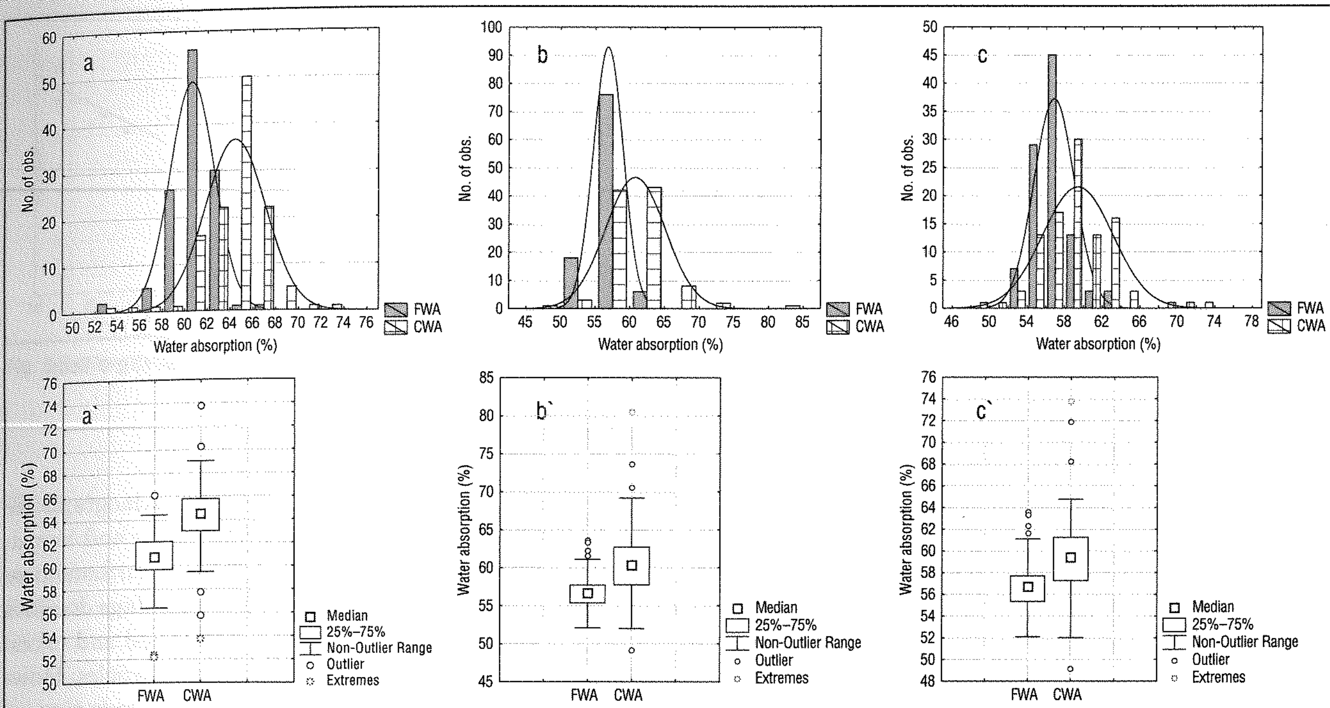

Fig. 2 Distribution of farinograph water absorption (FWA) and centrifuge water absorption (CWA) results: (a, a') harvest 2001; (b, b') harvest 2002 (2 g of flour used; (c, c') harvest 2002 (4 g of flour used)

Baking procedure

The experimental baking procedure was carried out according to Rapid Mix Test (RMT)[13]. Some of statistically proved extreme samples with negative and positive residuals were baked using both, the farinograph water absorption and the predicted water absorption (statistically calculated from obtained centrifuge water absorption using linear regression). The rolls volume yield was measured according to test procedure[13].

Results and discussion

Preliminary tests

In preliminary tests four centrifugation conditions were used (Tab. 1). The correlation between FWA and CWA (Tab. 2) was the highest using conditions I (5000 g, 5 min, room temperature). The centrifugation for 10 min at 5000 g weakened the correlation between FWA and CWA, probably due to damages of formed dough structure. When the centrifugal force of 5200 g was used, correlation coefficient was lower than using conditions I, however higher than using conditions II. The lowest correlation was found using conditions IV.

Relations between CWA and FWA

The possibility of water absorption determination using centrifuge was investigated with samples from two harvests. First investigations were done with samples from harvest 2001 using 2 g of flour obtaining high significant correlation to farinograph water absorption (discussed in further text). In 2002 investigations were cared out showing high correlation to farinograph water absorption by the use of 2 g of flour too, however somewhat lower than in 2001. Therefore in all of investigated samples centrifuge water absorption determination was repeated using samples besides 2 g, also 4 g of flour.

Figure 2 represents the distribution of obtained results. Generally seen it can be noticed that the results of farinograph water absorption (FWA) were lower that the results of centrifuge water absorption (CWA) in all of the investigated sample groups. It can be also seen that the most of samples from harvest 2001 had values of farinograph water absorption in range from 60 % to 62 %, and the samples from harvest 2002 had these values in somewhat lower range, from 56 % to 58 %. Non-Outlier ranges of FWA were from 56.5 % to 64.5 % (harvest 2001) and from 52.5 % to 60.5 % (harvest 2002). From these results it can be seen that the samples were harvest depend (different conditions during two seasons). The Min-Max widths of CWA results were higher than these of FWA results in all of the investigated groups. Extremes were found in results of CWA in every group. However, extremes were also found in results of FWA in samples from harvest 2001. There were outlier in both FWA and CWA with all of the investigated groups. Distribution of results had shown that using the chosen centrifuge conditions CWA did not directly correspond to FWA.

Relation between CWA and FWA can be seen in Figure 3. Correlation coefficient by linear regression was 0.936 and determination coefficient was 0.876 for the samples from

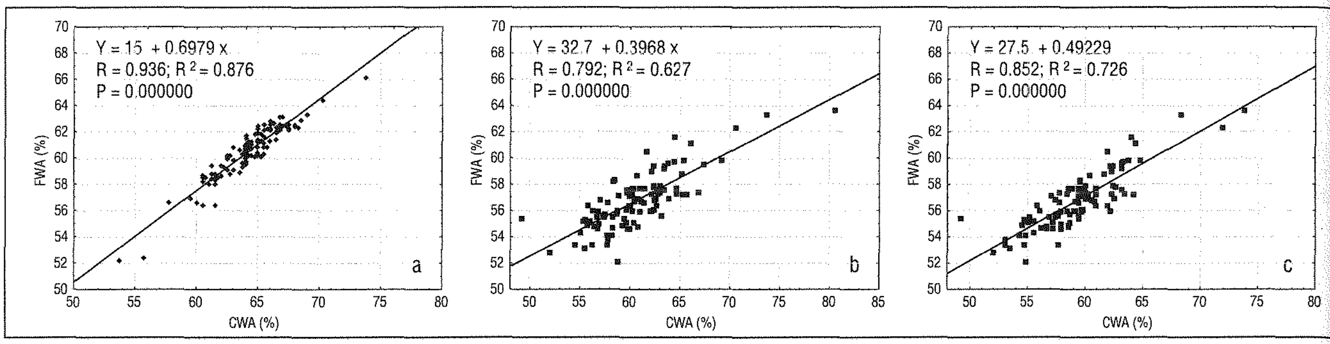

Fig. 3 Relationship between centrifuge water absorption (CWA) and farinograph water absorption (FWA): (a) harvest 2001; (b) harvest 2002 (2 g of flour used), (c) harvest 2002 (4 g of flour used)

harvest 2001. Lower correlation coefficient (R = 0.792; R^2 = 0.627) was found in relation CWA to FWA for the samples from harvest 2002 using 2 g flour for CWA determination. When 4 g flour of samples from harvest 2002 was used correlation coefficient increased to 0.852 and determination coefficient to 0.726. The regression showed that correlation between CWA and FWA in all of the investigated groups was high significant. However, the relation of CWA to FWA in samples from harvest 2002, when 2 g of flour were used, was not as high as in samples from the harvest 2001 proving that comparison of these two methods should be performed during two or more years since the results could be affected by many factors. One of them is low amount of flour for CWA determination requiring extreme working precision. The other reason for found differences can be the fact that Farinograph and centrifuge water absorption are determined under different conditions. In Farinograph the water absorption is determined during mixing and kneading. Flour particles are moistened and pressed at same time developing dough. On the other hand in centrifuge dough is formed after flour particles are fully moistened and excessive water is separated pressing the moisten particles. However, it should not been forgot that the flour properties are affected by extern factor such as climate, which can not be controlled[5]. The results in this paper showed that harvest year conditions influenced differences in water absorption ability of investigated sample groups (Fig. 2).

The FWA can be predicted applying values of CWA from linear regression (CWA to FWA). The distribution of FWA and predicted water absorption (PWA) results showed that values of FWA and PWA were very similar (Fig. 4). The medians were almost the same in all of the groups.

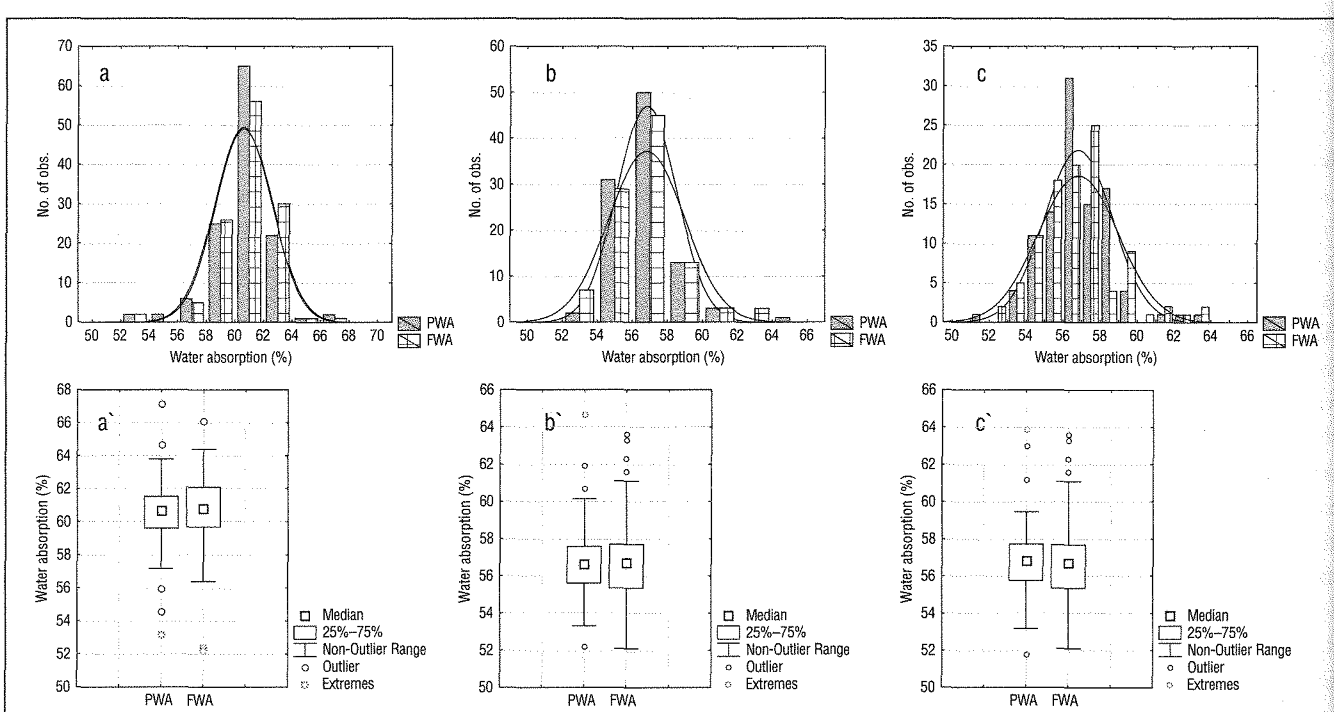

Fig. 4 Distribution of farinograph water absorption (FWA) and predicted water absorption (PWA) results: (a, a') harvest 2001; (b, b') harvest 2002 (2 g of flour used); (c, c') harvest 2002 (4 g of flour used)

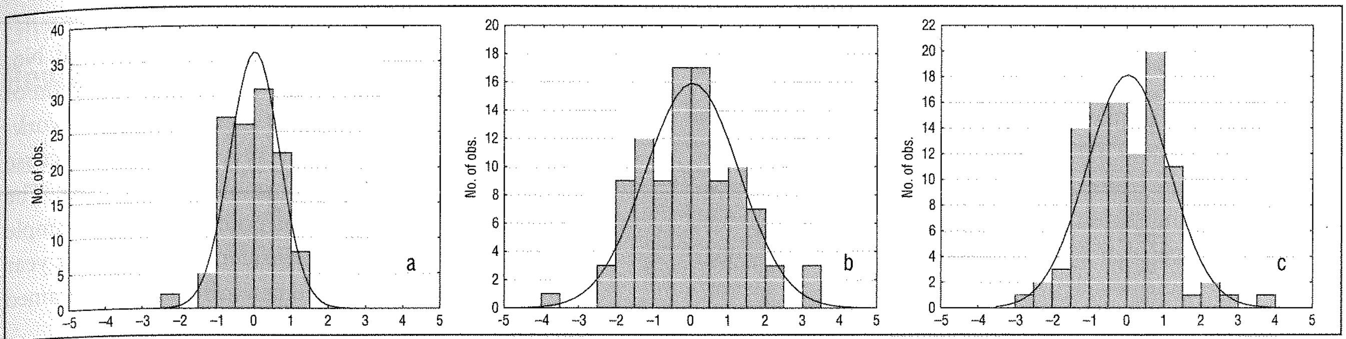

Fig. 5 Distribution of raw residuals: (a) harvest 2001; (b) harvest 2002 (2 g of flour used); (c) harvest 2002 (4 g of flour used)

When the residuals (difference between FWA and PWA) were calculated 86.4 % of all samples showed residuals in range from –1 % to 1 % in samples from harvest 2001, 52 % of samples from harvest 2002 (2 g of flour used) and 64 % of samples from harvest 2002 (4 g of flour used). Distribution of raw residuals is represented in Figure 5. It can be seen that the most of samples were in the area of expected values.

In Figure 6 influence of individual work (operator influence) can be seen. Variance analysis showed that there were not any significant differences between the results obtained by two operators.

Water absorption of extreme samples and baking test

Determination of extreme samples showed that four extremes were found in samples from harvest 2001, five extremes in samples from harvest 2002 (2 g of flour used) and four extremes in samples from harvest 2002 (4 g of flour used) were found out. These extreme residuals could have been influenced by the method procedure, because low amount of flour used in the method. However, three of these samples had the farinograph water absorption higher than 60 % and also three of them lower than 54 % showing extreme values of water absorption. These extreme values can be influenced by the content and composition of proteins and by the level of starch damage. Table 3 presents chosen parameters of extreme samples. It can be seen that there were not any significant relationship between protein content, sedimentation values to water absorption and to volume yield showing that these samples behave unpredictable due to unusual properties.

To find out how the result of baking test was influenced by higher difference between FWA and PWA than –1 % and 1 %, three chosen samples were baked using both FWA and PWA. Figure 7 represents results of baking tests. It can bee noticed that volume yields did not show significant differences. There were not differences between samples with negative residuals and positive residuals.

Concluding remarks

This study have investigated the possibility of centrifuge use for water absorption determination of wheat flours relating it to the water absorption determination using Brabender Farinograph and determining the best method parameters. The best conditions of centrifugation were: 5000 g, 5 min and room temperature using 1:5 flour water suspensions. Farinograph water absorption (FWA) can be predicted from centrifuge water absorption (CWA) applying linear regression. Differences between predicted water absorption (PWA) and farinograph water absorption (FWA) of most of samples were in range from –1 % to 1 %. The samples with low and high farinograph water absorption (FWA) showed often higher residuals (differences between PWA and FWA) being determined as extremes. Although the extreme samples showed higher residuals, differences in volume yield were not found when both FWA and PWA were used for baking performance. The results of water absorption determination applying centrifuge did not show any statistical deviation being reproduced by two assistances.

The results obtained in this paper show that the centrifuge method is acceptable for water absorption determination. This method needs lower amount of material and needs less

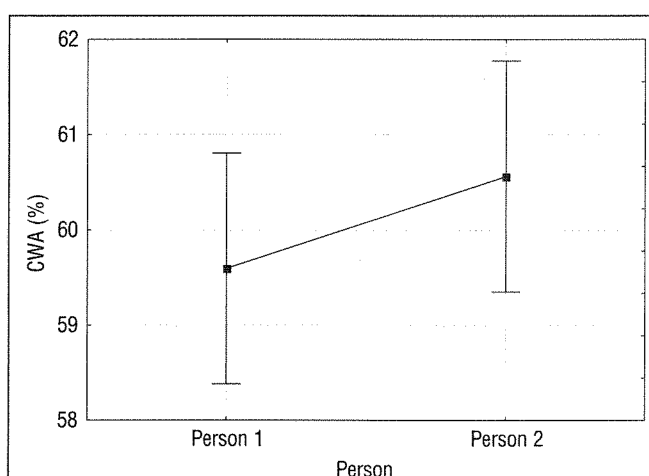

Fig. 6 Results of person influence on results of centrifuge water absorption (CWA)

Table 3. Chosen parameters of extreme samples

Sample	Farinograph water absorption [%]	Protein content [%]	Sedimentation value [ml]	Volume yield [ml/100 g flour]
		Harvest 2001; 2 g		
7	56.4	12.4	37	572
13	56.4	12.1	31	537
116	52.4	12.0	25	615
117	66.1	13.1	30	612
		Harvest 2002; 2 g		
66	61.6	12.8	33	607
73	60.5	15.9	69	650
97	52.1	11.2	16	613
98	55.4	13.2	45	664
		Harvest 2002; 4 g		
66	61.6	12.8	33	607
73	60.5	15.9	69	650
75	53.4	14.2	69	643
97	52.1	11.2	16	613
98	55.4	13.2	45	664

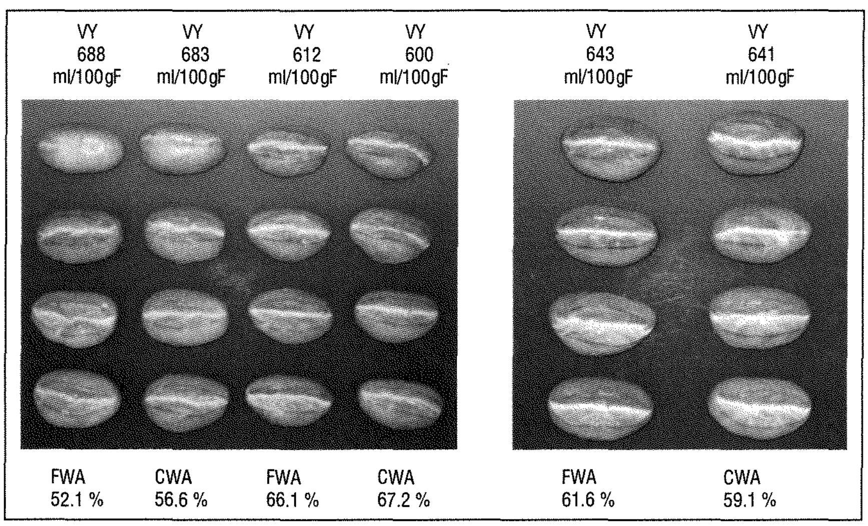

Fig. 7 Results of baking tests of chosen extreme samples (VY) volume yield; (FWA) farinograph water absorption; (CWA) centrifuge water absorption

time than water absorption determination according to standard method No. 115/1. However, during determination of water absorption by centrifuge the working precision is very important because of low sample amount being used. The other important point is that the sample properties are influenced by harvest year conditions and can influence the obtained results.

References

1) Bundessortenamt (Hrsg.): Beschreibende Sortenliste Getreide, Mais, Ölfrüchte, Leguminosen, Hackfrüchte. S. 97–114, Deutscher Landwirtschaftsverlag, Hannover (2002).
2) ICC: Standard-Methoden der internationalen Gesellschaft für Getreidechemie. Detmold (1995).
3) *Bloksma, A. H.* and *W. Bushuk*: In: *Pomeranz, Y.* (Ed.): Wheat Chemistry and Technology. pp. 131–217, AACC, St. Paul (1988).
4) *Denli, E.* and *R. Ercan*: Effect of Added Pentosans Isolated from Wheat and Rye Grain on some Properties of Bread. Eur. Food Res. Technol. **212**, 374–376 (2001).
5) *Anjum, F. M.* and *C. E. Walker*: Grain, flour and bread-making properties of eight Pakistani hard white spring wheat cultivars grown at three different locations for 2 years. Int. J. Food Sci. Technol. **35**, 407–416 (2000).
6) *Metho, L. A., J. R. N. Taylor, P. S. Hammes* and *P. G. Randall*: J. Sci. Food Agric. **79**, 1823–1831 (1999).
7) *Denli, E.* and *R. Ercan*: Effect of Added Pentosans Isolated from Wheat and Rye Grain on some Properties of Bread. Eur. Food Res. Technol. **212** (3), 374–376 (2001).
8) *Rychener, N.* und *N. Nemeth:* Mühle + Mischfuttertechnik. **132**, 53–54 (1995).
9) *Delwiche, S. R.* and *G. J. Weaver:* J. Food Sci. **59**, 410–415 (1994).
10) *Anderson, R. A., H. F. Conway, V. F. Pfeifer* and *E. L. Griffin Jr.*: Cereal Science Today, 4–11 (1969).
11) *Khattakt, S., B. L. D'Applonia* and *O. J. Banasik*: The Bakers Digest. p. 49–53 (1973).
12) *Gerstenkorn, P.*: Mühle und Mischfuttertechnik **40**, 647–649 (1973).
13) *Klüver, M.*: Standard-Methoden für Getreide, Mehl und Brot. Verlag Moritz Schäfer, Detmold (1994).