Effect of Ascorbic Acid on the Rheological Properties of Wheat Fermented Dough

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Abstract

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The effect of ascorbic acid on the rheological properties of wheat fermented dough from forty three wheat flour samples, represented two groups of flours, characterised (according to the ash content, protein content and Zeleny sedimentation value) the main Czech flour type has been studied. Standard analytical parameters (ash and protein contents, wet gluten, falling number, Zeleny sedimentation value), rheological investigation (maturograph, oven rise recorder), and laboratory baking test were used for the characterisation of flours and doughs. It was stated that the influence of the ascorbic acid addition on the fermented dough behaviour depends on the flour composition particularly in the proofing stage. Oven rise characteristics of dough and specific bread volume revealed smaller changes without significant differences between flours with lower (up to 0.6%) and higher (up to 0.7%) ash contents. An important correlation (r = 0.51–0.68) significant at 0.01 level has been found between specific bread volume and final rise of dough.

Keywords: ascorbic acid; wheat flour; fermented dough; maturograph; oven rise recorder; bread volume

The redox potential of a system, such as dough, is established by substances that possess oxidising and reducing properties. Practical experience has shown that for the best baking performance a definite optimum degree of oxidation exists for every flour. Since this optimum potential is seldom encountered naturally, certain oxidising agents are commonly used both in the mill and in the bakery to improve the baking quality of flours.

In countries where the law permits it, the treatment of flour with minute amounts of oxidising agents is an established practise. The effect of oxidising compounds is twofold: flour improvement and bleaching. Flour improvement refers to the changes in the rheological properties of the dough. Flour bleaching is due to the destruction of its yellow pigments, and it results in whiter flour and bread.

Oxidation generally affects the farinogram or mixogram of wheat flour only slightly (POMERANZ 1971). Its effect can be clearly demonstrated by extension tests (measured by the extensigraph or the alveograph). An increase in the resistance and a decrease in the extensibility of flour-water dough depends on the type, the amount of the agent, and the reaction time. These phenomena are correlated with a decrease in the thiol content (MATSUMOTO & HLYNKA 1959).

According to the Czech Food Law No. 110/97 and its declaration No. 298/97 the flour treatment may be performed with ascorbic acid (AsA) declared as E 300. AsA, although being itself a reducing agent, can exert an oxidising effect on the dough properties after its oxidation by atmospheric oxygen. The oxidation product, dehydro-L-ascorbic acid (DHA), can oxidise glutathione under the influence of a specific enzyme. The determination of thiol groups in the dough supports the conclusion that AsA is effective only if oxygen is present and its effect in the resting fermenting dough is greatly reduced by the presence of yeast which makes the conditions more anaerobic. Kuninory and Matsumoto (1963) and Matsumoto and Hlynka(1959) showed that AsA is oxidised rapidly to DHA during dough mixing, and that flour contains a dehydroascorbic acid reductase which is active at pH about 6.0. DHA was reduced rapidly in the dough to which glutathione was added (Carter & Pace 1965). The improving action of AsA, which belongs to the intermediate reaction rate oxidants, is due to the oxidation of SH groups in dough by DHA (Pyler 1988). Shewry and Tatham (2000) described the influence of redox reactions involving AsA during dough mixing and resting. The addition of AsA showed a significant weakening effect on the gluten washed out from the dough immediately after mixing, thus suggesting a predominantly reducing effect. After resting, AsA had a marked strengthening effect on the gluten network caused by an increase of the cross-linking of its proteins. The oxidising effect takes place predominantly during dough resting. According to Nakamura and Kurata (1997), the improving mechanism of AsA on the rheological properties of flour-water dough was mostly due to the development of its electron-donating capacity and reactive products such as O_2^-.

Flour is immune to over-treatment with AsA, the effects of the treatment at the level of 30 to 70 ppm being nearly constant. At the level of 70 to 100 ppm, AsA promotes a good development of dough at the conventional mixing speed and improves the bread quality by the production of a greater oven spring that results in finer crumb grain and a larger loaf volume. In the case of the mechanical dough development system, 75 ppm AsA is regularly used. An advantage of AsA is that excessive levels are not deleterious in dough (up 200 ppm), perhaps because the amount of oxygen necessary for its action is limiting. When too much AsA is added, the doughs resist deformation during moulding and may break open during proofing because of the lack of extensibility. Bread made from such dough has a small loaf volume with a rough crust. Its crumb exhibits many ruptured cells and may have large holes.

As interesting feature of AsA is that its use requires an intermediate proof during bread-making. De Ruiter (1968) showed that the best bread volume is obtained with 40 ppm addition and 10-min proof time. According to Příhoda and Novotná (1996) AsA addition increased optimal proofing time and produced gas volume in wheat fermented dough. Trewlis (1972), using AsA (labelled with a ^{14}C isotope) at a level of 75 ppm based on flour, demonstrated that there is practically no loss of it during dough mixing and fermentation but all the loss takes place upon baking. Of the total AsA added, 27–31% was converted into CO_2 that was released during baking, and the remainder appeared as the water-soluble L-threonic acid.

The objective of this study was to describe the improving effect of AsA on the rheological properties of full dough system during proofing, the oven spring and the baking process.

MATERIALS AND METHODS

Forty three samples of wheat flour divided into two groups according to the ash contents were taken from commercial mills in the course of five months (harvest 2001). The first set contained twenty flour samples with maximum ash content of 0.60% and the second set with maximum ash content of 0.70%. The effect of ascorbic acid was evaluated by the addition of 10 ppm. related to the flour weight.

The analytical flour quality was determined according to the Czech standard methods (ash content, wet gluten, protein content – ČSN 56 0512, Falling Number – ČSN ISO 3093, Zeleny value – ČSN ISO 5529).

The rheological properties of flour were evaluated by means of maturograph (Brabender, Germany) and oven rise recorder (Brabender, Germany) according to the producer recommendations.

The baking test was performed according to the Czech method and the protocol used was: flour 100%, compressed yeast 4%, salt 1.7%, sugar 1.5%, fat 1%, and water as necessary for the optimal consistency of 600 BU. The dough from 300 g of flour was prepared in farinograph (Brabender, Germany). Dough dividing and roll shaping were made by hand and after the standard proofing time the pieces of dough were baked at 240°C for 14 min. Bread volume was determined after two hours of cooling by means of rape seeds.

The parameters of wheat flour quality and the results of maturograph, oven rise recorder, and the baking test evaluation for each set without and with fortification with AsA are presented as average, minimum, and maximum values. The relation between the rheological parameters of dough (according to maturograph and oven rise recorder results) and the results of the baking test was evaluated using correlation analysis.

RESULT AND DISCUSSION

Flour quality parameters determined by standard methods are given in Table 1. Analytical characteristics of both sample sets are very similar except for the ash content and Zeleny sedimentation value, which can differentiate both flour sets significantly. For the production of rolls and buns, flours with a lower ash content (Czech name "bright sort") and a higher protein quality are usually used while for the bread products flours with a higher ash content (Czech name "semi-bright sort") are more suitable. The average values of the flour analyti-

Table 1. Average values of flour analytical parameters

Parameter	Ash (%)	Wet gluten (%)	Protein (%)	FN (s)	Zeleny value (ml)
Flours with lower ash contents					
Average	0.55	31.1	11.4	332	39
Min.	0.47	27.7	10.3	246	34
Max.	0.60	34.8	12.9	415	44
Flours with higher ash contents					
Average	0.68	31.1	11.3	319	36
Min.	0.60	27.3	10.5	256	32
Max.	0.70	35.2	13.1	384	42

Table 2. Average values of maturograph evaluation

Parameter	Final proof time (min)		Dough level (MU)		Dough elasticity (MU)		Proofing stability (min)	
	control	AsA	control	AsA	control	AsA	control	AsA
Flours with lower ash contents								
Average	39	44	688	772	202	211	5	6
Min.	34	40	610	710	180	180	2	4
Max.	46	50	760	860	230	240	8	10
Flours with higher ash contents								
Average	37	39	675	737	203	212	6	6
Min.	32	34	600	625	180	180	2	4
Max.	46	48	780	830	230	230	8	10

Table 3. Average values of OTG evaluation

Parameter	Dough volume (OU)		Baking volume (OU)		Final rise (OU)		Oven rise (OU)	
	control	AsA	control	AsA	control	AsA	control	AsA
Flours with lower ash contents								
Average	360	358	523	523	504	473	163	165
Min.	305	270	450	440	385	370	90	125
Max.	400	420	580	575	570	570	220	280
Flours with higher ash contents								
Average	356	354	502	517	485	470	147	163
Min.	290	260	410	445	400	370	100	100
Max.	450	450	610	610	610	610	215	236

cal parameters were typical for the Czech wheat production environment (protein 10.3–13.1%, FN 246–415s, Zeleny value 32–44 ml). The flour samples tested appeared, according to these characteristics, to be suitable for the standard manufacture of yeast-leavened dough in the industrial bakery but the specific bread volume and the shape ratio (Table 4) were found to be only up to the average. Oxidising agents such as AsA can improve both the dough technological characteristics and the final products.

The maturograph records the fermentation behaviour of dough during the proofing time by means of a sensing probe which touches the dough surface. With the help of an additional loading on this probe which occurs periodically, the elasticity

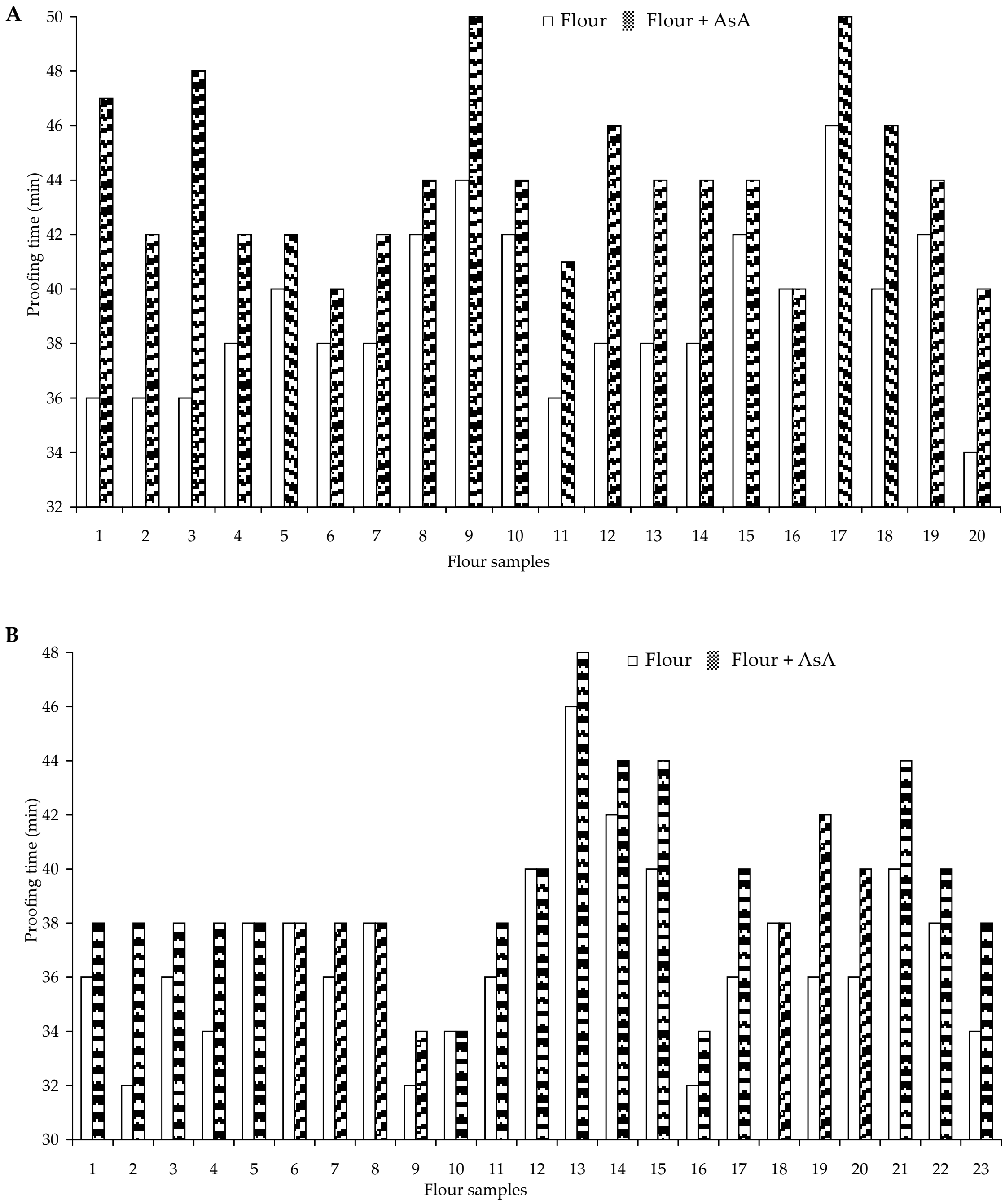

Figure 1. Influence of AsA on proofing time: A – flour with lower ash content and B – flour with higher ash content

Table 4. Average values of baking test evaluation

Parameter	Specific bread volume (ml/100 g)		Bread shape ratio	
	control	AsA	control	AsA
Flours with lower ash contents				
Average	333	338	0.63	0.67
Min.	313	318	0.61	0.62
Max.	357	358	0.66	0.73
Flours with higher ash contents				
Average	328	334	0.63	0.65
Min.	306	312	0.60	0.63
Max.	351	360	0.65	0.69

of the fermented dough is recorded. This cycle is repeated every 2 min and the typical zigzag form of the maturogram is produced. The curve rises until maximum dough maturity is reached and it drops thereafter. This action is recorded in maturograph units (MU) on the strip-chart. The evaluation of maturograms which expresses the dough behaviour without and with AsA addition during the proof period is given in Table 2. The proofing time (expresses the optimum time for reaching the maximum volume of the end product) was found in a similar range for both sets (range 34–46 min and 32–46 min); after the AsA addition, longer time is needed for flours with lower ash contents. Differences between the individual flours of both sets are shown in Figure 1. The dough level, describing the dough resistance against mechanical stress during proofing, is slightly higher in the case of flours with lower ash contents and with AsA fortification it steps up more significantly (84 MU against 62 MU). The dough firmness (expressed as elasticity) of fermented dough was similar in both sets of flour and was increased by the AsA addition in same range (approximately about 5%). The proofing stability which reflects the time tolerance of optimal proofing so as to ensure the highest volume of the final product is changed in same range (2–8 min). The increase by AsA is more significant in dough samples with a very low value of the proofing stability (from 2 to 4 min).

The oven rise recorder describes the changes in the volume of dough (at the point of maximum maturity) during baking in the oil bath. Due to the exact heat transfer, the temperature and the dough volume can be determined at any point of the process. The volume of dough increases with the oil temperature (from 30° to 100°C) and the piece ascends in the bath. The action is recorded in oven rise units (OU) on the strip-chart. The evaluation of the oven rise diagrams of the dough without and with AsA addition is shown in Table 3. The dough volume, which is indicated by the volume of the dough at the start of the baking period, was found to be similar in both sets of samples. After AsA addition, the dough volume changed in a wider range for flours with higher ash contents (260–450 OU against 270–420 OU). The baking volume (indicates the final volume of the baked goods) and its changes after the AsA addition are slightly higher in flour samples with higher ash contents. The effect of AsA is evident only in samples with small original volumes (increase about 10%). From these results it is apparent that the oven rise (the difference between the final bread and the dough volume) is lower in the set with higher ash contents but after the AsA addition the average value is comparable in both sets of flours. The final rise (represents the volume of the baked product after 11 min from the test beginning) describes the shrinkage of the volume mostly by the AsA action (about 6%).

As a result, nearly the same specific bread volumes were obtained by the laboratory baking test (Table 4) in both sets of flours (average 333 or 328 ml per 100 g of flour). In the case of the AsA addition, only an insignificant average volume increase was found (about 1%) but for the individual samples both an increase and a decrease were found (Figure 2). The bread shape ratio steps up approximately by 5% in both sets. As it is known, the influence of AsA was assessed as more important for flours with lower ash contents suitable for small bread products.

The correlation between the fermented dough characteristics as evaluated by the maturograph and the oven rise recorder, and the bread characteristics as evaluated by the laboratory baking test (Table 5) depends on the flour quality. In both sets of flour, a significant correlation between the specific bread volume and the final rise of dough was found as mentioned by De Ruiter (1968). The relationship between the baking volume and the final rise determined by the oven rise recorder was evident, but their relation to the maturograph parameters was highly influenced by both the ash

Table 5. Dough characteristics correlations

	Final proof	Dough level	Dough elasticity	Dough stability	Dough volume	Baking volume	Final rise	Oven rise	Specific bread volume	Shape ratio
Flours with ash content lower than 0.6% – $r_{0.01}$ **= 0.5616,** $r_{0.05}$ ***= 0.4433***										
Final proof	1									
Dough level	0.2765	1								
Dough elasticity	0.0304	0.3860	1							
Dough stability	0.2640	–0.1902	**–0.5820**	1						
Dough volume	–0.2774	0.1325	0.1066	0.1573	1					
Baking volume	0.0939	0.1559	0.0842	–0.0357	***0.6219***	1				
Final rise	–0.1293	0.2787	0.0925	–0.1803	0.4342	***0.5154***	1			
Oven rise	0.4356	0.0091	–0.0373	–0.2280	***–0.5312***	0.3331	0.0348	1		
Specific bread volume	0.1525	0.3467	0.1479	–0.0415	0.3903	0.3357	***0.5076***	–0.1068	1	
Shape ratio	0.4023	0.1913	0.2761	0.0758	–0.1885	–0.2117	–0.3127	–0.0021	–0.0013	1
Flours with ash content lower than 0.7% – $r_{0.01}$ **= 0.5268**										
Final proof	1									
Dough level	0.2596	1								
Dough elasticity	0.3930	**0.8376**	1							
Dough stability	–0.1319	0.0097	0.0247	1						
Dough volume	0.1036	**0.7486**	**0.5270**	0.1746	1					
Baking volume	0.3790	**0.7611**	**0.7740**	–0.0376	**0.6858**	1				
Final rise	0.3119	**0.7659**	**0.7063**	–0.0053	**0.7779**	**0.8604**	1			
Oven rise	0.2464	–0.2451	0.0715	–0.2775	**–0.6665**	0.0856	–0.1836	1		
Specific bread volume	0.4286	**0.7907**	**0.7314**	0.1686	**0.5351**	**0.6710**	**0.6830**	–0.0452	1	
Shape ratio	0.0625	0.4106	0.4723	–0.0716	0.2410	0.4136	0.4310	0.0937	0.2964	1

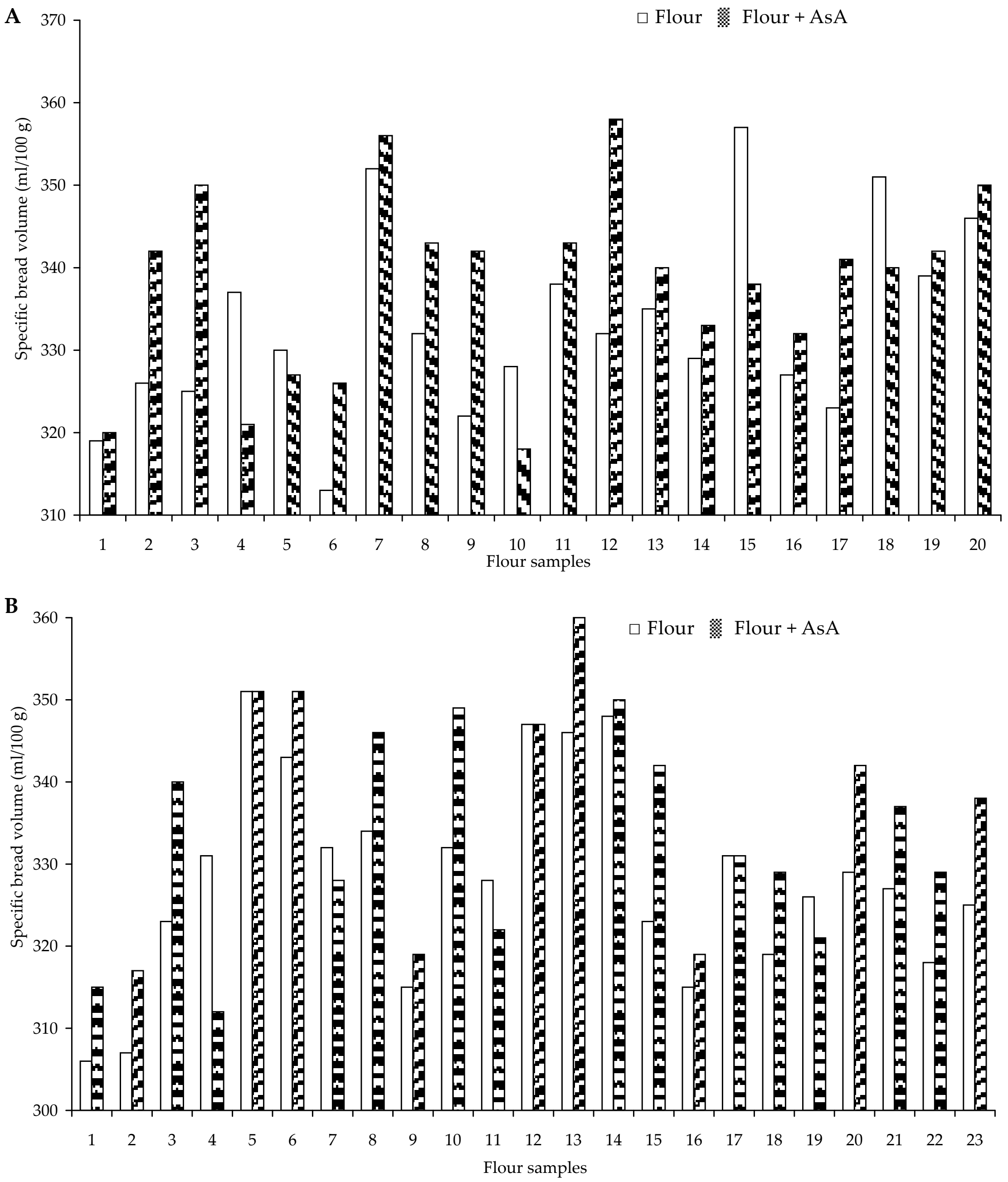

Figure 2. Influence of AsA on specific bread volume: A – flour with lower ash content and B – flour with higher ash content

content and the protein quality described explicitly by Zeleny sedimentation value.

Conclusion

The technological quality of two sets of white wheat flour samples with different protein quality described explicitly by Zeleny sedimentation value and ash contents was described by means of rheological methods (using the maturograph and the oven rise recorder) including a laboratory baking test. The influence of a small amount of ascorbic acid on optimal proofing time was significant – the increase was about 13% for flours with lower ash contents and about 5% for samples with higher ash contents. Dough stability was prolonged mostly in samples with very short initial values. Dough behaviour during oil baking in the oven rise tests was affected by the addition AsA at a low level, similarly as the specific bread volume in the baking test; important differences, however, were found between the individual flour samples. Bread shape ratio stepped of significantly by the AsA fortification. Significant correlation was obtained between the rheological parameters and the baking test results.

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Souhrn

Hrušková M., Novotná D. (2003): **Vliv kyseliny askorbové na reologické vlastnosti fermentovaného pšeničného těsta**. Czech J. Food Sci., **21**: 137–144.

Ve formě fermentovaného těsta byly studovány pekařské vlastnosti 43 vzorků pšeničných mouk, rozdělených podle obsahu popela do dvou skupin (světlé mouky s obsahem do 0,6 % a polosvětlé mouky s obsahem do 0,7 %) a jejich změny přídavkem kyseliny askorbové. Analytické znaky (obsah popela, bílkovin, mokrého lepku, číslo poklesu, Zelenyho sedimentační hodnota), reologické vlastnosti (měření na maturografu a OTG přístroji) a pokusné pečení byly použity pro hodnocení vlastností mouk a těst. Vliv přídavku kyseliny askorbové na chování fermentovaného těsta se významně projevil ve fázi dokynutí (prodloužení optimální doby dokynutí) a závisí na kvalitě mouk. Měrný objem pečiva a vlastnosti těsta při zapékání, zjištěné na OTG přístroji, vykazovaly nevýrazné změny v obou souborech mouk. Významné korelace (r = 0,51–0,68) na hladině 99 % byly zjištěny mezi měrným objemem pečiva a objemem těsta při zapékání.

Klíčová slova: kyselina askorbová; pšeničná mouka; fermentované těsto; maturograf; OTG přístroj

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