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EFFECTS OF VARIOUS BAKING ADDITIVES ON THE RHEOLOGICAL PROPERTIES OF WHEAT FLOURS

BAZI EKMEK KATKI MADDELERİNİN BUĞDAY UNLARININ REOLOJİK ÖZELLİKLERİ ÜZERİNE ETKİLERİ

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ÖZET: Oksidan ajanlar (Potasyum bromat ve askorbik asit), indirgen ajan (L-sistein) ve surfaktanlar (SSL ve DATEM)'ın üç ekmeklik buğday çeşitine ait unların reolojik özellikleri üzerine etkileri Brabender farinograf ve extensograf kullanılarak çalışılmıştır. Genellikle askorbik asit ve potasyum bromatın ($KBrO_3$) artan oranları su absorbsiyonu değerlerini etkilememiştir. Askorbik asit ve $KBrO_3$, kuvvetli ve orta gluten kalitesine sahip çeşitlerde hamur gelişme süresini biraz daha iyi etkilemiştir. Askorbik asitin olumlu etkisi $KBrO_3$'ın etkisine göre daha belirgindir. Surfaktanlar, bütün un çeşitlerinde özellikle stabilite, yoğurma tolerans indeksi ve valorimetre değerleri üzerinde kuvvetlendirici (strenghtening) etki yapmıştır. Bununla beraber, Bezostaya ve Kıraç unlarında, SSL su absorbsiyonu değerinde azaltıcı ve stabilite değeri üzerinde aşırı artırıcı etki yapmıştır. Oksidanların ilavesi Bezostaya ve Orso unlarında ekstensibilitede (E) önemli bir azalma, Kıraç'ın E değerinde ise artma ile sonuçlanmıştır. Her üç un örneğinde de oksidan oranları artırıldıkça maksimum direnç (Rm), kurve alanı (A) ve Rm/E değerleri de artmıştır. Orso örneğinin Rm/E değeri hariç, bütün un örneklerinde surfaktan oranlarının artışı ile Rm, A ve Rm/E değerleri, kontrol örnekleri ile karşılaştırıldığında önemli ölçüde artmıştır.

ABSTRACT: The effects of oxidizing agents (potassium bromate, ascorbic acid), reducing agent (L-cysteine) and surfactants (SSL and DATEM) on the rheological properties of flours of three bread wheat cultivars were studied using Brabender farinograph and extensograph. Generally increasing levels of ascorbic acid and potassium bromate ($KBrO_3$) did not affect the water absorption values. Ascorbic acid and $KBrO_3$ had slightly improving effect on dough mixing properties of the cultivars with strong and medium gluten quality. Improving effect of ascorbic acid was more noticeable than that of $KBrO_3$. The strengthening effects of surfactants were evident on some of the dough mixing parameters especially on stability, mixing tolerance index and valorimeter values of all cultivars. However, SSL caused a reduction in water absorption values of Bezostaya and Kıraç flours and an excessive increase in their stability values. Oxidant supplementation resulted in significant decreases in extensibility (E) values of Bezostaya and Orso flours while the E values of Kıraç increased. Maximum resistance (Rm), area under the curve (A) and Rm/E values of all flours have also increased with increasing oxidant levels. Rm, A and Rm/E values of all cultivars significantly increased with the increasing surfactant levels as compared to control samples except Rm/E values of Orso cultivar.

INTRODUCTION

Dough is a principal intermediate stage between the raw material, flour and the final product bread. The rheological properties of dough are extremely important to the baker. The machining properties of dough (e.g. dividing, rounding, sheeting and molding) and the final quality of bakery products are affected from rheological properties. Therefore, the study of rheological properties is a very important subject for cereal scientists (BLOKSMA, 1971).

A number of ingredients are used under the category of "dough conditioners" since their inclusion in a formula alters the rheological properties of dough. Dough conditioners as bakery additives have been highly beneficial to the food industry, particularly large scale bakeries. They allow the baker to compensate for large differences in flour quality. Three commonly used dough conditioners are oxidants, reductants and surfactants. Oxidizing agents have been used as most common bread improvers throughout the world. Addition of oxidants at optimum levels to flour or dough normally results in improved dough handling and bread quality (YAMADA and PRESTON, 1992). During the mixing, oxidizing agents convert SH groups on the gluten proteins to SS linkages between adjacent molecules building up the gluten matrix and providing a stronger dough. Sometimes, flour gluten strength is so great that the resulting dough is too tough and can not be molded. Such doughs are too strong because of too many crosslinks. This problem may be overcome by adding reducing agents that rupture a certain portion of the disulfide bonds. The most commonly used reducing agent is L-cysteine (STAUFER, 1983). Surfactants have also been used as dough conditioners to improve dough properties and baking performance resulting in uniform, high quality baked products over a wide range of processing conditions (BIRNBAUM, 1977).

The objective of this study was to investigate the effects of oxidizing, reducing agents and surfactants on the rheological properties of flours of three bread wheat cultivars with different gluten strengths.

MATERIALS AND METHODS

Materials

Three different wheat varieties, Bezostaya (hard red winter wheat), Kıraç (medium hard white winter wheat) and Orso (soft red wheat) were chosen to represent wheats that possess strong, medium and weak physical dough properties, respectively. The wheat samples were cleaned on a Carter Dockage Tester, and the wheatbug *(Eurygaster spp. and Aelia spp.)* damaged kernels are separated by hand picking. The hectoliter weight was determined using an Ohaus test weight apparatus and reported on an as is moisture basis. The 1000 kernel weight was determined by counting the number of seeds in 20 g of grain and reported on a dry basis (ULUÖZ, 1965). All of the tests on grain samples were performed in triplicate and the average values are reported. The wheat samples were milled into straight-grade flours in a Buhler laboratory mill.

Two oxidizing agents (potassium bromate and ascorbic acid) and a reducing agent (L-cysteine) were added to the flour samples at the 50, 100 and 150 ppm levels. The surfactants used included sodium stearoyl lactylate (SSL) and diacetyl tartaric acid esters of mono- and diglycerides (DATEM). The surfactants were added directly to the flours at the 0.5%, 1.0% and 1.5% levels and thoroughly blended into the flours in the dough mixer. The effects of these additives on the rheological properties of the flours were evaluated by using farinograph and extensograph.

Rheological Analysis

For the determination of water absorption, dough development time, stability, mixing tolerance index and valorimeter values of the wheat flours, a Brabender farinograph equipment with a 50 g mixing bowl (AACC Approved Method No: 54-21) was used (ANONYMOUS, 1983). Evaluation of farinograms was done according to SHUEY (1984).

The Brabender extensograph was used to test flours for extensibility (E), maximum resistance (Rm) values and area under the curve (A) by AACC Approved Method No: 54-10 (ANONYMOUS, 1983) The extensograph procedure was modified according to HOLAS and TIPPLES (1978). Dough extension curves were obtained at rest periods of 45, 90 and 135 min. Only the final rest period was utilized for comparing flour properties. The ratio value (Rm/E) was calculated from the value of maximum resistance and extensibility.

Statistical Analysis

Data related to extensibility, maximum resistance, area and ratio values were analyzed for variance using the MSTAT statistical package (ANONYMOUS 1988). When significant differences were found, the LSD (Least Significant Difference) test was used to determine the differences among means.

RESULTS AND DISCUSSION

The hectoliter weights of Bezostaya, Kıraç and Orso cultivars were 79.1, 81.5 and 78.1 kg/hl respectively. The 1000 kernel weights of Bezostaya, Kıraç and Orso cultivars were 34.0, 32.4 and 32.4 g, respectively.

The effects of all additives on the farinograph water absorption, dough development time, stability, mixing tolerance index and valorimeter values are shown in Table 1 for three wheat cultivars. Water absorption values did not seem to be affected from increasing levels of oxidizing agents for Bezostaya, Kıraç and Orso cultivars except the water absorption value of Orso at 150 ppm ascorbic acid level. Ascorbic acid had slightly improving effect on dough development time, stability, mixing tolerance index and valorimeter values of Bezostaya and Kıraç cultivars. The dough development time values of the present study are in agreement with those presented by LANG et al. (1992) obtained using mixograph. The effects of ascorbic acid on dough development time, stability and mixing tolerance index values of all cultivars were generally more noticeable than the respective values of $KBrO_3$. Utilization of $KBrO_3$ in breadmaking has been banned in various countries including Turkey because of

Table 1. Farinograph parameters of flour samples supplemented with oxidizing agents, reducing agents and surfactants

		BEZOSTAYA					KIRAÇ					ORSO				
Additivies	Level	WA	DDT	S	MTI	V	WA	DDT	S	MTI	V	WA	DDT	S	MTI	V
$KBrO_3$	0 ppm	60.2	6.0	8.2	50	65	56.6	2.8	3.2	135	38	56.0	1.0	1.8	175	30
	50 ppm	60.3	6.0	8.8	30	62	56.7	3.5	2.6	120	43	55.9	1.0	1.4	205	35
	100 ppm	60.7	5.5	10.0	40	62	56.5	3.0	3.0	120	39	56.0	1.5	1.8	208	37
	150 ppm	60.7	6.0	10.0	45	63	56.7	3.0	3.1	135	37	56.2	1.5	1.3	180	36
As. Acid	0 ppm	60.2	6.0	8.2	50	65	56.6	2.8	3.2	135	38	56.0	1.0	1.8	175	30
	50 ppm	60.2	8.0	9.2	45	69	56.6	3.0	3.8	115	37	55.7	1.0	2.3	150	30
	100 ppm	60.2	7.5	12.1	40	68	56.5	3.0	4.0	115	40	55.8	1.0	2.0	140	28
	150 ppm	60.2	7.0	12.5	25	68	56.5	3.5	4.0	120	41	57.8	1.0	2.1	150	28
Cystein	0 ppm	60.2	6.0	8.2	50	65	56.6	2.8	3.2	135	38	56.0	1.0	1.8	175	30
	50 ppm	61.6	4.0	6.0	40	53	56.7	2.3	1.9	120	31	55.8	1.0	1.0	200	24
	100 ppm	61.4	3.4	2.9	105	43	56.5	2.5	1.6	170	28	55.4	1.0	1.2	275	18
	150 ppm	61.6	3.0	1.8	170	38	56.6	2.5	1.4	235	27	57.4	1.0	1.2	295	15
SSL	0 %	60.2	6.0	8.2	50	65	56.6	2.8	3.2	135	38	56.0	1.0	1.8	175	30
	0.5 %	59.0	6.0	16.6	10	66	56.4	2.8	4.7	80	47	55.8	1.2	2.0	130	32
	1.0 %	57.8	5.5	26.5	10	68	55.2	3.0	11.3	40	51	55.6	1.2	2.5	100	37
	1.5 %	57.5	3.5	31.7	20	62	54.8	2.5	20.5	30	56	55.5	1.5	3.0	80	40
DATEM	0 %	60.2	6.0	8.2	50	65	56.6	2.8	3.2	135	38	56.0	1.0	1.8	175	30
	0.5 %	60.2	7.0	16.5	20	69	56.8	3.3	4.5	85	48	55.8	1.0	3.0	115	36
	1.0 %	60.2	7.0	18.4	20	72	56.4	3.7	5.5	80	54	55.5	1.0	3.3	110	36
	1.5 %	60.1	8.5	22.0	20	76	55.9	3.8	7.5	70	62	55.5	1.3	4.3	115	38

WA : Water Absorbtion(%)
DDT : Dough Development Time (min)
S : Stability (min)
MTI : Mixing Tolerance Index (B.U.)
V : Valorimeter

Table 2. Extensogram parameters of the flour samples supplemented with oxidizing agents

		BEZOSTAYA				KIRAÇ				ORSO			
Additives	Level	E	Rm	A	Rm/E	E	Rm	A	Rm/E	E	Rm	A	Rm/E
$KBrO_3$	0 ppm	191 a	364 a	92.0 a	1.91 a	214 a	38 a	8.8 a	0.18 a	182 a	99 a	22.1 a	0.54 a
	50 ppm	173 b	608 b	131.0 b	3.51 b	240 c	60 b	17.5 b	0.25 a	163 b	169 b	39.3 b	1.04 b
	100ppm	136 c	861 c	139.7 b	6.33 c	224 b	90 c	26.2 c	0.40 b	131 c	319 c	55.2 c	2.44 c
	150 ppm	105 d	1068 d	124.8 b	10.27 d	223 b	102 d	28.9 c	0.46 b	119 d	364 d	55.3 c	3.06 d
LSD ($p < 0.05$)		17.5	70.4	15.73	1.238	9.0	10.3	6.41	0.075	6.2	16.5	4.89	0.13
Ascor. Acid	0 ppm	191 a	364 a	92.0 a	1.91 a	214 c	38 a	8.8 a	0.18 a	182 a	99 a	22.1 a	0.54 a
	50 ppm	133 b	1008 b	154.2 c	7.60 b	242 a	130 b	46.7 b	0.54 b	157 b	267 b	61.6 b	1.72 b
	100 ppm	119 c	1045 b	141.9 b	8.81 bc	226 b	165 c	51.5 b	0.73 c	158 b	300 c	67.9 bc	1.90
	150 ppm	108 c	1055 b	133.3 b	9.85 c	203 d	198 d	51.9 b	0.98 d	154 b	330 d	72.1 c	2.15 c
LSD ($p < 0.05$)		13.5	84.1	10.34	1.229	10.3	9.2	5.24	0.075	22.3	14.4	7.57	0.290

E : Ekstensibility (mm)
Rm : Maximum Resistance (Brabender Unit)
A : Area (cm^2)
Rm/E : Ratio (Maximum Resistance / Extensibility)

Table 3. Extensogram parameters of the flour samples supplemented with surfactants

		BEZOSTAYA				KIRAÇ				ORSO			
Additives	Level	E	Rm	A	Rm/E	E	Rm	A	Rm/E	E	Rm	A	Rm/E
SSL	0 %	191	364 a	92.0 a	1.91 a	214 a	38 a	8.8 a	0.18 a	182	99 a	22.1 a	0.54 a
	0.5 %	181	539 b	123.1 a	2.99 b	246 b	70 b	20.4 b	0.28 b	194	124 c	30.6 b	0.64 b
	1.0 %	184	555 c	131.7 b	3.02 b	247 b	93 c	33.6 c	0.38 c	192	109 ab	29.5 b	0.57 a
	1.5 %	171	784 d	165.6 c	4.60 c	247 b	119 d	44.8 d	0.48 d	195	111 b	31.2 b	0.57 a
LSD ($p < 0.05$)		--	15.9	30.95	0.518	11.5	22.1	6.36	0.075	--	11.2	2.36	0.053
DATEM	0 %	191	364 a	92.0 a	1.91 a	214 a	38 a	8.8 a	0.18 a	182	99 a	22.1 a	0.54 a
	0.5 %	187	450 b	108.1 ab	2.42 b	244 b	73 b	19.7 b	0.30 b	177	140 b	34.0 b	0.79 b
	1.0 %	177	485 b	110.6 ab	2.74 b	244 b	82 b	27.8 c	0.34 b	181	146 b	34.1 b	0.81 b
	1.5 %	176	549 c	121.5 b	3.12 c	242 b	80 b	30.0 c	0.33 b	194	113 a	30.2 b	0.58 a
LSD ($p < 0.05$)		--	41.7	18.15	0.351	8.4	17.9	2.81	0.075	--	17.6	4.65	0.075

E : Ekstensibility (mm)
Rm : Maximum Resistance (Brabender Unit)
A : Area (cm^2)
Rm/E : Ratio (Maximum Resistance / Extensibility)

perceived health risks. Baking industry was therefore required to find an alternative oxidizing agent. Various studies indicate that ascorbic acid could be used successfully as an improver for dough preparation instead of $KBrO_3$ (LORENZ et al., 1995). This is confirmed by the results of the present study. Ascorbic acid itself is a reducing agent. During dough mixing it is rapidly oxidized enzymatically to dehydroascorbic acid which react with flour proteins much like any other oxidizing agent (TSEN, 1964).

As the level of L-cysteine was increased from 0 to 150 ppm, all farinogram properties especially mixing tolerance index, were deteriorated considerably. Increasing additions of L-cysteine caused dough development time to decrease (Table 1). This agrees with the work by WEAK et al. (1977) and LANG et al. (1992) but their work was performed by using mixograph. The adverse effect of L-cysteine was more drastic in the strong gluten cultivar, Bezostaya.

As shown in Table 1, the surfactants had strengthening effects on the stability, mixing tolerance index and valorimeter values of all cultivars. All supplementation levels of SSL resulted in lower water absorption values in both Bezostaya and Kıraç flours. SSL had undesirable decreasing effect on development time and excessive increasing effect on stability values of Bezostaya and Kıraç flours above 1.0% and 0.5% levels, respectively. Various workers reported similar results for dough development time (WATSON and WALKER, 1986) and stability (TSEN and WEBER, 1981). The high stability values of Bezostaya and Kıraç cultivars at these levels indicated that the doughs would not develop and are considered as too strong for bakery use. Although the farinograph properties of the weak cultivar Orso (especially stability and mixing tolerance index values) improved slightly by adding SSL and DATEM, the doughs were still weak. This observation indicates that this cultivar can not be used successfully for breadmaking unless it is blended with a stronger one.

The effects of both $KBrO_3$ and ascorbic acid on the extensogram E, Rm, A and Rm/E values are shown in Table 2 for three different cultivars (ÇELiK et al., 1996). When the Bezostaya and Orso flours were supplemented with $KBrO_3$ and ascorbic acid significant decreases ($p< 0.05$) were observed in the extensibility values as compared to respective control samples. However, E values of Kıraç flour were increased significantly at the 50 ppm level and above this level decreased for both oxidizing agents, but they were generally higher than the respective control samples.

As the oxidant levels were increased, Rm, A and Rm/E values of all flours increased significantly ($p < 0.05$) as compared to corresponding control samples (Table 2) which is in generally in agreement with the related literature (PYLER, 1973). The increases in Rm and Rm/E values of Bezostaya doughs were more pronounced than other flours. The effects of ascorbic acid on Rm and A values of all cultivars were more noticeable than $KBrO_3$ except the Rm values of Orso flours.

The ratio value, which is obtained by dividing maximum resistance (Rm) by extensibility (E) serves as an index of gluten quality. A higher value indicates buckier dough. The suitable combination of resistance and extensibility values results in desirable dough properties (WALKER and HAZELTON, 1996). For all cultivars both oxidizing agents had improving effect on Rm/E value at all addition levels. However, for the Bezostaya cultivar which has strong dough properties, addition of $KBrO_3$ above 50 ppm level and all addition levels of ascorbic acid resulted in bucky doughs.

It was not possible to draw extensograms of L-cysteine supplemented flours due to the drastic reductions in Rm values and excessive increases in E values (data not presented). These changes are caused by the cleavage of disulfide bonds and depolymerization of gluten proteins.

The effects of both SSL and DATEM on extensogram E, Rm, A and Rm/E values are shown in Table 3 for the three wheat cultivars. Although the effects of both surfactants on the E values of extensograms were not statistically significant for Bezostaya and Orso cultivars, the E values of Kıraç were increased significantly at 0.5% level, but did not change above this level for both surfactants. As the surfactant level was increased, Rm, A and Rm/E values of all cultivars were significantly increased ($p < 0.05$) as compared to respective control samples except Rm/E values of Orso cultivar. The increase in the elasticity due to addition of surfactants agrees with the related literature (PYLER, 1973). The effects of SSL on Rm, A and Rm/E values of Bezostaya and Kıraç cultivars were slightly better than DATEM. However, effects of these surfactants were similar on Rm, A and Rm/E values for Orso cultivar. As expected, the Rm/E values of all surfactant supplemented doughs were lower than the oxidant supplemented ones due to their softening effects.

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