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The effects of commercial fibres on frozen bread dough

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Abstract: The daily intake of dietary fibres in highly industrialized countries is at a low level and, therefore, adversely affecting human health. The objective of this research was to analyze the influence of different commercial fibres (originating from sugar beet pulp fibrex, and Jerusalem artichoke inulin HPX and GR) in yeast dough at a level of 5 %, on the rheological properties of dough and the quality of bread during frozen storage. Frozen dough characteristics were determined using a Brabender maturograph and test baking was followed according the AACC procedure. The dough was frozen at –18 °C and stored over a period of 60 days. The results concerning the dough (proving time and stability) and bread quality (volume and crumb quality) were statistically analyzed by multivariance Manova and discriminative analysis, which indicated that there was a significant difference between dough without fibres and dough with different fibres (fibrex, inulin HPX and GR). The discrimination coefficient points that the greatest influence of fibres on the final proof and proving stability is after 30 days (6.250) and after 0 days (6.158), respectively, but the greatest influence of fibres on bread volume and bread crumb quality (15.488 and 3.638, respectively) can be expected on non frozen dough, due to above mention their adverse the effect on gluten network.

Keywords: fibrex; inulin; frozen dough; bread quality.

INTRODUCTION

Bread has always been one of the most popular and appealing food products due to its superior nutritional, sensorial and textural characteristics. Bakery products, particularly bread, take a significant share in the food guide pyramid for daily food choices recommended by US Department of Health and Human Services,[1–3] and therefore can be a convenient food for adjusting the daily food intake according to specific needs. Dietary fibres in bread are a versatile functional food ingredients giving many benefits to human health [4–6] and playing a

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very important role in the human diet, helping in solving some digestive problems and also positively contributing to a long list of non infectious diseases.[3,7,8] The social and scientific modernization for the development of alternative or novel methods for the production and preservation of bakery products is freezing.[9]

Fresh bread is a product with a short shelf life and during its storage, a number of chemical and physical alterations occur, known as staling. Due to these changes, its freshness and crispiness deteriorate while crumb firmness and rigidity increase. Over the past few years, the bakery industry has exploited the advantages of freezing technology.[9,10] It is well recognized that temperature affects the performance of dough and yeast during preparation.[10] Frozen bakery products are expected to be characterized by quick preparation time and affordable price. They look and taste as if they were freshly and homemade.[5]

In frozen dough preparation, when prolonged frozen storage intervenes between dough formation and bread baking, many factors contribute to a deterioration of the products and adversely influence dough behaviour during freezing and thawing, resulting in the loss of consumer acceptability for bakery products.[5,6,11] In the technology of frozen dough, the main problem is damage to the gluten network due to crystallization and recrystallization of water, which results in loss of bread quality.[12,13] It has been shown that the influence of fibre characteristics on yeast activity and bread quality during 30 days freezing was beneficial.[14] The possibility of mathematical interpretation of commercial fibres on yeast dough during frozen storage is of particular interest both for those involved in frozen dough preparation and in thawing and baking and could positively contribute to a better quality of the final products. There are not many reports on the effects of different fibres incorporated into frozen yeast dough.

Objective of this paper is to present an analysis of the influence of three commercial fibres (fibrex, inulin HPX and GR) at a level of 5 % on dough rheology and the quality of bread during the freezing process. Regarding the mathematical analysis, this information is required either for the successful incorporation of different fibres types and/or an analysis of the effects of fibres on frozen dough to enable the production of consumer-acceptable, fibre-enriched bakery products.

EXPERIMENTAL

Material

For commercial bread production, white flour from a local industrial mill (moisture, ash and protein contents were 13.5, 0.45 and 11.2 % d.d., respectively), salt and compressed yeast were used. Fibrex with a particle size of less than 150 μm was a commercial product originnating from sugar-beet and produced by Denisco Sugar AB; while Inulin HPX and inulin GR fine, white powders characterized by an average degree of polymerization of more than 10 sugar units and 2 to 5 sugar units, respectively, were commercial products made from the root of Jerusalem artichoke and produced by "Orafti Active Food Ingredients", Belgium.

Dough preparation

Dough samples were prepared in a Farinograph bowl at a temperature of 30 °C according to the following dough formula: flour (100–95 %), fibres (fibrex, inulin HPX or inulin GR) (0–5 %), salt (2 %) and yeast (2.5 %). Water was added according to the Farinograph absorption, *i.e.*, to 500 BU: no fibres (60.4 %), fibrex 5 and 10 % (68.0 %), inulin HPX 5 % (56.6 %) and inulin GR 5 and 10 % (52.3 %). Round shaped dough, weighing 150 g, with or without 5 % of different fibres, was placed in a freezing chamber (Koma, Koeltechnishe Industrie, B.V., The Netherlands) at a temperature of –18 °C. After freezing, the samples were packed in PVC bags and stored at –18 °C for 0, 1, 30 and 60 days. After the required freezing period, dough pieces were kept for 2 h at ambient temperature and then placed in a maturograph fermentation chamber at 30±1 °C.

Dough characteristics

The rheological properties of the frozen and non-frozen dough during fermentation were determined in a Maturograf (Brabender, Duisburg, Germany). The procedure is not standardized, usually it is adjusted to bread making procedures.[15] The constituents and preparation of the dough for Maturograf determination were the same as those described for dough preparation. The Maturograph measures the behaviour of yeast dough during the final proofing under constant conditions, (temperature 30±1°C and relative humidity 80–85 %). After thawing (2 h), a dough piece was placed in the dough container under a stamp weighing 150 g. Depending on the dough's gas production, gas retention and elasticity characteristics, the pressure stamp is raised progressively to certain levels giving information about fermentation and dough handling.

Baking test

AACC Baking test (method 10-09.01) was applied to eliminate as much as possible the human element introduced by the operator. Dough or a dough piece after thawing was moulded by hand. The dough loaf was placed seam down in a greased tall baking form pan (length, 10.5 cm, width, 6.0 cm, bottom length, 9.3 cm). The end of proof was determined according to the Maturograph data. The dough constituents were the same as those used for dough preparation. The bread was baked for approximately 15 min in a Chopin laboratory oven at 260 °C, until the mass of baked bread ranged between 135 and 137 g. The quality of the bread was scored 24 h after baking. Bread volume and crumb quality was evaluated by five trained panellists. The bread volume was determined by the seed displacement method. Crumb grain is defined as the cell structure exposed when a loaf of bread is sliced. The best score is characterized by relatively large cells with thin walls (score 2.5), whereas a close grain consisting of small cells with thick walls has the worst score (0). Crumb elasticity is determined entirely by the sense of touch. The fingers are pressed lightly against the cut surface of a loaf and scored, the best being 4.5 and the worst 0. Crumb quality number is the sum of the scores for crumb grain and crumb elasticity, the maximum grade is 7 and minimum 0.[15]

Statistical analysis

All samples were prepared and analyzed in total 6 times and the average result is reported.

The results concerning dough (proofing time and stability) and bread quality (volume and crumb quality) were statistically tested by analysis of multivariance Manova and discriminative tested. ANOVA functions and Roy test with 0.05 significance level were used as the univariant statistical procedures to assess significant differences among the means.[16]

RESULTS AND DISCUSSION

Mathematical analysis of effect of fibres on behaviour of frozen dough at final proof

It has been claimed that freezing adversely affects the protein matrix and yeast viability.[6,7] Good dough handling is beneficial in the bread making process, positively contributing to an improved gas-retention capacity. Therefore, dough behaviour at the final proof is presented by the proof duration and proofing stability, (Table I). The mean value and standard deviation show that the duration of the final proof depends on the sample in respect to the type, *i.e.*, on the type of fibres and the length of storage at low temperatures. Keeping dough with inulin HPX under frozen conditions for a longer period, from 30 to 60 days, leads to a decrease in the duration of the final proof. According to the statistical data, the sample with inulin HPX differed significantly from the other samples. The final proof of the dough with inulin HPX and GR was shorter than that with fibrex (Table I, Figs. 1 and 2). These data may indicate that inulin either HPX or GR positively contribute to preserving the yeast fermentative activity during freezing, contrary to fibrex. The longest final proof time of the dough with fibrex can be negatively connected with the great ability of absorbing water from fibrex (68 %), resulting in the inability of the gluten to take water and forcing the baker to add more water to the dough with fibrex.

TABLE I. Effect of fibres on dough properties during freezing

Time, days	Final proofing time, min				Proofing stability, min			
	Mean value	Confidence interval		p^a	Mean value	Confidence interval		p^a
				0 % Fibres				
0	82±1.5[a]	80.75	83.91	0.833	15±2.4[a]	12.8	17.9	0.956
1	110±4.6	105.2	114.8	0.996	5±2.4[a]	2.79	7.88	0.956
30	128±2.8[a]	125.0	131.0	0.996	2±1.5	0.750	3.91	0.833
60	68±20	46.55	89.45	0.996	7±2.1[a]	4.80	9.20	0.988
				5 % Fibrex				
0	82±3.7[a]	78.76	86.57	0.626	7±2.3[a]	5.21	10.1	0.998
1	127±3.2[a]	124.3	131.0	0.959	2±1.3	0.670	3.33	0.518
30	132±10[a]	121.4	143.2	0.943	5±2.8	2.11	7.89	0.976
60	133±9.5[a]	123.0	143.0	0.518	3±1.1[a]	1.85	4.15	0.573
				5 % Inulin HPX				
0	81±3.4	78.05	85.28	1.00	4±1.0	3.58	5.75	0.272
1	112±4.1	108.3	117.0	0.964	8±5.4[a]	2.37	13.6	0.968
30	98±1.5	96.75	99.91	0.833	1±1.1	–0.150	2.15	0.573
60	45±6.5	38.13	51.87	0.996	6±1.5	4.75	7.91	0.833
				5 % Inulin GR				
0	85±3.2[a]	82.30	89.03	0.959	9±2.9[a]	6.58	12.8	0.946
1	115±3.4[a]	112.0	119.3	1.00	5±3.0[a]	1.69	7.98	0.750
30	121±1.6	119.6	123.0	0.682	1±1.6	–0.380	3.05	0.682
60	67±1.7	65.24	68.76	0.754	9±3.7[a]	5.82	13.5	0.993

[a]*p*-Test of conclusion

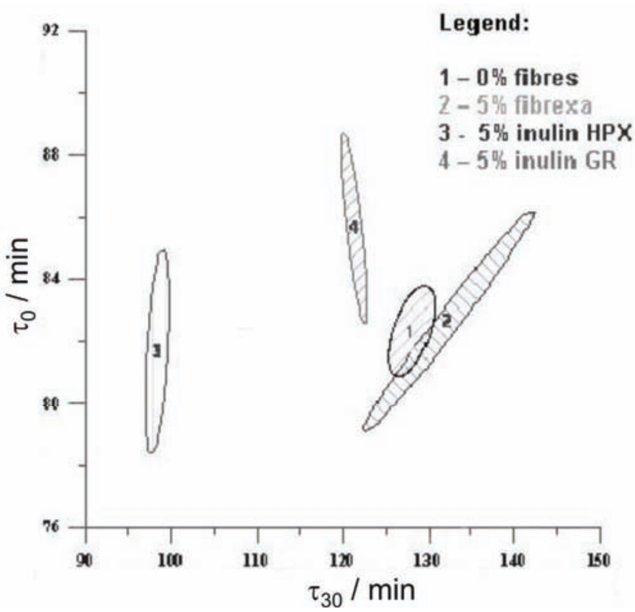

Fig. 1. Trust interval of the final proof of dough with fibres frozen for 0 day (τ_0) and 30 days (τ_{30}).

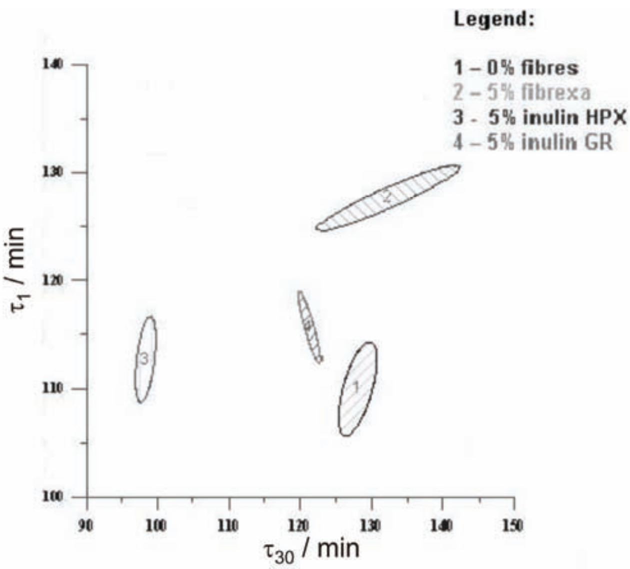

Fig. 2. Trust interval of the final proof of dough with fibres frozen for 1 day (τ_1) and 30 days (τ_{30}).

The influence of different fibres on the behaviour of dough at the final proof fermentation was analyzed by the multivariant procedure and discriminative analysis (Tables II and III).[16] The Manova test showed that there was a significant difference in the effect of different fibres on the dough properties during frozen storage (0, 1, 30 and 60 days) since $p = 0.000$, and the alternative hypothesis that there was a significant difference in the effect of the fibre type on the observed parameters during freezing was confirmed by the Roy test, since $p < 1$ (Table II). In non-frozen dough, the fibres do not have a significant influence on the final proof since $p > 1$, while the fibres have a far greater influence on the dough properties during freezing for 1, 30 and 60 days since $p < 1$ (Table II). The discrimination coefficient indicates that the greatest influence of fibres on the final proof and proofing stability was after 30 days (6.250) and after 0 days (6.158), respectively (Table IV).

TABLE II. Statistical analysis of the effects of fibres on the final fermentation on freezing of dough with fibres (*F* – Fisher test, *p* – confidence of the test)

Test	τ / days	Final proofing time, min		Proofing stability, min	
		F	*p*	*F*	*p*
Manova	4	20.0	0.0	10.6	0.0
Roy test	0	1.97	0.15	23.0	0.0
	1	24.3	0.0	3.21	0.04
	30	45.5	0.0	5.74	0.005
	60	62.6	0.0	8.46	0.001

TABLE III. Discriminative analysis of the effects of fibres on the final proof of frozen dough with fibres (Fisher test; $p = 0.0$ (confidence of the test))

τ / days	Final proofing time, min	Proofing stability, min
4	25.1	11.4

TABLE IV. Discriminative analysis of the effects of fibres on the final proof of frozen dough with fibres

τ / days	Final proofing time, min	Proofing stability, min
0	4.77	6.16
1	3.88	3.07
30	6.25	1.39
60	3.19	2.24

Based on the overall statistical calculation of discriminative analysis it can be stated that fibrex and inulin HPX affect the final proof after 1 day. The largest homogeneity is 100 % (Table V) indicating that the influence of these fibres is constant and uniform and depends on the fibre characteristics, *i.e.*, on their interaction with the gluten network. On the contrary, inulin GR showed different characteristics.

The discriminative analyses the presented date proved that fibres affect the final proof mostly at the beginning of freezing. Later, some interactions between the fibres and other dough constituents, such as ice crystals and yeast cells, also contributed to the quality of frozen dough during freezing.

TABLE V. Characteristics and contribution of the fibre characteristics to the final proof after freezing of the dough (how many samples differ from related value)

τ / days	Final proofing time, min					Proofing stability, min				
	0 % Fibres	5 % Fibrex	5 % Inulin HPX	5 % Inulin GR	Contri-bution %	0 % Fibres	5 % Fibrex	5 % Inulin HPX	5 % Inulin GR	Contri-bution %
0	Lower	Higher	The lowest	The highest	26.5	The highest	Lower	The lowest	Higher	47.6
1	The lowest	The highest	Lower	Higher	21.5	Higher	The lowest	The highest	Lower	25.3
30	Higher	The highest	The lowest	Lower	34.7	Higher	The highest	The lowest	Lower	2.00
60	Higher	The highest	The lowest	Lower	17.4	Higher	The lowest	Lower	The highest	25.1
Homo-geneity %	100	100	100	66.7	–	100	100	83.3	66.7	–

Statistical analysis from Table I prove that the type of the fibres and the length of freezing have an influence on the dough characteristics and that the dough with fibrex had the shortest proof stability during freezing for 1, 30, 60 days, particularly concerning both types of inulin. The greatest influence of fibres on the stability of fermentation was after 0 days of frozen storage (Table IV), because the fibres were not well incorporated into the gluten structure and had a negative effect on the gluten matrix, which was also confirmed by the fibre contribution, which was 47 %, Table V. The dough with inulin HPX and GR had homogeneities of 83.3 and 66.7 %, respectively, which are not stable proofing stabilities (Table V).

Mathematical analysis of the effect of fibres on the quality of bread made of frozen dough

The effect dough freezing on bread quality was assessed through the bread volume and crumb quality, Table VI. The mean value and standard deviation showed that the bread volume depended on the type of the sample, *i.e.*, on the type of incorporated fibre and the length of the low temperature storage.

The effect of the different fibres on the baking properties of bread made from frozen dough was analyzed by the multivariate procedure and discriminative analysis (Tables VII and VIII).[16] Differences in the effect of the fibres on the behaviour of dough after freezing (0, 1, 30 and 60 days) were examined by the Manova procedure. The Manova test (Table VII) showed that there was a significant difference between the effects of the studied fibres since $p = 0.0$. The alternative hypothesis that there is a significant difference in effect of fibres on observed parameter during frozen storage is tested by the Roy test. It was shown that during 1 and 30 days of freezing, the fibres did not have a significant influence on the bread quality since $p > 1$, while the fibres had a far greater influence on the bread volume and bread crumb quality after frozen storage for 30 and 60 days since $p < 1$ (Table VII). The discrimination coefficient proved that the greatest influence of the fibres on bread volume and breadcrumb quality (15.488 and 3.638) can be expected with non-frozen dough (Table IX), due to their above-mentioned adverse the effect on the gluten network.

TABLE VI. Effect of fibres on the baking properties of bread after freezing (*p* – test of conclusion)

τ / days	Bread volume, ml				Bread crumb quality[a]		
	Mean value	Confidence region		*p*	Mean value	Confidence region	
				0 % Fibres			
0	392±15.5[a]	376.2	408.8	0.996	6.4±0.2	6.11	6.59
1	340±35.2[a]	303.7	377.6	0.999	6.4±0.4	5.92	6.80
30	297±19.9[a]	276.6	318.4	0.996	5.2±1.3	3.92	6.58
60	287±15.8[a]	270.9	304.1	0.996	4.6±0.3	4.31	4.99
				5 % Fibrex			
0	257±39.1	216.5	298.7	0.996	5.2±1.3	3.93	6.57
1	292±32.9	258.0	327.0	0.996	5.7±0.9	4.75	6.65
30	245±15.8	228.4	261.6	0.996	5.3±1.0	4.20	6.40
60	277±43.5	231.8	323.2	0.953	4.9±1.0	3.92	6.04
				5 % Inulin HPX			
0	407±5.2[a]	401.6	412.4	0.996	6.9±0.1	6.83	7.00
1	363±4.5[a]	359.1	368.5	0.883	6.9±0.1	6.79	7.01
30	312±6.4[a]	305.5	319.1	0.996	6.3±0.5[a]	5.78	6.82
60	256±6.7[a]	249.7	263.8	0.998	6.6±0.3[a]	6.27	6.93
				5% Inulin GR			
0	366±4.0[a]	362.5	370.9	0.996	4.5±0.1	4.35	4.65
1	325±3.9	320.9	329.1	0.996	5.1±0.7	4.36	5.84
30	280±5.6	274.1	285.9	0.996	5.0±1.0[a]	3.98	6.10
60	233±4.2	228.6	237.4	0.943	2.9±0.5	2.42	3.38

[a]Bread crumb quality; maximum 7.0, minimum 0

TABLE VII. Statistical analysis of the effects of fibres on the properties of bread made from frozen dough (*F* – Fisher test, *p* – confidence of the test)

Method	Bread volume, ml			Bread crumb quality[a]		
	τ / days	*F*	*p*	τ / days	*F*	*p*
Manova	4	12.395	0.000	4	5.867	0.000
Anova	0	60.488	0.000	0 day	21.000	0.000
	1	9.106	0.001	1 day	1.481	0.249
	30	28.013	0.000	30 day	0.875	0.470
	60	6.336	0.003	60 day	11.173	0.000

[a]Maximum 7.0, minimum 0

TABLE VIII. Discriminative analysis of the effect of fibres on the properties of bread made from frozen dough (Fisher test, p = 0.0 (confidence of the test))

τ / days	Bread volume, ml	Bread crumb quality[a]
4	26.5	6.83

[a]Bread crumb quality; maximum 7.0, minimum 0

TABLE IX. Difference in the influence of the fibre types on the bread properties

τ / days	Bread volume, ml	Bread crumb quality[a]
0	15.5	3.64
1	0.641	0.271
30	8.18	1.36
60	8.23	1.12

[a]Bread crumb quality; maximum 7.0, minimum 0

The dough with incorporated inulin HPX had the greatest volume and differed significantly from other samples (Table VI and X) during the first 30 days of freezing, Figs. 3 and 4. The adverse influence of fibrex on the gluten structure found by Wang *et al*.[3] was confirmed in this study as the lowest bread volume was registered when dough containing these fibres was kept at low temperatures for the first 30 days of frozen storage. However, after 60 days, the beneficial effect of fibrex on the yeast activity positively contributed to the bread volume. As it was stated concerning the final proof data, inulin HPX was better incorporated into the gluten matrix, thus contributing the best to the bread volume as opposed to other types of fibres, with which dominating influence on the bread volume was the length of frozen storage. Dough with incorporated inulin GR had the lowest volume after 60 days of frozen storage (Table VI and X), as these fibres act as an inclusion element thus contributing to structure deterioration and poor volume.[18]

In period of 60 days of frozen storage, inulin HPX also positively contributed to the bread volume and crumb quality (Tables VI and X). The bread was evaluated with excellent grades, 6.3 to 6.9 out of a maximum of 7. Dough containing fibrex was evaluated as having the same quality regardless of the duration of the freezing period. Concerning fibrex and inulin HPX, the crumb quality remained constant regardless of the duration of frozen storage, contrary to samples without fibres or with inulin GR fibres. Bread with inulin GR was graded as good and attributed with the highest homogeneity. The protective effects of fibrex and inulin HPX against the adverse influence of low temperatures on dough was proved by the relatively uniform breadcrumb scores, particularly the high scores for inulin HPX was proved by the highest homogeneity (Table X). The greatest fibre contribution was registered by the bread volume and crumb quality numbers of 47.9 and 56.9 %, respectively, with non-frozen dough (Table X).

TABLE X. Characteristics and effects of the fibre characteristics on the baking properties of bread made from frozen dough (how many samples differ from related value)

τ / days	Bread volume, ml					Bread crumb quality[a]				
	0 % Fibres	5 % Fibrex	5 % Inulin HPX	5 % Inulin GR	Contri-bution %	0 % Fibres	5 % Fibrex	5 % Inulin HPX	5 % Inulin GR	Contri-bution %
0	Higher	The lowest	The highest	Lower	47.9	–	–	–	Good	56.9
1	Higher	The lowest	The highest	Lower	10.8	–	–	–	–	4.24
30	Higher	The lowest	The highest	Lower	17.4	Good	Good	Excel-lent	Good	21.3
60	The highest	Higher	Lower	The lowest	23.9	–	–	Excel-lent	–	17.5
Homo-geneity %	100	100	100	100	–	83.3	66.7	100	100	–

[a]Maximum 7.0, minimum 0

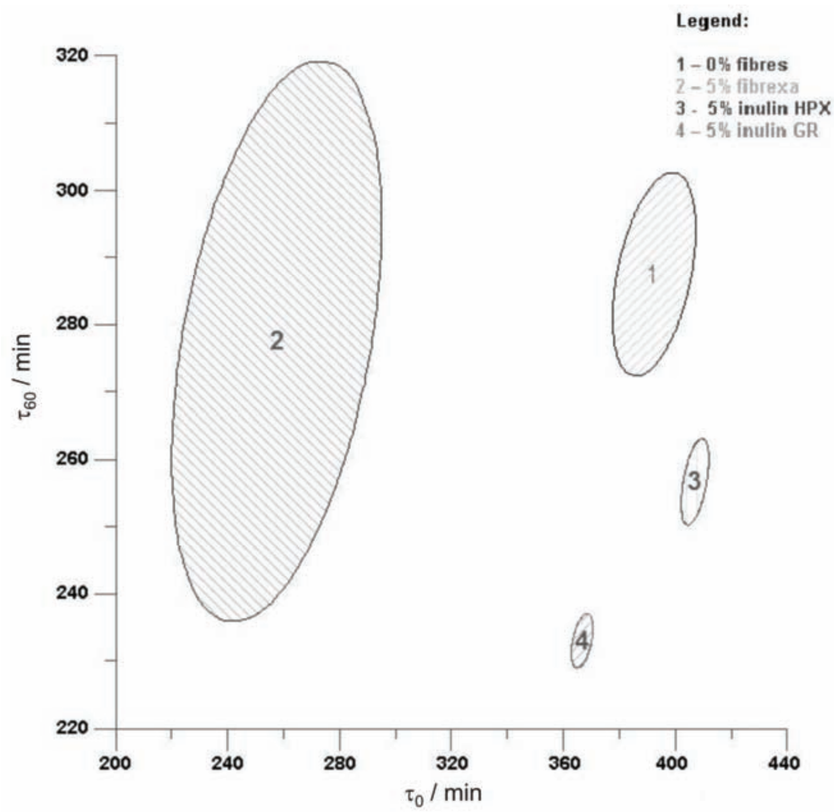

Fig. 3. Trust interval of bread volume with fibres after 0 (τ_0) and 60 (τ_{60}) days of frozen storage.

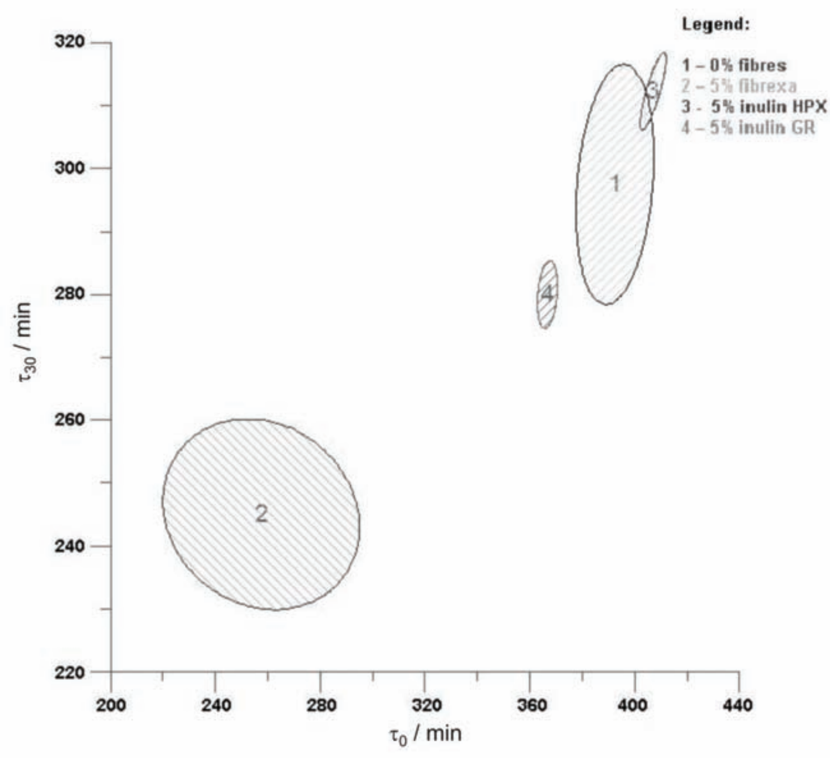

Fig. 4. Trust interval of bread volume with fibres after 0 (τ_0) and 30 (τ_{30}) days of frozen storage.

This indicates to the positive effects of HPX fibres on decreasing the negative effects of freezing. Inulin HPX was incorporated the best into the gluten matrix; hence, the resulting bread had the largest volume (Table VI). The volumes of the other breads with different types of fibres depended on the length of frozen storage, because ice crystals interfere with the gluten structure, which consequently decreases the volume of the bread (Table VI).

CONCLUSIONS

Statistical interpretation of the data proved that the fibre type and storage period influence the characteristics of dough and bread; at the beginning, the fibre characteristics exhibit a dominating adverse effect on the gluten network, but later, their interactions with other dough constituents positively contribute to dough and bread quality.

Multivariate and discriminative analyses indicated that there was a significant difference between the dough rheology without fibres and dough with three types of fibres (fibrex, inulin HPX and GR).

The discrimination coefficient proved that the highest effect of fibres was on the final proof after 30 days of freezing (6.250) and on the proofing stability of non-frozen (fresh) dough (6.16), while the effect of the fibres on the bread volume and crumb quality were the greatest in non-frozen (fresh) dough (15.5 and 3.64, respectively).

The statistical date proved that the long chains of inulin HPX were incurporate well into the gluten matrix and probably protected the yeast cells from the ice formed during freezing for 1, 30 and 60 days; hence, bread with the largest volume was obtained. The protective role of inulin HPX can be seen in the well-preserved quality of the final product after 60 days of frozen storage of the dough and the quality was the same as bread made of non-frozen dough without fibres.

The inulin GR fibres were incorporated into the gluten structure contributing to a deterioration of the gluten structure, which resulted in a diminution of the properties of the frozen dough, which in turn had an adverse effect on the bread volume and crumb quality.

The results from all sample highlighted the complex role of fibres in frozen dough.

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ИЗВОД

УТИЦАЈА ВЛАКАНА НА ОСОБИНЕ ЗАМРЗНУТОГ ТЕСТА И КВАЛИТЕТ ХЛЕБА

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У високоразвијеним земљама запажен је смањени дневни унос прехрамбених влакана које позитивно утичу на људско здравље. Циљ овог истраживања је анализа утицаја 5 % различитих врста влакана (Fibrex, комерцијални производ из влакна шећерне репе и инулин HPX велике и инулин GR мале молекулске масе пореклом из артичоке) на квалитет теста, при чему су праћене реолошке особине замрзнутог теста и квалитет хлеба са влакнима. Реолошке особине теста са влакнима прећене су на Брабендеровом матурограму, а хлеб је печен по стандардној AACC методи. Тесто је замрзавано на –18 °C и чувано 60 дана. Реолошке особине теста са влакнима (дужина завршне ферментације и стабилитет ферментације) и квалитет хлеба са влакнима (запремина и вредносни број средине) су статисички тестирани мултиваријаном методом Manova и дискриминативном анализом, при чему је доказано да постоји значајна разлика између теста без влакана и теста са различитом врстом влакана. Коефицијент дискриминације је показао да је највећи утицај влакана на завршну ферментацију је после 30 дана чувања (6,25) а на стабилитет ферментације (6,16) и квалитет хлеба (запремина хлеба 15,5 и вредносни број средине 3,64) код незамрзнутог теста.

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