Foods and Raw Materials, 2019, vol. 7, no. 1

E-ISSN 2310-9599
ISSN 2308-4057

Research Article
Open Access

DOI: http://doi.org/10.21603/2308-4057-2019-1-107-117
Available online at http:jfrm.ru

Effective technological scheme for processing triticale (*Triticosecale* L.) grain into graded flour

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Received September 29, 2017; Accepted in revised form February 15, 2018; Published June 08, 2019

Abstract: The present paper features Triticale grain processing. The research involved two Russian cultivars of Triticale grain, i.e. Ramzes and Saur. We investigated two schemes of processing these grain varieties into high-quality baker's grade flour. The first scheme was reduced and included only the processes of breaking and reduction, whereas the second scheme was more advanced and included breaking, sieving, sizing, and reduction processes. The paper gives a thorough description of the processing schemes, their parameters, and milling modes. A detailed analysis proved the high efficiency of the advanced scheme which presupposed the use of sieve purifiers. Their expediency was determined by the specifics of break dunst products at breaks I, II, and III. The Triticale flour varieties were produced by mixing various flows of the central, intermediate, and peripheral parts of the Triticale grain endosperm. The reduced scheme produced a 40% yield for the Ramzes variety (ash content = 0.70%, according to the State Standard 34142-2017*), while the advanced technological scheme resulted in a 63% yield. As for the Saur variety, the advanced scheme produced a total yield of 78%, which was 0.6% higher than in the reduced scheme. The advanced scheme resulted in a 46% yield of the T-60 flour variety, which had the lowest ash content among all the varieties of Triticale flour, whereas the reduced scheme failed to produce the flour of this variety. The experiment also involved the first-ever study of the rheological properties of Triticale flour varieties with Mixolab (Chopin Technologies, France). The study revealed significant differences in baking absorption, doughing time, batch, gluten, viscosity, amylase, and retrogradation. The best baking properties were displayed by T-70 and T-80 Triticale flours that were obtained from the central part of the endosperm, both in reduced and advanced processing schemes. However, the advanced scheme proved to be the most effective way of processing Triticale grain into baker's grade flour.

Keywords: Triticale grain, grain processing, reduced and advanced technological scheme, rheological and baking properties of flour

Please cite this article in press as: Kandrokov R.H., Pankratov G.N., Meleshkina E.P., Vitol I.S., and Tulyakov D.G. Effective technological scheme for processing triticale (*Triticosecale* L.) grain into graded flour. *Foods and Raw Materials*, 2019, vol. 7, no. 1, pp. 107–117. DOI: http://doi.org/10.21603/2308-4057-2019-1-107-117.

INTRODUCTION

The use of non-traditional grain products, such as Triticale, in various sectors of the food industry is currently attracting increasing attention of Russian researchers and manufacturers. The interest can be explained by the increasing acreage, new Triticale varieties, and numerous studies of their technological, biochemical, and biological potential [1–7].

Triticale is a laboratory-made hybrid of wheat and rye. Its nutritional values are superior to those of both parental plants [1]. In Russia, Triticale grain is currently used in compound feed and alcohol production. However, Triticale grain can substitute wheat baking flour as a very advantageous source of raw materials in the production of various pastries, e.g. cookies, biscuits, waffles, muffins, crackers, etc. Triticale flour can be used in the production of instant noodles and quick breakfasts, as well as dietary, therapeutic, and prophylactic bread varieties, e.g. wholegrain and multigrain bread [8–13]. In addition, Triticale grain can be used to manufacture mass-market pasta products. Other promising research areas are the technology of processing Triticale grain and bran for starch [15], dietary fibre [14, 16], and bio-

* State Standard 34142-2017 Triticale flour. Specifications. Moscow: Standartinform Publ., 2010. 8 p.

logically modified products [17, 18]. However, there is currently no industrial production of high-quality Triticale flour in Russia.

Over the past decade, foreign scientists have focused mainly on the biology of Triticale cultivars, their biological safety and development, the origin of hexaploid triticale, industrial production of triticale, its competitiveness with wheat, genomics, and biotechnology [19–28].

Until recently, Triticale grain has been considered as an analogue of rye, at least according to its technological properties [13]. However, Russian breeders have made it possible to develop and introduce new promising Triticale varieties into agricultural practice. These varieties have a predominance of wheat genotype, which affects the phenotypic characteristics of Triticale kernels, i.e. size, shape (sphericity coefficient ≥ 0.8), colour, as well as structural, mechanical, and technological properties [1].

The recent studies conducted have made it possible to obtain new data about the technological properties, biochemical composition, and varietal characteristics of Triticale grain and its products. The studies resulted in new technologies of Triticale flours production, as well as a new grit variety with specific properties that will be in demand in the baking, macaroni, confectionery, starch, meat, and other food industries [2, 3, 5, 7, 29, 30].

The present research aims at developing an effective technological scheme for processing Triticale grain into high-quality baker's grade flour.

STUDY OBJECTS AND METHODS

The experimental studies were conducted by the departments of complex grain processing and safety of grain and grain products at the All-Russian Scientific Research Institute for Grain and Products of its Processing (V.M. Gorbatov Federal Scientific Centre for Food Systems of the Russian Academy of Sciences). The experiment involved samples of two Triticale varieties: Ramzes (harvest 2014) and Saur (harvest 2015). Both cultivars were bred at the Don Zonal Research Institute of Agriculture (Rostov region, Russia). Table 1 shows the initial quality indicators of Triticale grain. The grain was prepared for milling according to the previously established parameters of hydrothermal treatment [2].

The milling was carried out on two milling and sorting aggregates: with fluted rollers (RSA-4-2) and with frosted rollers (RSA-4). The intermediate products were enforced in a laboratory sieve purifier. The set of sieves and the speed of the air flow depended on the size of the initial product. The milling products were sieved on a laboratory plansifter for 90 seconds. The parameters and regimes of milling corresponded to the 'Rules for organizing and conducting the technological process at flour mills'.

A research conducted in the laboratory 'Technology and equipment of the milling industry' (2014–2015) showed that the processing of Triticale grain into baker's grade flour is more similar to that of wheat in its technological properties [1, 13]. The grit formation process is characterized by a significant number of grits that consist of pure endosperms. The research employed the method of analysis developed for intermediate products of grain milling at the All-Russian Scientific Research Institute for Grain and Products of its Processing. According to the analysis, Triticale products were divided into 3 groups: the actual grits (particles of pure endosperm), clots of endosperm and shell, and tail-end products that differed in shape and colour. The analysis proved the need for the introduction of sieve purifiers [5]. The analysis also revealed a high content of grits in intermediate products of the high-quality milling of Triticale grain. Hence, it was found recommendable to extract the grits. The use of sieve purifiers in the high-quality milling of Triticale grain made it possible to increase the yield of top-quality flours, as well as to obtain granular substances and middling that can be used for pasta manufacturing.

The expediency of the extraction and enforcement of large-size grits of 560–950 micrometres (μm) was proved only for break I. It was revealed that middle-size grits (315–560 μm) were suspended during breaks I and II, while the small-size grits (224–315 μm) were suspended during breaks I, II, and III. The composition of the intermediate products of the fourth break was characterized mainly by the presence of bran particles with high ash content. Hence, it was found impractical for enforcement in a sieve purifier.

Thus, we developed an advanced technological scheme for milling Triticale grain with a sieve purifier and sizing. The scheme was based on the principle of gradual milling and sorting. The construction of the technological scheme was determined by the requirements for the finished products (quality and yield of flour), variety of grain, and productivity. The reduced technological scheme included four break systems (br.), six reduction systems (red.), and one scratch system (scr.) [22]. The technological process of the advanced scheme included four break systems, two sizing systems (sz.), three sieving (SV), and six reduction systems (red.) (Fig.1).

The break process of the advanced scheme consisted of the stage of grit formation (breaks I – II) and a scratch stage (break IV and reduction system VI). The sieving process involved a separate enforcing of large-size grits of the first break (SV-1), medium-size grits of break systems I + II (SV-2), and small-size grits of I + II + III breaks (SV-3) [5]. The parameters of the sieving process were characterized by extracting the tail-end fraction in an amount of at least 80% of the ini-

Table 1. Basic quality indicators of Triticale varieties

Triticale variety	Quality indicators				
	Mass of 1,000 kernels, g	Grain hardness, %	Grain-unit, g/l	Ash content, %	Moisture, %
Ramzes (2014)	31.8	18	625	2.07	10.2
Saur (2015)	33.2	44	661	1.99	9.3

tial mass. The through product of the sieve purifier SV-1 was directed to the frosted rolls of the first roller mill of the sizing system. The through product of sieve purifiers SV-2 and SV-3 were combined and directed for the milling to the roller mill of the first reduction system. Tailings from the first and second sieving systems, which made up 15–20%, were combined and sent for additional milling to the roller mill of the fifth reduction system. Tailings from the third sieving system were sent for additional milling to the roller grinding machine of reduction system IV.

The break systems used fluted rollers that were fluted back on the back. All the reduction and sizing systems used roller machines with frosted rolls. The modes of milling were characterized by a total 75% extraction of large-size dunst products and flour on grinding mill of breaks I, II, and III. The extraction mode on the grinding mill of the first break was 25–30%. The extraction mode on the grinding mill of sizing systems I, II, and III was 25–30%. The removal on the grinding mill of reduction systems I, II, and III was at least 50%.

The whiteness of Triticale flour was determined by measuring the reflectivity of a compacted smoothed flour surface with a photoelectric device. To determine the ash content, the flour and bran were burnt, and the mass of the non-combustible residue was measured. The baking absorption and the rheological properties were measured by recording the consistency of dough in the process of its formation from water and flour. The change in the consistency of the dough during kneading was measured with the help of a Mixolab system (Chopin Technologies, France). The baking properties were measured by using the method of laboratory bread ba-king from Triticale flour. The method involved the vo-lume (cubic centimetres) of bread made from 100 g of flour, as well as scoring the appearance and the bread crumb.

RESULTS AND DISCUSSION

The first stage of the research was devoted to studying the basic milling properties of the initial Triticale grain samples. After laboratory milling, we selected four flows of Triticale flour that were obtained both with reduced and advanced technological schemes.

Triticale flour varieties were formed by three flour flows: A, B, and C [3]. Stream A was the flour from the hcentral part of the endosperm obtained during reduction systems I, II, and III + sizing system I (advanced scheme) and the flour obtained on reduction systems I, II, and III (reduced scheme). Stream B was the flour from the peripheral part of the endosperm and the subaleurone layer obtained on the third and the fourth reduction systems and on breaks I, II, and III. Stream C consisted of endosperm fragments and shells from other technological systems.

Tables 2 and 3 present the quality indicators of Triticale flour flows of Ramzes and Saur varieties obtained according to different technological processing schemes.

Figs. 2 and 3 show cumulative ash curves of the reduction and quality formation processes for Ramzes and Saur flours. The cumulative curves (Figs. 1 and 2) demonstrate that the reduced scheme had three distinct stages of flour formation, where as the advanced technological scheme had two stages. A statistical analysis showed that cumulative curves can be represented as three and two linear segments for different milling schemes [3]. In case of Ramzes grain, the yield of T-70 Triticale flour (ash content ≤ 0.70%) was 40% for the reduced technological scheme. For the advanced technological scheme, the yield of T-70 flour was 63%. The overall yield of flour was higher by 3.4% according to the advanced scheme, as compared with the reduced scheme. However, the advanced scheme resulted in a 46% yield of T-60 flour variety, which has the lowest

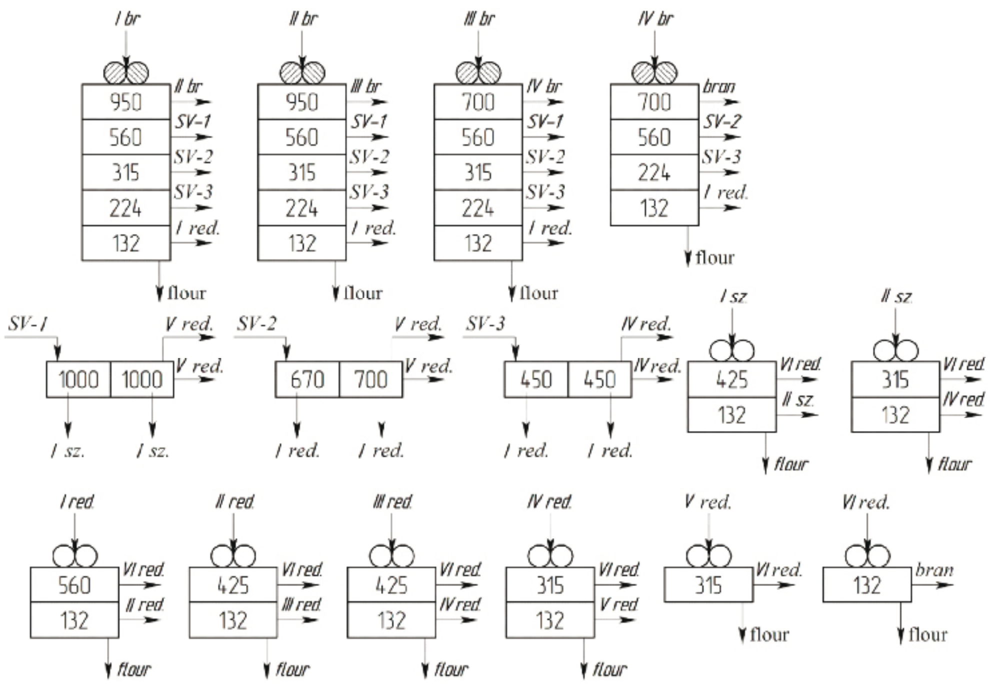

Fig. 1. Technological process of the advanced scheme for processing Triticale grain into high-quality baker's grade flour

Table 2. Quality indicators of Ramzes Triticale flour flows obtained according to different processing schemes

Product	Whiteness, conventional units		Ash content, %	
	Reduced scheme	Advanced scheme	Reduced scheme	Advanced scheme
Flour from:				
break I	45.0	46.7	0.87	0.69
break II	52.0	55.5	0.69	0.57
break III	51.7	46.5	0.84	0.74
break IV	29.4	33.8	1.59	1.27
sizing system I	–	57.9	–	0.64
sizing system II	–	45.4	–	0.83
reduction system I	50.0	60.7	0.71	0.50
reduction system II	48.7	54.2	0.70	0.57
reduction system III	44.0	41.4	0.69	0.85
reduction system IV	34.8	23.6	0.77	1.29
reduction system V	26.7	6.1	0.88	1.70
reduction system VI	13.3	–1.8	1.27	1.83
scratch system I	–5.9	–	1.63	–
Bran from:				
break systems	–	–	6.35	5.26
reduction systems	–	–	3.94	4.43

Table 3. Quality indicators of Saur Triticale flour flows obtained according to different processing schemes

Product	Whiteness, conventional units		Ash content, %	
	Reduced scheme	Advanced scheme	Reduced scheme	Advanced scheme
Flour from:				
break I	45.3	42.5	0.67	0.77
break II	51.8	55.1	0.57	0.50
break III	53.1	40.1	0.56	0.82
break IV	38.3	22.6	1.05	1.91
sizing system I	–	62.7	–	0.63
sizing system II	–	55.5	–	0.65
reduction system I	48.4	65.1	0.59	0.54
reduction system II	50.6	60.8	0.58	0.53
reduction system III	42.7	53.3	0.77	0.60
reduction system IV	29.2	43.3	1.02	0.75
reduction system V	15.7	25.8	1.28	1.19
reduction system VI	1.6	6.3	1.73	1.53
scratch system I	–16.6	–	2.17	–
Bran from:				
break systems	–	–	5.89	7.05
reduction systems	–	–	4.45	4.16

ash content (State Standard 34142-2017**). The reduced scheme resulted in 0% of T-60 flour.

When processing Saur grain variety, the yield of T-70 Triticale flour was 73% according to both schemes (Table 3). The overall flour yield increased by 0.6%. The advanced processing scheme resulted in obtaining 42% of Triticale flour with ash content ≤ 0.55%.

The second stage of the research featured the rheological properties [31] of ten separate flows of Triticale flour from Saur grain variety, obtained according to the advanced technological scheme by using a Mixolab system (Chopin Technologie, France). The Chopin+ protocol presupposes 5 research phases. Stage I lasts 8 min at 30°C; stage II lasts 15 minutes with a consistent increase in temperature at a rate of 4°C per minute from 30 to 90°C; stage III lasts 8 min at 90°C; stage IV lasts 10 min, with a consistent decrease in temperature from 90 to 50°C; stage V lasts 5 min at 50°C. The rotational input in the analyzed points of the graph, from the point of view of biochemical processes, characterizes: formation of the dough (C1); dough dilution (C2); the maximum rate of starch gelatinization (C3); and the beginning and the end of the retrogradation of starch (C4 and C5). ά, β, and γ are the rates of biochemical reactions (calculated values). The analysis also included the following indicators: the baking absorption of the dough, %; dough formation time, min; dough stability, min. The data of the integral evaluation of the rheological properties of the dough are visualized on the graph of the rotational input versus time in a particular temperature mode (Fig. 4, Tables 4 and 5) [31–33].

** State Standard 34142-2017. Triticale flour. Specifications. Moscow: Standartinform Publ., 2010. 8 p.

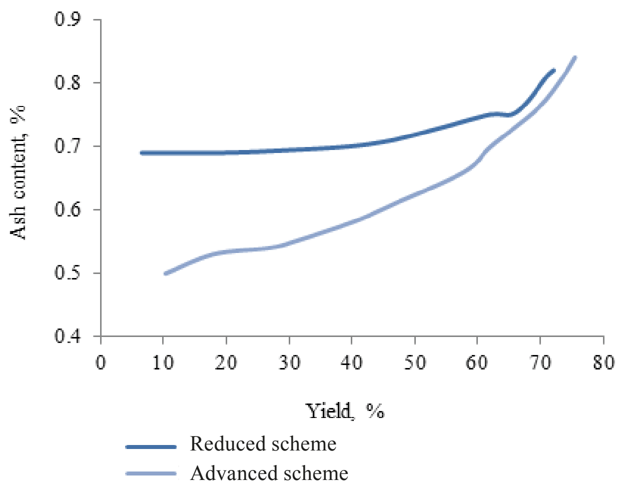

Fig. 2. Cumulative curves of ash content in Ramzes flour

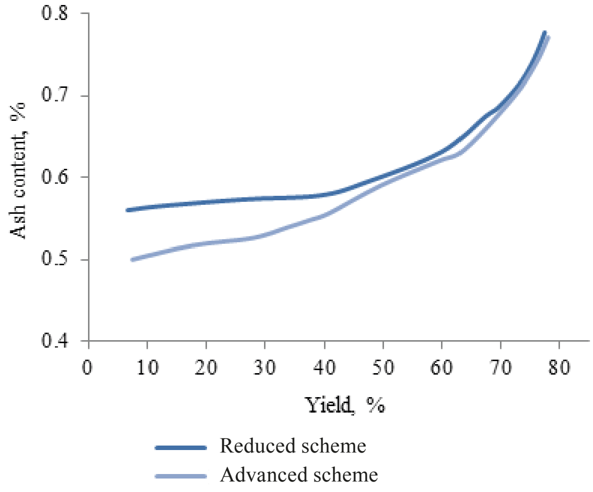

Fig. 3. Cumulative curves of ash content in Saur flour

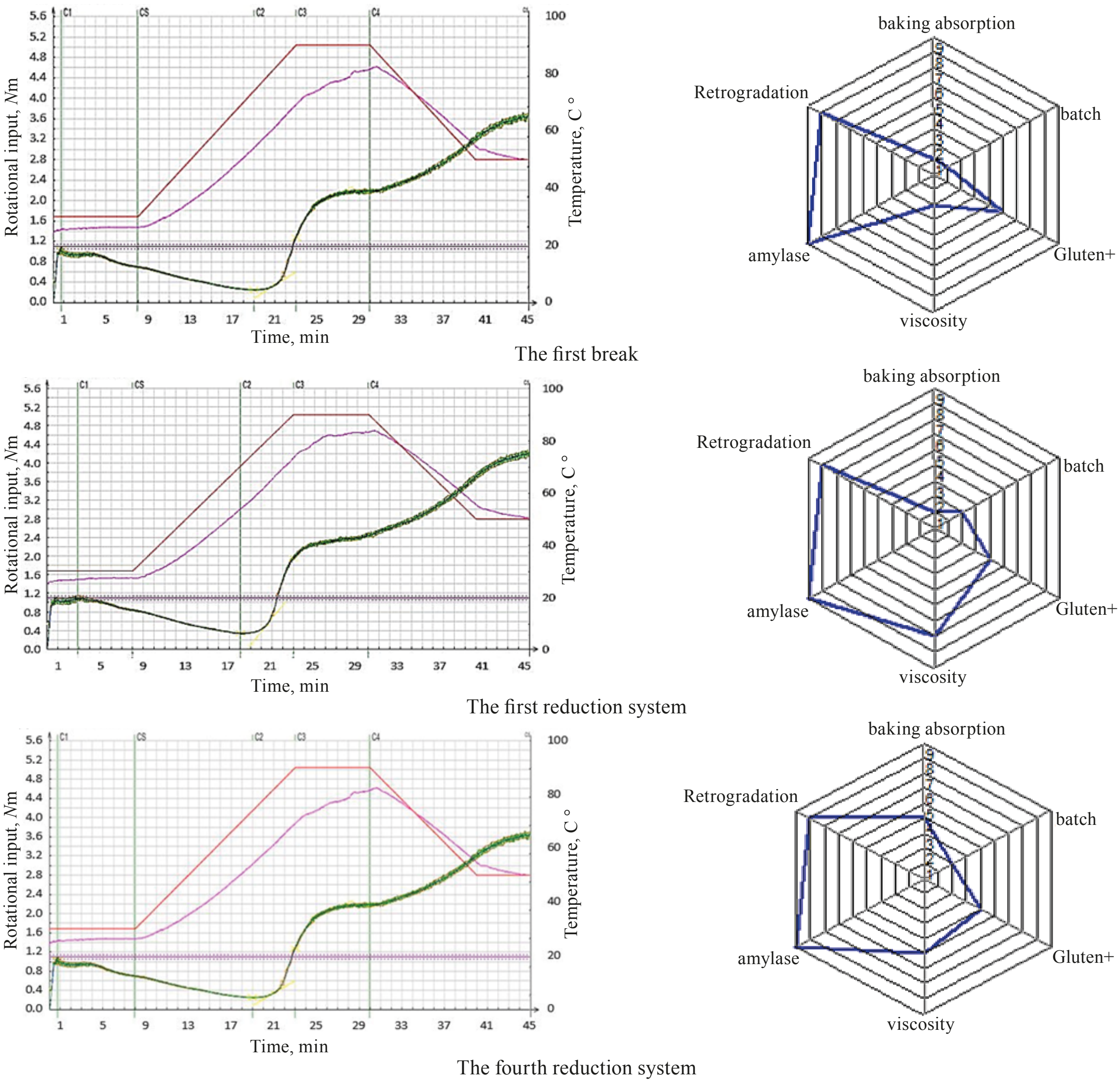

Fig. 4. Phases of rheological analysis of the dough and Mixolab profiles of Triticale Saur flour flows from different technological systems.

The rheological analysis made it possible to create graphical profiles inherent in each flow of Triticale flour. Fig. 4 shows the phases of the rheological analysis of the dough and the Mixolab profiles of the three flour flows: break I, reduction systems I and IV, since they demonstrated the greatest differences.

The viscosity value was different: 2, 7, and 5 scores for break I, reduction system I, and break system IV, respectively. It should be mentioned that viscosity depends on the state of starch, the activity of amylases, and the peripheral parts that contain non-starchy polysaccharides. The amylase index depends on the amylolytic activity of the flour. The higher it is, the lower the activity of enzymes. The starch retrogradation index is related to the rate of staling of the finished product. Its high value indicates a faster rate of staling.

Table 4 demonstrates that the baking absorption increased from the first reduction system to the sixth reduction system, which was connected with a larger number of peripheral water-absorbing particles in the flour. The first, second, and third breaks also showed an increase in baking absorption. The sizing system occupied an intermediate position between the break and the reduction systems. Its baking absorption was 55.0%.

During the first stage (C1), the flow stability was uneven. However, the stability time tended to decrease from reduction systems I – VI, which could also be connected with an increase in the content of peripheral particles and a decrease in the dough formation time.

At the second stage (C2) of the curve of the mixolabogram, one can observe the smallest rotational input, which is associated with the dough dilution and indirectly characterizes the state of the protein complex. Viscosity increased from breaks I – III. The sizing system had the lowest viscosity. The reduction systems demonstrated an increase in rotational input followed by its decrease, which was apparently due to an increase in the share of peripheral fractions in the flour of these systems.

During the third stage (C3), the starch granules broke down and gelatinized, which led to an increase in rotational input. There was a clear dependence of the increase in the rotational inputon the grain-size composition of the flour at the break system and its reduction at the reduction system.

During the fourth stage (C4), one could observe a gradual increase in the rotational input of the break systems and its decrease during the final reduction systems. The highest rotational input was registered during the second reduction system.

Table 6 visualizes the rheological characteristics of the flows as six consecutive indices: the index of water absorption index, the mixing index, the gluten index, the viscosity index, the amylase index, and the starch retrogradation index.

The fifth stage (C5) characterized the process of starch retrogradation during cooling and the rate of staling of the finished flour products. Here, the rotational input on the reduction systems fell significantly from 4.221 Nm on reduction system I to 2.731 Nm on reduction system I.

Table 4. Main parameters of the phases of rheological analysis of the dough of individual flows of Saur Triticale flour

Flour sample from:	Water absorption, %	Stability, min	C1	C2	C3	C4	C5
break I	54.2	4.42	1.030	0.253	1.273	2.178	3.644
break II	53.1	3.87	1.109	0.286	1.401	2.294	3.766
break III	53.5	4.78	1.226	0.335	1.809	2.245	3.529
sizing system I	55.0	5.23	0.992	0.299	2.031	2.438	3.859
reduction system I	54.1	5.62	1.093	0.335	1.947	2.449	4.221
reduction system II	55.0	5.72	1.159	0.367	2.035	2.490	4.150
reduction system III	57.0	5.42	1.156	0.372	1.820	2.441	3.957
reduction system IV	57.6	5.65	1.081	0.337	1.752	2.258	3.489
reduction system V	57.7	5.05	1.113	0.329	1.497	1.953	3.059
reduction system VI	58.3	4.62	1.236	0.354	1.875	1.826	2.731

Table 5. Calculated values of reaction rates * for individual flows of Saur Triticale flour

Flour sample from:	α, Nm/min	β, Nm/min	γ, Nm/min	Rotational input, Nm/min	Amplitude, Nm/min
break I	–0.036	0.130	0.088	3.644	0.134
break II	–0.056	0.160	0.078	3.766	0.141
break III	–0.064	0.374	0.010	3.529	0.140
sizing system I	–0.056	0.322	0.032	3.859	0.103
reduction system I	–0.060	0.286	0.038	4.221	0.108
reduction system II	–0.062	0.416	0.042	4.150	0.141
reduction system III	–0.056	0.292	0.020	3.957	0.168
reduction system IV	–0.058	0.316	0.020	3.489	0.073
reduction system V	–0.052	0.206	0.028	3.059	0.097
reduction system VI	–0.060	0.388	0.022	2.731	0.154

*) α is characteristic of the dilution reaction rate expressed by the angle of the tangent to the mixolabogram from the moment the temperature reaches 30°C to the point C2; β is characteristic of starch gelatinization reaction rate, expressed by the angle of the tangent to the mixolabogram on the C2 – C3 segment; γ is characteristic of the amylolysis rate, expressed by the angle of the tangent to the mixolabogram in the C3 – C4 segment.

Table 6. Indices of the Mixolab profiles for Saur Triticale flour

Flour sample from:	Indices of the Mixolab profiles					
	Water absorption index	Mixing index	Gluten index	Viscosity index	Amylase index	Starch retrogradation index
break I	1	1	5	2	9	8
break II	1	0	5	3	9	8
break III	1	2	2	6	8	8
sizing system I	2	1	5	8	8	8
reduction system I	1	2	4	7	9	8
reduction system II	2	2	3	8	9	8
reduction system III	3	2	3	6	9	8
reduction system IV	4	2	4	5	9	8
reduction system V	4	2	4	3	8	7
reduction system VI	5	2	3	3	8	7

The analysis of the graphical profiles (Fig. 4, Table 5) showed that the highest value of the baking absorption index was registered in the flour from the sixth reduction system. The high water absorption capacity could be explained by the fact that the system contained the largest number of peripheral parts of the kernels. The mixing index was related to the stability of the dough during kneading, which was 4.42 min for break I (1 score), 5.62 min for reduction system I (2 scores), and 5.65 min for reduction system IV (2 scores). The gluten index characterizes the stability of protein molecules when the dough was heated from 30°C to 60°C. It is rather difficult to interpret the gluten index since two very important phenomena occurred while the dough was being heated. First, starch granules began to swell; second, their structure remained unchanged, while the effect of α-amylase was insignificant. The consistency of the dough changes due to the changes in the structure of gluten proteins: hydrogen bonds break, stability of proteins improves, which is also related to their spatial structure, and, ultimately, the nature of these protein complexes [34, 35]. Such fractions of gluten proteins as gliadin and glutenin play a decisive role in gluten quality formation and its elastic properties. However, it is necessary to take into account the role of other compounds that interact with gluten proteins and affect the structure and properties of gluten. They are lipids, carbohydrates, and enzymes, namely proteases and their protein inhibitors, amylases, lipoxygenase [36].

The viscosity index scored 2 for the flour from break I, 7 for the flour from reduction system I, and 5 for the flour from reduction system IV. This indicator characterizes the phase at which the greatest number of physicochemical and biochemical parameters start to interact. It should be mentioned that the viscosity in these samples depended not only on the activity of amylases, but also on the state of starch, its quality characteristics, and the presence of peripheral parts containing non-starch polysaccharides. The amylase index indirectly characterizes the amylolytic activity of the flour. A high amylase index indicates a weak activity of α-amylase in all the flour flows. The starch retrogradation index is connected with the ability of the finished product to resist staling. A high value of this indicator characterizes a faster staling rate.

At the third stage of the research, we studied the samples of Ramzes and Saur Triticale flour from different flows to determine the baking properties. To form a Triticale flour variety, three flows had to be formed on the basis of cumulative ash curves. These flows were three components of different anatomical parts of the kernels (Z – ash content, Y – yield). The first flow was Triticale flour from the central part of the endosperm, the second flow contained the peripheral part of the endosperm and the subaleurone layer, and the third flow was the flour from endosperm fragments and well-grin-ded shells. Below one can see the algorithm for the formation of three flows that form the Triticale flour varieties.

Flow formation for the Ramzes Triticale flour:

Milling 1 (reduced scheme):

Flow A – break II + reduction system III + reduction system I.

Total: yield/ash content was 29.6/0.69; $Z_A = 0{,}686 + 0.302\times10^{-3}\ Y_A$; $R^2 = 0.82$.

Flow B – reduction system I + reduction system IV + break III + break II + reduction system V.

Total: yield/ash content 35.8/0.80; $Z_B = 0.615 + 0.211\times10^{-2}\ Y_B$; $R^2 = 0.98$.

Flow C – reduction system VI + break IV + break V.

Total: yield/ash content was 6.7/1.50; $Z_C = 0.080 + 0.011\ Y_C$; $R^2 = 0.99$.

Milling 2 (advanced scheme):

Flow A + B – reduction system I + reduction system II + break II + sizing system I + break I + break III + sizing system II + reduction system III.

Total: yield/ash content was 57.9/0.66; $Z_A = 0.462 + 0.319\times10^{-2}\ Y_A$; $R^2 = 0.97$.

Flow C – break IV + reduction system IV + reduction system V + reduction system VI.

Total: yield/ash content was 17.6/1.43; $Z_C = 0.086 + 0.990\times10^{-2}\ Y_C$; $R^2 = 0.99$.

Flow formation for the Saur Triticale flour:

Milling 1 (reduced scheme):

Flow A – break III + break II + reduction system II + reduction system I.

Total: yield/ash content was 39.3/0.58; $Z_A = 0.558 + 0.544\times10^{-3}\ Y_A$; $R^2 = 0.98$.

Flow B – break I + reduction system III + reduction system IV + reduction system V.

Table 7. Quality indicators for samples of Triticale grain flour

№	№ of milling, Triticale variety	Flour variety	Moisture, %	Gluten, %	Gluten quality		Falling number, sec
					Gluten Deformation Measurement	group	
1	Ramzes, milling 1	T-80	11.0	20.6	49	II (strong enough)	336
2	Ramzes, milling 1	T-120	11.0	19.5	50	II (strong enough)	322
3	Ramzes, milling 1	T-70	10.6	26.2	52	II (strong enough)	168
4	Ramzes, milling 2	T-80	11.0	26.7	71	I (good)	178
5	Ramzes, milling 2	T-120	10.8	20.8	46	II (strong enough)	305
6	Ramzes, milling 2	T-70	11.0	25.9	76	I (good)	167
7	Saur, milling 1	T-70	10.6	27.2	67	I (good)	171
8	Saur, milling 1	T-120	11.6	20.9	38	II (strong enough)	353
9	Saur, milling 1	T-80	9.8	27.6	66	I (good)	167

Table 8. Results of trial laboratory baking

№	Volume yield, cm^3/100 g		Shape stability	Weight, g		Appearance		
	Tin formed bread	Oven-bottombread		Tin formed bread	Oven-bottom bread	Shape	Crust surface	Crust colour
1	350	400	0.48	135	132	regular, semi-oval	slightly nodular	pale
2	350	350	0.48	136	132	regular, semi-oval	cracked crust	pale
3	390	380	0.45	135	133	regular, semi-oval	smooth, level	brown
4	430	450	0.51	134	128	regular, semi-oval	smooth, level	brown
5	380	400	0.52	140	134	regular, semi-oval	smooth, level	pale
6	460	470	0.58	134	130	regular, oval	smooth, level torn from three sides	brown
7	470	470	0.57	135	131	regular, semi-oval	smooth, level	brown
8	340	370	0.67	134	129	regular, semi-oval	smooth, level	pale
9	420	450	0.50	133	127	regular, semi-oval	smooth, level	brown

Total: yield/ash content was 30.3/0.83; $Z_B = 0.396 + 0.410\times10^{-2}\ Y_B$; $R^2 = 0.97$.

Flow C – reduction system V + reduction system VI + break IV.

Total: yield/ash content –was 7.8/1.58; $Z_C = -0.111 + 0.011\ Y_C$; $R^2 = 0.97$.

After that, the Triticale flour flows from different technological systems were mixed in order to obtain individual types of flour. As a result, three types of flour were obtained in accordance with the State Standard 34142-2017*** 'Triticale flour. Technical conditions': T-70, T-80, and T-120. The conventional name for the varieties includes the T index (Triticale), and a number that stands for the ash content × 100. Thus, T-60 flour was flow A with 0.60% ash content; flour T-70 was a mixture of A + B flows with 0.70% ash content; flour T-80 was a mixture of streams B + C with 0.80% ash content; flour T-120 was a mixture of flows A + B + C with 0.12% ash content.

All the formed triticale flour samples were analysed for such quality indicators as humidity, the quantity and quality of gluten, and the falling number (Table 7).

At the fourth stage of the research, we defined the baking properties of the nine samples of Triticale flour varieties, obtained according to different technological schemes (Table 8). The bread was baked from Triticale flour of various varieties according to the methodology of the State Committee on Agriculture. The volume yield for one tin formed bread was 340–470 cm^3/100g of flour and 350–470 cm^3/100g of flour for one oven-bottom loaf.

Tables 8 and 9 represent the results of the trial laboratory bread baking from nine samples of Triticale flour.

The tin formed bread baked from T-70 Saur flour had the largest volume yield, while the smallest volume yield belonged to the bread baked from T-120 Ramses flour (Fig. 5). The tin formed bread sample made from T-120 Ramses flour had the largest weight, whereas the lowest weight was registered for the sample made from T-80 Saur flour. Patterns with a smooth level surface had are regular semi-oval shape (samples 3–5, 7–9). Sample 1 had a slightly nodular surface. Sample 2 had a cracked crust; sample 6 was torn at three sides, respectively. The colour of the crust in samples 1, 2, 5, and 8 was pale due to the low activity of amylolytic enzymes. Samples 3, 4, 6, 7, and 9 had a brown crust. All the samples demonstrated a good crumb resilience and fine texture with uneven porosity. The thickness of the pore walls was found thick-walled and poorly developed for samples 1, 2, and 8. The taste was typical of Triticale flour bread. No stickiness, crunch, or crumbling were registered in any of the samples.

The best volume yield and total bakery assessment results belonged to the following samples: samples of Ramzes T-70 and T-80 (advanced scheme), Ramzes T-70 (reduced scheme), and Saur T-70 and T-80 (reduced scheme). These loafs also demonstrated the highest sensory assessment results (5 scores). The worst total bakery assessment belonged to the sample made from T-120 Ramzes Triticale flour (advanced scheme).

*** State Standard 34142-2017. Triticale flour. Specifications. Moscow: Standartinform Publ., 2010. 8 p.

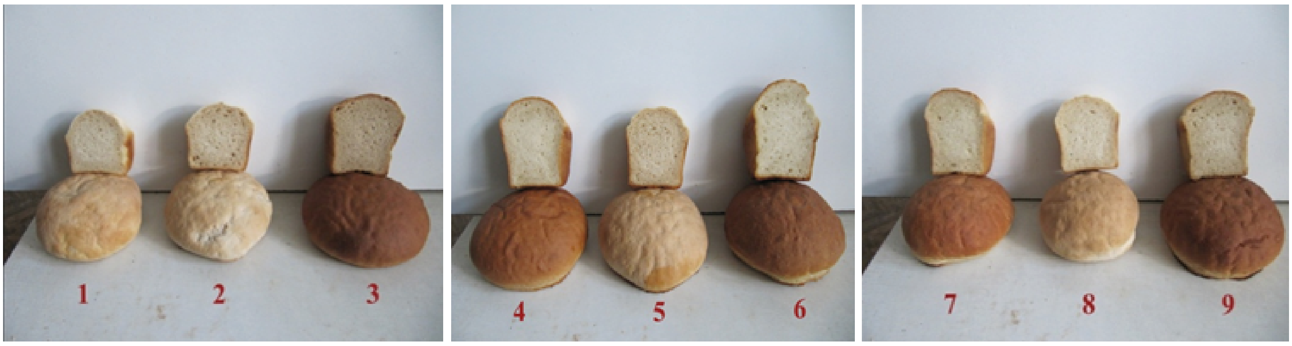

Fig. 5. Bread baked from the obtained varieties of Triticale flour

Table 9. Results of the trial laboratory baking

№	Porosity, %	Crumb condition		Sensory assessment	
		Elasticity, evenness, colour	Porosity	Appearance	Crumb
1	74	elastic, good, creamy-pale	fine, thick-walled, uneven, poorly developed	3	3
2	73	elastic, good, creamy	fine, poorly developed, thick-walled, uneven	2	3
3	78	elastic, good, dark	fine, thick-walled	5	5
4	81	elastic, good, creamy	fine, thick-walled	5	5
5	77	elastic, good, creamy-pale	fine, uneven	4	4
6	81	elastic, good, unevenly creamy-pale	fine, thin-walled	5	5
7	81	elastic, good, creamy-pale	fine, thin-walled	5	5
8	78	elastic, good, creamy-pale	poorly developed crumb	4	4
9	81	elastic, good, creamy-pale	fine, thin-walled, uneven	5	5

CONCLUSION

The research proved that, if processed according to the advanced technological scheme, Triticale grainincreases the total yield of flour by 0.6–3.4% compared to the reduced technological scheme. However, when Ramzes variety was processed according to the advanced scheme, the yield of T-60 flour with the lowest ash content (according to State Standard 34142-2017****) was 46%, and the reduced scheme failed to produce the T-60 flour at all. When Saur variety was processed according to the advanced scheme, it gave a 55% yield of T-60 Triticale flour, where the reduced scheme resulted in 48%.

The study also helped to establish the effect of the grain hardness on the grit formation and on the yield of graded flour.

Sieve purification of intermediate Triticale products proved to increase the yield of flour from the central part of endosperm and the total yield of graded flour.

The cumulative ash curve for Triticale flour processed according to the advanced technological scheme can be represented in the form of two, rather than three linear sections that are used to describe the reduced scheme.

The rheological properties of Triticale flour from various technological systems (flows) clearly demonstrated a regular increase in the baking absorption. Moreover, stability time during dough kneading decreased as the number of peripheral parts of the kernel. The state of protein-proteinase and carbohydrate-amylase complexes of individual flour flows had a more significant influence on the viscosity index. Other factors included non-starch polysaccharides from the peripheral parts of the grain. The index rose between the first and the third breaks and fell between the first to the sixth reduction systems.

T-70 and T-80 Triticale flour varieties, obtained from the central part of the endosperm, have excellent baking properties, both according to the reduced and the advanced schemes.

The advanced scheme with breaking, sieving, sizing, and reduction systems proved to be the most effective way to process Triticale grain into high-quality baker's grade flour.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this article.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to Professor A.I. Grabovets, Doctor of Agricultural Science, Head of the Department of Wheat and Triticale Breeding and Seed Production (Don Zonal Research Institute) for the Triticale grain samples.

FUNDING

The studies received governmental funding in the framework of research project No. 0586-2014-0002 for 2015-2017 'Development of biomechanical models for the transformation of wheat, oats, and triticale grain with the aim of their deep processing and obtaining new food products and ingredients for general and functional purposes'.

**** State Standard 34142-2017. Triticale flour. Specifications. Moscow: Standartinform Publ., 2010. 8 p.

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