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Evaluation of the Triticale Flour Blend Dough in the Mixing and Fermentation Processes

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Abstract**—**The research was accomplished on triticale flour blend, which was made from whole grain triticale, rye, hull-less barley flour and rice, maize flour. The aim of this research was to evaluate physico-chemical and sensory properties of triticale flour blend dough in the mixing and fermentation processes. For dough making was used triticale flour blend, yeast, sugar, salt, and water. In the mixing process ware evaluated moisture, acidity, pH, and dough sensory properties (softness, viscosity, and stickiness), but in the fermentation process ware evaluated volume, moisture, acidity, and pH. During present research was established that increasing fermentation temperature and time, increase dough temperature, volume, moisture, and acidity. The mixing time and fermentation time and temperature have significant effect ($p<0.05$) on triticale flour blend dough physico-chemical and sensory properties.

Keywords**—**Dough quality, dough fermentation**,** dough mixing, triticale flour blend.

I. Introduction

TRITICALE (*Triticosecale Wittmack*) is the first man-made cereal produced by crossing wheat (*Triticum* spp.) and rye (*Secale ceral* L.). The future of this crop is bright because it is environmentally more flexible than other cereals and shows better tolerance to diseases, drought, and pests than its parental species [1]. From the nutritional point of view, triticale has valuable dietary characteristics such as higher amounts of soluble dietary fiber and better total amino acid composition, in particular higher lysine as compared to wheat [2]. Also, triticale is capable of producing more biomass and grain yield compared with other cereals. This is particularly true in stress-prone ecologies where soil moisture is limiting, in areas with extreme temperatures and soil pH levels, and soil salinity. Triticale produces grain yields comparative to that of wheat and rye under optimal growing conditions and out-competes wheat and rye when conditions are less favorable [3]. Triticale is used mainly as a feed crop but it can be milled into flour and used to make bread, although adjustments are needed in recipe formulation because it does not have the same gluten content as wheat [4]. Triticale can be used as a replacement for soft wheat in biscuits, cakes, and cookies [5].

The technical information necessary for the evaluation of the flour quality is obtained on the basis of some indices determined through the organoleptical, chemical, rheological, and technological analyses. The number of the testing methods for defining the characteristics of flours is rising continuously, as a result of the striking necessity to anticipate their technological behavior [6].

The processing of bread can be divided into three basic operations: mixing or dough formation, fermentation, and baking.

The mixing process is the crucial operation in bakery industry by which the wheat flour, water, and additional ingredients are changed through the mechanical energy flow to coherent dough. The dough properties are strongly influenced by the way of their mixing [7]-[9]. The mixing process develops the dough into a three-dimensional viscoelastic structure with gas-retaining properties and incorporate air which will form nuclei for gas bubbles that grow during dough fermentation [10], [11].

In the process of fermentation, yeast produces carbon dioxide, alcohol and other compounds which enable dough to rise and modify its physical properties. It is essential step in the bread making technology in providing a link between the bubble structure created in the mixer and the final baked loaf structure [12], [13]. Fermentation of the sugars in bread dough produces carbon dioxide which diffuses through the dough matrix into the gas cell nuclei formed during dough mixing, the void fraction of the dough increases and dough density decreases [14].

The objectives of fermentation are to bring the dough to an optimum condition for baking. As with most of the processing steps an optimum level of fermentation depends on many factors, which include flour strength, enzymatic activity of the flour, formulation, yeast activity and the type of product desired [15]. During fermentation the dough development is continued, i.e., the dough becomes drier, less sticky, and much more elastic, and gas retention is improved [16].

After proof the dough must be heat-set, that is baked. The process is one of conversion of foam to a sponge [17].

Physical properties of flour and dough can affect the quality of the end products [18].

For expanding the range of bakery and pastry production in the world there are being developed various recipes for product enriching with fiber, especially β-glucan, proteins, vitamins, and other nutrients for a healthier diet. It can be done making a flour blend from whole grain triticale, rye, hull-less barley, rice, and maize flour. Thus, the aim of this research was to evaluate physico-chemical and sensory properties of triticale flour blend dough in the mixing and fermentation processes.

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II. Materials

Experiments were carried out in the Department of Food Technology at the Latvia University of Agriculture. Triticale, rye, and hull-less barley crops were harvested at the Priekuli Plant Breeding Institute (Latvia), rice and maize flour purchased from Joint Stock Company *Ustukiu Malunas* (Lithuania) were used in the current study. Triticale, rye, and hull-less barley were ground in a laboratory mill Hawos (Hawos Kornmühlen GmbH, Germany) obtaining whole grain fine flour. Flour blend was made from 60% of whole grain triticale, 15% of whole grain rye, 15% of whole grain hull-less barley, 5% of rice and 5% of maize flour. Ingredients, such as sugar, salt, water, and yeast are included in dough formulation in order to improve sensory properties and keep quality of bakery products.

III. Methods

A. Dough Preparation

All flour samples were mixed together in one flour blend. For dough sample preparation there was used flour blend (250g), dried yeast (7.8g), sugar (4.5g), salt (3.8g), and water (170ml). Water temperature was calculated from (1) and it was adjusted accordingly before adding to flour.

$$T_{water} = (2 \times T_{dough}) - T_{flour} \quad (1)$$

where:
T_{water} – temperature of the water, ºC;
T_{dough} – required dough temperature, ºC;
T_{flour} – temperature of the flour, ºC.

1. Mixing

Dough was mixed for duration of 6, 8, 10 or 15 minutes. In the research was done at three dough temperatures 20, 25, and 32°C for each mixing duration. For mixing process was used spiral type dough mixer "Kenwood KM400". Kneading time for each time was divided into stages:

- 6 minutes – the dough is mixed with one speed (slow);
- 8 minutes – 6 minutes slow, 2 minutes – fast;
- 10 minutes – 6 minutes slow, 4 minutes – fast;
- 15 minutes – 8 minutes slow, 5 minutes – fast, and 2 minutes – slow.

2. Fermentation

The dough fermentation process was completed at three fermentation temperatures 30, 35, and 40°C. Mixed samples were fermented for 10, 20, and 30 minutes. Physico-chemical properties were evaluated in mentioned fermentation times and temperatures.

B. Sensory Evaluation of Dough

The sensory analysis of dough was carried out by five experts assigning a score for dough sensory properties – consistency, extensibility and stickiness (Table I).

TABLE I
Sensory Properties of Dough

Sensory properties	Characterization	Quality number	Dough quality
Consistency	Soft, easily be formed, not dense	3	very good
	Average soft, slightly dense	2	average
	Very soft or dense, hard to form	1	unsatisfactory
Extensibility	Extensible, similar to the rye dough	3	very good
	A bit extensible	2	average
	Not extensible, immediately breaks down	1	unsatisfactory
Stickiness	A bit sticks around the mixer pot edges and arms	3	very good
	In mixing process sticks around the mixer pot edges	2	average
	Very sticky, in mixing sticks around the mixer pot edges	1	unsatisfactory

Higher total quality number (the sum of individual quality numbers), better quality of the dough.

C. Dough Physical-Chemical Properties

The following physical characteristics were analyzed.

- *Moisture content* of the triticale flour blend dough samples were determined using air-oven method (AACC, Method 44-15A, 2000).
- *Dough volume* was measured using 250ml marked container and its marking line starts from 1cm ($50cm^3$) to 6cm ($450cm^3$) where each 0.1cm are $8cm^3$. The average dough mass in container was 202.99±2.04g and average volume of dough samples before fermentation was 198.44±9.24.
- *pH* was measured by JENWAY 3510 pH-meter, Standard method LVS ISO 5542:2010.
- *Total titrable acidity (TTA)* was determined by titration, where a 10g sample was blended with 90ml distill water and the suspension was then titrated with a 0.1 mol/L NaOH to a final pH of 8.5. The TTA was expressed as the amount (ml) of NaOH used.

D. Statistical Analysis of Data

All analyses were performed in triplicate. The mean, standard deviation and p value were processed by mathematical and statistical methods. The data were subjected to one-way and two-way analysis of variance (ANOVA) by Microsoft Office Excel 2007; significance was defined at $p<0.05$.

IV. Results and Discussion

Mixing process can be affected by the parameters of mixer as mixer geometry, speed of mixing and added water temperature [19]-[21], which play a key role during formation of dough matrix and final quality of bakery products [22]. But, the purpose of fermentation is to bring dough to the optimum condition for baking. The amount of produced CO_2 depends on yeast, flour properties and fermentation temperature under standard conditions of the dough preparation which have strong effect on the final product quality [23].

A. Influence of Mixing Process on Dough Properties

For successful choice of the optimum mixing time and dough temperature for triticale flour blend dough, it is necessary to evaluate sensory properties (softness, viscosity and stickiness) of the dough after mixing. During mixing process there were selected four mixing times (6, 8, 10, and 15 minutes) and for each time three dough temperatures (20, 25, and 32°C), then after mixing was evaluated sensory properties, that are shown in Table II.

TABLE II
EVALUATION OF TRITICALE FLOUR BLEND DOUGH SENSORY PROPERTIES

Mixing time and temperature of dough	Sensory properties of dough			Total quality number
	Consistency	Extensibility	Stickiness	
6 min 20 °C	2	1	3	6
6 min 25 °C	2	2	2	6
6 min 32 °C	3	3	2	8
8 min 20 °C	2	1	3	6
8 min 25 °C	3	3	2	8
8 min 32 °C	1	1	1	3
10 min 20 °C	2	1	2	5
10 min 25 °C	3	3	2	8
10 min 32 °C	1	1	1	3
15 min 20 °C	3	1	2	6
15 min 25 °C	1	1	1	3
15 min 32 °C	1	1	1	3

Evaluating dough characteristics in Table II, it can be concluded that the best properties (total quality number 8) of triticale flour blend dough have the samples which were mixed for 6 minutes at dough temperature 32°C, 8 minutes at dough temperature 25°C, and 10 minutes at dough temperature 25°C. Samples which were mixed for 6, 8, and 10 minutes at dough temperature 20°C, they were dense and it was difficult to form them.

During mixing, the energy flow and the hydration processes are accompanied with a temperature increase. The temperature growth is dependent on the speed of mixing, but it is assumed that heating of dough during mixing is influenced by the type of the flour used and also by the type of mixer [9].

Samples which were mixed for 15 minutes at dough temperature 20, 25, and 32°C, were sticky and at the end of mixing time the dough sticked around the mixing pot edges. Fig. 1 shows the triticale flour blend dough which was mixed for long time (15 minutes) making sticky structure.

Fig. 1 Sticky and long mixed triticale flour blend dough

Samples which were mixed for 8 and 10 minutes at dough temperature 32°C were very sticky, that means the dough temperature was too high and the mixing time was too long. Therefore, choosing a longer mixing time cooler temperature of the dough should be selected.

From [24], [25] it is known that the mixing time and temperature are very important in mixing process - choosing longer mixing time and higher temperature of the dough, the dough is formed sticky and its structure can be broken down, but using low temperature and short mixing time, the dough is dense and not sufficiently flexible.

Wherewith, evaluating the sensory properties of dough, for the further studies the selected triticale flour blend dough samples were those which were mixed for 6 minutes, dough temperature 32°C, for 8 and 10 minutes, dough temperature 25 °C. These samples were used for evaluation of physic-chemical parameters in the dough mixing and fermentation processes.

Water assists in the control of dough temperatures and warming or cooling of dough can be regulated through water temperature. Cold water will generate cooler dough, while warmer water will create warmer dough [17].

In order to get the triticale flour blend dough with 32°C temperature that is mixed for 6 minutes, it was necessary to add water at a temperature of 42.93±0.05°C, wherewith at the end of mixing process obtaining dough temperature of 32.22±0.37°C. But, in the 8 and 10 minutes of mixing process, adding water of temperature 20.38±0.63°C, the dough temperature at the end of mixing was 25.35±0.35°C. The dough temperature can be influenced by the selected type of mixer, flour and the ambient temperature.

Considering the conditions and the choice of the mixer type, it is possible to provide a constant temperature of the dough. In the research flour temperature was 19.54±0.15°C and in the room where dough was prepared the temperature was 20.04±0.06°C.

Evaluating the dough acidity, pH and moisture values in the mixing process (Table III), it can be seen that the mixing time did not have significant ($p>0.05$) influence on the triticale flour blend dough acidity, pH, and moisture.

TABLE III
EVALUATION OF MIXED DOUGH PH, ACIDITY AND MOISTURE

Sample	Physical property values		
	pH	TTA[a] (mL 0.1N NaOH	Moisture, %
A*	6.055±0.016	1.90±0.02	39.20±0.31
B	6.097±0.016	1.79±0.04	38.79±0.45
C	6.083±0.010	1.85±0.03	38.64±0.25

Results are expressed as means of three independent experiments. Means ± SD. (*n = 3*)
[a] Total titrable acids
*A – dough mixed for 6 minutes, initial temperature of dough 32 °C
B – dough mixed for 8 minutes, initial temperature of dough 25 °C
C – dough mixed for 10 minutes, initial temperature of dough 25 °C

Small changes could also be affected by the temperature of the dough, because, as it is seen in Table III, higher acidity and moisture was for sample A, but for sample B and C dough moisture, acidity and pH values were within the error.

B. Influence of Fermentation Process on Dough Properties

In the fermentation process the dough physical properties change faster than in mixing process, because the dough is subjected to temperature elevation. Increasing the temperature of the dough, the activity of yeast increases causing gas and porosity formation in the dough changing its volume. Fermentation process is also proceeding an alcoholic and lactic fermentation, which changes the acidity and pH of the dough.

In the research it was found that, increasing the fermentation temperature, the dough temperature increases, it was observed mainly in the samples where the initial temperature was lower than the selected fermentation temperature. If the triticale flour blend dough temperature was higher than the fermentation temperature, it was observed to have the opposite effect, during the fermentation the dough temperature decreased. The effect of the fermentation time and temperature on the triticale flour blend dough temperature, which was mixed for 6 minutes is shown in Fig. 2.

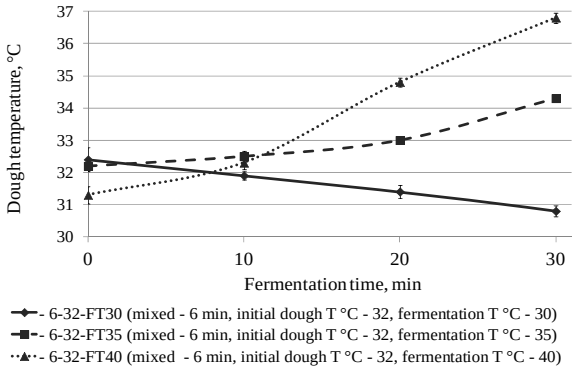

Fig. 2 Temperature changes during fermentation of 6 min mixed triticale flour blend dough

After 30 minutes of fermentation the triticale flour blend dough temperature for sample 6-32-FT30 decreased by 1.6°C. After mixing the dough temperature was 32.4±0.37°C, but at the end of fermentation it decreased to 30.8±0.17°C. Thus, each 10 minutes of fermentation, the triticale flour blend dough temperature decreased for about 0.5°C. The fermentation time and temperature effect on the temperature of the triticale flour blend dough sample which was mixed for 8 minutes is shown in Fig. 3, but for 10 minutes – in Fig. 4.

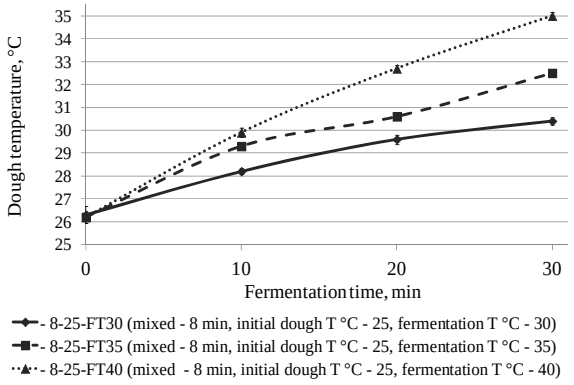

Fig. 3 Temperature changes during fermentation of 8 min mixed triticale flour blend dough

Temperature for other samples increased in the fermentation process and the major rise of temperature (8.9 °C) is for the sample 10-25-FT40. The most rapid increase of the triticale flour blend dough temperature was found in all samples which were fermented at temperature of 40°C. By the resulting data it can be concluded that the fermentation time and temperature have significant ($p<0.05$) influence on the changes of triticale flour blend dough temperature.

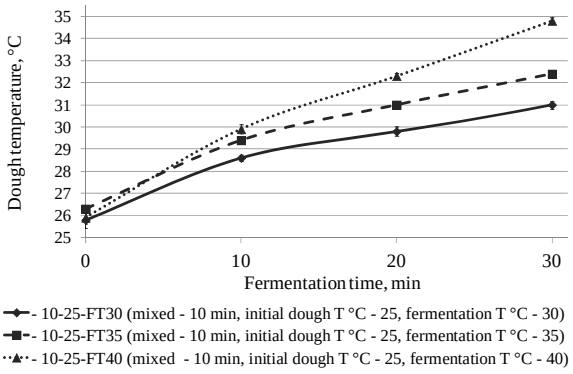

Fig. 4 Temperature changes during fermentation of 10 min mixed triticale flour blend dough

In assessing the dough temperature at the end of fermentation, none of analyzed samples reached the temperature of the fermentation chamber, the differences between the temperatures of the dough and temperatures of the fermentation chamber were average of 3 to 5°C.

Dough fermentation is an important stage in the bread-making process, in which the most distinctive change is the increase in the volume of dough. This stage produces the light, aerated and spongy characteristics of bread. During the

fermentation process, the forces exerted by growing gas bubbles deform the dough matrix which resists the growth of these bubbles. Therefore, the deformation of the dough matrix produced by the growth of the bubbles is predominantly that produced by an extensional flow [26].

Increasing the time and temperature of the fermentation, there are supported more-favorable conditions for yeast activity; as a result, in the dough fermentation process appears CO_2 which increases the volume of the dough. Fig. 5 shows the triticale flour blend dough volume changes in the fermentation process.

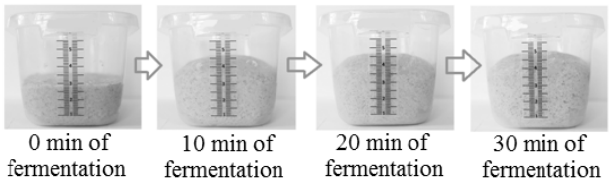

Fig. 5 Changes of triticale flour blend dough volume in the fermentation process

After the results obtained, at all fermentation temperatures and times the most triticale flour blend dough volume rised for the samples 6-32-FT30, 6-32-FT35, and 6-32-FT40 (Fig. 6). The fastest increase of the triticale flour blend dough volume was for all samples which were fermented at 40°C temperature, where the dough volume increased by 144cm^3, at the end of fermentation reaching 330±3.0cm^3.

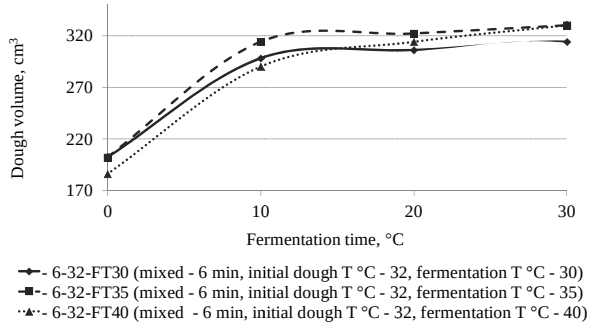

Fig. 6 Volume changes during fermentation of 6 min mixed triticale flour blend dough

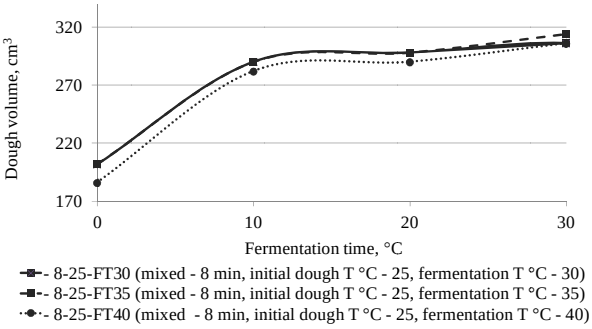

Fig. 7 Volume changes during fermentation of 8 min mixed triticale flour blend dough

The smallest increase of volume was found in the samples which were fermented at 30°C. For the sample 8-25-FT30 (Fig. 7) was obtained the smallest increase in dough volume, only 104cm^3. The effect of fermentation time and temperature on the volume of the triticale flour blend dough sample which was mixed for 10 minutes are shown in Fig. 8.

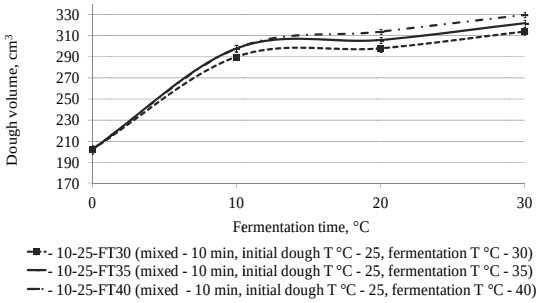

Fig. 8 Volume changes during fermentation of 10 min mixed triticale flour blend dough

The fermentation time and temperature have significant ($p<0.05$) influence on the volume changes of the triticale flour blend dough. Dough volume partly can be influenced by the dough temperature – higher is the dough temperature, more intensive is the fermentation process, in which the dough volume increases.

Consequently, from the assessment of the data, it can be concluded that the most appropriate temperature of the fermentation for the dough which is made from triticale flour blend is 35 or 40°C. Temperature of 30ºC is not suitable for the 30 minutes fermentation. In order to perform fermentation at this temperature, it is necessary to extend the time or use the dough with the initial temperature above 30°C.

In the assessment of the dough moisture changes during fermentation, it is evident that the moisture content increases in the dough made from triticale flour blend (Table IV).

TABLE IV
EVALUATION OF FERMENTED DOUGH MOISTURE, %

Sample	Fermentation time, min			
	0	10	20	30
6-32-FT30*	39.62±0.06	40.05±0.06	40.49±0.11	40.83±0.17
6-32-FT35	38.77±0.13	39.36±0.10	40.24±0.11	41.06±0.11
6-32-FT40	38.87±0.06	39.58±0.11	40.41±0.04	41.25±0.08
8-25-FT30	39.03±0.07	39.46±0.09	40.56±0.04	41.21±0.06
8-25-FT35	38.04±0.15	38.52±0.13	39.62±0.18	40.18±0.12
8-25-FT40	37.86±0.15	38.37±0.13	39.52±0.13	40.19±0.08
10-25-FT30	40.88±0.16	41.31±0.09	41.96±0.15	42.74±0.13
10-25-FT35	38.37±0.11	38.84±0.10	40.11±0.04	41.13±0.12
10-25-FT40	38.98±0.14	39.58±0.12	40.49±0.11	40.83±0.17

Results are expressed as means of three independent experiments. Means ± SD. (*n = 3*)

*the first number in the sample code: 6, 8, and 10 – means dough mixing time in the experiment, the second number 32 and 25 – corresponds initial dough temperature, but the letters and numbers FT30, FT35, and FT40 – fermentation temperature.

The smallest dough moisture changes during the fermentation were in the samples where mixing time was 6, 8, 10 minutes, fermentation time was 10 minutes at temperature 30°C, but the highest (2.94%) was for the sample which was mixed for 10 minutes, fermented for 30 minutes at temperature 40°C.

Moisture increase during the fermentation could affect protein seditions as result improve formation of liquid phases as well as alcoholic fermentation process in the event of sugars splitting in CO_2 and H_2O [27].

The fermentation time and temperature have significant ($p<0.05$) influence on the moisture of the dough.

Studying acidity (Table V) and pH (Table VI) changes during the fermentation, it can be concluded that the temperature and time of the fermentation have significant ($p<0.05$) influence on the dough acidity and pH.

TABLE V
EVALUATION OF TTA[a] DURING DOUGH FERMENTATION

Sample	Fermentation time, min			
	0	10	20	30
6-32-FT30*	1.90±0.06	2.98±0.05	3.06±0.04	3.20±0.05
6-32-FT35	1.90±0.05	3.13±0.04	3.28±0.05	3.44±0.08
6-32-FT40	1.91±0.06	3.31±0.04	3.52±0.05	4.05±0.05
8-25-FT30	1.78±0.10	2.75±0.06	2.91±0.07	3.11±0.06
8-25-FT35	1.79±0.07	2.86±0.06	3.07±0.06	3.20±0.04
8-25-FT40	1.80±0.14	3.01±0.03	3.46±0.04	3.72±0.04
10-25-FT30	1.84±0.05	2.83±0.06	2.96±0.05	3.18±0.05
10-25-FT35	1.84±0.04	3.02±0.06	3.16±0.04	3.30±0.04
10-25-FT40	1.87±0.07	3.10±0.02	3.49±0.05	3.87±0.08

Results are expressed as means of three independent experiments. Means ± SD. ($n = 3$)

[a]Total titrable acids (mL 0.1N NaOH)

*the first number in the sample code: 6, 8, and 10 – means dough mixing time in the experiment, the second number 32 and 25 – corresponds dough temperature, but the letters and numbers FT30, FT35 and FT40 – fermentation temperature.

TABLE VI
EVALUATION OF PH DURING DOUGH FERMENTATION

Sample	Fermentation time, min			
	0	10	20	30
6-32-FT30*	6.06±0.01	5.86±0.01	5.79±0.01	5.71±0.01
6-32-FT35	6.06±0.05	5.77±0.01	5.69±0.01	5.65±0.01
6-32-FT40	6.05±0.02	5.67±0.01	5.60±0.01	5.51±0.01
8-25-FT30	6.11±0.01	5.89±0.01	5.87±0.01	5.78±0.01
8-25-FT35	6.09±0.01	5.86±0.01	5.78±0.01	5.72±0.01
8-25-FT40	6.08±0.01	5.81±0.01	5.63±0.01	5.58±0.01
10-25-FT30	6.09±0.03	5.87±0.01	5.87±0.01	5.73±0.01
10-25-FT35	6.08±0.02	5.80±0.01	5.74±0.01	5.67±0.01
10-25-FT40	6.08±0.01	5.78±0.01	5.63±0.01	5.55±0.01

Results are expressed as means of three independent experiments. Means ± SD. ($n = 3$)

*the first number in the sample code: 6, 8, and 10 – means dough mixing time in the experiment, the second number 32 and 25 – corresponds dough temperature, but the letters and numbers FT30, FT35 and FT40 – fermentation temperature.

The increase of acidity and pH refers to assets an active yeast action that results in the fermentation of products with a sour reaction. By the end of the fermentation all studied samples showed that the range of acidity increased from 1.30±0.05 to 3.87±0.08, but pH decreased from 5.78±0.01 to 5.55±0.01.

After 30 minutes of fermentation the highest increase in acidity was found in the sample 6-32-FT40, which acidity increased by 2.14±0.05. The similar acidity upward trend was seen in the sample 10-25-FT40.

The smallest increase in the acidity was found in the samples 6-32-FT30, 8-25-FT30, and 10-25-FT30, which could be explained by low temperature of the fermentation, because at this temperature are not provided the optimum conditions for yeast activity.

V. Conclusion

The mixing time did not have significant ($p>0.05$) influence on the triticale flour blend dough acidity, pH, and moisture. The fermentation time and temperature have significant ($p<0.05$) influence on the triticale flour blend dough temperature, acidity, pH and moisture. The fermentation time and temperature have significant ($p<0.05$) influence on the volume changes of the triticale flour blend dough.

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