

## THE INFLUENCE OF BAKING TEMPERATURE ON THE QUALITY OF TRITICALE BREAD

Martins Sabovics, Evita Straumite, Ruta Galoburda

*Department of Food Technology, Faculty of Food Technology, Latvia University of Agriculture, Liela Street 2, Jelgava, Latvia,  
e-mail: martins.sabovics@inbox.lv*

### Abstract

During the baking, there occur different changes in dough depending on time and temperature – starch gelatinization, protein denaturation, enzyme inactivation, gas expansion, evaporation of moisture from the crumb and crust. Varying the baking time and temperature the bread physical-chemical parameters and volatile compounds profile change significantly. 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 the research was to investigate the influence of baking temperature on the physical-chemical properties and volatile compounds profile of triticale bread. Triticale bread was baked 45 minutes at  $160\pm 10$  °C,  $200\pm 10$  °C and  $240\pm 10$  °C temperature. Hardness, stickiness, colour ( $L^* a^* b^*$ ), moisture, water activity, pH and titrable acidity of triticale bread crumb using standard methods were evaluated, but only colour ( $L^* a^* b^*$ ) of bread crust was evaluated during research. The volatile compounds profile was identified in bread crumb and crust separately. During research it was established that increasing baking temperature the bread crumb moisture, water activity, stickiness and pH decreased, but hardness and acidity increased. Variation of the baking temperature has significant influence ( $p=0.02$ ) on bread crumb and crust colour. In the bread crumb and crust totally 26 volatile compounds were detected. There were identified 13 volatile compounds – common in all bread crumb and crust samples. All 26 volatile compounds belong to alcohols, aldehydes, acids, terpenes and ketones. Therefore it was ascertained that the baking temperature has significant influence ( $p<0.05$ ) on the quality of triticale bread.

**Keywords:** triticale bread, quality, volatile compounds.

### Introduction

Triticale (*Triticosecale wittmack*) is the first man-made cereal produced by crossing wheat (*Triticum* spp.) and rye (*Secale ceral* L.). The nutrition value of triticale is close to that of wheat and rye (Salmon et al., 2002). In order to extend the product assortment and improve their nutrition value, there can be used triticale, hull-less barley, buckwheat, hull-less oat and other grain flour that are used elsewhere in the world (Taketa et al., 2004). For expanding the range of bakery production in the world there are being developed various recipes for product enriching with fibre, 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 (Sabovics, Straumite, 2012).

In bread making, baking is a key step in which the raw dough piece is transformed into a light, porous, readily digestible and flavourful product, under the influence of heat. During baking, the most apparent interactions are volume expansion, crust formation, inactivation of yeast and enzymatic activities, protein coagulation and partial gelatinisation of starch in dough (Therdthai et al., 2002). The quality of baked product is affected by the time and temperature of the baking process (Mondal, Datta, 2008).

The baking temperature can affect the bread texture and surface colour. The formation of colour in bakery products during baking is widely known as browning. Browning is the result of non-enzymatic chemical reactions which produce coloured compounds during the baking process: such reactions are the Maillard reaction and caramelization (Purlis, 2010).

Taste, smell and the flavour are undoubtedly the most important attributes determining the quality of bread or baked cereals in general and one of the most important

attributes influencing the acceptance of the consumer (Hansen, Schieberle, 2005). Flavour is usually the result of the presence, within complex matrices, of many volatile and non-volatile components possessing diverse physical-chemical properties. Whereas, the non-volatile compounds contribute mainly to the taste, the volatile ones influence both – taste and aroma. A vast array of compounds may be responsible for the aroma of the food products, such as alcohols, aldehydes, esters, dicarbonyls, short to medium-chain free fatty acids, methyl ketones, lactones, phenolic compounds and sulphur compounds (Urbach, 1997).

For volatile compound investigation in bread samples can be used a solid-phase microextraction (SPME). Solid-phase microextraction is a relatively new sample preparation technique (Pawliszyn, 1997) before analysis through gas chromatography (Hook et al., 2002). SPME shows some advantages over other widely used techniques: solvent-free and rapid sampling, low cost, and higher sensitivity (Pawliszyn, 1997).

The aim of the research was to investigate the influence of baking temperature on the physical-chemical properties and volatile compounds profile of triticale bread.

### Materials and Methods

Experiments were carried out at the Department of Food Technology in the Latvia University of Agriculture.

Triticale, rye and hull-less barley crops cultivated at the Priekuli Plant Breeding Institute (Latvia), rice and maize flour purchased from Joint Stock Company Ustuniu Malunas (Lithuania) were used in the current study.

Triticale, rye and hull-less barley were ground in a laboratory mill Hawos (Hawos Kormmühlen 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 were included in dough formulation in order to improve sensory properties and keep quality of bread.

In the research two dough samples using sugar, salt, dried yeast and water, mixed for 8 and 10 min (dough temperature 25 °C) were prepared. Dough samples were fermented 30 min at temperature 35 °C. For baking process three temperatures – 160±10, 200±10 and 240±10 °C were chosen using one baking time 45 min. The following physical parameters were analysed in obtained triticale bread after cooling it to room temperature 21±2 °C.

- *Moisture content* of bread crumb was determined using air-oven method (AACC method 44-15.02).
- *pH* of bread crumb was measured by JENWAY 3510 pH-meter (Bibby Scientific Ltd., UK).
- *Titratable acidity* of bread crumb was determined by titration where the sample (5 g) was dissolved and dispersed in 50 mL distilled water. Phenolphthalein indicator 0.5 mL 1% was added and titrated with standardized 0.1N NaOH until a faint pink colour endures for 30 seconds.
- *Hardness and stickiness* (N) of bread crumb samples were determined on the Texture Analyser – TA.XT.plus Texture Analyser (Stable Micro Systems Ltd., UK), using a modified version of AACC method 74-09.01.
- *Water activity* of bread crumb was determined by standard ISO 21807:2004, AquaLab LITE device (Decagon Devices, Inc., USA).
- *Colour* of bread crumb and crust samples were measured in CIE L\* a\* b\* colour system using Tristimulus Colorimeter (ColorTec Associates, Inc., USA). Colour Tec PCM/PSM colour values were recorded as L\* (brightness) – the vertical co-ordinate runs from L\* = 0 (black) through grey to L\* = 100 (white); a\* (-a, greenness, +a, redness) – the horizontal co-ordinate, that runs from -a\* (green) through grey to +a\* (red) and b\* (-b, blueness, +b, yellowness) – another horizontal co-ordinate, that runs from -b\* (blue) through grey to +b\* (yellow) (Coulter, 2009). The measurements were repeated on different randomly selected locations at the surface of each crumb and crust sample (n=10).

*Volatile compounds* in bread crumb and crust were extracted using solid-phase microextraction (SPME) in the combination with gas chromatography/mass spectrometry. Fiber was coated with a thin polymer film – Carboxen/Polydimethylsiloxane (CAR/PDMS). The film thickness is 85 µm with bipolar polarity (Supelco, Inc., USA). Five grams of sample were placed in 20 mL vial (small glass bottle). Extration time is 65 min at 40 °C (incl., pre-incubation without

the fibre for 15 min, 40 °C). Volatile compounds from fibre were thermally desorbed in the injector of gas chromatograph PerkinElmer 500 GC/MS with a capillary column Elite-Wax ETR (60 m×0.25 mm i.d.; DF 0.25 µm). The details of the program used in GC/MS analysis are following: the initial temperature was 40 °C, held for 7 min, then ramped from 40 °C to 160 °C at a rate of 6 °C min<sup>-1</sup> and from 160 °C to 210 °C at a rate of 10 °C min<sup>-1</sup> with the holding time for 15 min. Mass spectrometer in Electron impact ionization mode was set on 70 eV as the electron energies, while the ion source temperature was set to 250 °C and inlet line temperature was set to 250 °C. Helium (he) was used as carrier gas at a constant flow of 1 mL min<sup>-1</sup>. Acquisition parameters in full scan mode: scanned m/z 40–300. Compounds were identified by comparing their mass spectra with mass spectral library Nist98.

The results (mean, standard deviation, p value) were processed by mathematical and statistical methods. Data were subjected to one-way analysis of variance (ANOVA) by Microsoft Office Excel 2007; significance was defined at p<0.05. Principal component analyses were processed by MultiBase2014.

## Results and Discussion

The comparison of baking temperature effect on changes of physical-chemical parameters and volatile compounds between the samples was done in the research. The triticale bread moisture and water activity are summarised in Table 1. In the baking time occurs evaporation of moisture and as well as decrease of the water activity.

Table 1

Moisture and water activity of triticale bread

Sample	Moisture, %	Water activity
M8-F <sup>1</sup>	47.08±0.07	0.961±0.002
M8-C45-T160 <sup>3</sup>	44.76±0.09	0.960±0.002
M8-C45-T200 <sup>3</sup>	43.74±0.07	0.959±0.001
M8-C45-T240 <sup>3</sup>	42.04±0.10	0.954±0.001
M10-F <sup>2</sup>	47.03±0.04	0.961±0.002
M10-C45-T160 <sup>3</sup>	44.57±0.09	0.960±0.001
M10-C45-T200 <sup>3</sup>	43.72±0.08	0.960±0.002
M10-C45-T240 <sup>3</sup>	42.12±0.03	0.953±0.001

<sup>1</sup> moisture of fermented dough before baking, dough mixed 8 min; <sup>2</sup> moisture of fermented dough before baking, dough mixed 10 min; <sup>3</sup> M8 means dough mixed 8 min, C45 – baking time (45 min), T160 – baking temperature (160 °C).

Smaller moisture losses comparing to the fermented dough before baking were found in sample M8-C45-T160 (2.32%) and M10-C45-T160 (2.46%), but the highest losses of moisture were in samples M8-C45-T240 and M10-C45-T240, as a result the moisture of samples decreased by 5.04% and 4.91%,

respectively. After obtained data evaluating, it could be concluded that not significant moisture evaporation for 8 min mixed dough, baked for 45 min at 160 °C, was found comparing with the sample M10-C45-T160. If fermented semi-finished product was baked at temperature 240 °C, moisture evaporation was the most intensive in M8-C45-T240 sample comparing with M10-C45-T240 sample. The water activity decreases with the increase of baking temperature. The changes in water activity basically paralleled the changes in moisture content, which was in agreement with study of Mathlouthi (2001) and Jakubczyk et al. (2008). Increasing the baking temperature also increases the acidity of bread, but pH decreases (Table 2).

Table 2

**Titrateable acidity and pH of triticale bread**

Sample	Acidity, °	pH
M8-F <sup>1</sup>	3.27±0.06	5.224±0.006
M8-C45-T160 <sup>3</sup>	3.30±0.04	5.211±0.008
M8-C45-T200 <sup>3</sup>	3.32±0.04	5.196±0.007
M8-C45-T240 <sup>3</sup>	3.40±0.05	5.099±0.004
M10-F <sup>2</sup>	3.30±0.04	5.189±0.006
M10-C45-T160 <sup>3</sup>	3.34±0.02	5.166±0.003
M10-C45-T200 <sup>3</sup>	3.40±0.01	5.097±0.004
M10-C45-T240 <sup>3</sup>	3.47±0.03	5.007±0.004

<sup>1</sup> moisture of fermented dough before baking, dough mixed 8 min; <sup>2</sup> moisture of fermented dough before baking, dough mixed 10 min; <sup>3</sup> M8 means dough mixed 8 min, C45 – baking time (45 min), T160 – baking temperature (160 °C).

The highest increase of titrateable acidity was found in M8-C45-T240 and M10-C45-T240 samples, comparing with acidity in the fermented dough. Evaluating the data of moisture, water activity, acidity and pH, it can be seen that the baking temperature has significant influence (p<0.05) on changes of bread moisture, water activity, acidity and pH parameters.

After bread cooling the bread crumb hardness and stickiness were analysed (Table 3). As evidence by the experimental results, the baking temperature has significant effect (p<0.05) on the crumb hardness and stickiness.

The softest (7.35±0.95 N and 7.79±0.82 N) bread crumb was acquired for triticale bread baked for 45 min at the temperature 160 °C, but the hardest bread crumb – for bread baked for 45 min at the temperature 240 °C. Comparing M8-C45-T160 and M8-C45-T240 samples, it can be seen that the the bread crumb was harder by 12.01 N. As a result the mixing time does not affect the bread crumb hardness, but bread hardness mainly depends on the baking temperature. Das et al. (2012) in their research found that by increasing the baking temperature increases the hardness of the bread, losing part of the moisture in baking process.

Table 3

**The hardness and stickiness of bread crumb**

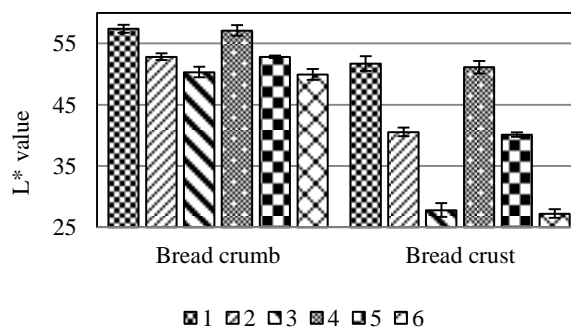
Sample <sup>1</sup>	Crumb hardness, N	Crumb stickiness, N
M8-C45-T160	7.35±0.95	-0.82±0.06
M8-C45-T200	14.53±0.83	-0.56±0.04
M8-C45-T240	19.36±0.92	-0.38±0.03
M10-C45-T160	7.79±0.82	-0.79±0.06
M10-C45-T200	14.92±0.51	-0.51±0.03
M10-C45-T240	19.81±0.25	-0.31±0.04

<sup>1</sup> Sample description: M8 means dough mixed (8 min), C45 – baking time (45 min), T160 – baking temperature (160 °C).

Evaluating triticale bread crumb stickiness after baking, it can be concluded that more sticky crumb was for M8-C45-T160 and M10-C45-T160 samples, presenting the negative force value -0.82±0.06 N and -0.79±0.06 N, respectively. Increasing the baking temperature the stickiness of the bread crumb decreases, where M8-C45-T240 (-0.38±0.03 N) and M10-C45-T240 (-0.31±0.04 N) showed lower stickiness of the bread crumb. The correlation analysis shows that the triticale flour blend crumb hardness (r=-0.983) and stickiness (r=-0.981) have strong negative correlation on the moisture content of the bread. Thus, it can be concluded that the moisture content in bread affects the crumb hardness and stickiness.

The triticale bread crumb and crust colour was measured after baking, taking into account the baking temperature. The baking temperature has significant influence (p<0.05) on bread crumb and crust colour changes.

Triticale bread crumb L\* colour component value (Fig. 1) at different baking temperatures of all baked samples was significantly different (p<0.05).

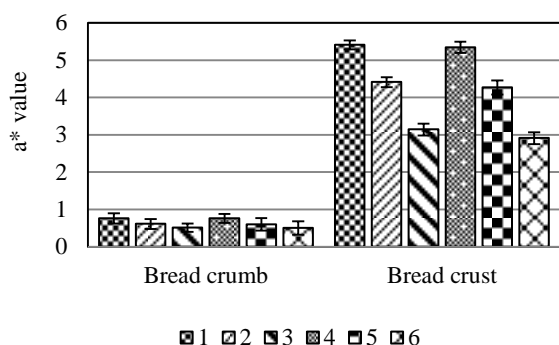


**Figure 1. The changes of bread crumb and crust L\* colour component value in different baking temperatures**

1 – M8-C45-T160, 2 – M8-C45-T200, 3 – M8-C45-T240, 4 – M10-C45-T160, 5 – M10-C45-T200, 6 – M10-C45-T240

The bread crumb becomes darker increasing the baking temperature. The dough mixing time did not have significant affect (p>0.05) on crumb colour component

L\* value. For example, the crumb L\* colour component value of sample M8-C45-T160 is  $57.40 \pm 0.66$  and of sample M10-C45-T160 –  $57.12 \pm 0.87$  was detected. Triticale bread baked for 45 min at 240 °C, apart from the previous dough mixing time, the colour of crumb and crust was obtained comparing to the other samples. After 45 min of baking at 240 °C the crust colour component L\* value was 1.8 times lower in comparison with the crust colour of M8-C45-T160 and M10-C45-T160 samples. The baking temperature has no significant impact ( $p=0.06$ ) on bread crumb dark/light shades, but significantly impacts ( $p=0.02$ ) crust colour of all samples. Differences among the bread crumb and crust colour was obtained during research, as a result the colour of crust becomes darker increasing the baking temperature. Such interconnection was observed, because at higher temperature caramelization and Maillard reaction occurs faster (Martins et al., 2000). The value of colour compound a\* of bread crumb was in range from 0.50 to 0.76 (Fig. 2), but of bread crust – from 2.91 to 5.41. Increasing the baking temperature, there are no significant ( $p=0.06$ ) changes of crumb colour a\* value, but the baking temperature significantly affects ( $p=0.03$ ) the crust colour. The colour value of the crust colour component a\* decreases by about  $2.27 \pm 0.14$  from sample M8-C45-T160 to M8-C45-T240.

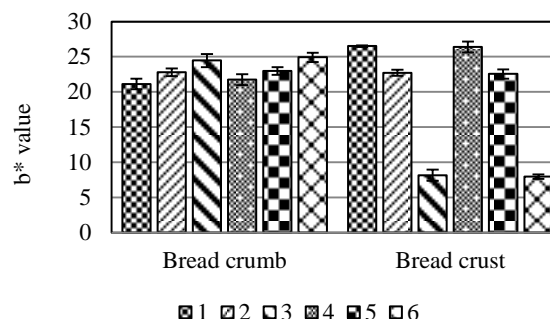


**Figure 2. The changes of bread crumb and crust colour compound a\* value during baking**

1 – M8-C45-T160, 2 – M8-C45-T200, 3 – M8-C45-T240, 4 – M10-C45-T160, 5 – M10-C45-T200, 6 – M10-C45-T240

The triticale bread crumb colour component b\* value was in the range from  $24.92 \pm 0.66$  (M10-C45-T240) to  $21.12 \pm 0.75$  (M8-C45-T160) (Fig. 3) and was not significantly affected ( $p=0.07$ ) by dough mixing time and bread baking temperature. Baking temperature has significant influence on crust colour component b\* value changes. The highest intensity of yellow colour was found for the crumb samples M8-C45-T160 ( $21.12 \pm 0.75$ ) and M10-C45-T160 ( $21.75 \pm 0.79$ ), but the lowest intensity of yellow colour was found for the crust samples M8-C45-T240 and M10-C45-T240, as  $8.14 \pm 0.80$  and  $7.94 \pm 0.31$  respectively. Increasing the baking temperature, component b\* value in crumb samples increases, but in crust – decreases. It means

that the bread crumb at higher baking temperature becomes yellowish. The yellow colour in the crust decreases increasing the baking temperature and this is mainly due to the fact that the rate of brown pigment formation increases with temperature (Das et al., 2012).



**Figure 3. The changes of bread crumb and crust b\* colour compound value during baking**

1 – M8-C45-T160, 2 – M8-C45-T200, 3 – M8-C45-T240, 4 – M10-C45-T160, 5 – M10-C45-T200, 6 – M10-C45-T240

The L\* a\* b\* colour values change similarly in all samples, what can be explained by moisture losses and brown colour formation during baking.

The volatile profile of different bread types has been widely investigated during the past years. These studies demonstrate that bread flavour is composed by different volatile compounds, belonging to several chemical classes, mainly heterocyclic compounds, alcohols, aldehydes, ketones, etc. Depending on the characteristic of each kind of bread, volatile compounds are present in well-defined ratios (Rehman et al., 2006; Bianchi et al., 2008).

Analysing of the volatile compounds in bread crumb and crust after baking overall there were identified 26 volatile compounds. All bread samples, which were baked at three different temperatures, contain 13 volatile compounds in common, identified both in crumb and crust. Among identified volatile compounds seven were alcohols (cyclobutanol, 4-penten-2-ol, 1-hexanol, 3-methyl-1-butanol, 3-methyl-2-hexanol, phenylethyl alcohol and maltol), two aldehydes (hexanal and heptanal), two acids (acetic acid and hexanoic acid), one ketone (3-hydroxy-2-butanone) and one terpene (carvone).

From all identified volatile compounds in bread crumb and crust samples the highest peak areas were for three alcohols – 4-penten-2-ol, 3-methyl-1-butanol and 1-hexanol, their peak areas are shown in Table 4. The peak areas of alcohols (4-penten-2-ol, 1-hexanol and 3-methyl-1-butanol) are higher in bread crumb than in crust. But there can be observed that, the peak areas of alcohols decrease in bread crumb and crust increasing baking temperature, which is related to volatility of alcohols. According to Schieberle (1996) the amount of flavour compounds formed in bread can be affected by yeast amount and activity, fermentation and baking time and temperature.

Peak areas of main alcohols in the triticale bread crumb and crust

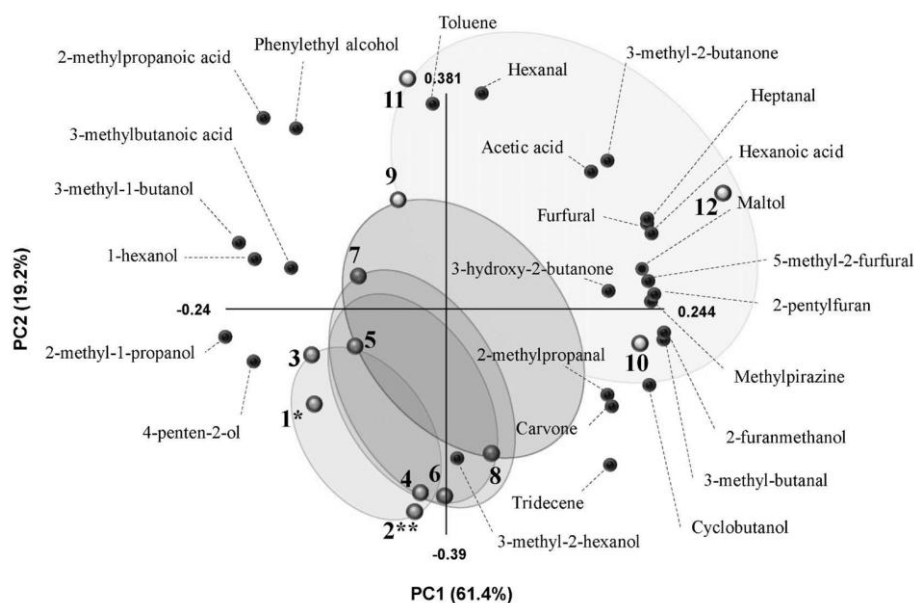
Samples		Peak areas of alcohols (PAU×10 <sup>6</sup> )		
		4-penten-2-ol	3-methyl-1-butanol	1-hexanol
M8-C45-T160	MC*	328.31±3.00	121.07±0.59	59.85±0.59
M8-C45-T160	GC**	187.95±3.04	61.77±2.29	22.07±0.77
M8-C45-T200	MC	214.97±2.80	103.47±0.75	51.78±0.54
M8-C45-T200	GC	171.68±2.37	43.72±1.17	17.76±0.70
M8-C45-T240	MC	98.21±3.96	72.91±0.30	21.62±1.64
M8-C45-T240	GC	51.96±2.11	16.47±2.90	4.13±0.85
M10-C45-T160	MC	329.86±4.96	121.66±0.98	68.38±0.35
M10-C45-T160	GC	190.83±2.20	83.13±0.07	32.13±0.88
M10-C45-T200	MC	254.25±4.97	108.37±0.24	60.80±0.88
M10-C45-T200	GC	175.67±2.50	47.17±0.06	20.17±0.32
M10-C45-T240	MC	108.29±3.65	85.76±0.03	30.71±0.46
M10-C45-T240	GC	56.89±2.24	24.55±0.12	10.46±0.51

\*MC – crumb; \*\*GC – crust

The volatility of alcohols is dependent on the temperature in which it starts disappearing (boiling point), such as 4-penten-2-ol volatility intensively occurs in 134–137 °C, 3-methyl-1-butanol – 131 °C, but 1-hexanol from sample starts disappear at 155–159 °C (Janežič et al., 2006). It also explains why peak areas in the bread crust of 4-penten-2-ol and 3-methyl-1-butanol are more loss than in crumb increasing the baking temperature.

The highest peak areas in bread crumb and crust of 4-penten-2-ol are identified in samples M8-C45-T160 and M10-C45-T160, but smaller ones – M8-C45-T240 and M10-C45-T240. The same regularities are observed for 3-methyl-1-butanol and 1-hexanol. The peak areas of 4-penten-2-ol in the

sample M8-C45-T160 of crumb and crust are 3.0 to 3.3 times higher than in the sample M8-C45-T240. The peak areas of 3-methyl-1-butanol in bread crumb are 2.1 to 4.4 times higher than in crust. Volatile compounds distribution in the triticale flour blend bread crumb and crust, depending on baking temperature is shown in Figure 4. Evaluating the principal component analysis of the data, the distribution of volatile compounds depending on baking temperature explained 61.4% and 19.2% of variation on PC1 and PC2, respectively. Variation of PC1 shows bread crumb and crust samples, while PC2 represents the volatile compounds dispersion in bread crumb and crust samples.



**\*Bread crumb**

- 1 – M8-C45-T160;
- 3 – M10-C45-T160;
- 5 – M8-C45-T200;
- 7 – M10-C45-T200;
- 9 – M8-C45-T240;
- 11 – M10-C45-T240

**\*\*Bread crust**

- 2 – M8-C45-T160;
- 4 – M10-C45-T160;
- 6 – M8-C45-T200;
- 8 – M10-C45-T200;
- 10 – M8-C45-T240;
- 12 – M10-C45-T240

Figure 4. Distribution of volatile compounds in the crumb and crust of the triticale bread samples

The baking time has significant impact on volatile compound formation, because  $F=26.50 > F_{crit}=1.53$  with a probability of  $p < 0.05$  (95%). In the bread crust samples (mixed 8 and 10 min and baked 45 min at 240 °C) were detected the most pronounced volatile odour. In this samples more volatile compounds with higher peak areas are such as methylpirazine, 2-pentylfuran, hexanoic acid, maltol, furfural, 5-methyl-2-furfural, 2-furanmethanol, acetic acid, 3-hydroxy-2-butanone, and heptanal. Some of these volatile compounds are forming in fermentation time, but most of them in caramelization and Maillard reaction. Volatile compounds detected in triticale bread crumb forms bread aroma profile, which includes fruit (4-penten-2-ol), malty (3-methyl-1-butanol and 2-methyl-1-propanol), honey (phenylethyl alcohol), green (hexanal, 1-hexanol), caramel (maltol), sweet (hexanoic acid, 3-methyl butanoic acid) aroma. But volatile compounds identified in bread crust supplement aroma profile with green bean (2-pentylfuran), bread (furfural) and butter (2-pentylfuran, 3-hydroxy-2-butanone) notes.

### Conclusions

Baking temperature has significant influence ( $p < 0.05$ ) on changes of bread moisture, water activity, acidity and pH parameters, as well as hardness of bread crumb. Baking temperature significantly influences triticale bread crust colour and volatile compounds formation in the crumb and crust.

Totally in all samples baked at different temperature were identified 26 volatile compounds. Detected volatile compounds in bread crumb form bread aroma profile, which includes fruit, malty, honey, green, caramel, sweet aroma, but volatile compounds identified in bread crust supplement aroma profile with green bean, butter and bread notes.

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