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Rowan powder based acidifying additive acidifying additive - an alternative to sourdough in the rye-wheat bread production

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Abstract. Rye is an important part of the cereal food culture in the Russia and Nordic, Baltic and Eastern European countries. Rye bread is often made of whole-grain flour using long-time sourdough. In Russia, rye bread began to be produced less and less often due to the complexity and duration of its technology. Therefore, the development of fast, natural and safe technologies is relevant. The aim of the research was to develop a nutritional acidifying additive based on plant materials (rowan powder, botanical species *Sorbus aucuparia*) for accelerated rye-wheat bread technology. With an increase in the new plant additive dosage above 3.5%, the dough lifting capacity deteriorated. The bread specific volume and the crumb compressibility deteriorated when additive dosage was higher than 3.5%. It all may be due to the acidity suppression of yeast activity in the dough. Taste and smell was also better in bread with new additive due to the rowan powder chemical composition. The optimum dosage of new additive rowan powder in rye-wheat bread formulation was 3.5% by weight of the flour. Usage of new additive with 0.1% of sodium diacetate allowed slowing down moulding. New acidifying with rowan powder allowed to create accelerated rye-wheat bread technology and to get bread with high consumer properties.

Key words: bread making, plant acidifying additive, sodium diacetate, accelerated bakery technologies.

INTRODUCTION

Rye is one of the most important cereal grains in Russia, Northern and Eastern Europe, where is traditionally used for rye bread (Valjakka et al., 2003; Sahlström & Knutsen, 2010; Poutanen et al., 2014; Juodeikiene, 2016). Rye bread is a good source of dietary fibre phenolic compounds, vitamins, and trace elements and minerals (Nilsson et al., 1997; Nyström, 2008; Rakha, 2010; Wrigley & Bushuk, 2010; Poutanen et al., 2014). Expanding research data about the various components of rye grain beneficial to health have increased the interest in rye bread assortment and technology. Rye bread is often made of whole-grain flour using sourdough technology (Poutanen et al., 2014; Juodeikiene, G., 2016).

In Russia, rye and rye-wheat bread production decreases last years and accounts for only 33% of the total assortment, while bread from wheat flour of different varieties accounts for 58.3% (Seregin & Mosolova, 2011). This is due to the complexity of sourdough bread technology. Traditional rye sourdough bread technologies are very time-consuming. The technological process (including fermentation of the starter and dough before cutting) usually lasts for 5–9 h, which is making the organization of the rye bread production too complicated and long (Kosovan, 2008; Poutanen et al., 2014; Juodeikiene, G. 2016; Stępniewska et al., 2019). Therefore, the development of fast, natural and safe technologies is relevant task (Dubrovskaya et al., 2019).

Baking properties of the rye flour are influenced by the functional properties of the main rye components such as starch, proteins and pentosans. The gelling properties of the starch together with the high α-amylase activity represent a critical factor for the rye baking technology. Starch and pentosans are very important components of rye flour. Pentosans play a main role in developing the dough properties at temperature below 45 °C, while starch has an influence on the structure of crumb when temperature exceeds 45 °C (Puchkova et al., 2005; Banu, 2007; Andersson et al., 2009; Buksa et al., 2010). Rye starch gelatinizes at temperatures of 55–70 °C, at which the activity of α-amylase is at a maximum (Gräber, 1999, Puchkova et al., 2005; Arendt et al., 2007, Rosentrater & Evers, 2018). In order to avoid excessive amylolytic breakdown of the starch, the pH of the dough is lowered for making rye soft bread. PH may be lowered by acid modification in a 'sourdough' process, preferably by lactic acid fermentation with species of *Lactobacillus* (Puchkova et al., 2005; Poutanen et al., 2014; Rosentrater & Evers, 2018), and by acidifying additives usage such as organic acid (Puchkova et al., 2005; Arendt et al., 2007; Gagiu et al., 2017; Gioia et al., 2017; Rosentrater & Evers, 2018. Dubrovskaya et al., 2019). Acidifying additives are more convenient to use, therefore, are widely used in Russia and in Europe.

The disadvantage of acidifying additives usage is the small spectrum of acids in their composition and low content of aromatic substances. Most commonly only one or two organic acid are used as acidifying additives in rye bread making. For example, during sourdough fermentation lactic acid, citric acid, acetic acid, pyruvic acid and succinic acid are produced (Valjakka et al., 2003; Ardent, 2007; Poutanen, 2009). That is why the taste and smell of bread made with acidifying additives is most often not pronounced compared to the sourdough bread, the crumb is a little sticky or crumbles; the color of the crusts is not bright enough. Nutritional value is lower than in bread made with sourdough (Corsetti et al., 2000; Poutanen, 2014; Dubrovskaya et al., 2019).

When accelerated technology and acidifying additives are used, bread quickly undergoes microbial spoilage and has short shelf-life. The most pressing problem is moulding and wild yeast development, due to the development of mould and yeast on the surface of the product. Mould - affected bread may contain mycotoxins - substances harmful to the human health (Corsetti et al., 2000; Kurtzman et al., 2010; Dubrovskaya et al., 2019; El Sheikha & Mahmoud, 2019).

The aim of our research was to create a multifunctional plant acidifying additive to increase the organoleptic and physicochemical quality indicators, nutritional value, shelf life and microbiological stability during storage of rye-wheat bread.

MATERIALS AND METHODS

Characteristics of ingredients

The powder from the fruit of the rowan (botanical species *Sorbus aucuparia*) was used as an enriching additive. Rowan powder has high acidity (40 degrees or 5.7% in terms of malic acid), has rich biochemical composition, as well as a significant amount of dietary fiber (56.3–59.9%) and volatile acids (2–3%) (Dubrovskaya, 2017).

The composition of the developed plant acidifying additive is: powder from the fruits of red-fruited rowan (67.7), dried whey (3.8), fermented rye malt (10.0), enzyme preparation 'Fungamil' (0.5), citric acid (18.0) (Dubrovskaya, 2012).

To enhance the effect of the developed plant acidifying additive with rowan powder (3.5%) and to increase the shelf life of rye-wheat ('Darnitsky') bread, a sodium diacetate in an amount of 0.1–0.3% by weight of the product was used. Its optimal amount was determined by the microbiological parameters of the finished bread and by the duration of the technological process. The control was the acidifying mixture with rowan powder without sodium diacetate.

Bread making procedure

To determine the optimal amount of the developed plant acidifying additive 'Citrasol – 6' in the formulation of rye-wheat bread ('Darnitsky'), test laboratory baking was carried out.

The dough was made from following ingredients (g per 100 g total amount of flour): rye flour (60.0), wheat flour baking first grade (40.0), new acidifying additive (2.5, 3.0, 3.5, 4.0 and 4.5), salt (1.5), and yeast (1.2). Water was added in an amount to ensure the humidity of the dough 48.0–48.5%. All the components were mixed in a kneading machine Ankarsrum Original Assistant (Sweden) at a speed of 200 rpm for 15 minutes. After mixing, dough was fermented at a temperature of 30 ± 2 °C for 60 minutes. Then, dough pieces were shaped into 300 g loaves, placed in baking forms, and leavened at a 35–40 °C until the volume was twice that of the initial volume. The leavened dough samples were baked in an oven SvebaDahlen (Sweden) at the temperature of 210 °C for 18 minutes with steam introduced for 6 seconds. The control was bread made with well-known acidifying additive 'Citrosol', developed by the St. Petersburg branch of State Research Institute of Baking Industry (Kosovan, 2008), which was used in amount of 3 g per 100 g total amount of flour.

Analysis of the biochemical composition of rowan powder

The analysis of the organic acid composition in the rowan powder was performed using gas-liquid chromatography with mass spectrometry (GC–MS) on an Agilent 6850 chromatograph (USA). Acidity was determined according to State Standard of the Russian Federation (State Standard of the Russian Federation, 1996).

Microbial contamination assessment

The number of mesophilic aerobic and facultative anaerobic microorganisms in rowan powder (MAFAM's quantity) was determined according to ICC Standard Method 133, the number of yeast and moulds was determined according to ICC Standard Method 134. The number of *Escherichia coli* group bacteria in 1 gram of the product was determined by plating the product and its dilutions on an agarized selective diagnostic

medium. After incubation at 37 °C, typical and atypical colonies were counted and the ability of bacteria from these colonies to ferment lactose with the formation of gas was determined (Standard of Russian Federation GOST 31747-2012, 2012). *Staphylococcus aureus* was determined according to Russian Standard GOST 31746-2012. Samples of the product and a series of dilutions were inoculated into a selective liquid nutrient medium and incubated at 37 °C for 24–48 h. Then it was inoculated to Petri dishes with Baird-Parker agar. Confirmation of the belonging of typical and atypical colonies to coagulase-positive staphylococci was carried out by studying the ratio of the identified microorganisms to Gram stain, determining the presence of catalase and coagulase in them.

Salmonella genus was determined according to Russian Standard GOST 31659-2012. Bacteria of the genus *Salmonella* may be present in the product in a small amount, along with a large number of other bacteria from the *Enterobacteriacea* family or other families. Therefore, preliminary enrichment was carried out necessary to detect a small number of bacteria of the genus *Salmonella* or sublethally damaged bacteria of the genus *Salmonella*. For this, a weighed mass of 25 g was introduced into buffered peptone water. T hen, they were incubated at a temperature of 37 ± 1 °C for 18 ± 2 h. After the culture, tetrathionate broth was introduced into Mueller-Kaufmann medium and incubated at a temperature of 37 ± 1 °C for 24 ± 3 h. Then was inoculated on xylose-lysine-deoxycholate agar in Petri dishes and incubated at a temperature of 37 ± 1 °C for 24 ± 3 h. Colonies presumably related to bacteria of the genus *Salmonella* obtained on Petri dishes were identified using biochemical tests.

The determination of spore-forming bacteria amount in the flour was carried out by plating a heated sample on meat-peptone agar. For this, 10 g of flour was mixed with 100 cm^3 of sterile water. The thoroughly homogenized mixture was heated in a water bath for 10 minutes at a temperature of 90–94 °C in order to inactivate all vegetative cells. Then a series of ten-fold dilutions were made from the heated suspension. 1 cm^3 of obtained dilutions was inoculated into sterile Petri dishes on meat-peptone agar, which was previously melted and cooled to 40 ± 1 °C and cultivated in a thermostat at 37 ± 1 °C. Grown colonies were counted (Blackburn K. de V, 2008).

The dough assessment

Mass proportion of moisture of the new plant acidifying additive was determined by drying at a temperature of 130 °C during 40 minutes in drier (SHS-1M, Russia). The dough lifting capacity was determined by the rate of floating up of the 10 g of dough with humidity of 45%, shaped in the ball, in a glass of water at a temperature of 32 °C (Puchkova, 2004). The increase in volume was calculated by the ratio of the final volume to the initial volume multiplied by 100% (Puchkova, 2004). Acidity was determined by titration, using 0.1 M solution of NaOH (Puchkova, 2004).

The gas-forming and gas-holding capacity of the dough was determined using a F3 Chopin Reofermentometer. Samples of the test weighing 315 g were placed on the bottom of the drum and preheated to 28.5 °C. A piston with a load of 2,000 g (4 plates of 500 g each) was installed on the dough and the system was tightly closed with a lid. The duration of the experiment was 90 minutes. The principle of the method is that the pressure generated by the dough in the fermentation process is alternately released into the atmosphere through a soda lime cartridge that retains carbon dioxide, the gas holding capacity of the sample is estimated from the volume of which, expressed in cm^3. The

rise of the dough in the fermentation process is estimated by the movement of the piston, which is mounted directly on the dough. During the analysis, two coordinate systems are displayed on the instrument display. On one (top) the dough rise dynamics are drawn in mm, on the second (bottom) – the dynamics of change in gas-forming ability and gas-holding capacity of the dough in mm of water column.

Assessment of baked bread

Assessment of quality

The assessment of bread quality levels was carried out in relation to the following properties: sensory parameters – (shape, surface, crumb colour, condition of crumb (porosity and texture), taste and smell; physic-chemical and physical parameters – moisture was determined by drying at a temperature of 130 °C during 45 minutes in a drier SHS-1M, Russia), acidity was determined by titration, using a 0.1 M solution of NaOH (State Standard of the Russian Federation GOST 5670–96, 1996), porosity was determined as the ratio of pore volume to the total volume of products, pore volume – as the difference between the volume of product and the volume of non-porous mass, specific volume – as the ratio of product volume to 100 g of bread, compressibility was determined on the automatic penetrometer Labor (Hungary). The swelling of the crumb was determined by the amount of water absorbed by the crumb of bakery products for a certain period of time (Goryacheva, 1983).

The chemical composition of the bread was obtained by calculation (Kosovan, 2008), taking into account the content of nutrients in the used raw materials (Skurikhin & Tutelyan, 2002).

Determination of water-soluble antioxidants content in bread was conducted by amperometric method using device 'Color Yauza-01-AA.' (Russian) according to Russian Standard (State Standard of the Russian Federation, 2010).

Sensory evaluation

The panel of 10 non-specialists was used to evaluate the sensory characteristics of the bread. Then, they were asked to evaluate separately appearance (shape, surface, crumb colour and the crumb (color, smell, taste, chewiness and porosity). The ranking scale ranged from 1 to 5 (5-like extremely, 4.5-like very much, 4-like moderately, 3.5-like slightly, 3-neither like not dislike, 2.5-dislike slightly, 2-dislike moderately, 1.5-dislike very much, 1-dislike extremely).

Mould spoilage assessment

The impact of the rowan powder on moulding of bread was investigated. Sterile bread slices were contaminated by a pure culture of the mould *Penicillium chrysogenum*. *Penicillium chrysogenum* was used in this study because this type of mould often infects bread (Blackburn, 2008). This strain was isolated from mouldy bread. It was identified and is used as a typical strain of *Penicillium chrysogenum*. Immediately after baking, the loaves were packed into sterile paper, placed in a sterile room, and cooled to a temperature of between 25–28 °C. After cooling the bread was cut in a sterile environment, with slices being taken at a size of 3.5×6.5 cm and at a thickness of 0.3–0.4 cm. The slices were placed on sterile Petri dishes. An aqueous suspension of a pure culture of the mould, *Penicillium chrysogenum*, was prepared for the inoculation of bread slices. The biomaterial of *Penicillium chrysogenum* was transferred from a tube

containing a pure culture of mould grown on malt agar to 1 cm^3 of sterile water using 'Tween-80' and thoroughly suspended. The suspension was inoculated into each slice of bread in three shots using a microbiological needle. Petri dishes with infected slices were incubated at a temperature of 25 ± 1 °C until the first signs of a growth of mould colonies appeared (Dubrovskaya, 2018).

Statistical analysis of the data

When analysing the results of experiments, standard approaches of probability theory and mathematical statistics were used: Duncan's test of two-factor analysis of variance with one repetition (ANOVA), Tukey tests (for a posteriori quality control of conclusions) and the Dunnett test for assessing the relationship with the test sample, paired t- test for samples with different variances to test the hypothesis of the difference between the two means.

RESULTS AND DISCUSSION

Rowan powder has high titratable acidity (40 degrees or 5.7% in terms of malic acid). That is why the content of different organic acids was established in the rowan powder (Table 1). It was found that rowan powder contained a large amount of organic acids including fatty and phenolic acids. Quinic (2002.68 mg 100 g^{-1} dried weight) and chlorogenic (11.5 mg 100 g^{-1} of dried weight) acids were represented in the greatest amount among the phenolic acids. Organic acids in rowan powder did not match the acids in the sourdough (Arendt et al., 2007; Poutanen, 2009), but it is important that they were represented by a wide range. This allows suggesting the effectiveness of the use of rowan powder as an acidifying additive and as smell and taste improver.

Table 1. Organic acid content in rowan powder

Acid	mg 100 g^{-1} of dried weight
malic	2,941.13 ± 146.15
succinic	66.01 ± 3.33
lactic	12.40 ± 1.10
sorbic	27.83 ± 1.96
2-hydroxypropionic	759.62 ± 36.95
3- hydroxypropionic	4.89 ± 0.26
phosphoric	63.64 ± 3.43
glyceric	29.20 ± 1.46
saccharic	0.16 ± 0.01
malonic	28.87 ± 2.01

Table 2. Microbial indicators

Indicators	Rowan powder	Requirements of TR CU 021/2011
MAFAM, CFU·g^{-1}	(1.2 ± 0.1) ·10^2	≤ 5·10^3
Moulds, CFU·g^{-1}	-	≤ 1·10^2
		The mass of the product (g) in which it is not allowed:
Escherichia coli group	-	1 g
Staphylococcus aureus	-	1 g
Pathogenic, including *Salmonella* genus	-	25 g

The microbiological safety of rowan powder was investigated for compliance with the requirements of the Technical Regulation of the Customs Union 'Food Safety' TR

CU 021/2011. Microbiological indicators of rowan powder fully complied with the requirements of TR CU 021/2011 (Table 2). Therefore, the powder can be safely used in the formulation of the acidifying additive and for bread making.

When the new acidifying additive was used, the acidity of the dough and bread increased (Table 3). This can be due to the high acidity of the rowan powder. At the same time, the dough lifting capacity also improved with increasing additives to 3.5%. This may be due to the fact that the rowan powder contained vitamins and minerals necessary for the nutrition of yeast (Kurtzman et al., 2011; Verheyen et al., 2015), while the acidity is not so high as to suppress yeast activity. With an increase in the dosage of the additive to 4.0 and 4.5%, the dough lifting capacity deteriorated compared to bread with a 3.5% of additive. This can be due to an increase in acidity which inhibits yeast (Zhou et al., 2014).

Table 3. Physical and chemical indicators of dough and bread*

Indicators	Control	Bread with new additive (g on 100 g of flour)				
		2.5	3.0	3.5	4.0	4.5
Dough:						
Acidity, degrees	9.4 ± 0.1^{a}	9.0 ± 0.1^{b}	10.0 ± 0.1^{b}	11.3 ± 0.2^{c}	12.3 ± 0.1^{d}	12.6 ± 0.1^{f}
Lifting capacity, min.	5.0 ± 0.1^{a}	5.0 ± 0.1^{a}	4.0 ± 0.1^{b}	3.0 ± 0.1^{c}	4.0 ± 0.1^{b}	4.0 ± 0.1^{b}
Bread:						
Acidity, degrees	6.0 ± 0.1^{a}	5.9 ± 0.1^{a}	6.4 ± 0.1^{b}	7.2 ± 0.1^{c}	7.8 ± 0.1^{d}	8.2 ± 0.1^{f}
Porosity, %	66.0 ± 0.2^{a}	66.0 ± 0.2^{a}	66.0 ± 0.2^{a}	67.0 ± 0.2^{a}	67.0 ± 0.2^{a}	66.0 ± 0.2^{a}
Specific volume, $cm^3\ g^{-1}$	1.89 ± 0.01^{a}	2.03 ± 0.02^{b}	1.9 ± 0.02^{c}	2.13 ± 0.02^{d}	1.98 ± 0.01^{f}	1.89 ± 0.02^{a}
Compressibility, U	26.0 ± 0.3^{a}	26.0 ± 0.1^{a}	28.0 ± 0.3^{b}	28.0 ± 0.1^{b}	27.0 ± 0.2^{c}	26.0 ± 0.1^{a}

* a–f = Means ± SD within the same line with different lowercase superscript letters denote significantly different among dough types ($p \leq 0.05$).

The bread specific volume and the crumb compressibility increased when the additive dosage increased to 3.5%. With a further increase of the additive dosage to 4.0 and 4.5%, the bread specific volume decreased. This can be associated with a slowdown in yeast activity in the dough due to high acidity (Zhou et al., 2014). Another reason may be sorbic acid presented in the rowan powder. Sorbic acid has detrimental effects on dough, bread and yeast-raised goods characteristics. The baked products may have reduced volume and an irregular cell structure (Gioia et al., 2017). With an increase in dosage of rowan powder, the content of sorbic acid in the dough also increased. This could affect the decreasing of specific volume.

Test baking results clearly demonstrated that optimal amount of new acidifying additive was 3.5% by weight of flour (Table 3). It allowed making bread with intensively dark brown colored crust, developed with thin-walled uniform porosity, not crumbly, with a pronounced harmonious taste and smell (Table 4). A further increase in the plant acidifying additive dosage was impractical because organoleptic and physico-chemical indicators worsen.

Since rowan powder contains organic acids having a preservative effect, the effect of new acidifying additives with rowan powder on the bread microbiological spoilage was investigated.

Yeast and mould were absent on the surface and in the crumb of bread after baking. In the control and in the bread made using 2.5% of the new acidifying additive, $1.1 \cdot 10^3$ and $0.5 \cdot 10^3$ CFU·g^{-1} of spore-forming bacteria were detected, respectively. In samples containing 3.0, 3.5 and 4.0% of the new acidifying additive, spore-forming bacteria were not found. This indicates that the acidifying additive inhibited spore-forming bacteria vital activity. The inhibitory effect was probably caused by the acids in rowan powder. High titratable acidity is known to effectively inhibit *Bacillus* strains (Oscroft et al., 1990; Katina et al., 2002; Lavermicocca, 2016).

Table 4. Bread sensory characteristics

Indicators	Control	Bread with new additive (g on 100 g of flour)				
		2.5	3.0	3.5	4.0	4.5
Crust						
Shape	4.80 ± 0.18^a	4.80 ± 0.13^a	4.81 ± 0.22^a	4.82 ± 0.32^a	4.82 ± 0.32^a	4.82 ± 0.32^a
Surface	4.80 ± 0.18^a	4.80 ± 0.13^a	4.81 ± 0.22^a	4.82 ± 0.32^a	4.82 ± 0.32^a	4.82 ± 0.32^a
Colour	3.20 ± 0.16^a	3.31 ± 0.19^a	3.89 ± 0.04^b	4.90 ± 0.15^c	4.90 ± 0.15^c	4.90 ± 0.15^c
Crumb						
Colour	3.5 ± 0.10^a	3.49 ± 0.38^a	3.64 ± 0.14^a	4.80 ± 0.21^b	4.81 ± 0.27^b	4.62 ± 0.32^b
Odour	2.78 ± 0.18^a	2.82 ± 0.28^a	3.99 ± 0.23^b	4.01 ± 0.06^b	4.00 ± 0.12^b	2.89 ± 0.12^a
Taste	2.75 ± 0.18^a	2.95 ± 0.18^b	3.19 ± 0.19^c	3.19 ± 0.19^c	4.09 ± 0.04^d	4.01 ± 0.04^f
Chewiness	3.19 ± 0.19^a	3.25 ± 0.15^a	3.34 ± 0.29^a	4.01 ± 0.10^b	3.92 ± 0.05^c	3.89 ± 0.14^c
Porosity	4.59 ± 0.23^a	4.63 ± 0.31^a	4.65 ± 0.25^a	4.69 ± 0.38^a	4.60 ± 0.22^a	4.60 ± 0.28^a

* a–f = Means ± SD within the same line with different lowercase superscript letters denote significantly different among dough types ($p \leq 0.05$).

It was found out that in the control bread slices, contaminated by P*enicillium chrysogenum,* the mould colonies growth was observed in 48 ± 2 h, and in samples with 2.5 and 3.0% of the new acidifying additive the mould colonies growth was observed in 56 ± 2 and 60 ± 2 h, respectively. On slices of bread made with 3.5 and 4.0% of acidifying additives mould growth slowed by a 24 h compared to the control. The usage of the rowan powder allowed slowing down the rye-wheat bread mould disease. However, this result is not successful enough. Obviously, organic acids content in new additive are not enough to stop moulding (Sadeghi Mahounack & Shahidi, 2001; Gioia et al., 2017).

Therefore, to enhance the effect of the plant acidifying additive with rowan powder and to increase bread shelf life, sodium diacetate was used in an amount of 0.1–0.3% by weight of the product (Sadeghi Mahounack & Shahidi, 2001). Its optimal amount was determined not only by the microbiological parameters of the bread, but also by the duration of the technological process, because when sodium diacetate was used the shelf life was extended. The control was prepared with a plant acidifying additive with rowan powder without sodium diacetate (Table 5).

It was established (Table 5) that with the addition of 0.1% sodium diacetate, the proofing time increased in 1.3 times compared with the control. The *Penicillium chrysogenum* mould colonies growth on bread slice with new acidifying additive containing 0.1% sodium diacetate was a day later than on the control. With the addition of 0.2 and 0.3% sodium diacetate, the proofing time increased by 1.9 and 3.9 times, respectively. Mould colonies in these samples were not detected during the entire storage period (7 days). The inhibitory effect in this case was probably due to the sodum diacetat action (Sadeghi Mahounack & Shahidi, 2001).

Therefore, it is recommended to use 0.1% sodium diacetate. With this concentration, the proofing time increased slightly, but the rate of mould development slowed down significantly.

Table 5. The effect of sodium diacetate in the new plant acidifying additive on the quality of the dough and bread

Indicators	Sodium diacetate quantity in new acidifying additive, %			
	0	0.1	0.2	0.3
Dough:				
Acidity, degrees N	9.5 ± 0.1^{a}	10.5 ± 0.1^{b}	10.9 ± 0.1^{c}	11.5 ± 0.1^{d}
Lifting capacity, min.	8.0 ± 0.1^{a}	9.0 ± 0.1^{b}	14.0 ± 0.2^{c}	35.0 ± 0.2d
Duration of proofing, min	35.0 ± 0.4^{a}	45.0 ± 0.7^{b}	66.0 ± 0.5^{c}	138.0 ± 0.1^{d}
Acidity, degrees N	6.4 ± 0.1^{a}	7.2 ± 0.1^{b}	7.6 ± 0.1^{c}	8.0 ± 0.1^{d}
Porosity, %	66.0 ± 0.1^{a}	67.0 ± 0.1^{b}	69.0 ± 0.1^{c}	66.0 ± 0.2^{a}
Specific volume, $cm^3\ g^{-1}$	1.9 ± 0.1^{a}	1.9 ± 0.1^{a}	2.0 ± 0.1^{a}	1.9 ± 0.1^{a}
Volatile acids, % of the total acidity	6.25 ± 0.03^{a}	10.10 ± 0.13^{b}	13.80 ± 0.02^{c}	16.90 ± 0.05^{d}
Quantity of alcohol, % of dried weight	0.50 ± 0.01^{a}	0.51 ± 0.01^{a}	0.64 ± 0.01^{b}	0.42 ± 0.01^{c}
The storage time before *Penicillium chrysogenum* growth, h	96 ± 1^{a}	120 ± 1^{b}	> 7 days	> 7 days

* a–f = Means ± SD within the same line with different lowercase superscript letters denote significantly different among dough types ($p \leq 0.05$).

The bread made with diacetate had the better compressibility then the control bread throughout the entire storage period (Fig. 1). The results confirmed the data obtained by Sadeghi Mahounack & Shahidi (2001), that sodium diacetate allows to inhibit bread staling.

Swelling decreased during storage (Fig. 2). The swelling capacity of the samples with rowan powder was higher than that of the control bread during the storage period. This is probably due to a decrease in the ability of colloidal substances in control bread to absorb water by compacting the structure of starch and proteins during bread aging. Besides the rowan powder has high fiber content with high swelling index. Staling of bread with rowan powder was slower, and it was confirmed by measuring of the compressibility (Fig. 2).

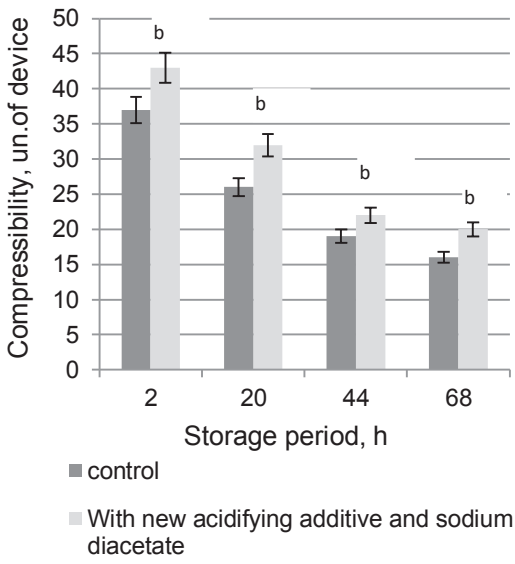

Figure 1. Crush compressibility during bread storage*.

* The letter (b) means the rejection of the hypothesis (a significant difference in the results at the level of 0.05), the calculated value of the t-value criterion is the tabular value of the t-student criterion.

The effect of the new acidifying additive with rowan powder (3.5%) on the nutritional value of rye-wheat bread is shown in Table 6.

The addition of rowan powder in the composition of a new plant acidifying additive showed a positive effect on the content of dietary fiber. Its content in relation to control increased by 10%. Therefore, due to the use of rowan powder, we can observe an increase in the daily requirements for these substances for adults.

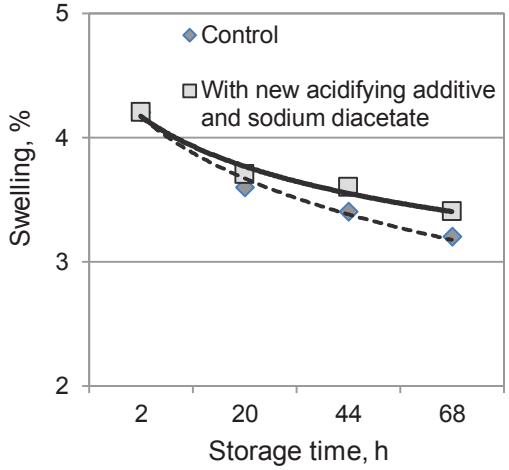

Figure 3. Change in the swelling of the crumb during the storage of bread.

Rowan powder in the composition of new plant acidifying additive had a positive effect on the content of vitamins and minerals. Vitamins A, E, ascorbic acid and mineral elements (manganese and selenium) were found in the experimental samples, while their content in the control bread was below the detection limit. Rowan powder had the significant effect on the enrichment of rye - wheat bread with vitamin B2 and iron.

Table 6. Satisfaction of daily requirements or nutrients

Substance	Consumption norm	Requirements, %		t*
		Control	Bread with 3.5% of new additive	
Proteins, g day^{-1}	75	8.1 ± 0.1	8.3 ± 0.1	3.34[a]
Fats, g day^{-1}	83	1.2 ± 0.02	1.2 ± 0.1	0.53
Digestible carbohydrates, g day^{-1}	365	11.8 ± 0.02	11.9 ± 0.2	4.05[a]
Dietary fiber, g day^{-1}	30	19.3 ± 0.1	21.7 ± 0.4	0.46
Vitamins:				
ascorbic acid, mg day^{-1}	90	-	1.0 ± 0.1	
A, mg day^{-1}	900	-	1.1 ± 0.1	
E, mg day^{-1}	15	-	5.5 ± 0.2	
B_1, mg day^{-1}	1.5	9.3 ± 0.1	9.3 ± 0.1	
B_2, mg day^{-1}	1.8	3.8 ± 0.1	4.0 ± 0.1	2.09
Minerals:				
Sodium, mg day^{-1}	1,300	25.7 ± 0.3	33.6 ± 0.5	19.35
Magnesium mg day^{-1}	400	8.8 ± 0.1	8.9 ± 0.1	0.65
Potassium, mg day^{-1}	2,500	7.3 ± 0.1	7.8 ± 0.2	2.74
Calcium, mg day^{-1}	1,000	2.3 ± 0.06	2.8 ± 0.1	4.55
Iron, mg day^{-1}	14	17.1 ± 0.2	20.7 ± 0.2	16.66
Manganese, mg day^{-1}	2	-	1.8 ± 0.2	
Zinc, mg day^{-1}	12	-	0.083 ± 0.012	

*The letter (a) means acceptance of the hypothesis (a slight difference in the results at the level of 0.05), the calculated value of the t-test does not exceed the tabular value of the Student's t-test (from 2.77 to 4.3).

It is known that the main sources of bio antioxidants for humans are food products based on plant materials. Rowan powder is known to contain antioxidant such as vitamins C and E, selenium and carotenes, etc.

When the total content of water-soluble antioxidants was determined, it was found that in bread prepared used new acidifying additive with rowan powder the content of water-soluble antioxidants was higher than in control by 55.6%.

Thus, studies have shown that the use of a new plant acidifying additive with rowan powder for accelerated technology of rye-wheat bread lead to an improvement in organoleptic and physico-chemical parameters, and antioxidant activity has increased.

CONCLUSIONS

New plant acidifying additive with rowan powder was created to improve the quality, nutritional value and microbiological stability of rye-wheat bread made in accelerated way without sourdough usage. With an increase in the new plant additive dosage above 3.5%, the dough lifting capacity deteriorated due to the suppression of yeast by the acidity. The bread specific volume and the crumb compressibility increased when the additive dosage increased to 3.5% and was worse when additive dosage was higher than 3.5%. This can also be associated with a slowdown in yeast activity in the dough due to high acidity. Taste and smell was also better in bread with new additive due to the rowan powder chemical composition. The optimum dosage of new additive rowan powder in rye-wheat bread formulation was 3.5% by weight of the flour. The bread with 3.5% of new additive had an intensely dark brown crust, developed thin-walled uniform porosity, non-wrinkling crumb, pronounced harmonious taste and smell of new acidifying additive allowed inhibition of spore-forming bacteria vital activity in bread and inhibition the rye-wheat bread mould disease, but it was not satisfactory enough. The sodium diacetate usage in an amount of 0.1% by weight of the product allowed significantly slow down the rate of mould development in bread without deterioration of bread quality. The bread made with diacetate had the better compressibility and swelling capacity then the control bread throughout the entire storage period. Bread with new additive contained more dietary fiber, vitamin B2 and iron. Vitamins A, E, ascorbic acid and mineral elements (manganese and selenium) were also found in bread with new additive, while in the control bread they were below the detection level. New acidifying with rowan powder allowed to create accelerated rye-wheat bread technology and to get bread with high consumer properties.

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