**The effect of yeast extract addition on bread quality parameters**

VLADIMIR FILIPOVIC1, JELENA FILIPOVIC2, VESNA VUCUROVIC1\*, VESNA RADOVANOVIC1, MILENKO KOSUTIC2, NEBOJSA NOVKOVIC3 and NATASA VUKELIC3

*1 University of Novi Sad, Faculty of Technology, Bul. cara Lazara 1, 21000 Novi Sad, Serbia*

*2 University of Novi Sad, Institute of Food Technology, Bul. cara Lazara 1, 21000 Novi Sad, Serbia*

*3 University of Novi Sad, Faculty of Agriculture, Trg Dositeja Obradovića 8, 21000 Novi Sad, Serbia*

# *\*Corresponding author: E-mail* [*vvvesna@uns.ac.rs*](mailto:vvvesna@uns.ac.rs)

# *Abstract*

The effects of yeast extract addition, with varied quantities of salt and sugar, on the chemical and mineral composition, colour and sensory properties of spelt bread, in order to obtain new products were investigated. The addition of 5% yeast extract positively influenced the mineral characteristics and increased protein content, for 30.77%. As a salt substitution, addition of yeast extract improved appearance without deteriorating texture descriptors and bread crumb quality, while the taste became more complex, but without increasing salty taste. Addition of sugar in samples with yeast extract, improved most sensory characteristics. Developed mathematical models of bread with yeast extract quality parameters were statistically significant, indicating on satisfactory approximation of bread quality parameters within the varied formla. Bread samples with addition of 5% of yeast extract, 1.5% of salt and 0% sugar were determined as the best from the aspect of overall quality. New product is obtained, with good total quality, higher level of nutritional value and reduced salt content.

*Keywords:* salt reduction, protein enriched product, nutritional value, mathematical models

RUNNING TITLE: BREAD WITH ADDED YEAST EXTRACT

INTRODUCTION

In accordance with the modern nutritionist opinions, cereal products such as bread enriched with functional components, are the most common foods in the daily diet1. Consumers have been increasingly interested in health effects of food or their components 2. Bread has a significant role in human diet regardless of ethnic or religious orientation. It is consumed on a daily basis, in wide range of types, qualities and all diets all over the world 3,4. The average consumption is approximately 70 kg of bread per capita per year, while European people consume on average 59 kg of bread per year though, there are remarkable differences across European countries 4. Its nutritional value and health benefits can be improved by adding bioactive component and decreasing the salt content in bread 3,5. These changes to bread formula are addressed to people who are not eager to modify their eating habits. On the other hand, these changes may be accompanied by the deterioration of sensory qualities that significantly affects the consumers' product acceptance 5. During milling of wheat grain, a high proportion of minerals, vitamins and fibers are lost resulting in a reduction in the nutritional value of the flour 6. Whole meal spelt wheat has higher protein and mineral elements (Fe, Zn, Cu, Mg and P) content compared to *Triticum Aestivum* 7,8. For this reason, whole meal and spelt species wheat were used for bread production.

Yeast extract, is a yeast product separated from inner yeast cells and usually is in the forms of liquid, paste or powder. It could be a functional source of nutrients and excellent natural seasoning, widely used as ingredient for the production of savory foods 9,10. Yeast extract is a natural ingredient composed of a variety of peptides, nucleotides, B-complex vitamins, minerals and high quality protein rich in essential amino acids 9.

Comparing composition of yeast protein and muscle protein, in terms of essential amino acids composition, results revealed striking similarity. Yeast protein is shown to contain all of the essential amino acids and to be a biologically complete protein 11.

Yeast extract can be used also as an ingredient for functional foods with health benefits production. Functional foods are conventional food products, which are taken as a part of normal diet and demonstrate health benefits beyond their nutritional properties 12. The effects of functional foods on the humans' health often are not easily measurable, their positive impact could be seen after the end of the perennial period of consumption 13.

Elevated dietary salt intake is an established risk factor for high blood pressure and salt reduction has consistently been shown to reduce cardiovascular events 14. Consequently, the World Health Organization issued a public health recommendation of a maximum intake for adults of 5 grams per day 15,16. For this reason, food industry should reduce the amount of salt added to food products in effort of improving public health 15,17.

The aim of the study is to test the addition of yeast extract, as an active ingredient, to the bread formula in effort to reduce the amount of salt and increase protein and mineral content and to obtain a new product on the market with enhanced nutritive value and good sensory characteristics.

# EXPERIMENTAL

*Material*

For whole meal bread production, flour from spelt, grown in the year 2018 in Serbia was used. Tested chemical composition is presented in table 1.

Salt, sugar and yeast are commercial products, taken from a local food market. Salt was produced by "SO PRODUCT" d.o.o Stara Pazova, Serbia, sugar was produced by “Crvenka”, Crvenka, Serbia yeast and yeast extract were taken from “Altech Serbia d.o.o” Senta, Serbia. Yeast extract chemical composition is presented in table 1.

Table 1. Chemical composition of whole meal spelt flour and yeast extract

|  |  |  |
| --- | --- | --- |
| Chemical compostion (% d.m.) | Whole meal spelt flour | Yeast extract |
| Moisture | 10.00 | 6.29 |
| Ash | 3.05 | 8.00 |
| Total sugar | 2.35 | 1.52 |
| Protein | 17.02 | 79.68 |
| Cellulose | 2.37 | 0.00 |
| Starch | 65.87 | 0.00 |
| Fat | 2.38 | 0.17 |

*Bread making procedure*

Bread was baked according to the slightly modified AACC method 18. The composition of bread dough was: spelt flour (in amount of 100g), yeast extract, salt and sugar (in amount determined by experimental plan in table 2), instant dry yeast, ascorbic acid and water in amounts of 0.5 g, 0.6 ml (1g ascorbic acid in 100 ml water) and 60 g, respectively.

Table 2 shows design matrix of varied bread formulas, with coded values, where -1, 0 and +1, represents added quantities of yeast extract, salt and sugar in amounts of 0, 2 and 5; 1.0, 1.5 and 2; 0, 5 and 10% d.m. on flour basis, respectively.

Table 2. Design matrix with coded values of yeast extract, salt and sugar addition as independent variables

|  |  |  |  |
| --- | --- | --- | --- |
| Sample no. | Yeast extract | Salt | Sugar |
| 0 | -1 | -1 | -1 |
| 1 | -1 | -1 | 0 |
| 2 | -1 | 0 | -1 |
| 3 | -1 | 0 | +1 |
| 4 | -1 | +1 | 0 |
| 5 | 0 | -1 | -1 |
| 6 | 0 | -1 | +1 |
| 7.1\* | 0 | 0 | 0 |
| 7.2\* | 0 | 0 | 0 |
| 7.3\* | 0 | 0 | 0 |
| 7.4\* | 0 | 0 | 0 |
| 7.5\* | 0 | 0 | 0 |
| 8 | 0 | +1 | -1 |
| 9 | 0 | +1 | +1 |
| 10 | +1 | -1 | 0 |
| 11 | +1 | 0 | -1 |
| 12 | +1 | 0 | +1 |
| 13 | +1 | +1 | 0 |

\*Repetitions in central point

Measured ingredients were placed in the farinograph bowl and mixed until peak time, previously determined by farinograph curve. Ingredients' temperature yielded final dough temperature of 30°C. After mixing dough was rounded by hand and placed in the fermentation cabinet at 30°C. Bulk fermentation lasted 150 minutes, while punching was done by hand, after 60 and 120 minutes from the beginning of the bulk fermentation. After bulk fermentation, dough was moulded by hand and placed in greased pan. Proofing was done at 32°C, at relative humidity of 75%, during 60 minutes. Baking was done for 25 minutes, at 230°C, at humidity provided by the oven.

*Basic chemical analysis*

Basic chemical analyses (protein, starch, fat, total sugar, and cellulose) of whole meal spelt flour and bread were determined according to the official methods of AOAC19.

*Mineral content of bread*

Mineral content of zinc, copper, magnesium, calcium and iron was determined using an Atomic Absorption Spectrophotometer, AOAC 20.

*Colour of bread*

The bread colour was measured using a tri-stimulus colour meter type CR-400 (Konica, Minolta, Tokyo, Japan) equipped with D65 illuminant. The results were expressed as per CIELab system in terms of coordinates: L\*- lightness (0, black to 100, white), a\*- redness (-a\*, green to +a\*, red), and b\*-yellowness (-b\*, blue to +b\*, yellow), C\* - differences in chroma (+ brighter, – duller). The measurements were observed under constant lighting conditions, at 28 ºC, using a colour attributes of white control plate, L\*=98.76, a\*=-0.04 and b\*=2.01 8.

*Bread crumb quality determination*

Bread crumb quality was quantified by sensory evaluation of both, texture analysis of crumb elasticity and crumb grain structure. Evaluation was performed twenty four hours after the baking by the panel of five trained evaluators using numeric scores that gave summary values ranging from minimum 0 to maximum 7 21.

*Sensory analysis*

Sensory analysis was conducted according to SRPS ISO 4121:2002 22. Team of six trained panelists identified descriptors, and scored sensory characteristics using 10-point scale (1 – lowest, 10 - highest intensity of descriptors). The following descriptors were evaluated: appearance, taste, aroma and texture. The panelists were asked to evaluate randomly coded 2 cm slice of bread and to rinse their mouth with water before and after each bread tasting. The sensory analysis was done 24 h after baking.

*Statistical analysis*

Response surface methodology (RSM) and Analysis of variance (ANOVA) were selected to estimate the main effects of the yeast extract, salt and sugar addition to the formula on the bread quality parameters. The accepted experimental design was according to Box and Behnken’s experimental plan 23, which uses minimum experimental runs for every tested independent variable optimization 24. The independent variables were quantity of yeast extract (X1), quantity of salt (X2) and quantity of sugar (X3). The dependent variables were the responses of chemical composition: (Y1– Y5); the responses of mineral composition (Y6 – Y10); the responses of instrumental colour and texture analysis (Y11 – Y15) and the responses of sensory analysis (Y16– Y31). A model was fitted to the response surface generated by the experiment. The model used was function of the variables:

(1)

The following second order polynomial (SOP) model was fitted to the data. Thirty-two models of the following form were developed to relate thirty-one responses (Y) to three process variables (X):

(2)

where βkij are constant regression coefficients.

ANOVA and RSM were performed using StatSoft Statistica, for Windows, ver. 12 program (STATISTICA 2012). The model was obtained for each dependent variable (or response) where factors were rejected when their significance level was less than 95 %.

For the purpose of ANOVA Tukey HSD analysis all testing was performed in three parallel runs.

*Z-Score analysis*

Z-Score analysis uses min-max normalisation of bread quality parameters transforming them from their original unit system in new dimensionless system where further mathematical calculations with different types of quality parameters are applicable 25. Maximum value of normalised score presents optimum value of all combined analysed parameters, indicating on optimum total quality:

, *k*=1-3, *j*=1-2 (3)

where *xk* are: proteins, starch, and cellulose, and *xj* are: fat, total sugars;

, *l*=1-5 (4)

where *xl* are: Zn, Cu, Mg, Ca and Fe;

, *m*=1-5 (5)

where *xm* are: L\*, a\*, b\*, C\* and bread crumb quality;

, *n*=1-8, *o*=1-8 (6)

where *xn* are: characteristic appearance, taste and aroma, crust colour intensity, colour uniformity, sweet taste, elasticity and pores uniformity, and *xo* are: crumb colour intensity, sour and salty taste, sour, yeast and pungent aroma, firmness and wall thickness;

, *p*=1-4 (7)

where *Sp* are *S1*, *S2*, *S3* and *S4*;

(8)

RESULTS AND DISCUSSION

Bread product is a complex multi component system consisting of bio macromolecules such as proteins, carbohydrates and lipids. Investigated breads were characterized by low protein content in the samples without yeast extract (samples 0–4), where addition of non-protein components (salt and sugar), reduced bread samples' protein content, table 3. The addition of yeast extract contributed to the statistically significant increase of protein content in bread, since yeast extract is rich in proteins 9,10, which can also be seen from graphical presentation of developed mathematical models of dependence of bread protein content from yeast extract, sugar and salt addition, figures S1a and S1b. Linear terms of yeast extract and sugar statistically significantly contributed to the SOP model forming.

Table 3. Average values and standard deviations of the chemical composition of the bread with yeast extract

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sample no. | Proteins  (% d.m.) | Starch  (% d.m.) | Fat  (% d.m.) | Total sugars  (% d.m.) | Cellulose  (% d.m.) |
| 0 | 17.20±0.19 c | 61.20±0.60 e | 2.30±0.03 h | 1.99±0.01 a | 2.64±0.05 e |
| 1 | 16.02±0.02 b | 58.17±0.41 d | 2.18±0.01 ef | 7.03±0.03 c | 2.50±0.03 c |
| 2 | 17.05±0.07 c | 60.91±0.13 e | 2.29±0.03 gh | 2.05±0.04 a | 2.66±0.04 e |
| 3 | 15.17±0.15 a | 55.27±0.51 b | 2.06±0.04 bc | 11.89±0.17 e | 2.41±0.03 b |
| 4 | 15.05±0.04 a | 57.31±0.63 cd | 2.12±0.04 cd | 6.99±0.02 c | 2.45±0.04 b |
| 5 | 19.03±0.17 e | 60.26±0.33 e | 2.24±0.07 fg | 1.99±0.02 a | 2.62±0.20 d |
| 6 | 16.14±0.15 b | 52.98±0.45 a | 2.02±0.03 ab | 11.11±0.10 d | 2.39±0.22 b |
| 7 | 16.93±0.10 c | 56.20±0.73 bc | 2.11±0.06 cd | 6.95±0.06 c | 2.48±0.02 c |
| 8 | 17.89±0.18 d | 57.71±0.39 d | 2.18±0.08 ef | 1.97±0.03 a | 2.47±0.02 c |
| 9 | 16.11±0.17 b | 52.69±0.68 a | 1.97±0.03 a | 10.86±0.12 d | 2.32±0.02 a |
| 10 | 20.95±0.07 e | 55.55±0.59 b | 2.07±0.03 cd | 7.02±0.08 c | 2.38±0.03 b |
| 11 | 20.06±0.19 f | 57.34±0.58 cd | 2.17±0.08 de | 2.04±0.03 a | 2.51±0.03 c |
| 12 | 18.20±0.27 d | 51.84±0.62 a | 1.96±0.02 a | 10.99±0.12 d | 2.29±0.02 a |
| 13 | 19.10±0.09 e | 53.17±0.24 a | 2.02±0.05 ab | 5.99±0.06 b | 2.44±0.04 b |

a-h Different letters in superscript in the same table column indicate on statistically significant difference between values, at level of significance of p<0.05 (based on post hoc Tukey HSD test)

Starch is dominant component in bread, where maximum value (61.2 0% d.m.) was observed in sample 0 and, as expected, the minimum content of starch (51.84 % d.m.) was observed in sample 12, table 3 and figures S2a and S2b. The addition of maximum quantity of yeast extract statistically significantly decreased starch content in bread (samples 10-13), due to the addition of non-starch component (yeast extract) to the bread formula. All three SOP linear terms, together with cross products of yeast extract x salt and salt x sugar were statistically significant in model forming.

The highest content of fat was in sample 0 (2.30 % d.m.), while the lowest was in sample 12 (1.96% d.m.), table 3 and figures S3a and S3b. Addition of yeast extract in quantity of 5% statistically significantly decreased fat content in bread. Addition of salt and sugar decreased fat content in bread also, since all of these additions are non-fat components. All three SOP linear terms were statistically significant in model forming.

The addition of yeast extract, did not statistically significantly changed the total sugar content of bread samples, figures S3a and S3b. The addition of higher quantities of salt indirectly affected the chemical composition of the bread. Total sugar content was statistically significantly affected by the addition of the sugar to the bread formula, and the highest values were observed in samples 3, 6, 9 and 12, table 3, while SOP linear terms for sugar and yeast extract were statistically significant.

The highest contents of cellulose were noticed in samples 0, 2 and 5 with 0% sugar (2.64, 2.66 and 2.62 % d.m., respectively), while the lowest content of cellulose was in sample 12 (2.29 % d.m.) with 10% sugar, table 3. From figures S5a and S5b it can be seen that only linear term of sugar statistically significantly contributed to the bread with yeast cellulose content mathematical model forming.

The daily quantities of mineral nutrients are, by nature, small, especially when compared to nutrients such as, macro minerals, but it is necessary for organisms to function 26. Addition of yeast extract to the bread formula statistically significantly increased contents of Zn, Mg and Ca, while it did not statistically significantly affected the Cu and Fe bread samples content, table 4. Linear SOP terms for yeast extract and sugar were statistically significant in all cases of bread mineral composition models, which can be seen form dependencies presented on figures S5a,b – S10a,b. Quadratic term for salt statistically significantly contributed to the Zn and Cu model forming, together with statistically significant quadratic term for sugar in case of Cu model. The highest values of Zn, Mg and Ca (26.48, 407.84 and 123.94 mg kg-1, respectively) were found in bread sample 11, which is characterized by the highest addition of yeast extract, table 4, figures S6a,b, S8a,b and S9a,b. Based on recommend minimum daily intake of mineral matter for a normal functioning of metabolism 26, the daily intake of 100 g of bread with yeast extract (in quantity of 5 %) fulfils 17.65 %, 29.20 %, 10.20 %, 1.24 % and 25.30 % of recommended daily intake of Zn, Cu, Mg, Ca and Fe, respectively.

As in case of changing the chemical composition of bread with added yeast extract, the addition of higher quantities of sugar and salt affected indirectly the mineral composition of bread.

Table 4. Average values and standard deviations of the mineral composition of the bread with yeast extract

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sample no. | Zn  (mg kg-1) | Cu  (mg kg-1) | Mg  (mg kg-1) | Ca  (mg kg-1) | Fe  (mg kg-1) |
| 0 | 22.94±0.22 de | 6.09±0.01 g | 294.93±4.91 cd | 81.17±0.51 b | 44.94±0.27 de |
| 1 | 21.81±0.35 bc | 5.70±0.06 de | 270.24±1.74 ab | 78.85±1.10 b | 41.55±0.22 ab |
| 2 | 22.91±0.22 de | 6.09±0.04 fg | 290.28±2.69 c | 81.71±0.70 b | 44.50±0.71 de |
| 3 | 20.73±0.09 a | 5.44±0.05 a-c | 265.83±3.00 a | 71.63±0.04 a | 40.83±0.61 a |
| 4 | 21.09±0.37 a | 5.51±0.05 b-d | 276.61±2.77 b | 78.86±0.94 b | 41.49±0.91 ab |
| 5 | 24.44±0.37 g | 5.93±0.05 fg | 351.47±3.36 g | 110.55±0.93 f | 45.80±0.69 e |
| 6 | 22.41±0.06 cd | 5.38±0.07 ab | 310.83±2.84 e | 99.14±0.75 d | 41.01±0.50 a |
| 7 | 23.42±0.02 ef | 5.67±0.04 c-e | 334.53±3.11 f | 99.56±0.73 d | 43.14±0.34 c |
| 8 | 24.01±0.39 fg | 5.87±0.05 ef | 340.12±4.93 f | 103.74±1.12 e | 44.84±0.30 de |
| 9 | 21.69±0.26 b | 5.25±0.05 a | 300.21±3.06 d | 94.80±0.73 c | 40.48±0.56 a |
| 10 | 25.27±0.21 h | 5.51±0.04 c-d | 380.52±4.12 i | 120.12±0.98 h | 43.64±0.50 cd |
| 11 | 26.48±0.18 i | 5.84±0.04 ef | 407.84±1.27 j | 123.94±1.56 j | 45.54±0.39 e |
| 12 | 24.06±0.30 fg | 5.27±0.07 a | 364.27±6.41 h | 114.69±1.13 g | 41.31±0.34 a |
| 13 | 24.65±0.18 gh | 5.44±0.08 a-c | 370.04±3.77 h | 120.11±0.09 h | 42.80±0.35 bc |

a-j Different letters in superscript in the same table column indicate on statistically significant difference between values, at level of significance of p<0.05 (based on post hoc Tukey HSD test)

Colour is an important organoleptic characteristic of baked products and it influences consumer choices 27. Addition of yeast extract in quantities of 2.5 and 5 % in bread products (samples of 5-13) contributed, in most cases, to the statistically significant increase of L\*, b\* and C\* parameters and statistically significant decrease of a\* parameter, table 5 and figures S11a,b – S14a,b. Only linear SOP term for yeast extract has shown statistical significance in all four models of colour characteristics. Based on the increase of parameters L\*and b\* it is possible to see the positive effect of the yeast extract on the bread colour, since its' lighter and more yellow colour than whole meal spelt flour. Due to the increased Fe content of bread samples with yeast extract addition (table 4), positive effects of yeast extract on bread colour characteristics can be probably attributed to catalyzation of oxidative reaction of ascorbic acid to dehydro-ascorbic acid 11, thus acting as dough improver.

Increasing levels of salt addition to the bread samples statistically insignificantly increased L\*, b\* and C\* values. While addition of sugar statistically insignificantly decreased L\* and increased C\* values, probably related to requirements for the initiation of colour formation during bread baking 28.

Addition of the yeast extract to the bread formulas statistically significantly improved bread crumb quality, comparing corresponding bread samples (2 and 11; 4 and 13), and analyzing modeled dependence of bread crumb quality from yeast extract addition, presented on figures S15a and S15b. Together with proposed mechanism of dough improvement by increased Fe content, yeast extract (containing dead yeast cells) acts as yeast food source 11, improving fermentation tolerance, loaf volume and overall bread crumb quality.

Salt concentration, however, is not only inﬂuential on the sensory acceptability of food in terms of taste. In case of bread, salt is an essential ingredient, being crucial for a proper development of dough structure. The interaction of salt with dough components such as gluten is very important due to inhibitory effect on proteolytic enzymes and direct interaction with flour proteins, providing better dough handling and oven spring 11,16. Proposed effects are contributing to higher bread crumb quality, as it can be seen form the statistically significant increase of the bread crumb quality results in the samples with higher salt addition (comparison of the samples 5 and 8; 10 and 13, and also from the figure S15a).

Analyzing yeast extract, as a salt substitution in the bread formulas, on texture characteristics, by comparing bread samples 4 and 10, it can be seen that addition of yeast extract only statistically insignificantly decreased bread crumb quality (for about 2.5 %).

Bread samples with sugar added in the highest quantities to their recipes had the highest bread crumb quality values, figure S15b, indicating that sugar acted as improver of textural characteristics of bread with added yeast extract. Added sugar promoted vigorous yeast fermentative activity, contributed to delayed gelatinization of starch and protein denaturation, consequently improving oven spring and bread crumb and pores quality 11. In case of bread crumb quality model, only linear term for sugar has shown statistical significance.

Table 5. Average values and standard deviations of the instrumental colour and bread crumb quality analysis of the bread with yeast extract

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sample no. | L\* | a\* | b\* | C\* | Bread crumb quality |
| 0 | 64.37±0.75 a | 5.36±0.06 e | 17.79±0.18 bc | 18.55±0.25 ab | 1.65±0.15 b |
| 1 | 64.14±0.72 a | 5.35±0.02 e | 17.21±0.21 a | 18.61±0.13 a-c | 4.15±0.15 e |
| 2 | 64.44±0.63 ab | 5.74±0.05 g | 17.98±0.13 c | 18.87±0.23 bc | 2.20±0.20 c |
| 3 | 64.37±0.80 a | 5.63±0.04 fg | 17.32±0.07 ab | 18.26±0.12 a | 5.00±0.00 i |
| 4 | 64.87±0.80 a-c | 5.51±0.02 ef | 19.06±0.33 d | 18.84±0.20 bc | 3.95±0.05 d |
| 5 | 65.99±0.75 a-e | 4.68±0.05 d | 19.29±0.22 de | 19.11±0.11 cd | 1.50±0.00 a |
| 6 | 65.15±0.34 a-d | 4.62±0.06 d | 19.68±0.12 ef | 19.51±0.27 de | 4.55±0.05 h |
| 7 | 66.88±0.60 c-e | 4.60±0.07 d | 19.30±0.17 de | 20.01±0.33 ef | 4.30±0.30 g |
| 8 | 66.45±1.00 b-e | 4.43±0.05 c | 19.45±0.21 d-f | 19.59±0.11 de | 2.25±0.25 c |
| 9 | 65.74±0.36 a-e | 4.38±0.05 c | 19.84±0.23 f | 19.79±0.20 e | 4.65±0.15 h |
| 10 | 67.09±0.17 de | 3.62±0.04 a | 20.81±0.16 g | 19.99±0.20 ef | 3.85±0.15 d |
| 11 | 67.79±0.69 e | 3.74±0.02 ab | 20.79±0.37 g | 20.58±0.11 g | 4.30±0.30 fg |
| 12 | 65.97±0.19 a-e | 3.66±0.02 a | 20.66±0.29 g | 20.49±0.05 fg | 4.20±0.20 ef |
| 13 | 70.04±0.93 f | 3.84±0.03 b | 21.05±0.32 g | 20.88±0.16 g | 4.25±0.25 e-g |

a-f Different letters in superscript in the same table column indicate on statistically significant difference between values, at level of significance of p<0.05 (based on post hoc Tukey HSD test

Table 6. shows results of the sensory analysis of the bread with yeast extract, from where it can be seen that yeast extract addition statistically significantly affected all: appearance, taste, aroma and texture descriptors. From the figures S16a,b – S31a,b it can be seen that yeast extract addition affected the increase of descriptors for characteristic appearance, crust and crumb colour intensity, colour uniformity, sweet, sour and salty taste, sour, yeast and pungent aroma and wall thickness, while affected the decrease of descriptors for colour uniformity, characteristic taste and aroma, firmness, elasticity and pores uniformity.

Lysine from yeast extract could be the major source of primary amines in proteins in Maillard reactions of condensation between reducing sugars and amino acids 28, providing the increased crumb colour intensity of the bread samples containing yeast extract.

Linear SOP term of yeast extract for characteristic appearance, crust colour intensity, crumb colour intensity and for all taste and aroma descriptors statistically significantly contributed to the SOP model forming. Quadratic term of yeast extract was statistically significant for sweet taste and yeast aroma models.

Different quantities of salt addition (comparison of the sample 1 and 4; 5 and 8; 10 and 13; figures S16a-S31a) statistically significantly increased the characteristic appearance, crust and crumb colour intensity, salty taste, pungent aroma and all texture descriptors, while decreased colour uniformity descriptors. Linear term for salt was statistically significant in cases of characteristic appearance, salty taste and yeast and pungent aroma models. Quadratic term for salt was statistically significant in cases of sweet taste and elasticity models.

Addition of sugar statistically significantly contributed to the increase of characteristic appearance, crust and crumb colour intensity, sweet and salty taste, pungent aroma, elasticity and pores uniformity descriptors. (comparison of the samples 11 and 12, figures S16b-S31b). Sugar added to the bread with yeast extract statistically significantly decreased colour uniformity, characteristic taste and aroma, firmness and wall thickness. Sugar addition in quantities of 5 and 10 % in samples with yeast extract addition of 5 % (samples 10 and 12), improved most of sensory characteristics in comparison to the bread samples with yeast extract addition but without sugar addition (sample 11).

Linear term for sugar statistically significantly contributed to the characteristic taste and aroma, yeast aroma, and all texture descriptors models' forming. Quadratic term for sugar was statistically significant only in case of elasticity model. Crops product term of yeast extract x sugar was statistically significant in cases of characteristic and salty taste, characteristic aroma and texture descriptors of firmness, elasticity and wall thickness models.

By comparing the effectiveness on sensory characteristics of yeast extract as a salt substitution in the bread samples recipes, by analyzing bread samples 4 and 10; 1 and 7; 3 and 6; it can be seen that addition of yeast extract improved appearance descriptors, without high deterioration of texture descriptors. In the Maillard reactions the type of flavor compound formed depends on the type of sugars and amino acids involved 28, so the taste of the samples with yeast extract became more complex, but without increasing salty taste. Aroma of the yeast extract bread samples was also changed, with statistically significantly increased descriptors of sour, yeast and pungent, what was expected.

Table 6.Average values and standard deviations of the sensory analysis of the bread with yeast extract

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sam-ple no. | Appearance | | | | Taste | | | |
| Chara-cteristics | Crust colour intensity | Crumb colour intensity | Colour unifor-mity | Chara-cteristic | Sweet | Sour | Salty |
| 0 | 5.1±0.3 a | 2.1±0.1 a | 2.0±0.1 a | 8.1±0.1 c | 9.0±0.0 h | 1.0±0.0 a | 1.0±0.0 a | 1.0±0.0 a |
| 1 | 6.1±0.2 c | 4.0±0.0 d | 4.2±0.2 b | 7.9±0.1 c | 8.0±0.0 g | 1.1±0.1 a | 1.0±0.0 a | 1.0±0.0 a |
| 2 | 5.0±0.0 a | 3.2±0.2 b | 4.1±0.1 b | 8.0±0.0 c | 8.1±0.1 g | 1.0±0.0 a | 1.0±0.0 a | 3.2±0.2 b |
| 3 | 6.0±0.0 c | 4.1±0.3 d | 4.0±0.3 b | 8.0±0.0 c | 3.1±0.3 ab | 2.0±0.0 b | 2.0±0.0 b | 2.0±0.0 c |
| 4 | 6.5±0.5 d | 4.0±0.0 d | 4.1±0.1 b | 8.0±0.0 c | 5.0±0.0 f | 2.1±0.2 bc | 2.0±0.0 b | 4.0±0.0 d |
| 5 | 5.5±0.4 b | 3.5±0.2 c | 6.0±0.0 cd | 8.1±0.1 c | 3.9±0.1 c | 3.1±0.1 d | 3.9±.01d | 2.1±0.2 b |
| 6 | 7.1±0.1 e | 7.1±0.1 g | 5.9±0.1 cd | 8.0±0.0 c | 3.2±0.2 b | 2.2±0.2 c | 2.0±0.0 b | 2.0±0.0 b |
| 7 | 6.5±0.2 d | 6.9±0.1 g | 6.0±0.0 cd | 8.0±0.0 c | 4.1±0.1 d | 4.3±0.3 e | 4.1±0.1 e | 3.1±0.1 c |
| 8 | 7.5±0.2 f | 5.5±0.5 e | 5.8±0.2 c | 8.0±0.0 c | 4.5±0.1 e | 3.0±0.0 d | 4.0±0.0 de | 5.2±0.2 e |
| 9 | 8.1±0.1 g | 8.0±0.0 h | 8.1±0.1 e | 8.1±0.1 c | 3.1±0.1 ab | 3.1±0.1 d | 3.2±0.2 c | 5.8±0.2 g |
| 10 | 7.2±0.2 e | 6.0±0.5 f | 6.1±0.3 d | 8.0±0.0 c | 3.1±0.3 ab | 8.1±0.1 f | 7.0±0.0 f | 4.0±0.0 d |
| 11 | 7.5±0.2 f | 9.5±0.5 j | 7.9±0.1 e | 7.9±0.1 c | 3.0±0.0 a | 9.5±0.2 i | 6.9±0.1 f | 3.1±0.1 c |
| 12 | 8.1±0.1 g | 9.9±0.1 k | 8.1±0.1 e | 7.5±0.1 b | 3.2±0.2 b | 8.5±0.2 g | 8.0±0.1 g | 5.5±0.2 f |
| 13 | 8.0±0.0 g | 9.0±0.0i | 8.0±0.0 e | 7.2±0.2 a | 3.1±0.1 ab | 9.0±0.0 h | 8.1±0.1 g | 6.2±0.2 h |
|  | Aroma | | | | Texture | | | |
|  | Chara-cteristic | Sour | Yeast | Pungent | Firmness | Elasticity | Wall thick-ness | Pores unifor-mity |
| 0 | 8.8±0.2 i | 1.0±0.0 a | 2.1±0.1 a | 3.2±0.2 c | 7.8±0.2 i | 2.1±0.1 a | 8.8±0.2 k | 2.5±0.5 b |
| 1 | 7.6±0.1 g | 1.1±0.1 a | 2.0±0.0 a | 2.2±0.1 a | 2.5±0.5 b | 4.5±0.3 d | 3.1±0.1 b | 7.0±0.0 e |
| 2 | 8.5±0.5 h | 1.0±0.0 a | 2.0±0.0 a | 2.5±0.1 b | 7.5±0.5 h | 2.5±0.5 b | 7.4±0.4 i | 3.5±0.5 c |
| 3 | 3.0±0.0 a | 2.1±0.1 bc | 3.2±0.2 c | 2.6±0.1 b | 2.1±0.1 a | 8.5±0.3 h | 2.5±0.5 a | 8.5±0.5 j |
| 4 | 4.7±0.3 f | 2.0±0.0 b | 3.0±0.2 b | 3.2±0.2 c | 5.0±0.0 f | 5.2±0.2 f | 5.5±0.5 f | 6.5±0.5 d |
| 5 | 3.7±0.2 c | 3.7±0.3 e | 5.2±0.2 d | 5.1±0.1 e | 8.5±0.3 j | 2.5±0.5 b | 8.0±0.0 j | 2.2±0.2 a |
| 6 | 3.0±0.0 a | 2.2±0.2 c | 5.5±0.5 e | 5.0±0.0 e | 2.6±0.4 b | 4.5±0.5 d | 3.2±0.2 b | 7.8±0.2 h |
| 7 | 3.9±0.1 d | 4.0±0.0 f | 6.1±0.1 g | 4.8±0.2 d | 5.1±0.1 f | 8.8±0.1 i | 5.0±0.0 e | 7.5±0.1 g |
| 8 | 4.4±0.1 e | 3.8±0.2 e | 5.9±0.1 f | 6.1±0.1 f | 7.5±0.5 h | 2.5±0.5 b | 6.8±0.2 h | 3.5±0.0 c |
| 9 | 3.0±0.0 a | 3.0±0.0 d | 7.2±0.2 i | 7.5±0.5 i | 3.2±0.2 d | 5.0±0.0 e | 3.5±0.5 c | 8.0±0.0 i |
| 10 | 3.0±0.0 a | 7.1±0.1 g | 6.9±0.1 h | 7.2±0.2 h | 5.9±0.1 g | 5.5±0.5 g | 6.5±0.5 g | 6.5±0.4 d |
| 11 | 2.9±0.1 a | 7.0±0.0 g | 7.5±0.2 j | 7.0±0.0 g | 3.0±0.0 c | 4.6±0.4 d | 3.5±0.5 c | 7.0±0.0 e |
| 12 | 3.3±0.3 b | 8.2±0.2 h | 8.1±0.1 k | 7.5±0.2 i | 5.1±0.1 f | 3.5±0.5 c | 5.1±0.1 e | 7.2±0.2 f |
| 13 | 3.3±0.3 b | 8.3±0.3 h | 8.0±0.0 k | 7.6±0.3 i | 3.5±0.5 e | 4.5±0.5 d | 4.0±0.0 d | 7.5±0.0 g |

a-k Different letters in superscript in the same table column for the same sensory descriptor indicate on statistically significant difference between values, at level of significance of p<0.05 (based on post hoc Tukey HSD test)

Tables S1-S4 show regression coefficients of thirty-one SOP models of chemical and mineral composition, instrumental colour, texture and sensory characteristics of bread with yeast extract. The statistical significance of individual coefficients is marked and also values of coefficient of determination (R2) are shown. Calculated critical values with critical values of independent variables are also presented in these tables. High values of R2 in all developed models (ranging from 0.881 to 0.999) indicated that applied models for the responses of chemical and mineral composition, instrumental colour, bread crumb quality and sensory characteristics of bread with yeast extract were adequately fitted to the experimental data. Using presented data quadratic equations, which describe SOP models of bread with yeast extract quality parameters, can be completed. Data obtained from these models can be used for quality of bread with yeast extract prediction and optimization.

Table 7. Score values of the bread with yeast extract quality parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sample no. | S1 | S2 | S3 | S4 | *Score* |
| 0 | 0.66 | 0.52 | 0.23 | 0.56 | 0.49 |
| 1 | 0.45 | 0.22 | 0.34 | 0.73 | 0.43 |
| 2 | 0.67 | 0.48 | 0.34 | 0.54 | 0.51 |
| 3 | 0.28 | 0.06 | 0.40 | 0.66 | 0.35 |
| 4 | 0.41 | 0.15 | 0.48 | 0.57 | 0.40 |
| 5 | 0.73 | 0.76 | 0.34 | 0.33 | 0.54 |
| 6 | 0.30 | 0.28 | 0.53 | 0.58 | 0.42 |
| 7 | 0.47 | 0.48 | 0.59 | 0.54 | 0.52 |
| 8 | 0.59 | 0.64 | 0.42 | 0.39 | 0.51 |
| 9 | 0.29 | 0.17 | 0.56 | 0.48 | 0.37 |
| 10 | 0.56 | 0.69 | 0.55 | 0.39 | 0.55 |
| 11 | 0.70 | 0.92 | 0.66 | 0.47 | 0.69 |
| 12 | 0.32 | 0.45 | 0.57 | 0.35 | 0.42 |
| 13 | 0.53 | 0.59 | 0.78 | 0.35 | 0.56 |

Table 7 shows the result of the Z-Score analysis providing the information about segment and total quality of tested bread samples. The highest value of *S1* of bread sample with addition of 2.5% of yeast extract, 1% of salt and 0% sugar, indicated on the best chemical composition, while the highest value of *S2* of bread sample with addition of 5% of yeast extract, 1.5% of salt and 0% sugar, indicated on the best mineral composition. The highest value of *S3* of bread sample with addition of 5% of yeast extract, 2% of salt and 5% sugar, indicated on the best colour and bread crumb quality, while the highest value of *S4* of bread sample with addition of 0% of yeast extract, 1.0% of salt and 5% sugar, indicated on the best sensory characteristics. The best total quality is determined for the bread sample containing 5% of yeast extract, 1.5% of salt and 0% sugar addition.

CONCLUSIONS

From presented results it can be concluded following:

Bread samples with added yeast extract were characterized by improved nutritional profile, due to increased high quality protein from yeast, Zn, Mg and Ca content. Colour and bread crumb quality of bread samples with yeast extract was significantly improved. Yeast extract addition statistically significantly affected all bread samples' sensory characteristics descriptors.

Analysis of yeast extract, as a salt substitution, in the bread formulas have shown that yeast extract improved appearance without deteriorating texture descriptors and bread crumb quality, while taste became more complex, but without increasing salty taste.

Although addition of yeast extract deteriorated overall sensory characteristics, combination of sugar and yeast extract addition, improved most sensory characteristics, enhancing overall acceptability of bread samples.

Developed mathematical models of thirty-two bread with yeast extract quality parameters were statistically significant. Results showed that calculated and observed responses corresponded very well, indicating on satisfactory approximation of bread quality parameters in dependence of addition of yeast extract, salt and sugar.

Bread samples with addition of 5% of yeast extract, 1.5% of salt and 0% sugar were determined as the best from the aspect of overall quality.

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ИЗВОД

**Утицај додатка екстракта квасца на параметре квалитета хлеба**

ВЛАДИМИР ФИЛИПОВИЋ1, ЈЕЛЕНА ФИЛИПОВИЋ2, ВЕСНА ВУЧУРОВИЋ1\*, ВЕСНА РАДОВАНОВИЋ1, МИЛЕНKО KОШУТИЋ2, НЕБОЈША НОВKОВИЋ3, НАТАША ВУKЕЛИЋ3

*1Универзитет у Новом Саду, Технолошки факултет, Бул. цара Лазара 1, 21000 Нови Сад, Србија*

*2Универзитет у Новом Саду, Научни Институт за прехрамбене технологије, Бул. цара Лазара 1, 21000 Нови Сад, Србија*

*3Универзитет у Новом Саду, Пољопривредни факултет, Трг Доситеја Обрадовића 8, 21000 Нови Сад, Србија*

Испитан је утицај додатка различите количине екстракта квасца, соли и шећера, на хемијски и минерални састав, боју и сензорна својства хлеба од органске спелте, како би се добио нови производ на тржишту. Додатак 5% екстракта квасца на масу брашна од спелте позитивно је утицао на нутритивне карактеристике хлеба повећањем садржаја протеина у хлебу за 30,8% и обогаћењем минералима. Додатак екстракта квасца побољшао је изглед без погоршања дескриптора текстуре и квалитета хлеба, док је укус постао комплекснији, али без повећавања сланог укуса. Додатак шећера у узорцима са екстрактом квасца, побољшао је већину сензорних и текстуралних карактеристика хлеба. Развијени математички модели параметара квалитета хлеба са екстрактом квасца били су статистички значајни, указујући на задовољавајуће предвиђање параметера квалитета хлеба у оквиру граница варираних рецептура. Додатак 5% екстракта квасца, 1,5% соли и 0% шећера се показао као оптималан са аспекта укупног квалитета хлеба. Хлеб од спелте обогаћен екстрактом квасца (2,5-5%) имао бољи хемијски и минерални састав, боју и сензорна својства, с повећаним нивоом нутритивне вредности и смањеним уделом соли.

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