MOKSLO TAIKOMIEJI TYRIMAI LIETUVOS KOLEGIJOSE, 2018 Nr.14, p. 118-123
ISSN 1822-1068/ eISSN 2335-8904, http://ojs.kaunokolegija.lt/index.php/mttlk/index

POSSIBILITIES OF BREAD ENRICHMENT WITH MINERALS BY USING SUGAR BEET MOLASSES

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Abstract. Various scientific researches proved that the most important macro and microelements for human health are potassium, calcium, iron, magnesium. Sugar beet molasses (SBM), which is a concentrated liquid extract and a by-product of sugar refining, is full of mentioned macro and micronutrients. The aim of the research is to study the possibilities for the use of sugar beet molasses in the production of rye bread enriched with minerals. For the study, the sugar beet molasses from JSC *Lietuvos cukrus* Ltd was used. Five samples of rye bread (control, 8%, 10%, 12%, 14% addition of SBM to flour mass) were prepared and baked. To estimate the influence of sugar beet molasses on the quality and acceptability of the bread for consumers, the sensory evaluation of the bread samples was carried out; the moisture content, the acidity, the actual acidity, the specific volume of the bread were defined; the number of minerals in molasses was estimated by laboratory tests; and also the nutritional value of the bread was calculated. The study showed that when up to 10% molasses is added to the total flour mass in rye bread, the sensory parameters in comparison with the control product are superior: better aroma, the appearance of dark colour, soft texture and good taste. There was no significant impact on the specific volume and titratable acidity of the bread. The most acceptable for evaluators was the bread with 50 g molasses added to 1kg bread sample. The results showed that the mineral content (K, Fe, Ca) of the rye bread samples were significantly improved. The bread that contains molasses is a good source of iron (14.31-18.08% of DRIs).

Keywords: sugar beet molasses, mineral content, rye bread.

Introduction

Sugar beet molasses is a concentrated liquid extract that is a by-product of sugar refining. It is a thick, tight, sticky, dark brown liquid. Molasses was one of the first sweeteners very often used in human nutrition in the diet of the poor population due to its price lower in comparison to refined sugar or honey (Asadi et al, 2006; Šarić et al, 2016). Beet molasses has a high content of solids (around 80%) and contains about 20-28% of water (Calabia, Tokiwa, 2007). Molasses contains in average 50-60 % of sugar: about 51% saccharose, 1% rafinose, 0.25% glucose and fructose, melibiose and galactose, 5% proteins, 6% betaine, 1.5% nucleosides, purine and pyrimidine bases, organic acids and bases, but it does not contain fats and fibrous materials (Ou, 1985). Apart from these ingredients, sugar beet molasses is a significant source of numerous minerals, especially K, Ca, Fe, Na and Mg. An especially important fact is that all mineral components of molasses are in the dissolved state (Škrbić et al, 2010; Koprivica, Misljenovic et al, 2009). In addition, molasses contains free and bound amino acids (Filipčev et al, 2015; 2016).

About 20% of the total mass consists of non-sucrose organic matter, by a range of important bioactive compounds in particular of non-protein nitrogen-containing substances such as betaine, crude proteins, non-nitrogen substances, vitamins, etc. On the basis of the fact that about 4 kg of molasses result from 100 kg of beets, it is striking that almost the entire amount of nicotinic acid contained in the beets arrives in the molasses. Molasses contains B-complex vitamins: pantothenic acid (5-11mg), pp factor (5,1mg), B1 (130mcg), B2 (41mcg), B6 (0,54mg), inositol (577-800 mg), folic acid (0,021), biotin (4-13 mcg), also other growth substances. These materials exert a stimulative effect on the growth of the yeast (Mirzaei-Aghsaghali, 2008).

The colouring matters that appear in the course of the manufacture of sugar, caramel materials, are the result of thermal decomposition of saccharose. They contain no nitrogen; polyphenol-iron complexes - pyrocatechol, which occurs in the epidermis and the head of beets (in amounts around 0.02%); melanoidines - condensation products of reducing sugars and amino acids molasses; melanins - beet tyrosinase on access of air it introduces the oxidation of various aromatic compounds (pyrocatechol, tyrosine) and products blackish-grey discolouration (Olbrich, 1963; Honig, 2013).

Molasses has the humectant and antioxidant properties and influences the activity of final products. Taking into account the high content of solids and diversity of chemical composition of sugar beet molasses, the idea of testing the possibilities of application of sugar beet molasses as an osmotic medium in osmotic dehydration of fruits and vegetables was imposed (Koprivica, Misljenovic et al, 2009). Beet molasses is one of the most excellent sources of betaine, suitable to increase betaine content in, for example, baked food (Heikkila et al, 1992; Rajakylä et al, 1983; Filipčev et al, 2015; 2016). Beet molasses has marked antioxidative potential and has been recognized as suitable to be exploited on a large scale as a source of antioxidants and as an ingredient in functional foods (Chen et al, 2015). The food enriched with beet molasses showed enhanced mineral and antioxidant profile (Valli et al, 2012; Filipčev et al, 2010, 2012, 2015, 2016). The sugar beet molasses polyphenols (gallic acid, cyanidin-3-O-glucoside chloride) showed bacterio-static activity against the growth of four food-borne pathogens. The gallic acid showed the strongest antioxidant activity. The results suggested that SBM is a natural source of antioxidant for preparing functional foods. Liu et al (2014) demonstrate that chromium containing complexes from molasses show promise in reducing insulin resistance in the instances of Type 2 diabetes, and that among the chromium complexes, glucose tolerance factor performs the best.

Molasses has special importance as a safe additive in the preparation of fermented feeds, the so-called silage. Sugar syrup and molasses from beet processing were assayed as low-cost and available substrates for the enzymatic synthesis of fructooligosaccharides (Ghazi et al, 2006). Beet molasses is the most widely used substrate for baker's yeast production by its availability and low cost, composition and absence of toxic substances as well as fermentation inhibitors (Bekatorou et al, 2006). Beet molasses is used as a substrate for the production of lactic acid by *Lactobacillus delbrueckii* NCIMB 8130 in static and shake flask fermentation (Bekatorou et al, 2006). Bacterial friendly cellulose is produced from beet molasses using *Gluconacetobacter xylinus* ATCC1 0245 (Keshk et al, 2006). Molasses is a raw material for the production of activated carbon (Glonek, 2016), xanthan gum (Funahashi et al, 1987; Kalogiannis, 2003). The largest amounts of molasses are used for bio ethanol production.

Extensive research activities are going on with the aim to introduce molasses as a valuable ingredient in bakery, confectionery and meat processing industry. On the contrary, sugar beet molasses has not had greater application in the human diet, primarily because of its distinct earthy taste, which makes it unattractive for consumption (Steg and Van Der Meer, 1985; Filipčev and Lević, 2010). However, numerous studies have shown that it is possible to incorporate sugar beet molasses in various food products without negatively affecting their palatability. It can be used to supplement wheat bread at 5-10% level (flour basis), at up to 25% in semi-sweet biscuits, and as honey replacer at up to 50% in formulations of gingerbread-type biscuits (Filipčev et al, 2010, 2012; Šimurina et al, 2006, 2008, 2012, 2017; Šarić et al, 2016).

The aim of the research is to study the possibilities for the use of sugar beet molasses in the production of the rye bread enriched with minerals.

Materials and Methods

Physical-chemical investigation of sugar beet molasses.

For the study, sugar beet molasses from JSC *Lietuvos cukrus* Ltd were used.

The total protein content in the sugar beet molasses was determined using the Kjeldahl method.

The determinations of the content of minerals (K, Fe, Ca, Mg) in molasses were conducted after dry mineralization of the samples. Measurements were carried out with Atomic Absorption Spectrometry, with excitation in acetylene-air flame in a UNICAM 939 apparatus.

Preparation of bread samples

Rye bread samples were prepared at the Laboratory of Food Technologies at Klaipeda State University of Applied Sciences in accordance with the leavened bread production technology.

First of all, rye leaven was prepared from rye flour, water and the mother leaven sourdough with Lactobacilli at 1:1,25:0,25 ratio. It was divided into 5 equal pieces, 240g each. 5 rye bread samples were prepared with different content of molasses: 1st - control, 2nd with 40g of SBM (8% addition of SBM from flour mass), for the next, the SBM amount was increased by 50g (10%) respectively till 70 g (14%). The mass was leavened at 32-34°C for 12 hours. Further, the bread samples were prepared according to the recipe presented in Table 1.

Table 1. Recipes of bread samples

Sample	C	M1	M2	M3	M4
Sourdough, g	240	240	240	240	240
Ray flour, g	400	400	400	400	400
Wheat flour 550D, g	100	100	100	100	100
Molasses, g	0	40	50	60	70
Water, g	300	260	250	240	230
Salt, g	12	12	12	12	12
Caraway, g	10	10	10	10	10
Sugar, g	30	30	30	30	30

The obtained mass of bread samples was mixed in the mixer "Kitchen Aid" (Germany) for 20 min, the dough was leavened in a thermostat at the same temperature for 4 hours. Then the dough was put up in forms, leavened once more for 30 minutes at 32-34°C and baked in the oven "Metos Chef" at 250°C for 45 minutes. The baked products were stored for

60 min at room temperature (18-20°C), placed in plastic bags and stored for 24 hours.

Physical-chemical investigation of the bread

The loaf volume was measured by rapeseed displacement method, cm^3, of the standard ICC 131.

The specific volume was calculated as loaf volume to weight ratio, cm^3 g-1, of the standard ICC 131.

The moisture content of the crumb was measured by the humidity measuring device Kern MLS 50-3HA 160N.

pH was measured by the pH-meter ORION 3STAR.

Total titratable acidity was expressed as the amount of 1N NaOH (ml) consumed for the neutralization of free acids per 100g of bread sample of the standard LST 1553:1998.

The sensory evaluation of the bread was carried out using a 5-point scale by a group of 8 assessors. The bread was evaluated for colour, taste, aroma, the appearance of crust, texture and overall acceptability, with the score 1-5, where 1 represented extremely disliked and 5 extremely liked.

Mathematical statistical analysis of the data

The wheat bread baking experiments were repeated twice along with the investigation of 5 samples. The mathematical statistical data analysis was performed using MS Excel software. The nutritional and energy values were calculated using a specific Excel spreadsheet.

Results and Discussion

The chemical composition studies of molasses were performed partly at the Chemistry Laboratory at Klaipeda State University of Applied Sciences and partly at the laboratory of the National Food and Veterinary Risk Assessment Institute. The results of the chemical investigation of sugar beet molasses are presented in Table 2.

Table 2. Chemical composition and characteristics of sugar beet molasses

Water content, %	21.77
Sucrose, %	47.6
Total Fat,%	0.10
Protein, %	6.2
Ash content, %	16.62
pH	8.3
K, mg/100g	1590±68.2
Mg, mg/100g	28.02±0.36
Fe, mg/100g	17.6±2.82
Ca, mg/100g	326.9±45.1

In the Lithuanian molasses, the sugar content ranges 47,6%, and this result meets the standards, meanwhile Šarič et al (2016) discovered the 49.7 - 51% amount of sucrose, the amount of protein (6.2) was defined very similar to the results of researches from other countries (6.0-13%). The amounts of calcium and magnesium in Lithuanian molasses is very similar to the one described by other authors; however, the amount of potassium in Lithuanian molasses was found to be less than expected (1590 mg/100g) in comparison with the results of Šarič et al (2016) studies (3751 mg/100 g). According to this study, the amount of iron was determined to be higher, 17.62 mg/100 g in comparison with Šimurina et al (2012) results,10.21 mg/100g and Šarič et al (2016), 13.49 mg/100g.

Molasses was applied in bread over 10-14% (flour basis) range. The output of all the five baked bread samples turned out to be similar and amounted to 89.87 to 90.8%; the dependence of the output on the sugar beet molasses content was insignificant. Increasing molasses doses had a softening effect and resulted in a darker colour of the bread mass (see Picture 1).

Picture 1. The colour of the flesh of bread samples C – control, M1 – 40g, M2– 50g , M3 – 60g , M4 – 70g of molasses

It was found that upon the increase of SBM, the moisture content of the product decreased slightly (see Table 3). The total titratable acidity varied between 3.88 and 4.36 ml 1N NaOH. A significant increase in the pH and a decrease in titratable acidity were determined because the minerals Ca, Mg, K neutralize acids formed in bread during fermentation.

Table 3. Characteristics of bread samples

Sample	**Moisture content** %	**pH**	**Total titratable acidity** ml 1N NaOH	**Specific volume** m3 g-1
C	41.11±0.2	4.47±0.02	4.36±0.1	1.73±0.02
M1	40.75±0.2	4.92±0.02	4.28±0.1	1.75±0.02
M2	40.26±0.2	5.44±0.02	4.22±0.1	1.79±0.02
M3	39.80±0.2	5.62±0.02	4.10±0.1	1.80±0.02
M4	39.52±0.2	5.71±0.02	3.88±0.1	1.79±0.02

The values of sensory analysis: the colour, taste, aroma, texture and the overall acceptability for control and fortified with SBM loaves of bread are presented in Table 4. The bread with 8%-10% addition of SBM from flour mass had a better taste, the colour of the flesh, texture and overall acceptability compared to control bread. However, higher SBM content considerably reduced the taste and aroma of the bread, an earthy taste of molasses was perceptible. The highest mean overall acceptability score (4.4) was observed in M2 bread (fortified with 10% of SBM from flour mass). The bread samples M1 and M3 have also been evaluated well. The results suggested that higher doses than 10 g/100 g flour would not be recommended.

Table 4. Sensory evaluation of the bread samples

Sample	C	M1	M2	M3	M4
The colour of the flesh	4.53	4.67	4.53	3.93	3.73
Taste	3.67	3.87	4.33	3.27	3.20
Aroma	4.33	4.27	4.13	3.4	3.27
Texture	3.93	4.07	4.47	3.4	3.33
The appearance of the crust	4.2	4.33	3.73	3.67	3.47
Overall acceptability	3.93	4.07	4.4	3.53	3.40

In order to assess the bread nutritional value and the increase in the content of minerals, nutritional and energy values were calculated using the recipe, product composition database and chemical laboratory tests of sugar beet molasses (see Table 5).

Table 5. Nutrition and energy values of bread samples

Sample	C	M1	M2	M3	M4
Energy, kJ	882	919	928	937	946
Energy, kcal	211	220	222	224	226
Total Fat, g	0,88	0,88	0,88	0,88	0,88
Saturated Fat, g	0,10	0,10	0,10	0,10	0,10
Total Carbo-hydrates, g	47,76	49,72	50,21	50,70	51,19
Sugars, g	3,30	5,20	5,68	6,16	6,63
Dietary Fiber, g	4,89	4,89	4,89	4,89	4,89
Protein, g	5,12	5,37	5,43	5,49	5,55
Salt, g	1,20	1,21	1,21	1,22	1,22
Ca, mg	17,34	30,26	33,49	36,71	39,94
Mg, mg	23,98	25,07	25,34	25,61	25,89
Fe, mg	1,30	2,00	2,18	2,36	2,53
K, mg	126,22	189,8	205,70	221,59	237,49

As the results revealed, the application to improve the quality of the special bread enriched with molasses seems to be justified. Under Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers, adults are recommended to consume 2000 mg of potassium, 800 mg of calcium, 375 mg of magnesium, 14 mg of iron per day. The reference mineral content in all of the bread samples is calculated and presented in Table 6.

Table 6. Reference mineral content in 100g of bread samples

Sample	C	M1	M2	M3	M4
Calories, %	10,55	10,98	11,09	11,19	11,30
Total Fat, %	1,25	1,25	1,25	1,25	1,25
Saturated Fat, %	0,48	0,48	0,48	0,48	0,48
Total Carbo-hydrates,%	18,37	19,12	19,31	19,50	19,69
Dietary Fiber	16,30	16,30	16,30	16,30	16,30
Sugars,%	2,22	2,22	2,22	2,22	2,22
Protein,%	10,24	10,73	10,86	10,98	11,10
Ca,%	2,17	3,78	4,19	4,59	4,99
Fe,%	9,28	14,31	15,57	16,83	18,08
K,%	6,31	9,49	10,28	11,08	11,87
Mg,%	6,39	6,69	6,76	6,83	6,90

Addition of molasses resulted in significant increase of Fe, K, Ca and Mg content in relation to the control. The total potassium and calcium contents in the control and enriched variants increased from 126.22 to 237.49 mg/100 g (meeting 6.39–11.87% of DRIs for K) and from 17.34 to 39.94 mg/100g (2.17-4.99% of DRIs for Ca), respectively. In the enriched bread, the iron content increased from 1.30 mg/100g to 2.53 mg/100g (9.28-18.08% of DRIs for Fe). The results are similar to the results in the research of other authors (Filipčev et al, 2010), where the most marked was the increase in K content: 89.1% in wheat bread with molasses. The mineral content varied depending on the supplementation level. An especially marked increase was observed in the calcium, potassium and iron content: K increases ranging from 50% for lower supplementation level and up to 88% for higher supplementation level; the increase in iron ranged between 54.20–94.83%; the increase in calcium ranged between 74.50–130%. The magnesium contents increased less markedly and ranged between 4.54–7.96%.

Sugar beet molasses can be used to 8-10% of flour mass in rye bread to obtain a product with improved nutritional characteristics and acceptable textural and sensory properties as well as improved mineral content.

Conclusions

1. Sugar beet molasses is a source of many bio-valuable components. The results of chemical investigation suggested that SBM is a natural source of minerals for preparing functional foods.
2. The present results suggest that the sugar beet molasses could be incorporated successfully in rye bread. The study showed that when up to 10% of molasses is added to the total flour mass in rye bread, the sensory parameters in comparison with the control product are superior: better aroma, the appearance of dark colour, soft texture and good taste. There was no significant impact on the specific volume and titratable acidity of the bread. The most acceptable for evaluators was the bread with 50 g molasses added to 1kg bread sample.
3. The results revealed that the mineral content (K, Fe, Ca) of the rye bread samples was significantly improved. The bread that contains molasses is a good source of iron (14.31-18.08% of DRIs).

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DUONOS PAPILDYMO MINERALINĖMIS MEDŽIAGOMIS, NAUDOJANT CUKRINIŲ RUNKELIŲ MELASĄ, GALIMYBĖS

Anotacija

Siekiant padidinti mineralinių medžiagų kiekį duonoje, jos papildymui naudota cukrinių runkelių melasa. Cukrinių runkelių melasa yra koncentruotas skystas ekstraktas, susidarantis kaip šalutinis cukraus rafinavimo produktas. Tai tirštas, tąsus, lipnus, tamsiai rudos spalvos skystis. Melasa turi didelį sausų medžiagų kiekį (apie 80 %), joje yra vidutiniškai 51 % sacharozės, 1 % rafinozės, 0,25 % gliukozės ir fruktozės, 5 % baltymų, 6 % betaino, 1,5 % nukleozidų, purino ir piramidino bazės, organinių rūgščių ir bazių. Be šių ingredientų, cukrinių runkelių melasa yra reikšmingas daugybės mineralinių medžiagų, ypač K, Ca, Na, Fe ir Mg šaltinis. Melasa buvo papildyta tradicinė juoda ruginė duona, gaminama su raugu. Melasos buvo dėta nuo 30 iki 70 g. Tyrimai parodė, kad dedant į duoną nuo miltų masės iki 10 % melasos, juslinės savybės palyginus su kontroliniu gaminiu yra geresnės: pagerėja aromatas, atsiranda tamsi spalva, minkšta tekstūra, malonus skonis. Reikšminga įtaka duonos specifiniam tūriui, porėtumui ir titruojamajam rūgštingumui nenustatyta. Labiausiai vertintojams priimtina duona su 50g melasos 1kg duonos bandiniui. Tokią duoną galima įvardinti kaip geležies (14,98 % nuo RMV) šaltinį.

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