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QUALITY OF BISCUITS AS AFFECTED BY ADDITION OF FIBRE

Viera Šottníková, Radka Langová, Luděk Hřivna, Šárka Nedomová, Miroslav Jůzl

ABSTRACT

The aim of the study was to propose formulas with addition of bamboo and hemp fibre and grape seed flour in an amount of 3, 6 and 9% and then assess the effect of added fibre on the quality of biscuits. A total of 20 samples were baked, in half of the samples the basic ingredient was wheat flour, and in the rest of samples spelt flour was used. During a baking experiment, it was found that the best effect on the product volume and the weight after baking had bamboo fibre. Minor baking losses occurred in biscuits with wheat flour. The best sensory results were attained with the sample having 3% of grape seed flour with a spelt flour base. The crispiest was the sample made from spelt flour with 3% of hemp fibre and the wheat samples with bamboo fibre were of the lightest colour. Control samples had the highest nutritional values and biscuits with added bamboo fibre contained the lowest energy in both formulas.

Keywords: fibre; biscuit; baking experiment; sensoric assessment; nutritional value

INTRODUCTION

Biscuits are very popular in the food industry. **Kumar et al. (2015)** indicate in their study that annual consumption of biscuits per person is 10 to 15 kg in developed countries. The biscuits are popular owing to their sensory attributes, long shelf life, relatively low price, suitable packaging sizes and availability **(Vitali, Dragojević and Šebečić, 2009; Brownlee et al., 2017)**. Due to competition in the market and increased demand for healthy, natural and functional products, the aim is to improve the nutritional value and functionality of biscuits by changing their nutritional composition. The beneficial properties and positive effect of fibre on the human organism are known for decades. Many studies show its association with body weight and insulin levels in the blood. Foods rich in fibre are digested more slowly and absorption of nutrients takes longer, which increases the feeling of satiety and consequently longer breaks between meals and lower energy intake. Although the energy gain from fibre is small, its main function is to protect and act as prevention against many non-infectious diseases of mass occurrence, such as heart and blood vessel diseases, colon cancer and tumours, obesity, and diabetes. It affects the excretion of hormones by glands with internal secretion, including cholecystokinin, which is secreted by cells in the small intestine, stimulates pancreatic secretion, and controls the central feeling of satiety. It helps to reduce postprandial glucose levels, unsaturated fats, blood triacylglycerols, and LDL cholesterol **(Marko, Rakická and Šturdík, 2015; Van Der Kamp et al., 2010)**.

Enriching biscuits with different types of fibre not only improves viscosity, texture, sensory properties and product durability with its physicochemical properties, but also reduces the energy value of the product **(Vitali, Dragojević and Šebečić, 2009; Brownlee et al., 2017)**. Through the formula adjustment and fortification, they are made to suit different uses, such as for sick, children, athletes or army **(Kadlec, Melzoch and Voldřich, 2012)**.

Scientific hypothesis

We are expecting the significant effect of added fibre on the quality of biscuits. Based on spectrophotometric color measurement it was assumed that the lightest colour would have the samples with bamboo fibre and the darkest color would have samples with grape seed flour.

According to sensoric analysis we assumed that the best evaluated sample would be the sample containing 6% of bamboo fibre even if both flours were used.

Based on the strength measurement we assumed that the smallest strength would be measured at samples enriched with hemp fiber.

MATERIAL AND METHODOLOGY

Biscuits of two kinds of flour were baked. The base consisted of wheat and spelt flour to which bamboo and hemp fibre and grape seed flour were added in an amount of 3, 6 and 9%. Subsequently, the quality of durable bakery products affected by the fibre was examined. Biscuits were baked and assessed in the pilot plant and laboratory of the Institute of Food Technology at Mendel University in Brno.

Two formulas were proposed (Table 1 and Table 2). The standard mixture consisted of wheat and spelt flour to which the selected fibre was added, always in the same proportion – 3, 6 and 9%.

Table 1 Proposed formula with a wheat flour base.

Sample no.		1	2	3	4	5	6	7	8	9	10
Wheat flour[g]		350	339.5	329	318.5	339.5	329	318.5	339.5	329	318.5
Powdered sugar [g]		120	120	120	120	120	120	120	120	120	120
Butter [g]		130	130	130	130	130	130	130	130	130	130
Vanilla sugar [g]		4	4	4	4	4	4	4	4	4	4
Lemon zest [g]		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Eggs* [pcs]		2	2	2	2	2	2	2	2	2	2
Fibre	**[g]**	0	10.5	21	31.5	10.5	21	31.5	10.5	21	31.5
	[%]	0	3 (2.91)**	6 (5.82)	9 (8.73)	3 (1.8)	6 (3.6)	9 (5.4)	3 (1.14)	6 (2.28)	9 (3.42)

Note: *Eggs were of size M (53 – 63 g). **The numbers in brackets indicate the actual fibre content declared by the manufacturer on the individual fibre packaging, converted to the percentage of the given formula.
Sample no. 1: control without fibre.
Samples no. 2 – 4: bamboo fibre in an amount of 3, 6, and 9%.
Samples no. 5 – 7: hemp fibre in an amount of 3, 6, and 9%.
Samples no. 8 – 10: grape seed flour in an amount of 3, 6, and 9%.

Table 2 Proposed formula with a spelt flour base.

Sample no.		11	12	13	14	15	16	17	18	19	20
Spelt flour [g]		350	339.5	329	318.5	339.5	329	318.5	339.5	329	318.5
Powdered sugar [g]		120	120	120	120	120	120	120	120	120	120
Butter [g]		130	130	130	130	130	130	130	130	130	130
Vanilla sugar [g]		4	4	4	4	4	4	4	4	4	4
Lemon zest [g]		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Eggs*[pcs]		2	2	2	2	2	2	2	2	2	2
Fibre	**[g]**	0	10.5	21	31.5	10.5	21	31.5	10.5	21	31.5
	[%]	0	3 (2.91)**	6 (5.82)	9 (8.73)	3 (1.8)	6 (3.6)	9 (5.4)	3 (1.14)	6 (2.28)	9 (3.42)

Note: **Eggs were of size M (53 – 63 g). **The numbers in brackets indicate the actual fibre content declared by the manufacturer on the individual fibre packaging, converted to the percentage of the given formula.
Sample no. 11: control without fibre.
Samples no. 12 – 14: bamboo fibre in an amount of 3, 6, and 9%.
Samples no. 15 – 17: hemp fibre in an amount of 3, 6, and 9%.
Samples no. 18 – 20: grape seed flour in an amount of 3, 6, and 9%.

The technology of production started with sifting flour and then mixing it with other loose ingredients (powdered sugar, vanilla sugar, fibre, and lemon zest). In the next step, softened butter and eggs (both yolks and whites) were added. All ingredients were worked together and kneaded for 7 minutes to develop smooth dough that was left to restin a cool place (10 °C) for 2 hours; meanwhile other doughs were prepared.

After the maturation phase, the dough was rolled with a special rolling pin having an adjustable dough sheet thickness set to 4 mm, so that all biscuits were of even height. Biscuits were cut out from all the doughusing round stamps with embossed patterns of 5.5 cm in diameter; the edges of shaped biscuits were higher due to the embossing pattern used. The cut-out biscuits were placed on a baking tray lined with parchment paper and put in a preheated hot air rotary oven at 160 °C for 15 minutes.

The baked biscuits were laid on stainless steel tables and left to cool freely. After cooling, on the same day, the physical measurement was carried out, followed, on the next day, by sensoric assessment using the proposed questionnaire and colour measurement using a spectrophotometer.

Sensoric assessment of biscuits

All samples were assessed the next day after baking. A panel of 10 trained judges completed the sensory questionnaire. A total of 20 samples with different fibre added were assessed. The questionnaire was composed of 10 questions and biscuit samples were assessed for colour, hardness (break strength), aroma, surface, shape and homogenity, taste, ease of bite, adhesion to palate, bite swallowing, and overall impression.

Hardness measurement

The biscuit strength was measured using the TIRATEST 27025 (TIRA Maschinenbau GmbH, Germany) on the day of their technological production. A penetration test at a rate of 100 $mm.min^{-1}$ was used to determine the brittleness of biscuits, with a stick of 3 mm diameter used as extension and a path of 5 mm. The strength was measured in [N].

Colour measurement using a spectrophotometer

The colour of biscuits was measured the day after the technological production, using the Konica Minolta CM-3500d spectrophotometer with a 30 mm measuring aperture and D65 illumination mode, in the reflectance mode with SCE (specular component excluded). The samples were measured from the bottom of the biscuit, each twice by attaching.

Determination of nutritional value

To determine the nutritional value of baked biscuits, the nutritional values per 100 g of ingredient used as declared by the manufacturer on the package were needed. The measured values were recalculated to the amount of ingredient used in the formula. The final data was converted to the weight of biscuits after baking and the results were again indicated per 100 g of baked biscuits.

Statisic analysis

Statistical comparison of samples using the Duncan's test was done separately for each kind of flour. Dependencies between measurements of individual sensory characteristics were assessed by factor analysis, with factor rotation according to a simple VARIMAX method Statistical test results were calculated using the STATISTICA CZ 12 software, the chosen significance level was 0.05. Statistical test results were calculated using the STATISTICA CZ 12 software, the chosen significance level was 0.05.

RESULTS AND DISCUSSION

Baking experiment

From the results of baking experiment measurements the following summary of characteristics was evaluated: weight of biscuits after baking [g], baking loss [%], product volume (mL.100 g^{-1}) and index number [-].

The weight of individual samples after baking differed based on the fibre used and its physicochemical properties. In the wheat-based formula, the control sample weighed 596 g, the highest weight showed the biscuits with addition of bamboo fibre (no. 2, 3, 4) and the sample no. 10 (with 9% of grape seed flour); other samples weighed under 600 g.

Among the samples no. 11 to 20, the highest weight had the control sample (608 g). The weight of samples no. 12, 13, and 14 was higher than 590 g, other samples weighed less. In both formulas, the percentage weight of biscuits increased with the increasing amount of bamboo fibre and grape seed flour added. On the contrary, the weight of hemp fibre samples decreased with the decreasing amount added. In contrast, **Gómez et al. (2010)** found no significant influence of the fibre type on the weight of the products, and no significant differences were foundas regarded the percentage of added fibre.

The highest value of the weight lost by baking in samples no. 1 to 10 showed sample no. 8 (with the addition of 3% of grape seed flour) with a loss of 15.41% and the lowest loss (10.51%) was also calculated for the addition of grape seed flour in sample no. 10. In samples no. 11 to 20, sample no. 17 (with 9% of hemp fibre) had the greatest loss in baking (21.01%), while sample no. 14 (with 9% of bamboo fibre) had the smallest (11.69%). In both wheat and spelt-based formulas, the lowest value of baking loss showed samples to which bamboo fibre was added; the loss in baking diminished with its enrichment. This is due to the binding capacity of bamboo fibre of up to 700%. At higher binding capacity, the dough was tough and poorly workable.The same result was obtained by **Gómez et al. (2010)**. Thus, with adding more fibre, it is necessary to improve the technological development which incorporates into the dough other ingredients inhibiting the water absorption **(Raymundo, Fradinho and Nunes, 2014)**. In the case of hemp fibre, on the other hand, the losses increased with higher percentage added due to the higher fat content in fibre. In general, smaller baking losses occurred in samples no. 1 to 10, due to the wheat flour that contains less fibre as compared to the spelt flour, which is whole grain. As also stated in study by **Frakolaki et al. (2018)**, higher fibre content in spelt flour negatively affects the dough rheology and product quality**.** Losses higher than 18% were recorded only in samples with spelt flour, samples no. 16, 17 and 18, and higher losses were also obtained in sample no. 15 (17.41%) which may mean that hemp fibre in an amount of 3, 6 and 9% and the addition of 3% of grape seed flour has a negative effect on the physical properties of the dough.

The smallest volume in samples no. 1 to 10 was observed for sample no. 10 (with 9% of grape seed flour) and the largest volume in sample no. 4 (with 9% of bamboo fibre). In the case of spelt flour biscuits, the sample no. 17 (with 9% of hemp fibre) had the lowest volume, i.e. 11.2% less compared to the control, while the sample no. 14 with the addition of bamboo fibre had the largest volume, 14% more than the sample no. 11, which was the control sample without fibre.

In both formulas, the largest volumes were observed in biscuits enriched with bamboo fibre that increased their volume with the addition of fibre. By contrast, in the case of hemp fibre and grape seed flour, the volume of samples decreased with their addition. The volumes of spelt flour-based samples (no. 11 to 20) were generally smaller.

Contrary to this, **Hrušková and Švec (2016)** found that biscuits with the addition of hemp seed flour, both fine and wholemeal, had their shape and volume unchanged.

Regarding the index number, arching slightly increased in wheat and spelt flour formulas (samples no. 1 to 20) with the addition of bamboo fibre. In samples no. 1 to 10, the most flattened was the fibre-free control (no. 1) with an index number of 0.1. In samples where the basic ingredient was spelt flour, all samples had the value of 0.09, except samples no. 13 and 14 with the addition of bamboo fibre (0.1 points) which were the most arched. Index numbers ranged from 0.09 to 0.12, meaning that fibre does not affect the shape and arching of biscuits too much.

Sensoric assessment of biscuits

The best impression from the wheat-based samples gave the sample no. 3 enriched with 6% of bamboo fibre (21 points), while the sample no. 10 with 9% of grape seed flour was the worst. In the second formula, the sample no. 18 was the best with 18.7 points and the worst overall impression was given by sample no. 14 with 28.1 points. The samples of both formulas were classified into one homogeneous group according to the Duncan's test, i.e. no statistical differences were found between them (p >0.05).

In grape seed flour and hemp fibre samples, the colour was the worst from the sensoric properties, and the surface was the best rated, while in the bamboo fibre samples the surface was the third worst rated property and the colour was the best rated descriptor. Unlike the wheat flour samples, the colour of all spelt flour samples was the worst rated of all of the selected attributes. It is, however, noticeable that the colour in the bamboo fibre samples was rated better than that in the hemp fibre and grape seed flour samples. Another observed difference is that samples with grape seed flour and bamboo fibre have the ease of bite as the second worst-rankedin the displayed properties, while in hemp fibre, rating of this property is comparable to that of the surface, shape and taste.

The relationships between the ratings of individual sensoric properties were determined using the factor analysis with a simple VARIMAX method of factor rotation (Table 3).

Based on the method, three significant factors were identified. The first factor was based on the close relationship of taste, adhesion, swallow ability, and overall impression. From a connection with the overall impression it can be concluded that taste, adhesion and swallow ability can be the main sensoric properties upon which the judge assesses the food in question. The second factor was based on an assessment of hardness, ease of biting and aroma. The third factor revealed the continuity of surface and shape assessments.

Measuring the colour of biscuits on a spectrophotometer

The results were expressed in accordance with the CIE L*a*b colour scheme with respect to D65 illumination. The higher the L* values in the graph, the lighter the colour of the sample.

In terms of the L* variable, which determines lightness from black to white, Duncan's test found that samples no. 5 to 10 had significantly lower values (p <0.05) and the sample no. 4 had statistically significantly higher (p <0.05) values, which statistically differs from all other samples from group 1 to 10. As the bamboo fibre amount increased, the biscuits were lighter in colour. Among the spelt flour samples, it was found that the samples no. 15 to 20 had statistically significantly lower values (p <0.05) of the L* variable. The lightest sample (59.2%) was the sample with 6% bamboo fibre added.

For both formulas, the Duncan's test divided samples into five homogeneous groups with alpha significance level = 0.05. The darkest samples were the result of grape seed flour – sample no. 9 with 51.3% and sample no. 20 with 43%. Also **Maner, Sharma and Banerjee (2015)** found that grape seed flour gave biscuits their brown colour.

Biscuit strength assessment

For samples with wheat flour (1 – 10), the Duncan's test found that samples no. 3, 5 and 10 had statistically significantly lower (p < 0.05) hardness values compared to the control and the sample no. 8 had statistically significantly higher value than the control.

According to **Cappa, Lucisano and Mariotti (2013)**, the fibre binds water and retains it in the product during baking, so the fortified products are softer compared to the control, which corresponds to samples no. 2, 3, 4, 5 and 10 with the wheat flour base and samples no. 15, 16, 17, 18 and 20 with the spelt flour base. If the water content in the product is small, as with durable baking products, the ingredients compete with each other for water, and the fibre cannot perform its function as well as hydrocolloids that increase the dough's ability to bind water.

When comparing samples no. 11 to 20 in terms of hardness N, samples no. 15 and 17 showed statistically significantly lower values of hardness compared to the control and samples no. 12, 13 and 14 statistically significantly higher (p <0.05) values. Samples of both formulas (1 to 20) were classified in five homogeneous groups using the Duncan's test with alpha significance level of 0.05. Furthermore, it was demonstrated that in both groups the smallest strength was measured in samples containing 3% of hemp fibre (no. 5 and 15) with average values of 23.9 and 20.8 N respectively. **Mancebo et al. (2017)** found that all fibre-enriched biscuits showed greater strength than the control and the biscuits with bamboo fibre added were the hardest.

Table 3 Factor analysis with a simple VARIMAX method of factor rotation.

Variable	Factor 1	Factor 2	Factor 3
Colour	0.35	0.14	-0.45
Hardness	-0.29	**0.79**	-0.07
Aroma	0.26	0.66	-0.08
Surface	0.12	-0.08	**0.84**
Shape and homogeneity	0.28	0.09	**0.81**
Taste	**0.81**	0.11	-0.11
Ease of bite	0.34	0.62	0.20
Adhesion	**0.74**	-0.07	0.33
Swallowability	**0.86**	-0.10	0.18
Overall impression	**0.75**	0.14	0.31

Table 4 Nutritional values of biscuits with wheat flour converted to 100 g.

Sample no.	Fibre amount [%]	Energy value [kJ/kcal]	Fats [g]	Saturated fatty acids [g]	Carbohydrates [g]	Sugars [g]	Proteins [g]	Salt [g]	Fibre [g]
1	0, control	1980.83/473.12	20.91	12.65	63.63	21.62	8.85	<0.01	1.76
2	3, bamboo	1904.84/455.13	20.23	12.28	60.32	20.88	8.38	<0.01	3.31
3	6, bamboo	1899.47/453.6	20.21	12.27	59.27	20.85	8.22	<0.01	4.99
4	9, bamboo	1887.72/451.35	20.18	12.24	58.03	20.89	8.03	<0.01	6.53
5	3, hemp	1962.55/468.85	20.92	12.67	62.03	21.46	8.91	<0.01	2.75
6	6, hemp	1957.97/467.86	20.97	12.59	60.83	21.46	9.04	<0.01	3.87
7	9, hemp	1952.50/466.74	21.21	12.69	59.68	21.45	9.16	<0.01	4.77
8	3, grape seed flour	1978.11/472.11	20.96	12.67	63.06	21.79	8.87	<0.01	2.47
9	6, grape seed flour	1975.64/472.27	21.01	12.69	62.49	21.96	8.89	<0.01	3.04
10	9, grape seed flour	1973.08/472.44	21.07	12.71	61.91	21.14	8.91	<0.01	3.61

Table 1 Nutritional values of with spelt flour converted to 100 g.

Sample no.	Fibre amount [%]	Energy value [kJ/kcal]	Fats [g]	Saturated fatty acids [g]	Carbohydrates [g]	Sugars [g]	Proteins [g]	Salt [g]	Fibre [g]
11	0, control	1929.64/459.18	20.61	12.44	56.04	21.36	10.4	<0.01	5.18
12	3, bamboo	1915.06/457.91	20.54	12.42	54.88	21.29	10.15	<0.01	6.75
13	6, bamboo	1903.65/454.81	20.5	12.42	53.82	21.25	9.91	<0.01	8.36
14	9, bamboo	1892.23/452.18	20.47	12.41	52.75	21.21	9.67	<0.01	9.87
15	3, hemp	1925.00/458.21	20.7	12.45	55.07	21.38	10.56	<0.01	7.17
16	6, hemp	1923.52/458.00	20.83	12.48	54.19	21.37	10.64	<0.01	7.48
17	9, hemp	1922.18/457.30	20.96	12.51	53.3	21.35	11.24	<0.01	8.29
18	3, grape seed flour	1927.52/459.18	20.67	12.48	55.67	21.54	10.38	<0.01	6.15
19	6, grape seed flour	1925.40/459.18	20.71	12.47	55.3	21.69	10.33	<0.01	6.71
20	9, grape seed flour	1923.27/459.18	20.75	12.49	54.93	21.85	10.3	<0.01	6.96

Nutritional values of biscuits

The calculated nutritional values per 100 g of wheat-based biscuits are shown in Table 4. The highest energy value, in addition to the control sample no. 1 (1,980.83 kJ), contained sample no. 8 (1,978.11 kJ) with 3% of grape seed flour. The least energy was contained in sample no. 4 (1,887.72 kJ) with the addition of 9% of bamboo fibre.

Table 5 shows the nutritional values per 100 g of spelt-base biscuits. The highest calorific values were calculated for the control sample no. 11 (1,929.64 kJ) and for sample no. 18 (1,927.52 kJ) with 3% of grape seed flour and the lowest energy values were reported for samples with bamboo fibre added (no. 11 to 14).

In both formulas, the control sample (no. 1 and no. 11) without the addition of fibre had the highest energy value because the formulas contained 100 percent of the flour amount. Samples no. 11 to 20 contained more fibre due to the spelt flour in which the amount of dietary fibre per 100 g is higher than in the wheat flour.

Bamboo fibre samples contained the most fibre due to the amount of fibre contained (97%) per 100 g of fibre. Biscuits enriched with grape seed flour contained the least fibre, but data from the study by **Maner, Sharma and Banerjee (2015)** clearly indicate that products enriched with grape seed flour have a positive effect on consumer health. Flour made from grape seeds and press cakes is nutritious and has antioxidant properties. It can be deduced from the results of the study by **Bilgiçli, İbanoglu and Herken (2007)** that fibre as a substitute for wheat flour reduces energy intake, but also the digestibility of proteins.

CONCLUSION

The aim of the study was to create formulas and subsequently to determine the effect of fibre additions on the quality of biscuits. Bamboo and hemp fibre and grape seed flour were used in the amounts of 3, 6 and 9 %. The basis of the first formula was wheat flour, while the second formula contained the spelt flour as the primary ingredient.

We performed a baking experiment, sensory evaluation, hardness measurement by TIRA test, spectrophotometric color measurement and a nutritional value was calculated. It can be concluded from the results that the fibre as a substitution for the flour used reduces the energy intake, but also the digestibility of proteins, improves the functionality and nutritional value of the biscuits by changing their composition.

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Contact address:

*Viera Šottníková, Mendel University in Brno, Faculty of Agronomy, Department of Food Technology, Zemědělská 1, 613 00, Brno, Czech Republic, Tel.: +420545133068 , E-mail: viera.sottnikova@mendelu.cz

Radka Langová, Mendel University in Brno, Faculty of Agronomy, Department of Food Technology, Zemědělská 1, 613 00, Brno, Czech Republic, Tel.: +420545133194 , E-mail: radka.langova@mendelu.cz

Luděk Hřivna, Mendel University in Brno, Faculty of Agronomy, Department of Food Technology, Zemědělská 1, 613 00, Brno, Czech Republic, Tel.: +420545133196 , E-mail: ludek.hrivna@mendelu.cz

Šárka Nedomová, Mendel University in Brno, Faculty of Agronomy, Department of Food Technology, Zemědělská 1, 613 00, Brno, Czech Republic, Tel.: +420545133193 , E-mail: sarka.nedomova@mendelu.cz

Miroslav Jůzl, Mendel University in Brno, Faculty of Agronomy, Department of Food Technology, Zemědělská 1, 613 00, Brno, Czech Republic, Tel.: +420545133264 , E-mail: miroslav.juzl@mendelu.cz

Corresponding author: *