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GLUTEN-FREE PRODUCT INNOVATION WITHOUT USE OF ANY FOOD ADDITIVES

Martina Fikselová[1*], Jana Kolačkovská[1], Stanislava Lukáčová[1], Nikola Babirádová[1], Ľubomír Belej[1], Vladimír Vietoris[1]

[1]Faculty of Biotechnology and Food Sciences, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 94976 Nitra, Slovakia

[*]e-mail: martina.fikselova@uniag.sk

Abstract

Celiac disease is one of the most common metabolic disorders. Patients suffering from celiac disease have a limited intake of nutritionally and sensory valuable foods. On the other side, due to the absence of gluten in this kind of food there is found very often high representation of artificial food additives in order to replace gluten technological properties. The aim of this work was to design innovative gluten-free muesli bars, with no food additive use, sensory and nutritionally valuable, in terms of high protein and fiber content, no addition of sugar and labelled by approved nutrition claims.

The muesli products were prepared from three types of gluten-free flakes, namely oats, rice and buckwheat and using of raw materials such as mixture of nuts, seeds, lyophilized fruit, mango puree and oligofructose, together, represented by 13 variants of samples (standard sample included). Prepared products were assessed by texturometric analysis and sensory evaluation (panel test). We analyzed the texture of all gluten-free bars by the TA.XT Plus texturometer (Stable Micro Systems, Surrey, Great Britain).

Sensory analysis showed, that sample consisting of oatmeal, a mixture of nuts and oligofructose was the most acceptable by trained evaluators. The use of nuts in the preparation of muesli bars showed good textural and taste properties. The worst rated were bars prepared from rice flakes. The sample prepared from rice flakes, a mixture of nuts and oligofructose showed the highest firmness that is undesirable from consumer point of view. We can confirm the use of three nutritional claims on all designed gluten free products for protein content, high fiber and with no added sugars are by the appropriate EU regulatives.

Due to the lack of quality products for celiacs on the market, we recommend designed additive free samples prepared from oatmeal and buckwheat flakes to producers in order to expand the range of quality products for people with gluten-free diet in the future.

***Key words**: Celiac disease, Gluten-free food, Muesli bars, Texture analysis, Sensory analysis, Food additives.*

1. Introduction

Celiac disease is defined as chronic enteropathy mediated by small bowel immunity that is induced in genetically predisposed individuals by dietary gluten exposure [1]. The prevalence of celiac disease is estimated at approximately 1% of the total population [2]. A lifelong gluten-free diet is the only accepted medical treatment for gluten-related disorders. Despite the importance and effectiveness of a gluten-free diet, adherence to it remains a difficult goal [3]. Commercially available gluten-free products are often less palatable and less available. Some gluten-free products are not cost-effective, and labeling on the label "gluten-free" is sometimes questionable because cross-contamination with gluten can occur [4]. Many studies have been conducted in recent years to evaluate the extent to which people with celiac disease can enjoy a safe, nutritious, tasty and cheap diet. Three controversial issues have emerged: the high cost of a gluten-free diet, the availability and variety of gluten-free products, and possibly the lower nutritional value of a gluten-free diet [5]. Restrictions on dietary intake of wheat can have serious consequences for the intake of essential nutrients and other beneficial ingredients, unless equivalent alternative resources are provided [6]. The gluten-free diet is deficient in dietary fiber,

protein, folate, iron, potassium, and zinc, while higher levels of fats, sugars, and sodium are detected in most surveys [7]. The range of gluten-free products provides significantly lower contents of protein, magnesium, potassium, vitamin E, folic acid and sodium compared to gluten-containing products, which tends to have lower calcium content and a higher fat content [8]. A potential source of harmful compounds are enzymes used as food additives in processed gluten-free products [9]. Gluten replacement is one of the most challenging problems for the bakery industry. Bakery products such as bread, pastries or cakes are traditionally made from wheat flour. Their gluten-free versions are usually processed using rice flour [10], but may have undesirable properties such as low volume, inappropriate coloring and poor structure and texture due to the low gas retention capacity in rice flour [11]. Thus, in order to obtain quality gluten-free bakery products without additives with similar nutritional characteristics as gluten-containing products, they were designed from rice flour and other grains, such as sorghum, amaranth, quinoa and others, aimed at improving not only baking but also physical and sensory properties of gluten-free bakery products[12]. Gluten-free bread had a significantly higher content of fats and dietary fiber. All gluten-free products showed lower protein content than standard products. Only 5% of gluten-free breads were fortified with four essential nutrients (calcium, iron, niacin and thiamine), only 9% of gluten-free bread products were fortified with thiamine, riboflavin and niacin and 28% of breads were fortified with calcium and iron only. This absence of fortification may increase the risk of micronutrient deficiency in celiacs [7]. The existence of gluten-free products of high quality and affordable price is very important for the quality of life of celiacs and the sustainability of public support [13].

The aim of this work was to innovate/develop gluten-free muesli bars with no addition of sugar, high fiber and protein content. Subsequently, to evaluate the obtained products using texture and sensory analysis as they are one of the most important properties for consumers.

2. Materials and Methods

2.1 Materials

The subject of this research was to design the muesli bars made of oat, rice and buckwheat flakes, compared to standard sample prepared from spelt flakes. We prepared one standard sample and 4 sets of samples, using oatmeal, rice and buckwheat flakes in each set. In the first set we used only walnuts and mango puree, in the second set we used a mixture of seeds, the third set consisted of flakes and a mixture of nuts and in the fourth set we used a mixture of seeds in combination with lyophilized fruit. In the second and the third sets we used oligofructose in order to make it tasty, healthy and to connect the raw materials, in the first and fourth sets we used mango puree. From each set we prepared a mixture from which we formed and prepared bars. The obtained samples are marked with letters, given in Table 1.

Table 1. Labeling of muesli bars

Label	Main composition
A	Standard
B	Oat flakes, walnuts and mango puree
C	Rice flakes, walnuts and mango puree
D	Buckwheat flakes, walnuts and mango puree
E	Oat flakes, oligofructose, chia, sesame, sunflower and flax seeds
F	Rice flakes, oligofructose, chia, sesame, sunflower and flax seeds
G	Buckwheat flakes, oligofructose, chia, sesame, sunflower and flax seeds
H	Oat flakes, oligofructose, almonds, walnuts, hazelnuts
I	Rice flakes, oligofructose, almonds, walnuts, hazelnuts
J	Buckwheat flakes, oligofructose, almonds, walnuts, hazelnuts
K	Oat flakes, mango puree, lyophilized bananas, lyophilized strawberries, flax, sunflower and chia seeds
L	Rice flakes, mango puree, lyophilized bananas, lyophilized strawberries, flax, sunflower and chia seeds
M	Buckwheat flakes, mango puree, lyophilized bananas, lyophilized strawberries, flax, sunflower and chia seeds

For preparation of the standard sample we used spelt flakes, walnuts, oil and honey to make it sweet. Raw materials used per 100 g were as follows: spelt flakes 35 g, walnuts 30 g, vegetable oil 10 g, honey 25 g.

2.1.1 Main procedure steps at preparing of muesli bars

Half of the flakes was treated by grinding. Rice flakes were put into a warm water to make them soften. Nuts were cut into small pieces and mixed with flakes and remaining raw materials into a compact mixture. The mixture was left for a short time. Bars were formed at 8 x 8 cm size and of thickness about 2 cm. The last step was baking at 160 ^{0}C for 15 minutes.

2.2 Methods

2.2.1 Texture analysis

We used the TA.XT plus texture analyser (Stable Micro Systems, Surrey, Great Britain) as it is capable to measure any physical product characteristic such as

hardness, fracturability, adhesiveness. AP/36R probe with a strain gauge was used for analysis. The resulting values were expressed in Newton units as the force required to compress/break the product. We inserted whole products into the texturometer and performed three replicates at each sample, mean results and standard deviations in Microsoft Excel were calculated.

2.2.2 Sensory analysis of products

Sensory analysis of muesli bars was performed in the sensory laboratory by the panel test using trained evaluators. The evaluation questionnaires were focused on the selected sensory parameters of the formed bars, rating them at the taste, appearance, structure, smell, the appearance on the cut and the overall impression.

2.2.3 Nutrition claims application

All necessary information was taken into account including the approximate nutritional composition of the components used. Nutrition claims (no added sugar, high fiber and protein content) were designed at the recipe development so that we could apply them on the products. We used data from the official Slovak food composition database online held under the Food Research Institute of the Slovak National Agricultural and Food Center.

3. Results and Discussion

Muesli bars are consumed by about 16% of children and 7.5% of adults. It is a popular dish, especially in Australia, with per capita consumption considered to be the third highest in the world after Canada and the United States [14].

At taste evaluation of our products, the most delicious sample was shown to be H (Table 1), containing oatmeal, a mixture of nuts and oligofructose that is probably due to the fact that in commercially sold muesli bars there is a frequent combination of nuts and flakes. Standard sample followed, containing spelt flakes, oil, nuts and honey. Sample containing buckwheat flakes, a mixture of nuts and oligofructose, was also well evaluated. The sweet taste was clearly dominant in sample H (oat flakes, nuts and oligofructose), perhaps because of it, this sample was preferred and highest rated. The least tasty was bar containing rice flakes, nuts and mango puree, together with sample F (rice flakes, a mixture of seeds and oligofructose). Samples containing rice flakes were evaluated as the worst. Products had a bland taste, compared to others.

The fruity taste was most pronounced in samples M (buckwheat flakes, seeds, puree and lyophilised fruit) and K (oat flakes, seeds, puree and lyophilised fruit), in which mango puree also lyophilized bananas and strawberries were present. We selected mango puree in order to supply the fruit component and connect the raw materials, as well as to create an interesting taste of the products. Puree for connecting the raw materials used, seems to be a suitable alternative for producers in muesli bars. Lyophilized fruit retains a certain content of minerals and vitamins during processing, as well as color and taste [15], so it is suitable for their use in muesli products. These products are enriched with a fruit component and are more suitable alternative than the application of classically dried sugar-containing fruit. Lyophilisation ensures long-term enzymatic stability of the products, so the dried fruit retains up to 98% of the nutritional value [15]. By Antonini *et al*. [16] the addition of chia seeds to products will provide the content of polyunsaturated fatty acids.

As early as 1995, muesli bars were not so popular, but in 2012 they already contributed an estimated 12.5% to the total energy from food and their popularity is still growing. Flaked muesli bars can be a potential source of positive ingredients and nutrients [14].

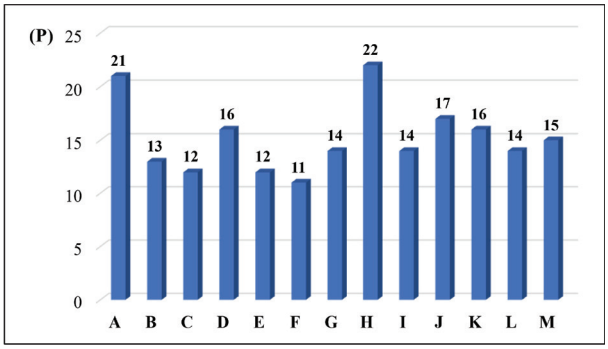

Figure 1. Smell of muesli bars
***Sample A (standard),**
B - D (1 set with walnuts, B - oat flakes,
C - rice flakes, D - buckwheat flakes),
samples E - G (2 set with seed mixture, E - oat flakes,
F - rice flakes, G - buckwheat flakes),
H - J (3 set with a mixture of nuts, H - oat flakes,
I - rice flakes, J - buckwheat flakes),
sample K - M (4 set with lyophilized fruits and seeds,
K - oat flakes, L - rice flakes, M - buckwheat flakes)

Sample H with oatmeal, nuts and oligofructose was confirmed to be the best in parameter of smell (Fig. 1), that may be due to the presence of nuts. Followed by sample A (standard), with walnuts and honey, that showed the typical delicious smell of muesli bars. Typical muesli and sweet aroma significantly dominated in sample H (39.6% muesli and 37.5% sweet aroma), followed by standard sample (31.6% muesli and 30.6% sweet aroma). In contrast, muesli

aroma was the least pronounced in sample F (8.7%) (rice flakes, seeds and oligofructose), which was also the worst evaluated for the overall aroma of products. Sample F, containing rice flakes, a mixture of seeds and oligofructose was identified as the least attractive as these flakes are almost odorless, neutral and the plant seeds used do not show any smell. The smell of the raw materials used was also reflected in sample H (30.9%) (oat flakes, nuts, and oligofructose), where in particular the mixture of nuts gives a pleasant feeling.

By evaluation of the overall texture parameter of the sensory analysis, again sample H (21 points) from oat flakes, nuts and oligofructose confirmed to be the best accepted. We can assume that the combination of flakes with a mixture of nuts and oligofructose creates a suitable texture of the products, also serves to properly connect the raw materials, thus achieving the desired shape and cohesiveness.

Santos *et al*., [17], state that consumers require a suitable texture and crunchiness of muesli products. If the moisture content in these products increases due to the sorption of atmospheric water, the result is humidification and a soft texture and loss of crunchiness of products. The hardness parameter was also to be the best evaluated in sample H (36.7%) (oat flakes, nuts and oligofructose), as the nuts forming its structure are hard and give the muesli bars density. Sample J (32.9%) with buckwheat flakes, nuts and oligofructose also showed high hardness, probably for similar reasons as the previous sample. Sample E consisting of oat flakes, seeds and oligofructose, is considered to be the least hard, and plant seeds are also less hard than nuts. So we can recommend the use of nuts for the production of bars, also due to their beneficial effects on health. They are characterized by high content of vitamins, minerals, dietary fiber, and are also a good source of plant proteins. Macronutrients, micronutrients and other healthy bioactive compounds contained in nuts and dried fruit can synergistically contribute to reducing the risk of cardiometabolic and other non-communicable diseases [18].

In the evaluation of cohesion, the sample H (oat flakes, nuts and oligofructose) again gained the best points as the most compact as kept its shape even after baking and cutting. The surface area and structure of the products were the highest rated at sample H as well. Sample H showed also the best appearance on the cut, retaining its shape and cohesiveness during slicing. Sample J followed with buckwheat flakes, nuts and oligofructose.

In the Figure 2 there are shown the results of the overall appearance of our muesli bars. For consumers, the appearance of the products is crucial. The color of muesli products is very important feature of their commercialization. Maillard and caramelization reactions are some of the reasons that products made at higher temperatures and low moisture content are redder, with higher content of melanoidins, while caramelization also ensures the sweetness and smell of the sticks [17].

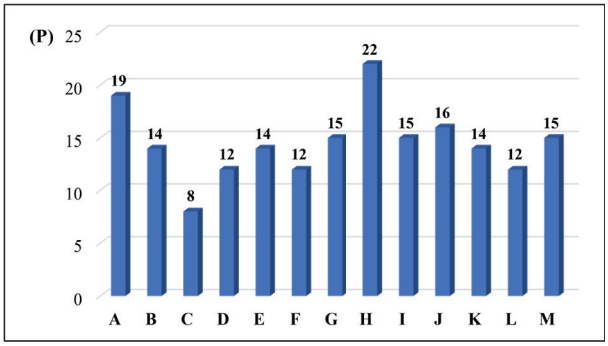

Figure 2. Overall appearance of muesli bars
***Sample A (standard),**
B - D (1 set with walnuts, B - oat flakes,
C - rice flakes, D - buckwheat flakes),
samples E - G (2 set with seed mixture, E - oat flakes,
F - rice flakes, G - buckwheat flakes),
H - J (3 set with a mixture of nuts, H - oat flakes,
I - rice flakes, J - buckwheat flakes),
sample K - M (4 set with lyophilized fruits and seeds,
K - oat flakes, L - rice flakes, M - buckwheat flakes)

Sample C (8 p), containing rice flakes, nuts and mango puree, was evaluated as the worst. Overally, the samples containing the rice flakes were rated least by points, this may be due to the fact that the flakes themselves were almost tasteless and hard. The use of rice flakes in muesli bars is a suitable potential for muesli product manufacturers, as they are easily digestible and are a suitable gluten-free alternative to flakes, but it is important to process them correctly to ensure a suitable texture and taste in the products.

The popularity of muesli bars attracted the attention of public health, government and media, but also in the sense they have a "higher fat content and added sugars" [14].

By the texturometric evaluation (Figure 3), the firmness of the standard sample was determined to be the lowest (1484.54 N) compared to all other samples. Applying the oil together with the honey ensured softer consistency of the products, which is not desired, because they are crumble at handling. By evaluation of the first set of products, consisted of flakes (B-oat, C-rice, D-buckwheat), walnuts and mango puree, sample B (7848.78 N) containing oat flakes showed the highest firmness. In contrast, sample D (2385.38 N) with buckwheat flakes showed the lowest firmness.

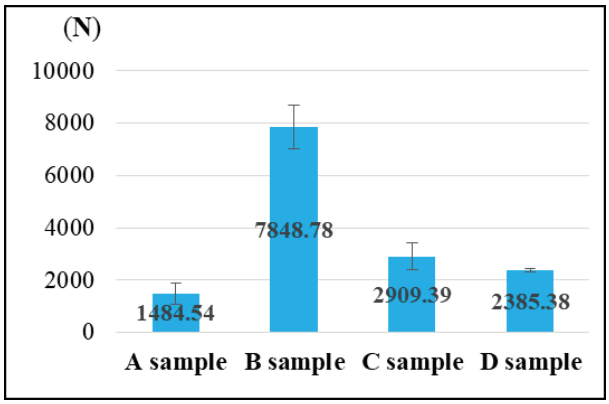

Figure 3. Firmness (N) determined by texturometry in the first set of samples
***Sample A (standard), B - D (1 set with walnuts, B - oat flakes, C - rice flakes, C - buckwheat flakes)**

In the second set (E - oat, F - rice, G - buckwheat) made of the mixture of seeds and oligofructose addition (Figure 4) significantly the highest firmness showed sample F (5847.47 N) with rice flakes. Ávila *et al*., [19], recommends the use of rice flakes in muesli products due to their favourable textural properties.

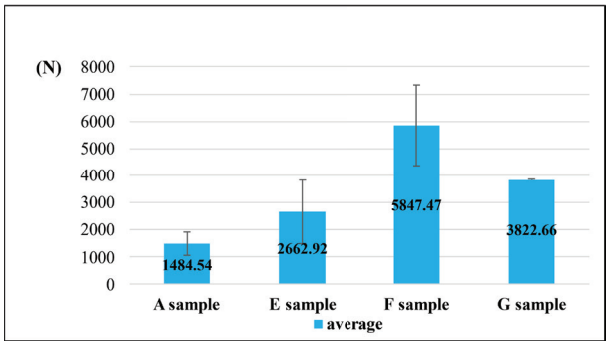

Figure 4. Firmness (N) determined by texturometry in the second set of samples
***Sample A (standard), E - G (2 set with seed mixture, E - oat flakes, F - rice flakes, G - buckwheat flakes)**

The third set of products consisted of flakes (H-oat, I-rice, J-buckwheat), a mixture of nuts and oligofructose. The highest firmness among all samples (Figure 5) was again confirmed at the sample of rice flakes I (11253.26 N). Contrary, sample J (2356, 74 N) from buckwheat flakes showed the lowest firmness. Yildiz *et al*., [20], state that by the addition of buckwheat flakes to the products, the hardness of these products increases, which would be in line with our finding compared to the standard sample. The nut did not require high compression work in the texture analysis [21]. The appropriate texture of muesli bars is a key feature of the products [17]. It seems that the optimal firmness of the muesli bars is around 8000 N.

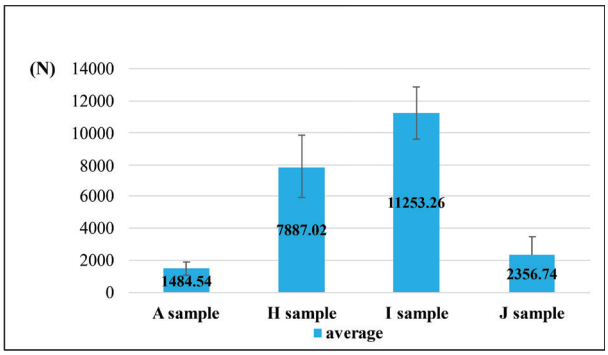

Figure 5. Firmness (N) determined by texturometry in the third set of samples
***Sample A (standard), H - J (3 set with a mixture of nuts, H - oat flakes, I - rice flakes, J - buckwheat flakes)**

In the fourth set, consisting of flakes (K - oat, L - rice, M - buckwheat), a mixture of seeds, lyophilized fruit and mango puree, the samples (Figure 6) showed very similar firmness, probably due to the application of lyophilized fruit, which retains consistency and hardness [15]. The highest firmness was shown by sample K (8519.77 N) at oat flakes and the lowest by sample L (7655.36 N) at rice flakes.

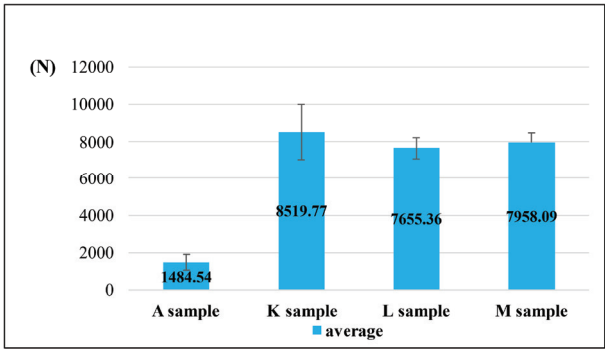

Figure 6. Firmness (N) determined by texturometry in 4 set of samples
***Sample A (standard), K - M (4 set with lyophilized fruits and seeds, K - oat flakes, L - rice flakes, M - buckwheat flakes)**

Hutchings *et al*., [21], analyzed the texture of different types of bars and found that commercial muesli bars have a high hardness and require relatively high compression work in the texturometric analysis.

3.1 Possible application of nutritional claims

The Regulation (EC) No. 1924/2006 [22] defines the nutrition claim as "any claim which states, suggests or implies that a food has particular beneficial nutritional properties due to the presence, absence, increased or decreased levels of energy or a particular nutrient or other substance". We calculated the approximate nutritional composition of products so that we could apply approved nutritional claims on the products.

The first nutrition claim proposed was: protein source as this claim may only be made where at least 12% of the energy value of the food is provided by protein [22]. The protein content in our bars ranged from 12 to 12.64% (in the first set 12.16%, in the second set 12.08%, in the third set 12% and in the last set 12.64% of energy value). Our muesli bars would therefore meet the protein content requirement and it could be declared that the bars are a source of protein.

Ferreira *et al*., [23], demonstrated the positives of chia seeds, namely the high content of alpha lipoic acid but also proteins, dietary fiber, minerals and antioxidants. Also sunflower seeds show a high content of unsaturated fatty acids, dietary fiber [24]. As for flax seeds, Xie *et al*., [25], state that they are rich in unsaturated fatty acids, which have beneficial effects in the prevention of chronic diseases. They also contain a lot of vitamins, minerals and dietary fiber. Therefore, our prepared samples in the second set, but also in the fourth set contained the just mentioned plant seeds.

High dietary fiber may only be made where the product contains at least 6 g of dietary fiber per 100 g or at least 3 g of dietary fiber per 100 kcal [22]. The amount of dietary fiber ranged from 6.01 to 32.11 g per 100 g (in the first set 6.01 g per 100 g, in the second set 32.11 g, in the third set 25.86 g and in the fourth set 9.18 g). We could therefore claim that the muesli bars formed showed high dietary fiber content.

The third proposed claim was: no added sugar - as no sugar has been added to the food, and any other claim that may have the same meaning for the consumer can only be made if the product does not contain any added monosaccharides or disaccharides, or any other food used for its sweetening properties. If the sugar is naturally occurring in the food, the label should also state: "Contains natural sugars" [22]. Overall, we could label the sticks as gluten-free, with protein content and a high dietary fiber content, without added sugar.

4. Conclusions

- Due to the lack of muesli bars for celiac on the market, we would recommend samples prepared from oatmeal and buckwheat flakes to muesli producers for production and to expand the range of products for people with gluten-free diet. Commercial products of this type are prepared using various food additives that we wanted to replace.
- We recommend to prolong their shelf life for example by packaging, such as vacuum packing. Suitable components for the preparation of muesli products are nuts and seeds, which provide important proteins, minerals, vitamins and dietary fibre that are often missing in celiac diets and patients.

Acknowledgement

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5. References

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