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Using brewer's spent grain as a byproduct of the brewing industry in the bakery industry

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1. SUMMARY

The utilization of food industry byproducts is one of today's important environmental and economic tasks. Byproducts that form during food production are typically used for feed purposes, but in many cases these materials can also be used in the production of human foods. The brewer's spent grain left behind after brewing beer is a byproduct with favorable nutrition parameters, with low sugar and high fiber and protein contents. The main objective of our experiments was the reintroduction of brewer's spent grain into the food industry, with a focus on innovation and sustainable development, by utilizing it in commercially available bakery products (salty medallions / wafers) formulated and regulated in the Hungarian Food Codex. Brewer's spent grain consists of vegetable proteins and fibers (inactive malt), which may improve the compositional characteristics when preparing bakery products. In the course of our research, medallions enriched with brewer's spent grain were prepared, of the beneficial parameters of which its high dietary fiber content should be highlighted, which can contribute to the realization of a health-conscious diet for consumers. A diet rich in dietary fiber, combined with an adequate amount of exercise, can reduce the risk of developing certain diseases (e.g., cancer and cardiovascular diseases).

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2. Introduction

Brewer's spent grain is a byproduct of the brewing technology (***Figure 1***), which is usually utilized as animal feed, but in many cases it is transported from manufacturing plants as waste. With our experiments, we were looking to answer the question whether brewer's spent grain can be reintroduced into the food industry, and whether enrichment with it has a proven positive effect on the nutrition characteristics of medallions made from wheat flour.

Figure 1. Brewer's spent grain (BSG)

3. Brewery byproducts

The brewing industry uses various grains to produce malt. In addition to the usual and most often used barley (*Hordeum vulgare* L.) and wheat (*Triticum aestivum* L.), other grains such as maize (*Zea mays* L.), rice (*Oryza sativa* L.), oats (*Avena sativa* L.), millet (*Pancium miliaceum* L.), rye (*Secale cereale* L.), sorghum (*Sorghum bicolor* L.), spelt (*Triticum spelta* L.), quinoa (*Chenopodium quinoa* Willd.), buckwheat (*Fagopyrum esculentum* Moench) and amaranths (*Amaranthaceae*) are used more and more often as sources of starch **[2, 4, 36, 37, 39,]**.

In order to achieve the targeted organoleptic and chemical properties of the different recipes, malt blends are commonly used, which not only affects the properties of the final product, i.e., beer, but at the same time also affects the byproducts **[5, 26, 29]**.

In the brewing process, the goal is to obtain the maximum extract content from malt and the additives during mashing. The byproduct left behind after the filtration of the mash is called brewer's spent grain, also known as inactive malt **[3, 10, 38, 40]**.

Brewer's spent grain accounts for about 85% of the byproducts generated during the brewing process **[25, 34]**. According to some studies, the disposal of brewer's spent grain as waste may be of environmental concern, which is why one possible use of brewer's spent grain in aquaculture feed is being addressed. In feed intended for fish, it can effectively replace soybean meal at a rate of 50% as a potential source of protein **[8, 12, 13]**.

Other brewery byproducts include malt germ, hot lees, brewer's yeast and other gases, such as carbon dioxide **[11, 33, 35]**.

3.1. Nutritional parameters of brewer's spent grain

Brewer's spent grain is a valuable source of nutrients. Data on the average nutrient content per 1000 g dry matter are shown in ***Table 1***. It is a useful source of protein and fiber, rich in vitamins (mainly B_1, B_2 and B_6) and minerals, especially calcium, phosphorus, magnesium, potassium and sodium **[1]**.

Table 1. Chemical composition of Brewer's Spent Grain (BSG) ***[1]***

Nutrient composition	1000 g of dry matter	Described in %
Protein	233 g	2.33
Digestible protein	225 g	2.25
Fat	71 g	0.71
Ash	46 g	0.46
Fiber	195 g	1.95
Starch	45 g	0.45
Kalcium (Ca)	4 g	0.04
Foszfor (P)	6.2 g	0.062
Magnézium (Mg)	1.7 g	0.017
Nátrium (Na)	0.18 g	0.0018
Kálium (K)	0.47 g	0.0047
Methionin	4.4 g	0.044
Lysin	9.7 g	0.097
Linoleic acid	24 g	0.24
Vitamin K	4.5 mg/kg	n.i.
Vitamin B1	25 mg/kg	n.i.
Vitamin B2	25 mg/kg	n.i.
Vitamin B6	9 mg/kg	n.i.
Carotene	17 mg/kg	n.i.

3.2. Enrichment possibilities of bakery products with brewer's spent grain

The regulations for bakery products can be found in prescription 1-3/16-1 of the Hungarian Food Codex (HFC) **[17]**. According to the definition of the HFC, enriched foods are products that contain a significant amount of one or more complementary food components. These products are not necessarily developed for general consumption, but are targeted at a specific target group **[7, 32]**. In the case of brewer's spent grain added to the dough of bakery products, it can also be called an enrichment, since following drying and crushing/grinding, brewer's spent grain can also be used in bakery products in the form of flour.

According to the literature, one of the most practical uses of brewer's spent grain is composting, but it can also be used as an enrichment agent in the production of foods, such as baking bread, in a proportion of 5 to 10% **[40]**. When brewer's spent grain is used in a higher proportion, the crumb of the bread may be sticky **[15]**. As a result of the enrichment, the dietary fiber content of the finished product increases. Dietary fiber has a beneficial effect on the functioning of the stomach, the small intestine and the colon **[14, 41]**. According to literature data, the consumption of dietary fiber by the Hungarian population is only 20-25 grams, compared to the recommended 30-35 grams per day. Enrichment with brewer's spent grain would not only increase fiber intake, but also protein intake **[9, 28, 30]**. Due to its easy digestibility, barley malt in the inactive form is also used in many cases in products for small children, and its infusion has a digestion stimulating effect **[27, 31]**.

4. Materials and methods

4.1. Preparation of products enriched with brewer's spent grain

During our experiments, our control medallion recipe was compiled as defined in the Hungarian Food Codex **[17]**. In the case of the enriched products, light (barley) and dark (a 1:1:1 mixture of Chateau black dyeing malt and barley malt roasted to chocolate color and to black color) malts were used in different concentration relative to the weight of the flour. The medallions were prepared with both malts at 10%, 25% and 50%

enrichment levels. After adequate mixing, the dough of the medallions was prepared from the ingredients in the recipe (***Figure 2***), the balls of 4-5 cm diameter were formed from the dough, and the products were prepared by baking the balls at 150 °C for 45 seconds using an electric medallion oven (***Figure 3***).

Names and abbreviations of the samples prepared:

- C: Control malt
- LM 10%: Light malt, 10% enrichment
- LM 25%: Light malt, 25% enrichment
- LM 50%: Light malt, 50% enrichment
- DM 10%: Dark malt, 10% enrichment
- DM 25%: Dark malt, 25% enrichment
- DM 50%: Dark malt, 50% enrichment

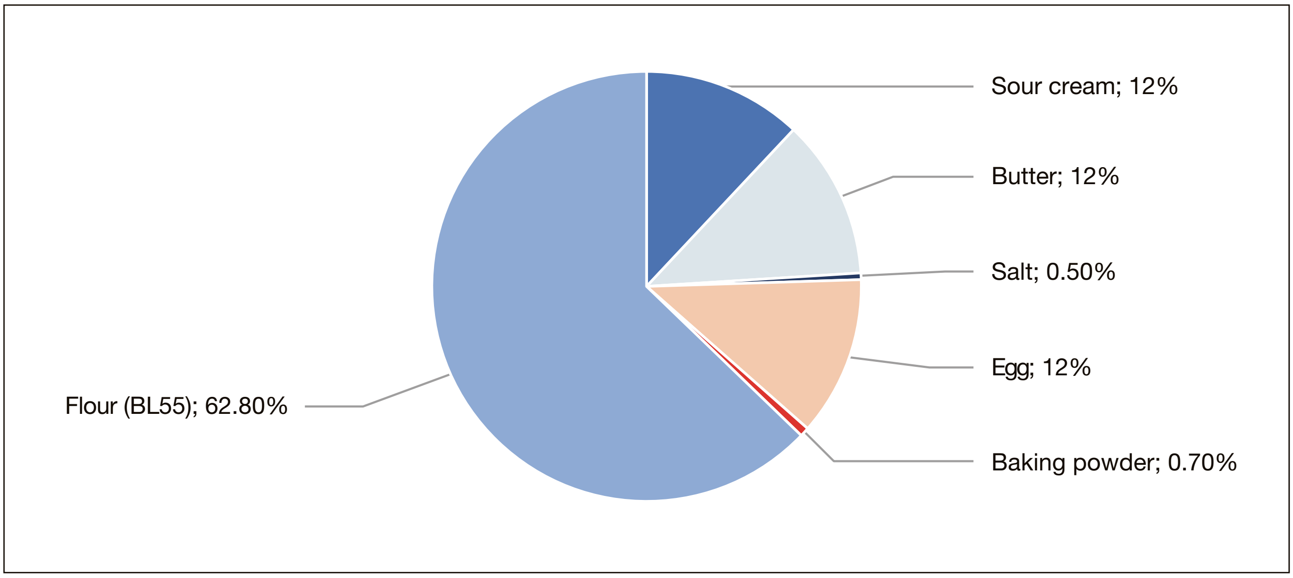


Figure 2. Components of the medallion snacks

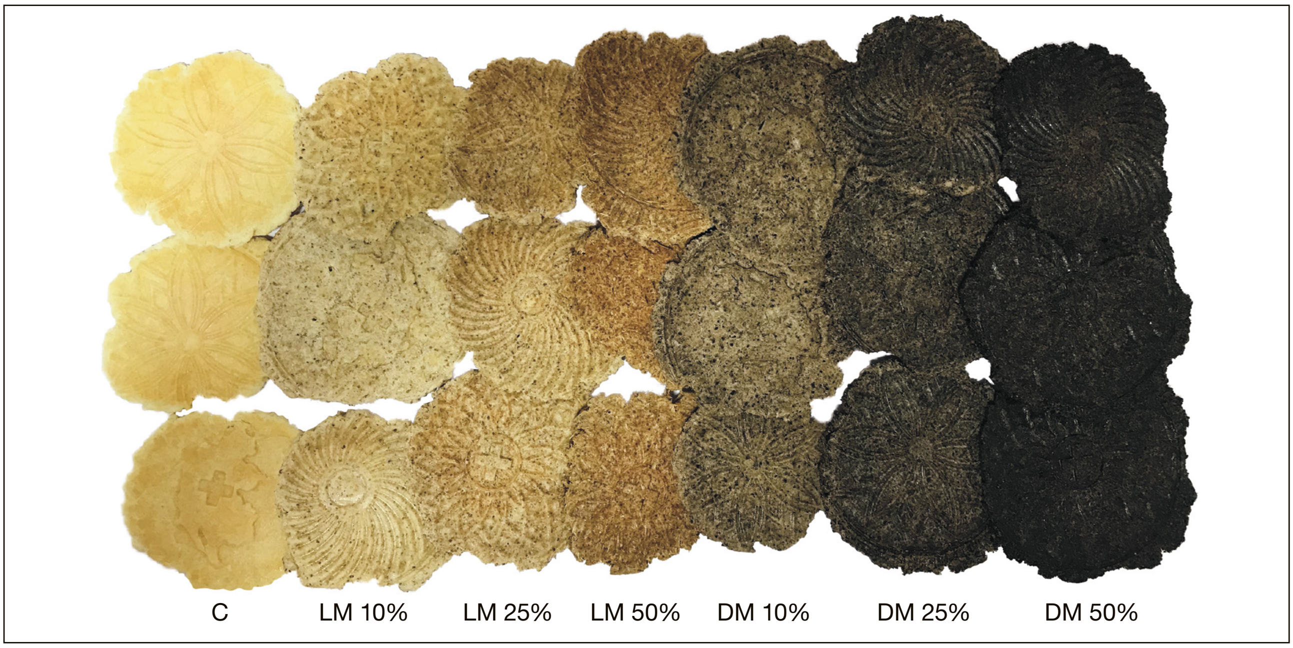


Figure 3. Baked medallion snacks

4.2. Chemical characteristics of the medallions enriched with brewer's spent grain

Laboratory analyses were carried out in triplicate in the laboratories in the Institute of Food Technology and the Institute of Food Science of the Faculty of Agricultural and Food Sciences and Environmental Management of the University of Debrecen. The test were performed according to the relevant standards and methods (***Table 2***).

Table 2. Methods of determination

Total polyphenol content determination **[6]**	Folin-Ciocalteu reagent
Flavonoid content determination **[6]**	Catechin reagent
Dry matter content, Moisture content determination **[22]**	(MSZ 20501-1:2007 2. fejezet) Drying cabinet
Crude protein content determination **[19]**	Kjeldahl method (MSZ 20501-1:2007 7.)
Fat content determination **[24]**	Soxhlet extractor (MSZ 20501-1:2007 4.1.)
Carbohydrate content determination **[16, 23]**	Calculation
Dietary fiber content determination **[18]**	(MÉ 3-2-2008/1. sz. irányelv)
Common salt content determination **[20]**	(MSZ 20501-1:2007 3.2. szakasz)
Energy content determination **[42]**	Calculation (1169/2011/EU rendelet)
Organoleptic analysis **[21]**	Questionnaire, tasting (MSZ 20501-2:2018)

MSZ: Hungarian Standard; MÉ: Codex Alimentarius Hungaricus

4.2.1. Total polyphenol content

In terms of the total polyphenol content of medallions enriched with brewer's spent grain, higher values were recorded in each case compared to the control sample (***Figure 4***). The medallion enriched with light malt at a concentration of 50% (LM 50%) had the highest total polyphenol content of 85.17 mg GAE/100 g. Of the raw materials, the test was also performed on the light and dark malt. Dark malt had a higher total polyphenol content (132.18 mg GAE/100 g) than light malt (102.22 mg GAE/100 g).

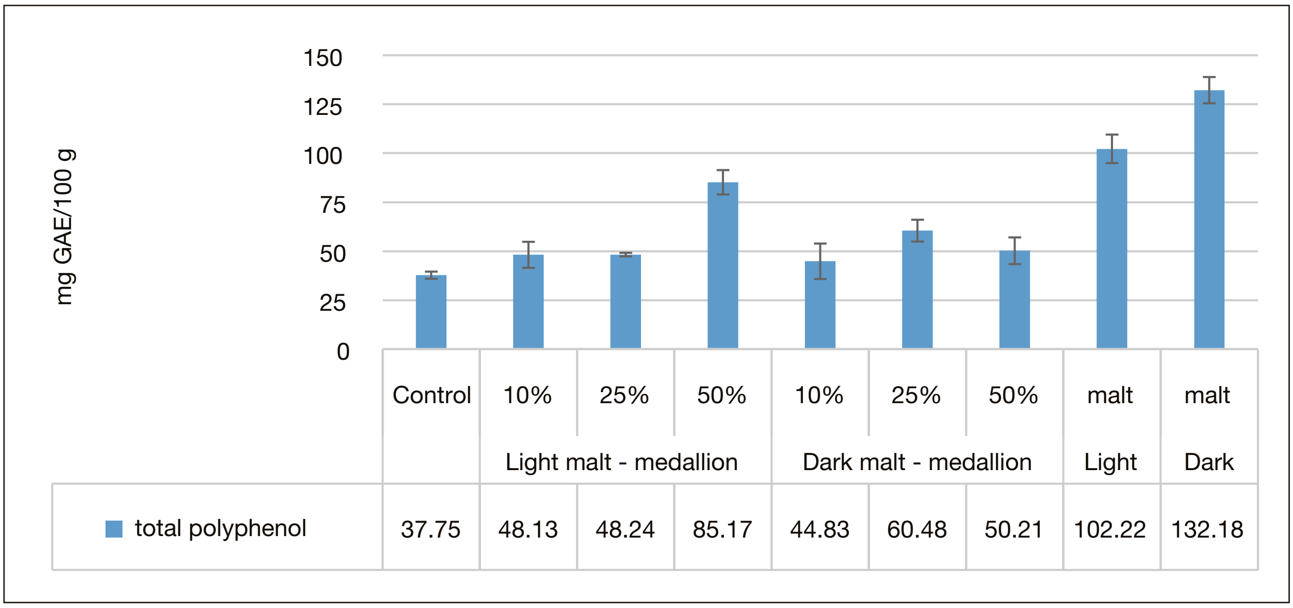


Figure 4. Total polyphenol content of the enriched products

4.2.2. Flavonoid content

Regarding the flavonoid content of the medallions, it was found that enrichment with brewer's spent grain resulted in an increase in the flavonoid content. Compared to the control sample, higher values were observed in this case (***Figure 5***). DM 50% medallion enriched with brewer's spent grain had the highest flavonoid content, with a value of 27.32 mg CE/100 g.

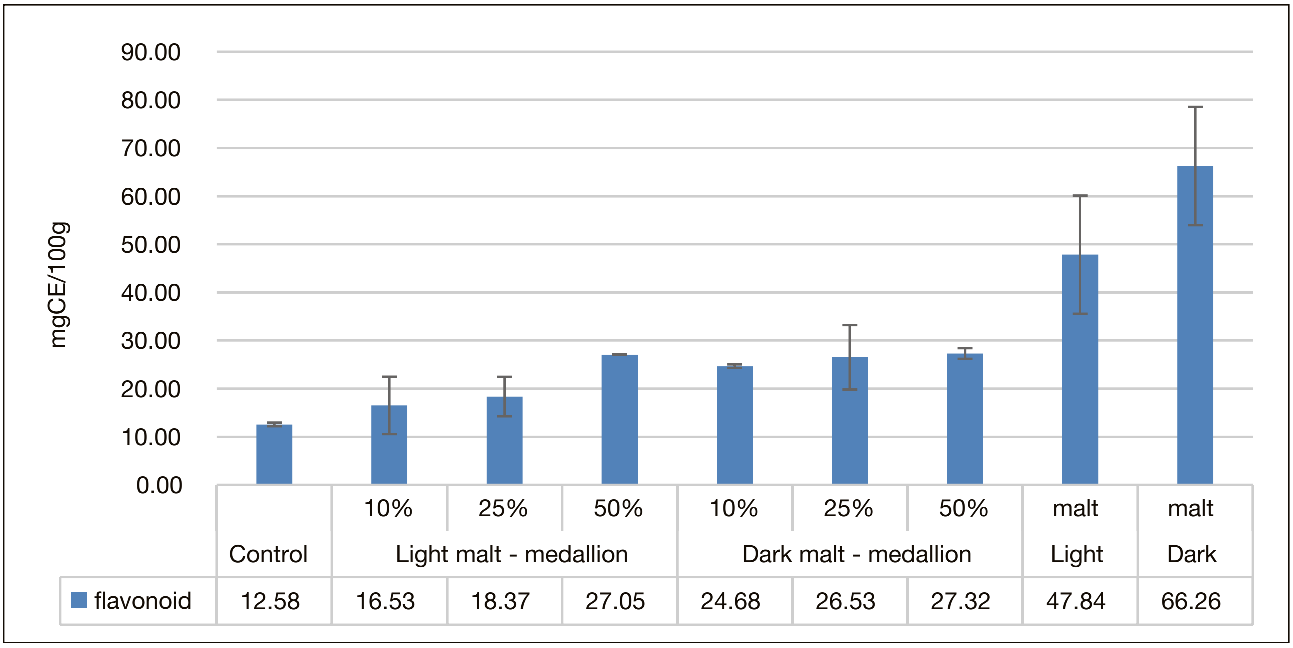


Figure 5. Flavonoid content of the enriched products

4.2.3. Dry matter content, moisture content

In the case of the dry matter content (***Figure 6***), only the medallion with the code DM 10% had a higher value, 93.52%, compared to the control sample. We found that in the case of samples made from light and dark malt, the products enriched with smaller amounts of brewer's spent grain had a higher dry matter content. With respect to the average of dry matter content values, higher values were measured in the samples enriched with dark malt, but the difference of only a few tenths of a percent did not prove to be significant.

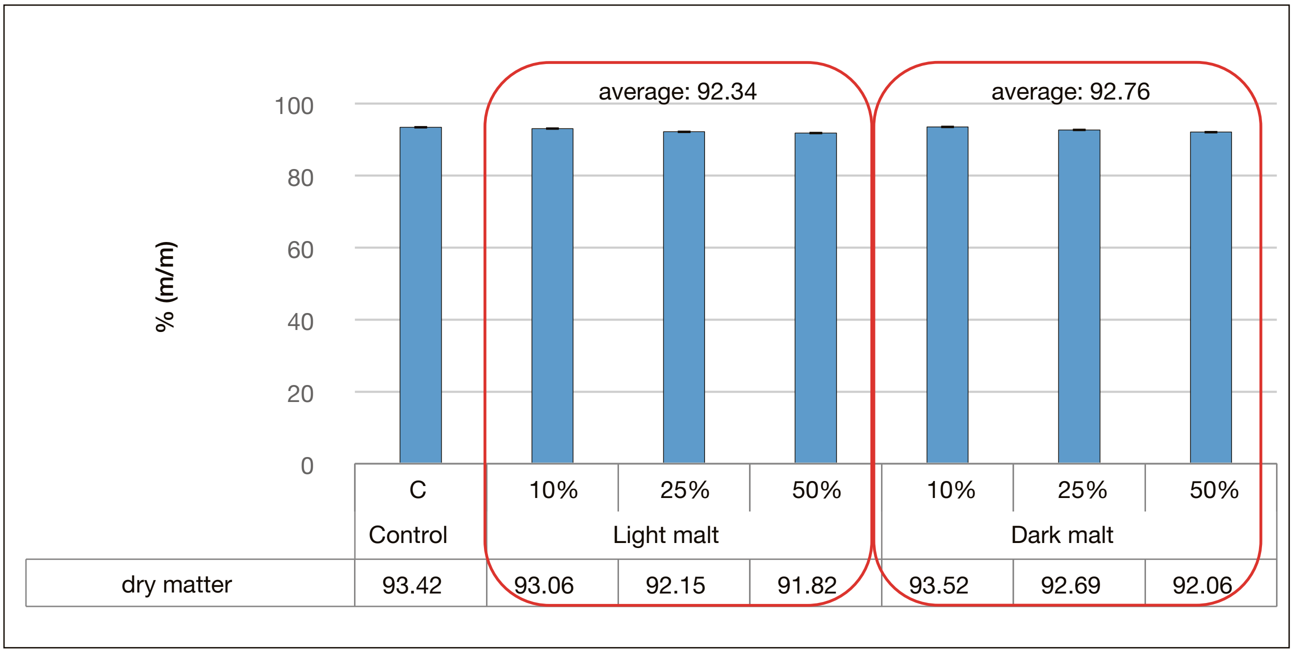


Figure 6. Dry matter content of the enriched products

4.2.4. Crude protein content

In terms of protein content (***Figure 7***), higher values were obtained for all of our enriched products compared to the control sample. Medallion with the code LM 50% had the highest protein content (13.04%). The average protein content of the products enriched with light malt, 11.88%, was higher than the average of the medallions enriched with dark malt (11.56%).

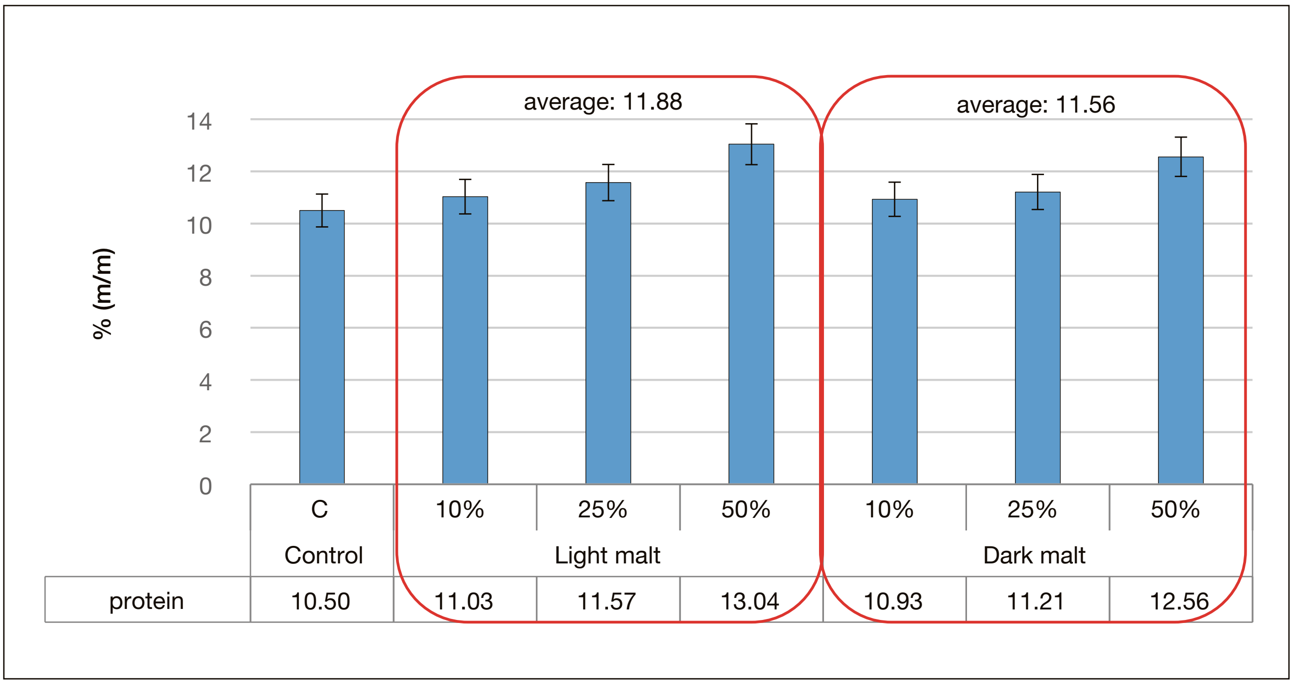


Figure 7. Crude protein content of the enriched products

4.2.5. Fat content

During the examination of the fat content, higher values were measured in all cases compared to the control sample. As the enrichment concentration increased, the fat content of the medallions increased as well, both in the case of samples enriched with light malt and dark malt (***Figure 8***). The average value of the products with different light malt enrichment was 21.15%, while in the case of dark malt, the value was 23.76%. For all products enriched with dark malt, a higher fat content was measured compared to the products enriched with light malt (LM 10% - 19.55%; LM 25% - 20.49%; LM 50% - 23.4% and DM 10% - 19.7%; DM 25% - 23.72%; DM 50% - 27.87%).

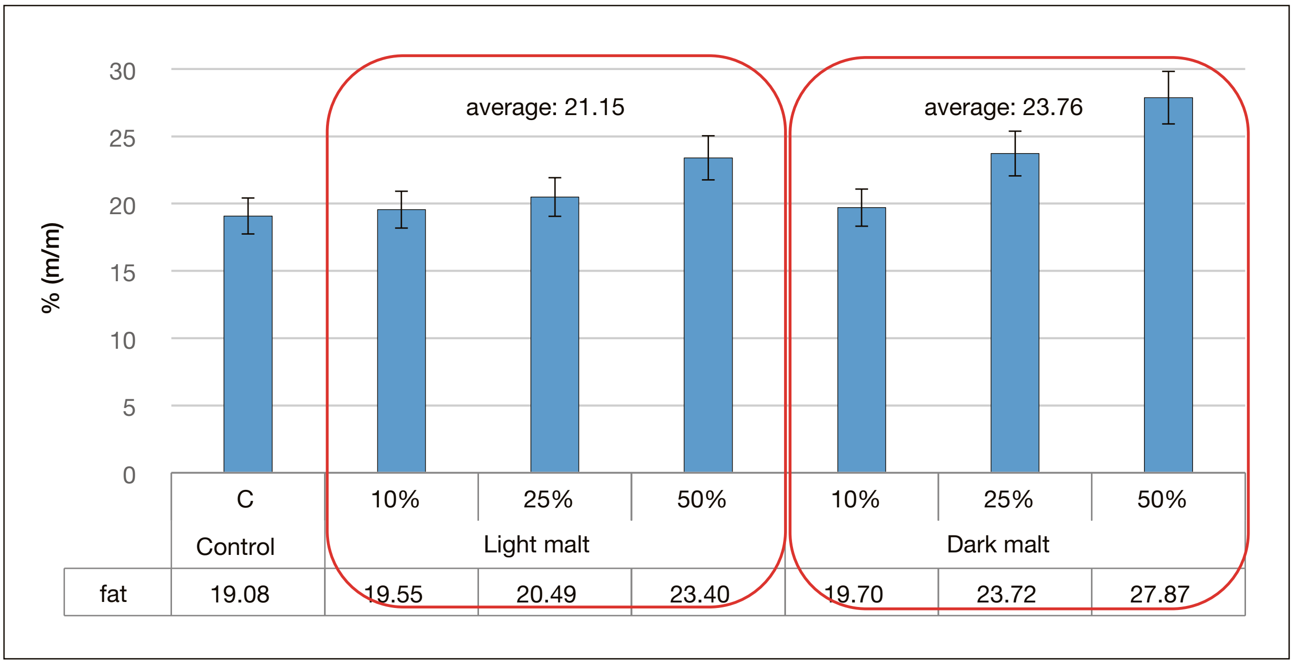
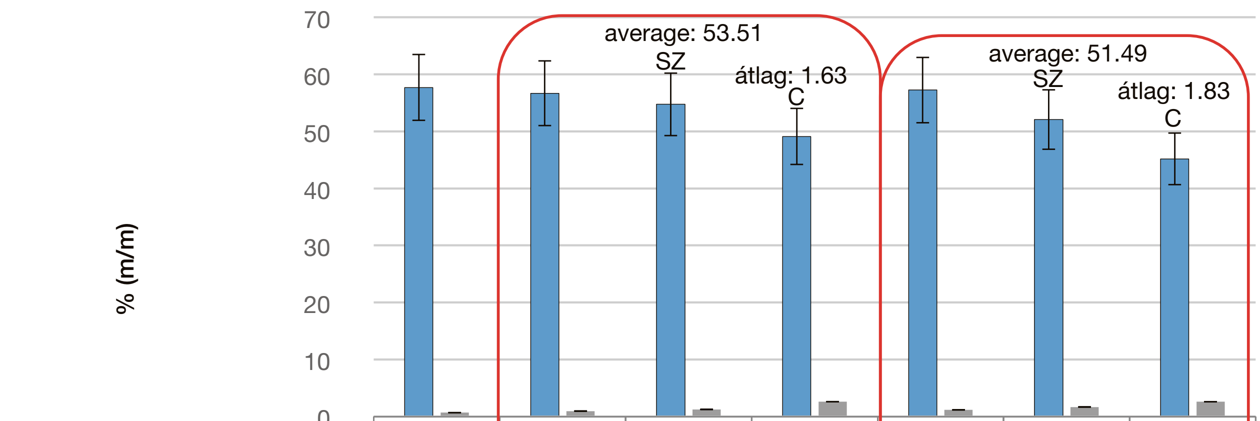


Figure 8. Fat content of the enriched products

4.2.6. Carbohydrate content

Of the data for total carbohydrate content (***Figure 9***), the highest value, 57.7%, was obtained for the control medallion, of which sugar accounted for 0.7%. This characteristic was found to be 57.23% for the sample coded DM 10%. It was true for all products enriched either with light or dark malt that the carbohydrate content decreased with the increasing rate of enrichment. Sample LM 50% had the highest sugar content of 2.62%.

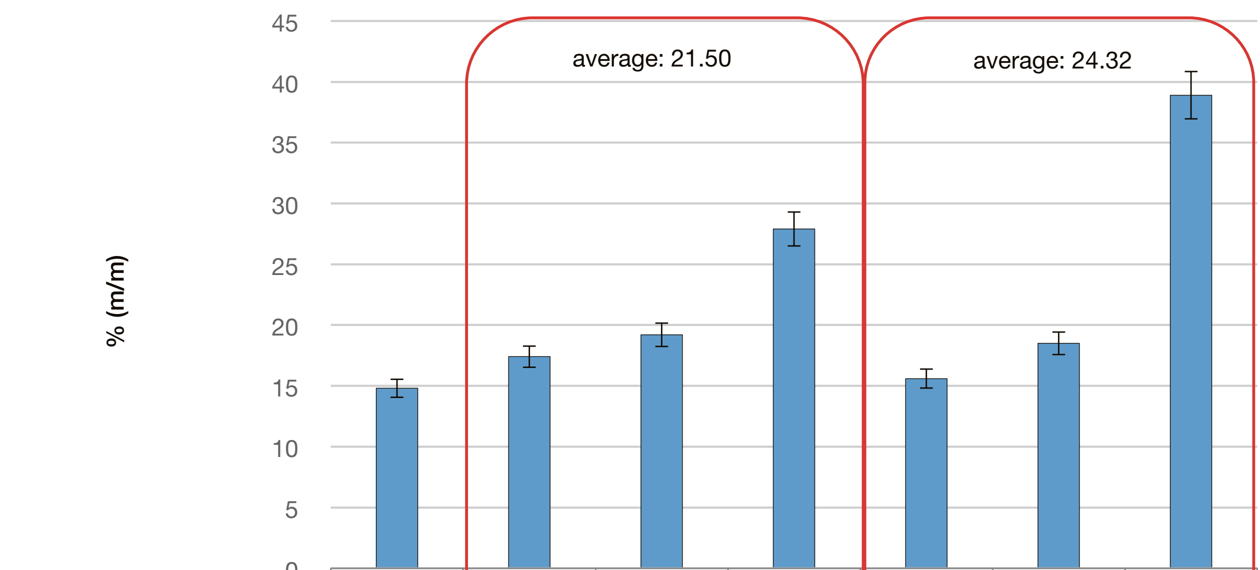


	C	10%	25%	50%	10%	25%	50%
	Control	Light malt			Dark malt		
carbohydrate	57.70	56.68	54.73	49.11	57.23	52.07	45.18
sugar	0.70	0.98	1.26	2.62	1.18	1.69	2.61

Figure 9. Carbohydrate content of the enriched products

4.2.7. Dietary fiber content

The dietary fiber content of the medallions was higher than that of the control medallion without enrichment for all enriched products (values ranged from 10 to 40%). The dietary fiber content increased with the rate of enrichment for the medallions enriched with both types of malt, however, the values of LM 10% (17.4%) and LM 25% (19.2%), as well as those of DM 10% (15.6%) and DM 25% (18.5%) were similar to each other, as opposed to the medallions enriched with 50% malt. The highest value was obtained for medallion DM 50% (38.9%), followed by the dietary fiber content of sample LM 50% (27.9%). The outstanding value is almost double of the value of the control sample (***Figure 10***).

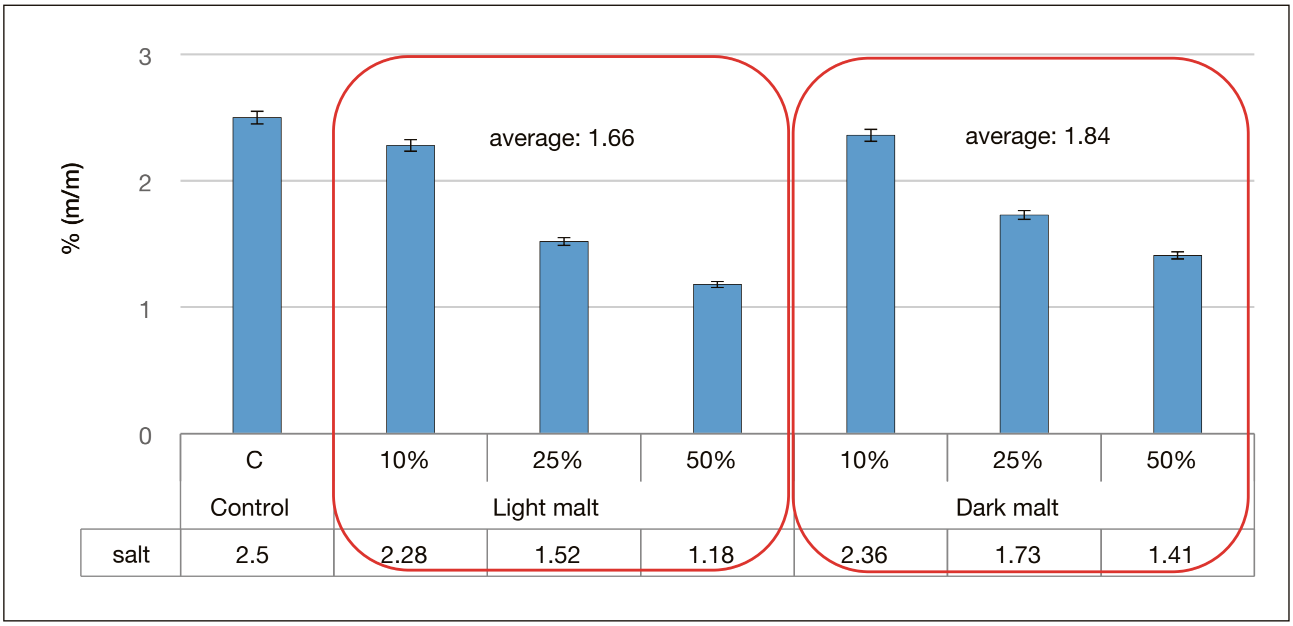


	C	10%	25%	50%	10%	25%	50%
	Control	Light malt			Dark malt		
dietary fiber	14.8	17.4	19.2	27.9	15.6	18.5	38.9

Figure 10. Dietary fiber content of the enriched products

4.2.8. Common salt content

When measuring the salt content of each medallion (***Figure 11***), the highest value was obtained for the control medallion (2.5%). This was followed by the products with an enrichment of 10% (LM 10% 2.28% and DM 10% 2.36%), then the products with an enrichment of 25% (LM 25% and DM 25%), and finally the medallions with an enrichment of 50% (samples LM 50% and DM 50%). The medallions enriched with dark malt always exhibited higher values (2.36%; 1.73%; 1.41%) than their light counterparts (2.28%, 1.52%, 1.18%).

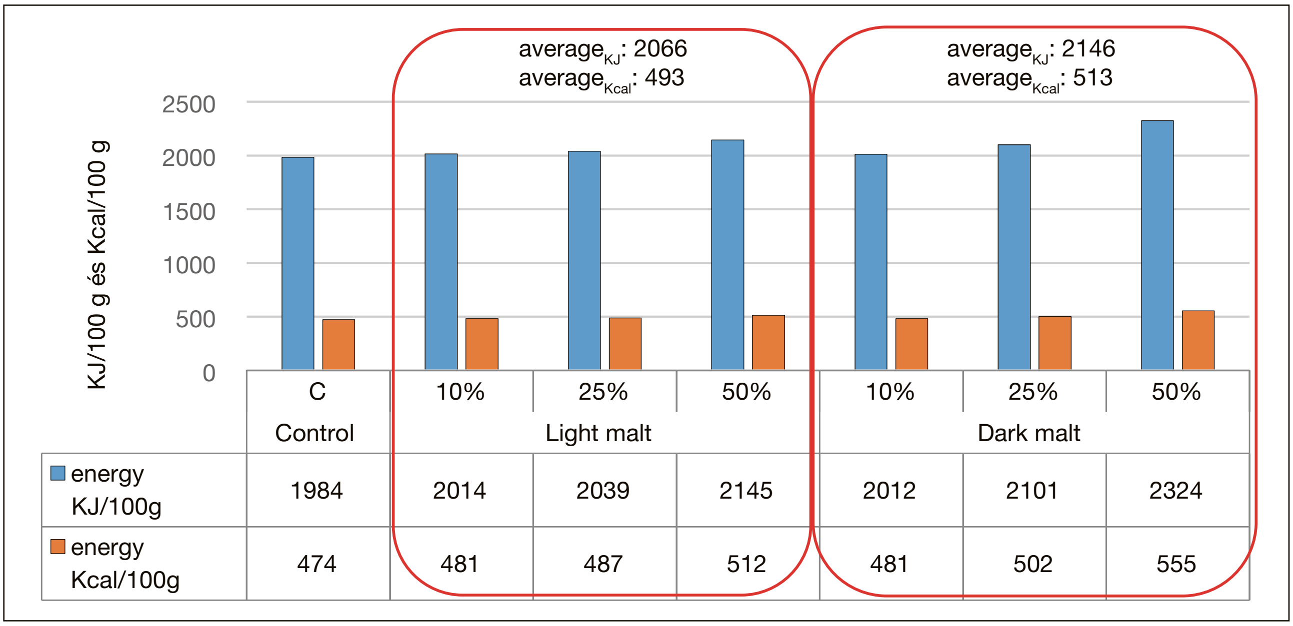


	C	10%	25%	50%	10%	25%	50%
	Control	Light malt			Dark malt		
salt	2.5	2.28	1.52	1.18	2.36	1.73	1.41

Figure 11. Common salt content of the enriched products

4.2.9. Energy content

During the study, the energy content of the medallions was also determined (***Figure 12***). The energy content value of the control medallion (1984 kJ/100 g, 474 kcal/100 g) was exceeded in all cases by the enriched medallions. The medallion enriched with 50% dark malt had the highest energy content of 2324 kJ/100 g (555 kcal/100 g). In terms of energy content, the data were almost identical, showing only small differences compared to the control sample and also to each other.



	C	10%	25%	50%	10%	25%	50%
	Control	Light malt			Dark malt		
energy KJ/100g	1984	2014	2039	2145	2012	2101	2324
energy Kcal/100g	474	481	487	512	481	502	555

Figure 12. Energy content of the enriched products

4.2.10. Organoleptic analysis

In April 2019, 20 judges were asked to evaluate, by tasting and completing a questionnaire, the following four organoleptic characteristics: appearance, smell, taste, texture. They were able to express their opinions using a scale from 1 to 5, where 1 meant very bad and 5 meant delicious.

As a result of the sensory examinations, it was found that enrichment with brewer's spent grain deteriorated the properties of the products in all cases (***Figure 13***). Irrespective of the malt type, there was only a slight difference between the 10% and 25% enrichments, while the 50% enrichment resulted in a large decrease. All parameters of the products with 10 and 25% enrichment with light malt fell into the good category (with values above 4.0), so we definitely would like to continue our research with these two products.

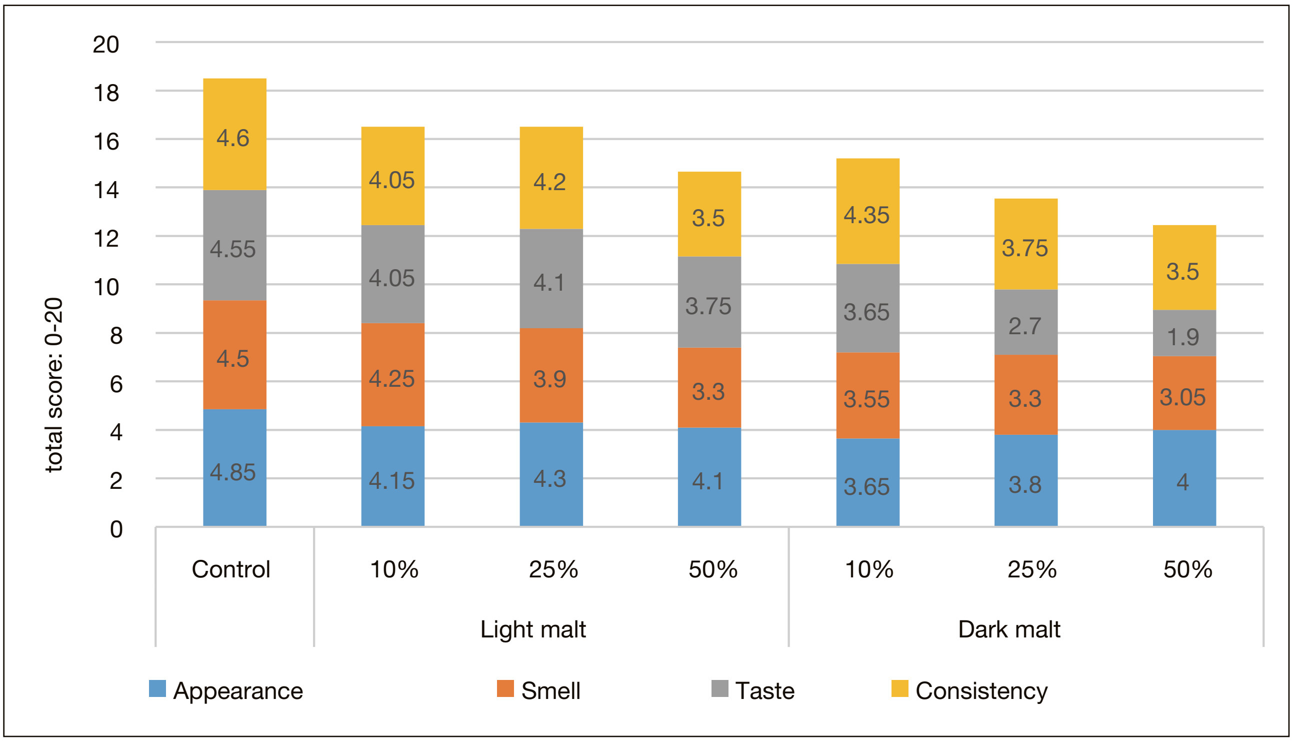


Figure 13. Organoleptic analysis of the enriched products

5. Summary and recommendations

In terms of the total polyphenol, flavonoid, protein, fat, dietary fiber and energy content, higher values were measured in all cases compared to the control sample, whereas a decrease was found for three of the parameters analyzed: dry matter, carbohydrate and common salt content. This effect can be considered advantageous in the case if parameters with reduced values, especially because of the reduced carbohydrate content, while among the chemical components with increased values, the increase in fiber content is particularly important. It is possible to introduce the utilization of brewer's spent grain in the baking industry, and the enrichment of wheat flour medallions with brewer's spent grain had a positive effect on their nutritional values. However, as a result of the enrichment, based on the data of organoleptic analysis, a certain unfavorable change in the properties of the medallions (apeearance, smell, taste, texture) could be observed, but the results of the enrichment with light brewer's spent grain show that an edible product can be prepared by further developments aimed at improving the organoleptic properties.

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