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Адреса редакції:

Національний університет
харчових технологій
вул. Володимирська, 68
Київ 01601, **Україна**

e-mail: **ufj_nuft@meta.ua**

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Contents

Quality assessment of sponge cake with reduced sucrose addition made from composite wheat and barley malt flour

Marko Jukić[1], Gjore Nakov[2], Daliborka Koceva Komlenić[1], Franjo Šumanovac[1], Antonio Koljđeraj[1], Jasmina Lukinac[1]

1 – Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology, Osijek, Croatia
2 – Institute of Cryobiology and Food Technologies, Agricultural Academy – Sofia, Bulgaria

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Corresponding author:

Marko Jukić
E-mail:
mjukic@ptfos.hr

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Abstract

Introduction. The aim of this study was to investigate the effects of replacing part of the wheat flour (WF) with brewer's barley malt flour (BMF), while reducing the sucrose in the recipe, on the quality characteristics of sponge cakes.

Materials and methods. For the production of sponge cake samples, WF and three different types of brewer's BMF (*Pilsen*, *Amber* and *Black*) were used in different ratios with simultaneous reduction of sucrose addition. The content of reducing sugars in WF and BMF was determined, as well as the moisture content and water activity in sponge cake samples. Determination of specific volume, colour in CIE*L*a*b** space, texture profile analysis (TPA) and sensory analysis using the nine-point hedonic scale were also performed.

Results and discussion. The contents of reducing sugars were 0.43, 7.75, 17.05 and 61.02 g/100 g in WF, *Amber*, *Pilsen* and *Black* BMF, respectively. Since sucrose is known to be an excellent ingredient for lowering water activity, both moisture content and water activity in the sponge cake samples increased significantly when the addition of sucrose was reduced. The specific volume decreased from 1.99 cm^3/g in the control WF sample to 1.79 cm^3/g in the WF sample with reduction of sucrose content by 50.0%. Reducing the sucrose addition significantly increased the hardness and chewiness, while the resilience and cohesiveness of the cake decreased ($p < 0.05$). Addition of 20% BMF and reduction of sucrose to 83.3% of the original recipe mitigated these effects and there were no statistically significant differences between these samples and the control WF sample in terms of specific volume and texture parameters. The addition of BMF significantly affected all colour parameters of the sponge cake crumb ($p < 0.05$). *Amber* BMF:WF (20:80) sponge cake with reduced sucrose addition (83.3%) had the highest sensory scores for colour, appearance and overall acceptability. *Pilsen* BMF:WF (20:80) with reduced added sucrose (83.3%) had the best odour and the best taste was the WF control sample.

Conclusion. By replacing WF with BMF in the production of sponge cakes, a very wide range of sponge cake products with different quality characteristics, improved nutritional and functional properties can be obtained. BMF has significant amounts of its own sugars, which can minimize the effect of the reduction of sucrose content in the sponge cake recipe.

Introduction

Sponge cakes are considered to be food with low nutritional value because they usually contain high amounts of refined wheat flour (WF) and sucrose. Consumption of so-called sweetened grain products, which include sponge cakes, significantly increases the intake of sugar and decreases the intake of fibre (Frary et al., 2004). This has a negative impact on the quality of the human diet and increases the risk of various diseases such as diabetes, dental decay and obesity, and thus also hypertension and cardiovascular diseases. Therefore, all attempts to increase the nutritional value of these types of products are welcome. One way to achieve this goal is to use non-wheat flour in a sponge cake recipe. For fermented products, such as bread, the use of non-wheat flour is limited as a significant amount of gluten is desirable to produce quality products (Ho et al., 2018). However, this is not the case for products such as sponge cakes. Sponge cakes are foam-like products and their structure depends mainly on the incorporation of air bubbles into the foam during the mixing phase and on the functionality of sucrose and eggs in the recipe (Godefroidt et al., 2019). Since gluten is not so important for making sponge cake, many recipes have been developed with flours from other grains and even legumes (Sobhy et al., 2015). Barley flour has long been used as a substitute for WF in the manufacture of various cereal-based products, including different types of cakes (Gupta et al., 2009; Khalek, 2020; Sangeeta and Chopra, 2013).

Barley grain is considered more nutritious than wheat due to a higher content of β-glucan, insoluble fibre, vitamins, minerals and phenolic substances (Farag et al., 2022). However, as far as we know, no attempt has yet been made to use barley malt flour (BMF) for making sponge cake. Barley malt is normally used in the production of beer and other barley malt-based beverages and in small quantities in the production of bakery products to optimise amylolytic activity (diastatic malt) and in confectionery to improve colour and flavour (non-diastatic malt) (Pyler and Gorton, 2008). The malting process consists of four steps: steeping, germination, kilning and/or roasting, and cleaning the malted grains from rootlets and impurities. During the malting process, barley undergoes numerous changes in its composition and its functional and nutritional properties. During germination, there is an intensive synthesis of hydrolysing enzymes (β-glucanase, amylases and proteases) and a moderate change in the main components of the barley grain (starch, proteins, β-glucan) (Celus et al., 2006; Gupta et al., 2010; Šimić et al., 2015). Elevated temperatures during kilning and/or roasting step abort these modifications and contribute to the development of the colour and flavour of the malt (Hertrich, 2013). Malting is considered a process that improves the nutritional value of barley by increasing the digestibility of protein and the bioavailability of vitamins B and C and minerals (copper, calcium, zinc and manganese) (Baranwal, 2017), increasing antioxidant activity through the release of bound phenolic compounds and the generation of Maillard reaction products (Carvalho et al., 2016).

Although the use of non-wheat flour is widespread and does not cause major problems in the production of sponge cakes, the situation is quite different when sucrose is reduced because sucrose is not only a sweetener but an ingredient that significantly affects the technological quality of sponge cakes (Godefroidt et al., 2019). Sucrose plays a multiple role in creating the structure of the sponge cake. It facilitates the incorporation of air and improves the stability of the foam (Goranova et al., 2020), delays the development of gluten and the gelatinisation of starch, so that the cake can expand better before it sets and the texture becomes softer (Godefroidt et al., 2019; Paton et al., 1981).

The aim of this study was to investigate the effects of replacing part of the WF with three different types of brewer's BMF with a simultaneous reduction of sucrose in the recipe on the physical and sensory properties of sponge cakes.

Materials and methods

Materials

Commercial plain WF (Tena-Žito Ltd., Đakovo, Croatia) and three different types of brewer's BMF were used for this study: *Pilsen* (enzymatically active), *Amber* (low-enzymatically active) and *Black* malt (non-enzymatically active). (Slavonija slad d.o.o., Nova Gradiška, Croatia; Boortmalt, Antwerp, Belgium). Protein content was 10.6, 11.2, 11.1 and 10.8% in WF, *Pilsen*, *Amber*, and *Black* BMF respectively. Shortening (Zvijezda d.d., Zagreb, Croatia), sucrose, eggs, milk, and sodium bicarbonate ($NaHCO_3$) were purchased from a local market.

Reducing sugar content in flour

The content of reducing sugars in WF and BMF was determined using AACC International Method 80-68.01 (Schoorl method) (AACC, 2010). Since maltose is the dominant reducing sugar in malt, the results of reducing sugar content were expressed on a maltose basis. The measurements were carried out in triplicate for each sample.

Sponge cake production

The sponge cakes were prepared according to the procedure of Velioğlu et al. (2017) with slight modifications. The quantities of raw materials (100 g flour base) are given in Table 1. First, the total amount of eggs and sugar was added to the bowl of an electronic mixer (Gorenje MMC800W, Slovenia) and the mixture was stirred with a wire attachment for 4 minutes at maximum speed until a voluminous foam was formed. The other raw materials were then added and mixing continued at a lower speed for a further 4 minutes. The accurately weighed sponge cake mixture (175 g) was distributed into moulds, which were placed in the oven (Wiesheu Minimat Zibo, Wiesheu GmbH, Germany). Baking was carried out at 180 °C for 20 minutes in triplicate batches.

Moisture content and water activity (a_w)

Moisture content was determined according to AACC International Method 44-15.02 (AACC, 2010) and water activity with the Hygropalm AW1 indicator (Rotronic, USA).

Physical analysis

The specific volume (cm^3/g) of the sponge cakes was measured using the VolScan Profiler (Stable Micro Systems, UK).

Texture profile analysis (TPA) was performed using the TA.XT2i Texture Analyzer (Stable Microsystems Ltd., Surrey, UK). The sponge cake samples were cut into cubes (30x30x30 mm) and subjected to double compression at 40% with 5 s delay between compressions and a test speed of 1 mm/s. An aluminium plate with a diameter of 75 mm was used. Hardness (N), cohesiveness, resilience, and chewiness (N) were determined from the TPA curves.

The colour of the cross-section of sponge cakes was measured using the CR -400 chromameter (Konica Minolta, Japan) and expressed in a CIE$L^*a^*b^*$ colour model. The L^* value ranges from 0 (black) to 100 (white) and represents the lightness or luminance of the sample. The a^* and b^* values range from -128 to 127 and represent the green-red (a^*) and blue-yellow (b^*) axes of the colour space. The total colour difference (ΔE) between the control and sample sponge cakes was calculated according to the CIE76 colour difference equation (Mokrzycki and Tatol, 2011).

Table 1

Formulation of sponge cakes made from composite flours containing wheat flour (WF) and barley malt flour (BMF)

	WF (g)	BMF (g)	Sucrose [1] (g)	Shortening (g)	Sunflower oil (mL)	Milk (mL)	Egg (g)	$NaHCO_3$ (g)
WF (Control)	100	-	79.5 (100%)	28.4	22.7	45.5	40.0	2.4
WF	100	-	66.2 (83.3%)	28.4	22.7	45.5	40.0	2.4
	100	-	53.0 (66.6%)	28.4	22.7	45.5	40.0	2.4
	100	-	39.8 (50.0%)	28.4	22.7	45.5	40.0	2.4
PILSEN:WF	80	20	66.2 (83.3%)	28.4	22.7	45.5	40.0	2.4
	60	40	53.0 (66.6%)	28.4	22.7	45.5	40.0	2.4
	40	60	39.8 (50.0%)	28.4	22.7	45.5	40.0	2.4
AMBER:WF	80	20	66.2 (83.3%)	28.4	22.7	45.5	40.0	2.4
	60	40	53.0 (66.6%)	28.4	22.7	45.5	40.0	2.4
	40	60	39.8 (50.0%)	28.4	22.7	45.5	40.0	2.4
BLACK:WF	80	20	66.2 (83.3%)	28.4	22.7	45.5	40.0	2.4
	60	40	53.0 (66.6%)	28.4	22.7	45.5	40.0	2.4
	40	60	39.8 (50.0%)	28.4	22.7	45.5	40.0	2.4

[1] Percentage of added sucrose compared to standard recipe.

Sensory analysis

The sensory assessment of the sponge cakes was conducted by a panel of eleven semi-trained evaluators with previous experience in sensory analysis. The nine-point hedonic scale was used to asses individual sensory characteristics: colour, appearance, odour, taste, and overall acceptance. The scores were: like extremely (9), like very much (8), like moderately (7), like slightly (6), neither like nor dislike (5), dislike slightly (4), dislike moderately (3), dislike very much (2), and dislike extremely (1).

Statistical analysis

Analysis of variance (ANOVA) and multiple comparison post-hoc Fisher Least Significant Difference (LSD) test were performed ($p < 0.05$) using XLSTAT software (Addinsoft, New York, USA).

Results and discussion

In this study, WF was partially replaced by brewer's BMF (*Pilsen*, *Amber*, and *Black* BMF). The ratios of the prepared BMF:WF composite flours were 20:80, 40:60 and 60:40, respectively. The addition of sucrose was reduced to 83.3, 66.6 and 50.0% (66.2, 53.0 and 39.8 g/100 g flour base), compared to the original sponge cake recipe in the ratios 20:80, 40:60 and 60:40 BMF:WF, respectively. The sponge cake made from 100% WF and 100% (75 g/100 g flour base) added sucrose served as the control sample. In order to evaluate only the influence of sucrose on the quality characteristics of the sponge cake, WF sponge cakes with reduced sucrose addition were also prepared.

Reducing sugar content

The reducing sugars content in WF and BMF was 0.43, 7.75, 17.05 and 61.02 g/100 g in WF, *Amber, Pilsen* and *Black* BMF, respectively (Table 2). The content of reducing sugars in BMF samples is significantly higher ($p < 0.05$) than in WF. This is due to the enzymatic hydrolysis of starch and thermal dextrinization in the kilning/roasting stage of malt production, where a certain proportion of starch is broken down into various dextrins and short-chain sugars, many of which have a reducing potential.

Table 2

Reducing sugars content in wheat flour (WF) and barley malt flours (BMF)

Flour	Reducing sugar content (g/100 g)[1]
WF	0.43±0.09^{d}
Pilsen BMF	7.75±0.21^{c}
Amber BMF	17.05±0.19^{b}
Black BMF	61.02±0.32^{a}

[1] The values are Mean±SD (n = 3). Different letters (a–d) indicate statistically significant differences ($p < 0.05$)

Maltose is the dominant sugar in malt, followed by maltotriose and glucose. Moreover, the dextrin content is proportional to the applied temperature in the final malting step, which is evident from the results obtained, where the reducing sugar content was highest in *Black* BMF and lowest in *Pilsen* BMF (Duke and Henson, 2008; Koljonen et al., 1995). This was to be expected as the kilning temperature for *Pilsen* malt is in the range of 50–85 °C, roasting of *Amber* malt is done at 100–150 °C and for *Black* malt at 230 °C. The higher the temperature and the longer the roasting, the more dark dextrins are formed. Thus, the roasting of *Black* malt produces a very dark, almost black colour, which comes from the pyrodextrins (Srivastava et al., 1970). Since starch hydrolysis during malting produces maltodextrins together with various simple sugars, the exact molecular composition is not known. Therefore, the results obtained should be understood as the total reduction potential and not the exact content of reducing sugars.

Moisture content and water activity (a_w) of BMF:WF sponge cakes

Sucrose has many functions in the production of sponge cakes. One of the most important functions of sucrose is its moistening (hygroscopic) effect and its influence on water activity. It is very important to keep water activity as low as possible to prevent spoilage and staling of products. Therefore, the reduction of sucrose in the sponge cake recipe is a very difficult task.

Table 3

Moisture content and water activity (a_w) of sponge cakes

BMF:WF	Sucrose (%) [1]	Moisture content (%)	Water activity
WF (Control)			
0:100	100	21.4±0.1^{j} [2]	0.851±0.016^{h}
WF			
0:100	83.3	23.7±0.2^{de}	0.924±0.005^{bc}
0:100	66.6	24.8±0.0^{b}	0.945±0.003^{a}
0:100	50.0	25.9±0.3^{a}	0.946±0.015^{a}
PILSEN:WF			
20:80	83.3	21.6±0.2^{ij}	0.875±0.012^{g}
40:60	66.6	22.5±0.0^{gh}	0.901±0.003^{de}
60:40	50.0	23.9±0.1^{cd}	0.924±0.009^{bc}
AMBER:WF			
20:80	83.3	22.0±0.3^{hi}	0.881±0.001^{fg}
40:60	66.6	23.0±0.1^{fg}	0.900±0.006^{def}
60:40	50.0	24.2±0.1^{cd}	0.914±0.006^{cde}
BLACK:WF			
20:80	83.3	22.2±0.1^{hi}	0.850±0.008^{h}
40:60	66.6	23.3±0.4^{ef}	0.883±0.009^{fg}
60:40	50.0	24.4±0.1^{bc}	0.916±0.002^{cde}

[1] Percentage of added sucrose compared to original recipe.

[2] The values are Mean±SD (n = 3). Different letters (a–j) indicate statistically significant differences ($p < 0.05$)

The results of moisture content and water activity are summarised in Table 3. The moisture content and water activity in the control WF sponge cake sample were 21.4% and 0.851 respectively. When the addition of sucrose was reduced, both the moisture content and water activity increased significantly. The highest moisture content and water activity were obtained in sponge cake with 50% added sucrose. In this sponge cake sample, the moisture content was 25.9 and the water activity was 0.946. This was to be expected as sucrose is known to be an excellent ingredient for lowering water activity in various products. Similar results were obtained in the study by Milner et al. (2020), when cakes with sucrose had a significantly lower moisture content and water activity than samples in which sucrose was partially replaced by whey permeate, apple pomace, polydextrose and oligofructose.

When BMF was used as a partial substitute for WF in the ratio 20:80 and sucrose was reduced to 83.3% of the original recipe, moisture content increased slightly but water activity remained well below 0.900. Water activity was 0.875, 0.881 and 0.850 for *Pilsen*, *Amber* and *Black* BMF:WF (20:80), respectively. This was much lower than the WF sample with the same degree of sucrose reduction (83.3%), where a water activity of 0.924 was measured. This can be explained by the fact that BMF has significant amounts of its own sugar, which can weaken the effect of the reduced sucrose addition in the sponge cake recipe. A similar attenuating effect of BMF was observed in the production of biscuits with reduced sucrose content (Jukić et al., 2022).

Further reducing the amount of sucrose added (66.6% of the original recipe) and increasing the amount of BMF (40%) increased the water activity, but it was still within an acceptable range (bellow 0.883-0.901) and significantly lower than samples with the same amount of sucrose. In samples with a BMF:WF ratio of 60:40, the water activity remained similar or even lower than in WF samples with a sucrose addition of 83.3% of the original formulation, even when the sucrose addition was reduced to 50%.

Physical properties of BMF:WF sponge cakes

The formation of the cake structure during baking is controlled by the occurrence of three phase transitions: water evaporation, gelatinisation of starch and thermosetting of egg white and gluten proteins.

Table 4

Specific volume and texture properties of sponge cakes

BMF:WF	Sucrose (%) [1]	Specific volume (cm^3/g)	Hardness (N)	Cohesiveness	Resilience	Chewiness (N)
WF (Control)						
0:100	100	1.99±0.03^{b} [2]	23.3±3.2^{de}	0.68±0.02^{a}	0.88±0.03^{ab}	15.5±1.3^{gh}
WF						
0:100	83.3	1.94±0.01^{bc}	27.6±0.3^{cd}	0.68±0.00^{a}	0.89±0.01^{a}	18.6±0.0^{fg}
0:100	66.6	1.78±0.03^{d}	42.6±3.4^{b}	0.63±0.00^{bcd}	0.86±0.00^{abc}	26.5±2.1^{bc}
0:100	50.0	1.79±0.05^{d}	50.1±0.9^{b}	0.57±0.00^{ef}	0.85±0.01^{bcd}	28.3±1.0^{b}
PILSEN:WF						
20:80	83.3	2.11±0.02^{a}	20.2±0.3^{de}	0.65±0.00^{ab}	0.89±0.02^{a}	13.3±0.4^{h}
40:60	66.6	1.89±0.04^{c}	32.5±2.1^{c}	0.63±0.01^{bc}	0.85±0.00^{bcd}	19.8±1.0^{def}
60:40	50.0	1.77±0.03^{de}	44.0±3.4^{b}	0.55±0.00^{f}	0.80±0.00^{ef}	22.7±1.7^{cde}
AMBER:WF						
20:80	83.3	1.91±0.03^{c}	27.7±2.5^{cd}	0.64±0.00^{bc}	0.88±0.01^{ab}	17.6±1.3^{fg}
40:60	66.6	1.71±0.02^{f}	42.3±2.3^{b}	0.61±0.03^{cd}	0.85±0.01^{bcd}	25.1±0.3^{bc}
60:40	50.0	1.47±0.02^{g}	77.3±1.8^{a}	0.57±0.00^{ef}	0.81±0.01^{def}	42.6±1.1^{a}
BLACK:WF						
20:80	83.3	2.05±0.01^{a}	18.6±4.6^{e}	0.66±0.02^{ab}	0.86±0.01^{abc}	11.7±2.4^{h}
40:60	66.6	1.81±0.05^{d}	32.2±2.0^{c}	0.59±0.01^{de}	0.83±0.01^{cde}	18.9±1.5^{efg}
60:40	50.0	1.72±0.01^{ef}	46.4±2.9^{b}	0.54±0.00^{f}	0.78±0.03^{f}	23.0±0.4^{cd}

[1] Percentage of added sucrose compared to original recipe.
[2] The values are Mean±SD (n = 3). Different letters (a–g) indicate statistically significant differences ($p < 0.05$)

The addition of sucrose affects all three factors by regulating water activity, raising the gelatinisation temperature of starch and increasing the denaturation temperature of proteins. In this way, the thermal stability of the proteins is increased and they form a network with the incorporated swollen and gelatinised starch granules (Godefroidt et al., 2019; van der Sman and Renzetti, 2021).

One of the most important indicators of the quality of sponge cakes is the formation of a porous structure, which forms when air is incorporated during batter mixing and the volume increases during baking. Evaluation of the specific volume of a sponge cake serves as an excellent tool to assess the porosity of a product (Psimouli and Oreopoulou, 2012). The results showed that the addition of sucrose plays a decisive role in the porosity of the sponge cakes (Table 4). A higher specific volume indicates greater porosity. The specific volume decreased from 1.99 cm^3/g in the control WF sample to 1.79 cm^3/g in the WF sample with 50.0% reduced sucrose addition. This is consistent with the study by Sangeeta and Chopra (2013), where a 10% reduction in sugar content reduced cake volume by almost 8%. Specific volume is directly related to the texture of sponge cakes. A high specific volume means a low cake density and consequently a softer texture of the product. Therefore, by reducing the addition of sucrose, the hardness and chewiness increased significantly, while the resilience (elasticity) and cohesiveness of the cake decreased. The use of BMF in a 20:80 ratio and the reduction of sucrose to 83.3% of the original recipe mitigated this deterioration and there were no statistically significant differences between these samples and the control WF sample in terms of specific volume and texture parameters. Further reduction of sucrose and addition of higher amounts of BMF significantly deteriorated the specific volume and textural properties of sponge cakes. This is particularly evident in sponge cakes made with *Pilsen* and *Black* BMF. The probable reason for this negative effect is that although these BMFs contain significant amounts of reducing sugars, the starch content is considerably reduced due to intensive starch hydrolysis during malting of barley, and starch is one of the key factors in the formation of sponge cake structure. This lower starch content should be taken into account in future studies when BMF is used as a substitute for WF. A similar effect on the textural properties of sponge cake was found by Gupta et al. (2009) in their study on the effects of partial replacement of WF with barley flour. Their results showed that adding barley flour up to 40% increased the hardness and chewiness and reduced the volume, cohesiveness and elasticity of the cake.

The interdependence between sucrose addition, water activity, specific volume and texture parameters of sponge cake was demonstrated and described by correlation analysis (Table 5).

Table 5

Correlation matrix of data for specific volume and texture properties of sponge cakes

Variables	**Water activity**	**Specific volume (cm^3/g)**	**Hardness (N)**	**Cohesiveness**	**Resilience**	**Chewiness (N)**
Sucrose (%)	-0.729**	0.781**	-0.808**	0.934**	0.834**	-0.720**
Water activity	-	-0.573*	0.629*	-0.571*	-0.361	0.633*
Spec. volume (cm^3/g)	-	-	-0.950**	0.725**	0.696**	-0.928**
Hardness (N)	-	-	-	-0.722**	-0.636*	0.982**
Cohesiveness	-	-	-	-	0.890**	-0.599*
Resilience	-	-	-	-	-	-0.491

$^{*}p < 0.05$; $^{**}p < 0.01$

The results showed that there were significant correlations ($p < 0.01$) between sucrose addition and water activity (r = -0.729), specific volume (r = 0.781), hardness (r = -0.808), cohesiveness (r = 0.934), resilience (r = 0.834) and chewiness (r = -0.720). The highest correlation (r = -0.950) was between the specific volume and the hardness of sponge cake.

In this study, the colour of the sponge cake crumb was measured using the CIE*L**a*b** colour, as this model approximates human vision. The *L** value stands for the lightness or luminance of the sample, and the *a** and *b** values stand for the "green-red" and "blue-yellow" axes of the colour space.

Table 6

Colour of sponge cakes

BMF:WF	Sucrose (%) [1]	*L**	*a**	*b**	Δ*E*
WF (Control)					
0:100	100	$76.4±0.8^{a}$	$-2.8±0.1^{i}$	$23.6±0.5^{de}$	-
WF					
0:100	83.3	$76.4±0.8^{a}$	$-2.7±0.1^{hi}$	$23.1±0.3^{ef}$	0.5
0:100	66.6	$76.5±2.2^{a}$	$-2.6±0.2^{hi}$	$23.0±0.8^{f}$	0.7
0:100	50.0	$76.4±2.5^{a}$	$-2.5±0.1^{h}$	$22.8±0.7^{fg}$	0.9
PILSEN:WF					
20:80	83.3	$69.5±1.3^{b}$	$0.2±0.2^{g}$	$22.4±0.4^{gh}$	7.6
40:60	66.6	$65.2±1.9^{c}$	$1.5±0.2^{f}$	$23.9±0.4^{d}$	12.0
60:40	50.0	$59.2±1.3^{d}$	$2.7±0.1^{e}$	$24.9±0.7^{c}$	18.1
AMBER:WF					
20:80	83.3	$56.0±0.9^{e}$	$6.7±0.3^{c}$	$30.4±0.6^{b}$	23.5
40:60	66.6	$47.6±0.7^{f}$	$9.9±0.4^{b}$	$31.4±0.5^{a}$	32.4
60:40	50.0	$38.2±2.1^{g}$	$11.2±0.4^{a}$	$31.9±1.3^{a}$	41.5
BLACK:WF					
20:80	83.3	$24.3±0.7^{h}$	$6.6±0.2^{c}$	$14.3±0.4^{i}$	53.8
40:60	66.6	$15.0±0.8^{h}$	$3.5±0.4^{d}$	$6.6±0.7^{j}$	64.0
60:40	50.0	$14.1±1.0^{h}$	$1.7±0.2^{f}$	$3.8±0.3^{k}$	65.6

[1] Percentage of added sucrose compared to original recipe.
[2] The values are Mean±SD (n = 3). Different letters (a–j) indicate statistically significant differences ($p < 0.05$)

Unlike biscuits, where the colour is largely determined by the amount of sucrose added in the recipe, the colour of sponge cakes is more strongly influenced by added eggs and other coloured ingredients. From the results of the colour determination shown in Table 6, it can be seen that the addition of sucrose had no effect on the colour of the sponge cake crumb. There were no statistically significant differences between the control WF sample and the WF samples with reduced sucrose addition in the *L**, *a** and *b** values and the (Δ*E*) total colour difference was very small (0.5–0.9).

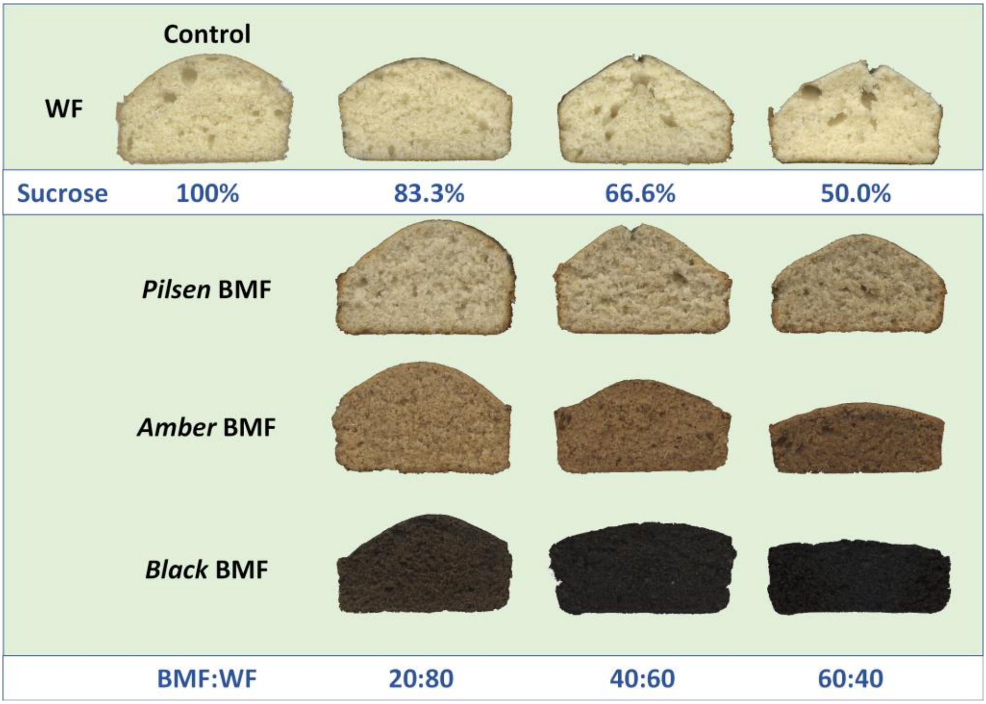

Figure 1. Sponge cakes made from composite flours containing wheat flour (WF) and barley malt flour (BMF)

The addition of BMF significantly influenced all colour parameters of the sponge cake crumb ($p < 0.05$). The colour changes depended on the type of BMF used and its amount in the recipe. The colour of BMF comes from the process of barley malting and the intensity of the colour is directly proportional to the temperature during kilning and/or roasting (Hertrich, 2013). The lightest BMF was the *Pilsen* BMF, slightly darker with an intense amber hue was the *Amber* BMF, while the *Black* BMF was the darkest, almost black. Consequently, the sponge cakes with *Pilsen* BMF were the lightest among the three composite sponge cakes, and the cakes with *Black* BMF were the darkest. The addition of the *Amber* BMF caused the highest increase in a^* and b^* values, resulting in a reddish amber colour of the sponge cakes. The lowest $L^*a^*b^*$ values were observed in the *Black* BMF:WF cakes, as these samples had a very dark colour even at a BMF:WF ratio of 20:80. These samples also had the largest colour difference (ΔE) compared to the WF control sample. The total colour difference (ΔE) between the control WF sample and the *Pilsen* BMF:WF cakes was the smallest, but even with a BMF:WF ratio of 20:80, this difference was > 5, which is the smallest difference that can be easily perceived by the consumer (Mokrzycki and Tatol, 2011). Since many types of BMFs can be found on the market, it can be concluded that by using them in the production of sponge cakes, it is very easy to influence the colour of the product and achieve a more attractive appearance of the cakes (Figure 1).

Sensory evaluation

The results of the sensory evaluation, which was carried out using the nine-point hedonic scale, are shown in Table 7. The sensory evaluation showed that by reducing the sugar content in the sponge cake samples, all sensory ratings decreased, confirming the importance of adding sucrose in the production of sponge cake and its multifunctionality. *Black* BMF:WF sponge cakes had the lowest sensory scores, followed by WF cakes with reduced added sucrose.

Table 7

Sensory evaluation of sponge cakes

BMF:WF	Sucrose (%) [1]	Colour	Appearance	Odour	Taste	Overall acceptance
WF (Control)						
0:100	100	7.4±1.4^{ab}	7.6±1.2^{a}	7.1±1.8^{ab}	7.6±1.8^{a}	7.4±1.2^{ab}
WF						
0:100	83.3	6.8±1.3^{abc}	6.6±0.5^{abc}	7.1±1.2^{ab}	6.9±1.6^{ab}	6.9±1.1^{ab}
0:100	66.6	6.7±1.4^{abc}	6.1±1.1^{abcd}	6.6±1.6^{ab}	6.1±1.6^{abc}	6.4±1.7^{ab}
0:100	50.0	6.0±1.9^{abcd}	5.1±1.4^{cd}	6.2±2.1^{ab}	5.9±2.5^{abc}	5.8±1.7^{abcd}
PILSEN:WF						
20:80	83.3	7.5±1.1^{ab}	7.1±1.4^{ab}	7.6±1.0^{a}	7.0±1.9^{ab}	7.3±1.1^{ab}
40:60	66.6	7.3±1.7^{ab}	7.2±1.4^{ab}	7.3±1.2^{a}	6.4±1.9^{abc}	7.1±1.3^{ab}
60:40	50.0	7.0±1.9^{abc}	6.0±1.7^{abcd}	6.7±1.7^{ab}	6.2±2.1^{abc}	6.5±1.8^{abc}
AMBER:WF						
20:80	83.3	7.9±0.8^{a}	7.8±1.1^{a}	7.3±0.9^{a}	7.0±1.3^{ab}	7.5±1.0^{a}
40:60	66.6	7.4±1.1^{ab}	6.6±1.0^{abc}	6.9±1.1^{ab}	6.3±1.6^{abc}	6.8±1.2^{ab}
60:40	50.0	6.9±1.1^{abc}	6.3±1.3^{abc}	6.5±1.4^{ab}	6.0±2.5^{abc}	6.4±2.1^{abc}
BLACK:WF						
20:80	83.3	4.5±3.0^{d}	5.9±2.1^{bcd}	4.2±3.1^{cd}	4.5±2.8^{cd}	4.8±2.7^{cd}
40:60	66.6	3.2±1.9^{e}	3.4±2.0^{ef}	3.0±3.1^{cd}	3.0±2.8^{de}	3.2±2.3^{de}
60:40	50.0	2.3±1.5^{e}	2.5±2.5^{f}	2.5±3.3^{d}	2.3±1.8^{e}	2.4±1.8^{e}

[1] Percentage of added sucrose compared to original recipe.

[2] The values are Mean±SD (n = 3). Different letters (a–e) indicate statistically significant differences ($p < 0.05$)

Amber BMF:WF (20:80) sponge cake with reduced sucrose addition of 83.3% had the highest sensory scores for colour, 7.9, and appearance, 7.8, resulting in the highest overall acceptability score of 7.5, placing this sample between "like moderately" and "like very much" on the nine-point hedonic scale. *Pilsen* BMF:WF (20:80) sponge cake with reduced sucrose addition, 83.3%, had the best odour, 7.6, and WF control sample had the best taste, 7.6. The panellists emphasised the pleasant aroma and rich flavour of *Pilsen* and *Amber* BMF:WF composite sponge cakes, and the attractive colour and caramel-like taste of *Amber*

BMF:WF cakes. This is consistent with the research of Gupta et al. (2009) where the sponge cake samples with 20% barley flour achieved the best sensory results. Further increasing the addition of *Pilsen* and *Amber* BMF and reducing the sucrose content lowered the liking scores of the sponge cakes, but there were no significant differences (p <0.05) compared to the control sample, even with a BMF:WF ratio of 60:40 and a 50% reduction in sucrose addition.

The low sensory rating of the *Black* BMF:WF composite sponge cakes was to be expected as the *Black* BMF had a distinct "roasted" flavour, but for comparison it was used in this study in the same quantities as *Pilsen* and *Amber* BMFs. The samples with *Black* BMF added resulted in the highest level of disagreement among the panellists (highest standard deviation). Most rated these samples as inferior and considered them undesirable, with a bitter taste and too dark a colour. Nevertheless, some panellists found these samples interesting precisely because of their special taste and chocolate-like appearance. It can be concluded that Black BMF should be used in much smaller quantities (e.g. < 10%) as an effective colouring agent. Apart from the detrimental effect on flavour and taste, the use of this type of BMF in large quantities should also be considered from a safety point of view, as highly roasted BMF can contain significant amounts of acrylamide and therefore the amount of its addition should be kept to a minimum in order to comply with health regulations.

Conclusion

1. By replacing WF with BMF in the production of sponge cakes, a very wide range of sponge cake products with different quality characteristics and improved nutritional and functional properties can be obtained, as many types of brewing malts can be found on the market.
2. BMF has significant amounts of its own sugars, which can minimize the effect of the reduced sucrose addition in the sponge cake recipe.
3. By substituting WF with up to 40% *Pilsner* or *Amber* BMF while reducing the addition of sucrose to 66.6% of the original recipe, the sponge cakes retained similar qualitative characteristics to the control WF sponge cake samples.
4. The *Black* BMF:WF composite sponge cakes had a pronounced "roasted" flavour and taste, and poorer technological properties compared to control WF samples. Therefore, it can be concluded that *Black* BMF should only be used in much smaller quantities (e.g. < 10%) as an effective colouring agent.

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