Quality evaluation of sponge cake with milk thistle (*Silybum marianum* L.) seed powder addition

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Abstract

Introduction. The characteristics of sponge cakes with partially replaced of wheat flour with milk thistle seed powder are presented in this study.

Materials and methods. Milk thistle (*Silybum marianum* L.) seed powder was used to partially replace wheat flour in sponge cake preparation. Baking loss, moisture content, water activity, volume, porosity, texture, crust and crumb colour, sensory analysis, antioxidant activity, and total phenol content were determined in sponge cake with milk thistle seed powder.

Results and discussion. Increasing the level of wheat flour substitution with milk thistle powder from 0 to 20% decreases the volume and porosity of cakes. The addition of milk thistle powder influenced the texture and crumb color of the baked sponge cakes. The hardness and chewiness of baked sponge cakes had an upward trend with increasing milk thistle powder amounts, whereas the cohesiveness, resilience and springiness showed a reverse trend. For the crust and crumb colour the $L*$ and $b*$ values decreased, while the $a*$ value increased, showing that darker, redder and less yellow samples were obtained. The milk thistle addition had a positive effect on the total phenols content by increasing it from 63.93 (control sample) to 121.94 mg gallic acid equivalents, (GAE)/100 g (sample with 20% replacement of wheat flour with milk thistle powder). Simultaneously, the highest antioxidant activity (44.70%) was recorded for the sample with 20% milk thistle seed powder. The sensory analysis pointed out that the sponge cake with the replacement of 5 and 10% wheat flour with milk thistle seed powder was the most acceptable.

Conclusions. The incorporation of milk thistle seed powder in sponge cake formulations enriched its biological value in terms of total phenol content and antioxidant activity. However, some technological quality parameters decreased. The sensorial evaluation showed that to produce sponge cakes with high quality, replacement of wheat flour with milk thistle seed powder should not exceed 10%.

Introduction

Pastry products such as cakes or cookies were initially considered as special treats for certain occasions, but nowadays they are consumed much more frequently, even as regular snacks thus contributing to the increase in sugar consumption (Hashem et al., 2018). Sponge cake, either the American version (chiffon cakes, feather or daffodil sponges, angel food cakes, nut sponge cakes) or the European version (génoise, French biscuit, ladyfingers) is the basis of various pastries and confectionery. The basic ingredients are eggs, sugar and wheat flour, their ratio varying from 50:25:25 to 42:42:15%, depending on the preparation method and other used ingredients such as oil, starch, cocoa, and baking powder (Hui, 2007). The majority of macronutrients in the composition of sponge cake are carbohydrates which are provided by flour and sugar and which, if consumed in excess, are stored in the form of adipose tissue, thus contributing to the appearance of obesity, the development of cardiovascular disease and type 2 diabetes (Stanhope, 2016). Two main topics are addressed when improving sponge cake quality: (1) sustainability by capitalizing on white cabbage outer leaves (Prokopov et al., 2015), aquafaba (Mustafa et al., 2018), and ginseng mark (Park et al., 2008); (2) increasing the biological value by incorporating fibers from carrots (Salehi et al., 2016a) or *Euchema* algae powder (Huang andYang, 2019), high quality proteins from button mushrooms (Salehi, et al., 2016 b), polyphenols from jujube (Najjaa et al., 2020) or olive stone (Jahanbakhshi & Ansari, 2020) powders.

Use of milk thistle (*Silybum marianum* L.) seeds in bakery is in line with main trends in application of novel natural additives for food production (Stabnikova et al., 2021). This novel raw material is still seems to be underestimated in food technology. There are limited data concerning milk thistle seeds chemical composition. According to Apostol et al. (2017) defatted seeds are a good source of protein (20.35%), lipids (11.69%), carbohydrates (38.16%) from which crude fiber (27.24%), and minerals. In the same context, numerous studies have demonstrated the hepatoprotective (Post-White et al., 2007) and anticarcinogenic (Tamayo and Diamond, 2007) effect of the milk thistle seeds. All these properties are due to silymarin, a flavonoid that acts as a protective agent in the human body (Valková et al., 2020).

There are only few studies that present the use of milk thistle seeds in food matrices, this being mostly used for extending the shelf life of the products (Menasra and Fahloul, 2019; Ochrem et al., 2021; Timakova, 2019). Considering this fact, the sponge cake enrichment with milk thistle seeds powder is a valuable and actual topic.

The aim of research was to evaluate the influence of wheat flour replacement with milk thistle seed powder on quality parameters of sponge cakes.

Materials and methods

Materials

In the sponge cake production eggs, sugar and wheat flour (premium quality) were used as main ingredients. Defatted by cold pressing milk thistle seed powder (2020 production year) was used to replace the wheat flour in the sponge cake recipe. More than 80% of milk thistle powder consisted of particles with a size of 40–60 µm, however, it was sifted by the same sieve as wheat flour. The powder was added to the sponge cake composition ~~by~~ to substitute 5, 10, 15 and 20% of wheat flour. The physico-chemical indicators of the used raw materials are shown in Table 1.

Table 1

Physico-chemical indicators of the used raw materials

Ingredients	**Content, %**					**Acidity, degrees**
	Carbohydrates	**Fibers**	**Proteins**	**Fat**	**Moisture**	
Wheat flour (premium quality)	73.1	1.3	10.7	0.9	14.0	1.9
Whole eggs	0.7	-	12.7	11.5	74.0	-
Sugar	99.8	-	-	-	-	-
Milk thistle seed powder	10.8	27.0	21.2	7.0	7.0	3.1

Preparation of sponge cake

The sponge cake was prepared in laboratory conditions using as main raw materials eggs, sugar and wheat flour, and as auxiliary materials salt and milk thistle powder (further as "MT"). The sponge cake formulations are shown in Table 2.

Table 2

Formulations of sponge cake samples

Ingredient, g	Control*	MT5	MT10	MT15	MT20
Wheat flour	100	95	90	85	80
Milk thistle powder	0	5	10	15	20
Egg melange	200	200	200	200	200
Sugar	100	100	100	100	100
Salt	1	1	1	1	1

*Control, MT5, MT10, MT 15 and MT20: sponge cake prepared with 0%, 10%, 15%, and 20% replacement of wheat flour with milk thistle powder, respectively

The experimental sponge cake samples were prepared as described by Gisslen (2008). Firstly, egg melange, sugar and salt were combined and the bowl was set over a water bath and stirred until the mixture reached 43 °C. The warm mixture was then beaten using a KitchenAid (TILT-Head Stand Mixer) until a light and thick foam was obtained. The wheat flour was mixed with milk thistle seed powder, and then the mix was twice sifted. Then, the flour mix was gently folded into the egg foam until it was all blended in. For each sample 50 g of sponge cake batter was immediately panned (the cake pan with 8 cm in diameter and 4 cm in height) and baked at 180 °C for 20 min.

Determination of baking loss

Baking loss were determined by weighing the batter before and after baking according to the formula:

$$BL\% = \frac{m_{batter} - m_{sponge}}{m_{batter}} \cdot 100\%$$

where BL is the bakink loss value, %;

m_{batter} is the mass of the batter, g;

m_{sponge} is the mass of the baked sponge cake.

Determination of moisture content

Moisture contents ~~of~~ in batters and sponge cakes were determined according to AOAC method 925.10 (AOAC, 2002).

Determination of water activity

Water activity was determined according to (Hussain et al., 2021) using the rotronic water activity meter (INSTRUMART, USA).

Determination of porosity

Porosity was determined as described by Rumeus and Turtoi (2013) using the Juravliov device.

Determination of volume of the sponge cake samples

Volume of the sponge cake samples was determined according to (Lu et al., 2010), by the rapeseed displacement method.

Determination of crumb texture

Crumb texture analysis was carried out after cooling the cakes for 8 h. Small pieces (3x3x3 cm) were cut from the middle of each cake and the crust was removed. The texture profile measurements were taken using a TA.HDplusC texture analyzer (Stable Micro Systems, United Kingdom) with a 36 mm diameter cylindrical probe, 50% compressing and a test speed of 1.0 mm s^{-1}.

Determination of colour

Colour evaluation of baked cakes was carried out using a Konica Minolta colorimeter CR-400 (Osaka, Japan). Values of $L*$, $a*$ and $b*$ colour coordinates were measured for each cake sample. To assess the impact of milk thistle addition, colour difference *ΔE* and whiteness index (*WI*) were calculated.

$$\Delta E = \sqrt{\left(L_{sample} - L_0\right)^2 + \left(a_{sample} - a_0\right)^2 + \left(b_{sample} - b_0\right)^2}$$

$$WI = 100 - \sqrt{(100 - L)^2 + a^2 + b^2}$$

where ΔE is the total colour difference;

L is the lightness of the sponge cake;

a is the redness of the sponge cake;

b is the yellowness of the sponge cake.

Determination of total phenol content and antioxidant activity

The total phenol content was assessed using AOAC Folin Ciocalteu assay (Blainski et al., 2013). The antioxidant activity of researched sponge cake samples was evaluated using the 1,1-diphenyl-2-picryl-hydrazyl (DPPH) free radical (Sharma and Bhat, 2009). In both cases, a DR-5000 spectrophotometer (Hach Lange, Manchester, United Kingdom) was used.

Sensory evaluation

In order to perform sensory analysis of sponge cakes twenty panelists (median age of 40 years) employed at the Department of Food and Nutrition, Technical University of Moldova were involved. In order to assess the effect of milk thistle on the sensory quality of sponge cake a 5-point hedonic scale ranging from 0 ("dislike extremely") to 5 ("like extremely") was used. Quality parameters as appearance, colour, taste, texture and flavour were analyzed using ISO 6658:2017.

Statistical analysis

All experiments were performed in triplicates. The results are given as mean±standard deviation (SD). The data were statistically analyzed by XLSTAT software (2020 version) with ANOVA.

Results and discussion

Effect of milk thistle seed powder addition on sponge cake moisture content, baking loss and water activity

During baking, the sponge cake loses its mass, both moisture and dry matter. Moisture loss accounts for 95-96% of the total baking losses by evaporation from the outer layers of the batter. Dry substance loss consists 4-5% of the total losses and consists from the losses of volatile substances present in the batter (Mondal and Datta, 2008). To determine the impact of the milk thistle seed powder addition on the sponge cake baking losses, batter and cake moisture content was determined. The results are presented in Table 3.

Table 3

Effect of milk thistle seed powder addition on sponge cake baking loss and water activity

Sample	Moisture content, %		Baking loss, %	a_w
	Batter	Cake		
Control*	48.19±0.03^a	38.66±0.11^c	9.84±0.06^a	0.780±0.008^b
MT5	48.16±0.02^a	39.01±0.09^b	9.42±0.05^a	0.781±0.007^a
MT10	48.07±0.04^{ab}	39.15±0.12^b	9.01±0.02^b	0.781±0.011^a
MT15	48.04±0.06^b	39.86±0.16^a	8.88±0.06^b	0.780±0.004^b
MT20	47.98±0.03^b	41.62±0.08^a	7.11±0.04^c	0.772±0.008^c

* MT5, MT10, MT 15 and MT20: sponge cake prepared with 0%, 10%, 15%, and 20% replacement of wheat flour with milk thistle powder, respectively

Note: Results are expressed as mean±standard deviation, insignificant ($p > 0.05$), in each column different letters $^{a\text{-}c}$ mean significant differences ($p < 0.001$).

At the batter preparation stage, there were no significant differences ($p < 0.05$) in the moisture content, which varied between 47.98 – 48.19%. However, after baking, the moisture variations of the baked samples were higher 38.66– 41.62%. Thus, the addition of milk thistle seed powder in sponge cake formulations contributed to the decrease of baking loss up to 7.11% for the MT20 sample compared to 9.84% for the control sample. This can be explained by the higher degree of hygroscopicity of the milk thistle seed powder, which is probably due to the high fiber content (27% compared to 1.3% for wheat flour). The same decreasing trends of baking loss were observed when supplementing sponge cake with *Euchema* algae (Huang and Yang, 2019), *Opuntia humifusa* (Kim et al. 2012), coffee silverskin (Ateş et al., 2019).

The water activity of the sponge cake samples did not change significantly ($P < 0.05$), thus it can be mentioned that milk thistle seed powder does not increase the microbiological stability of the sponge cakes. Only in the case of MT20 the a_w reached the 0.772 value compared to 0.780–0.781 for other samples. A higher water activity (0.900–0.907) of sponge cake was mentioned by Lu et al. (2010) when substituting wheat flour with green tea in amounts of 10, 20 and 30%.

Effect of milk thistle seed powder addition on sponge cake volume and porosity

Porosity plays an important role for the pastry products (Ghendov-Mosanu et al., 2020). Besides the fact that it contributes to a more attractive commercial appearance, porosity represents a means of facilitating digestibility, as it increases the surface area of saliva and gastric juice action on product components. From the physical point of view, the sponge cake porosity is defined as the ratio of crumb's air pockets volume and the crumb volume (Baeva et al., 2012). In the present research, a direct relationship was established between sponge cake porosity and volume (Pearson correlation coefficient r=0.98), and an inversely proportional one between the amount of milk thistle seed powder and these two parameters (Figure 1). Thus, the volume of MT20 sponge cake decresed to 59.56 ml compared to 72.78 ml for the control sponge cake, while porosity decreased from 80.12% (control) to 75.34% (MT20).

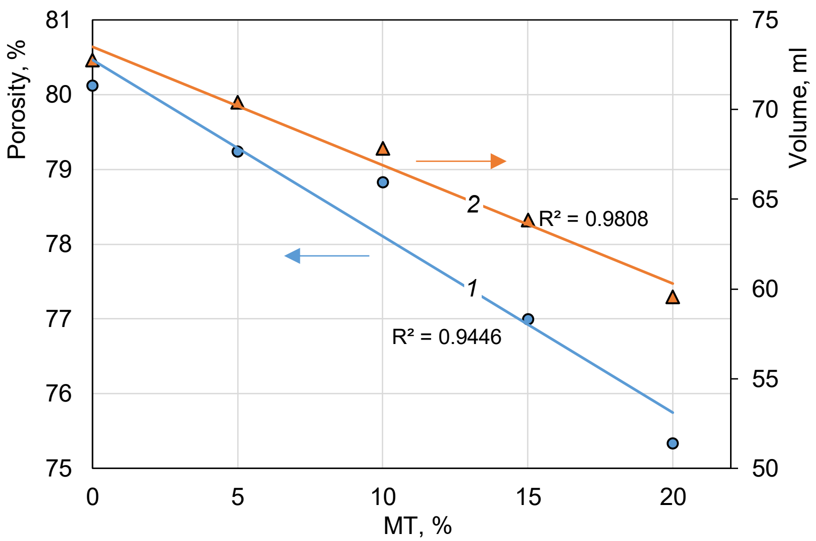

Figure 1. Relationship between the concentration of milk thistle seed powder and porosity (P) and between the concentration of milk thistle seed powder and volume of the enriched sponge cake (V):
1 – Porosity; 2 – Volume

Regression analysis shows that more than 90% decrease of volume or porosity in the enriched sponge cake is caused by milk thistle seed powder addition. Several studies have shown a decrease in the sponge cake volume when enriching formulations with plant materials (Hosseini Ghaboos et al., 2018; Lu et al., 2010; Maravić et al., 2022).

Effect of milk thistle seed powder addition on sponge cake colour

Crust colour

The colour of the crust is one of the first quality indicators that are appreciated by the consumer, and which greatly influences its degree of acceptability. The impact of milk thistle seed powder addition on the colour of sponge cake crust and crumb is shown in Table 4. Significant differences between the values of the chromatic parameters of the control sample and those prepared with the addition of milk thistle seed powder were obtained.

The dark brown colour of the crust is mainly due to the Maillard reaction, and the replacement of wheat flour with milk thistle seed powder in sponge cake formulations seems to accelerate this reaction, thus obtaining a darker crust. This may be caused by the high content of amino acids in milk thistle seed powder, the presence of which may intensify the reaction of melanoid formation (Polovnikova et al., 2022). Similarly, numerous studies have shown an increase of total colour difference (ΔE) of sponge cake crust when substituting wheat flour with other plant materials (Jahanbakhshi and Ansari, 2020; Najjaa et al., 2020; Noor Aziah et al., 2011).

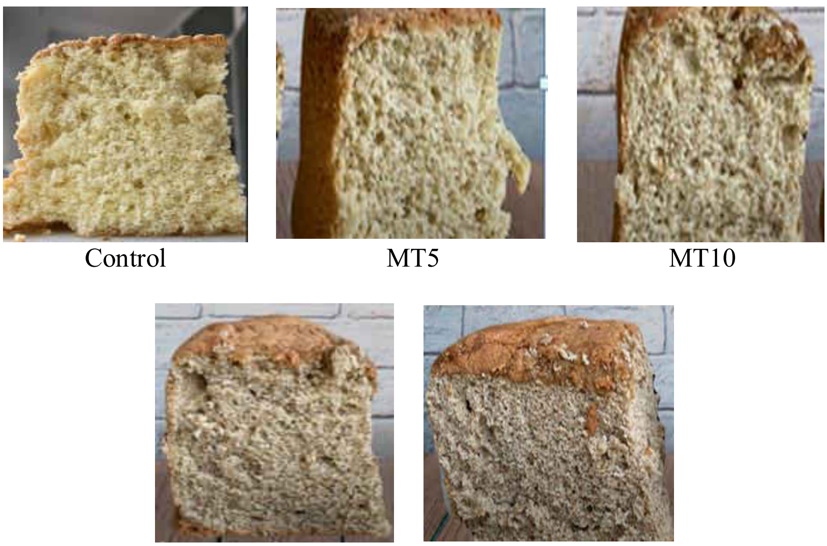

Figure 2. Cross sections views of sponge cakes enriched with milk thistle seed powder

Table 4

Effect of milk thistle seed powder addition on sponge cake colour

	Control	MT5*	MT10	MT15	MT20
Crust colour					
L	69.95±1.25^{d}	58.16±1.25^{c}	46.08±1.25^{b}	44.69±1.25^{b}	37.66±1.25^{a}
a	5.82±0.12^{a}	9.68±0.12^{b}	9.87±0.12^{b}	10.38±0.12^{bc}	13.84±0.12^{c}
b	46.99±1.14^{c}	43.42±1.14^{bc}	41.58±1.14^{b}	40.02±1.14^{b}	36.45±1.14^{a}
ΔE	-	12.00±1.09^{a}	24.81±1.09^{b}	26.60±1.09^{b}	34.78±1.09^{c}
Crumb colour					
L	80.33±1.22^{b}	73.95±1.09^{b}	58.88±1.12^{a}	56.45±0.98^{a}	49.69±0.87^{a}
a	-2.90±0.14^{a}	-2.08±0.08^{ab}	0.30±0.01^{ab}	1.51±0.05^{ab}	2.13±0.10^{b}
b	24.75±0.014^{c}	20.27±0.65^{b}c	17.70±0.11^{b}	14.22±0.16^{ab}	10.49±0.20^{a}
ΔE	-	7.84±0.11^{a}	22,80±0,58^{b}	26,47±0,26^{b}	34.17±0.78^{c}
WI	68,25±1,38 ^{b}	66.93±1.43^{b}	55.23±1.21 ^{ab}	54.16±1.27 ^{ab}	48.56±1.10^{a}

*MT5, MT10, MT 15 and MT20: sponge cake prepared with 0%, 10%, 15%, and 20% replacement of wheat flour with milk thistle powder, respectively

Note: Results are expressed as mean±standard deviation, insignificant ($p > 0.05$), in each line different letters $^{a\text{-}d}$ mean significant differences ($p < 0.001$).

Crumb colour

Significant differences ($p < 0.05$) were observed among the crumb colour parameters of the sponge cakes variants. The values of luminosity ($L*$) and yellowness ($b*$) parameters of the control sponge cake were higher compared with the MT sponge cakes, while the redness ($a*$) showed a increasing tendency with the MT upward trend. This behaviors of $L*$, $a*$ and $b*$ parameters indicate that a darker, redder, and less yellow crumb was obtained because of wheat flour substitution with MT. The decrease of $L*$ and $b*$ values can be explained by the fact that some compounds of MT are water-soluble, respectively assigning a different colour to the batter mass and the baked product. Similarly, Menasra and Fahloul (2019) mentioned that biscuit became darker with milk thistle powder addition. The ability of milk thistle powder to change the chromatic values of pastry products was also demonstrated by Bortlíková et al. (2019) on its application in functional biscuits formulation. The effect of different ingredients on sponge cake colour was also reported by Lu et al. (2010), who found that green tea powder addition led to an increase in sponge cake lightness and yellowness, and on contrary, to a decrease of $a*$ values. It was shown that addition of black garlic powder, Jujube (*Zizyphus lotus* L.), and olive stone powder to sponge cake can lead to a decrease in $L*$ and $b*$ values but an upward in $a*$ values (Jahanbakhshi and Ansari, 2020; J.-S. Lee et al., 2009; Najjaa et al., 2020).

During the research, an inversely proportional relationship was established between the total colour difference *ΔE* and the whiteness index *WI*. With the increase in the MT level in the sponge cake formulation, *ΔE* showed a major upward to 34.17 in the case of the MT20 sample, while *WI* diminished from the value of 68.25 for the control sample to 48.56 for the MT20.

According to Maji & Dingliana, (2018) the just noticeable difference (JND) of colour between two objects (ΔE^*_{00}) equals to 1. Taking into account that the lowest value for *ΔE* was obtained for the MT5 sponge cake (ΔE = 7,84), it can be concluded that all prepared sponge cake variants could be verifiably distinguished according to colour by eyes only.

Effect of milk thistle seed powder addition on sponge cake texture parameters

Sponge cakes are characterized as having a light, airy texture. In this research the texture of sponge cake samples was analysed in terms of hardness, springiness, resilience, cohesiveness and chewiness (Table 5).

Table 5

Effect of milk thistle seed powder on sponge cake texture parameters

	Control	MT5	MT10	MT15	MT20
Hardness, g	115.24±4.21[a]	131.88±5.18[ab]	134.87±6.01[b]	158.96±4.34[c]	177.96±5.26[c]
Springiness, mm	0.99±0.02[a]	0.96±0.04[a]	0.96±0.02[a]	0.90±0.02[b]	0.84±0.01[b]
Chewiness, g·mm	66.57±3.12[a]	72.27±4.08[ab]	75.15±4.34[b]	85.74±6.53[bc]	96.99±4.22[c]
Resilience	0.35±0.01[a]	0.33±0.02[a]	0.29±0.02[ab]	0.27±0.01[b]	0.28±0.01[ab]
Cohesiveness	0.58±0.02[b]	0.55±0.01[a]	0.56±0.01[b]	0.54±0.03[a]	0.55±0.01[a]

Control, MT5, MT10, MT 15 and MT20: prepared with 0, 10, 15 and 20% replacement of wheat flour with milk thistle powder, respectively

Note: Results are expressed as mean±standard deviation, insignificant ($p > 0.05$), in each line different letters [a-c] mean significant differences ($p < 0.001$).

Hardness is used to describe the force exerted on the surface of the product when it is deformed under the action of the teeth in the mouth. The softer the product is, the lower hardness it has (Lu et al., 2010). The obtained data show that with the increase in the MT level, the hardness of the sponge also increases from the initial values of 115.24 to 177.96 g. This is probably caused by the fact that the milk thistle fibers absorbed and bounded the water that during baking should have participated in the formation of gluten from the wheat flour. Gluten, in turn, is able to keep CO_2 and air bubbles trapped in the batter structure that during baking increase their volume, thus increasing the porosity and volume of the baked sponge cake (Rodríguez-García et al., 2014). A similar tendency was also noted for the chewiness, which increased with increasing amounts of MT. Springiness and resilience, as they have some similarities, showed a descending trend with the increase of MT concentration. Sponge cake variants had the lowest springiness and resilience of 0.84 mm and 0.28 respectively, when the wheat flour was substituted with MT in a 20% proportion. Likewise, the cohesiveness of the sponge cakes decreased with the increase in the proportion of the MT. Sponge cakes had the lowest cohesiveness values of 0.55 when the proportion of the MT was 20%. However, differences in samples' cohesiveness were not statistically significant ($p> 0.05$). Thus, for the use of the MT sponge cakes as layers for cakes, the revision of the formulation is required, especially regarding the amount of liquid for impregnation in order to obtain a cake with a low hardness and chewiness. Earlier, Lu et al. (2010) have reported the hardness and chewiness to increase, and the springiness and resilience to decrease with the addition of green tea powder (Lu et al., 2010). Contrastingly, Wang et al. (2020) obtained a gradual decline of hardness with the increase of Japonica rice flour proportion in sponge cake formulation, while resilience and springiness increased (Wang et al., 2020).

Total phenol content and antioxidant activity

The aim of MT addition is actually to enhance the biological value of sponge cake, which is especially conferred by the antioxidants present in MT (Vaknin et al., 2008). According to Yaldiz (2017), milk thistle seeds are rich in tannins and flavonolignans that exhibit a high antioxidant activity (Yaldiz, 2017). In this context, the total polyphenols content and the antioxidant activity of sponge cake variants were determined (Table 6).

Table 6

Total phenol content and antioxidant activity of sponge cakes

Sample	Total Polyphenol Content, mg GAE/100 g	Antioxidant Activity, %
Control	63.93±1.23[a]	7.86±0.34[a]
MT5	75.88±1.56[ab]	14.62±0.27[ab]
MT10	80.76±2.13[b]	19.37±0.76[b]
MT15	90.05±1.97[b]	23.84±0.47[c]
MT20	121.24±3.21[c]	44.70±0.64[d]

Control, MT5, MT10, MT 15 and MT20: prepared with 0%, 10%, 15%, and 20% replacement of wheat flour with milk thistle powder, respectively

Note: Results are expressed as mean±standard deviation, insignificant ($p > 0.05$), in each column different letters [a-d] mean significant differences ($p < 0.001$).

The data show that the MT sponge cake have significantly ($P > 0.05$) higher amount of polyphenols (75.88–121.24 mg GAE/100 g) than the control variant (63.93 mg GAE/100 g). This can be explained by the high content of polyphenols in MT (4.38 mg/g) in comparison with wheat flour (0.33 mg GAE/g). Javeed et al. (2022) reported that milk thisle seed have a polyphenol content of 1.70 mg GAE/g (Javeed et al., 2022). An increase in the antioxidant activity was observed with the increase of MT concentration in sponge cake formulation. The results are in accordance with those mentioned by Nowak et al. (2021) who studied the influence of solvent on the total phenols content and antioxidant activity of different milk thistle parts. In the study was shown that 70% ethanol is the best solvent in order to obtain the highest values for the studied indicators (Nowak et al., 2021). In our study, the same solvent was used.

Sponge cake sensory scores

The sensory attributes of sponge cake in terms of appearance, crust and crumb colour, crumb texture, taste and flavor were evaluated after 12 hours from preparation. The results of the sensory analysis of sponge cake variants with different MT concentrations are shown in the Table 7.

As noticed, wheat flour substitution by MT in sponge cake formulation did not significantly ($P < 0.05$) influence the crust colour, the lowest liking score being registered for MT20 (4.50). Regarding the crumb colour, the evaluation score manifested a decline as the MT level increased. A similar tendency was noticed for the texture of sponge cake. The taste and flavor of sponge cake counterparts had a significantly lower ($P > 0.05$) acceptability score in the case of MT20. According to the results of the organoleptic analysis, it can be concluded that among the most successful samples were those with a concentration of 5% and 10% MT, because MT faded the specific smell of egg and the overly sweet taste of sponge cake. In the end, they were appreciated as the most balanced samples. MT15 and MT20 were scored with a lower overall acceptability for the following reasons:

(1) The samples do not have pleasant crumb colour;

(2) The samples with 15% and 20% MT have too dominant taste, as well as the aroma of MT is too dominant";

(3) In the sample with 20% MT some sandy powder particles are felt.

The control sponge cake reached the highest overall acceptability score (4.94), while the MT20 sponge cake had the lowest value (4.16).

Table 7

Sponge cake sensory evaluation

	Taste and flavour	Crust colour	Crumb colour	Appearance	Texture	Overall acceptability
Control	4.82 ± 0.04^{b}	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	4.90 ± 0.01^{ab}	4.94 ± 0.04^{ab}
MT5	4.84 ± 0.03^{a}	4.82 ± 0.02^{a}	4.85 ± 0.04^{a}	4.76 ± 0.02^{b}	4.84 ± 0.05^{a}	4.82 ± 0.02^{a}
MT10	4.64 ± 0.04^{b}	4.71 ± 0.03^{a}	4.70 ± 0.05^{a}	$4.58 \pm 0.05b^{a}$	4.62 ± 0.03^{b}	4.65 ± 0.05^{b}
MT15	4.43 ± 0.02^{b}	4.62 ± 0.06^{a}	4.42 ± 0.05^{b}	4.50 ± 0.03^{ab}	4.45 ± 0.02^{b}	4.48 ± 0.06^{ab}
MT20	4.13 ± 0.04^{c}	4.50 ± 0.05^{a}	3.82 ± 0.04^{d}	4.26 ± 0.01^{b}	4.10 ± 0.05^{c}	4.16 ± 0.02^{c}

Control, MT5, MT10, MT 15 and MT20: prepared with 0%, 10%, 15%, and 20% replacement of wheat flour with milk thistle powder, respectively

Note: Results are expressed as mean±standard deviation, insignificant ($p > 0.05$), in each column different letters $^{a\text{-}d}$ mean significant differences ($p < 0.001$).

Conclusions

1. The replacement of wheat flour with milk thistle powder in sponge cake formulation reduced the baking losses, and enhanced moisture content.
2. The volume and porosity of sponge cakes decreased significantly with the increasing milk thistle powder amounts. The volume decreased from 72.78 ml for the control sponge cake to 59.56 ml when wheat flour was replaced by 20% milk thistle powder. Porosity decreased from 80.12% (control) to 75.34% for the sponge cake with 20 milk thistle powder.
3. The colour of sponge cake crumbs with milk thistle seed powder became darker, less yellow (L* and b* values decreased) and redder (a* values increased). Simultaneously, the whiteness index of sponge cake crumb showed a downward trend with the increase of milk thistle seeds powder addition.
4. The hardness and chewiness of sponge cakes increased with the increasing milk thistle seed powder amount, being in the range of 115.24–177.96 g and 66.57–96.9 g·mm, respectively. A reverse trend was exhibited by springiness, resilience and cohesiveness of sponge cakes.
5. The addition of milk thistle seed powder to the sponge cake formulation led to increase in the polyphenol content and antioxidant activity of cakes.
6. The results of sensory analysis pointed out that a partial replacement of 5 and 10% wheat flour with milk thistle seed powder was the most acceptable.

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