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Effect of soapwort extract on physical and sensory properties of sponge cakes and rheological properties of sponge cake batters

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Abstract

Soapwort extract yields relatively stable, soap-like foam in aqueous solution because of its saponin content. The objective of this study was to utilise the advantage of the high foam forming capacity of soapwort extract in the production of sponge cakes. Egg white proteins were partially replaced with soapwort extract in the sponge cake formulation. The effects of soapwort extract addition on the rheological and physical properties of cake batters and on the physical and sensory properties of sponge cakes were determined. Replacing egg white proteins with soapwort extract, up to 75% by weight, did not have any significant influence on the specific gravity of batters ($p > 0.05$). Addition of soapwort extract into the cake mixture did not influence the flow behaviour indices (n) of cake batters nor the consistency indices (K) of cake batters. In general, replacing egg white proteins with soapwort extracts (up to 75% by weight) did not alter physical properties of sponge cakes. Replacing egg white proteins with soapwort extract had no unfavourable influence on the sensory properties of sponge cakes. Indeed, sponge cakes formulated with soapwort extract (by replacing egg white proteins by 50% and 75% on weight basis) received significantly higher chewiness scores than did control cakes ($p < 0.05$). This study showed that egg white proteins could be partially replaced with soapwort extract in the formulation of sponge cakes.

Keywords: Egg white proteins; Saponin; Soapwort; Sponge cake

1. Introduction

Soapwort (*Gypsophila arrostii*) belongs to the genus *Gypsophila*, and grows naturally in south Russia and Asia Minor. The roots of several *Gypsophila* species, including European species, for example *G. paniculata*, *G. arrostii*, *G. fastigiata*, and *G. perfoliata* contain saponin and are known in the trade as *Saponariae albae radix* or White Soapwort Root (Hänsel, Keller, Rimpler, & Schneider, 1998). *G. eriocalyx*, *G. arrostii* var. *Nebulosa* and *G. perfoliata* var. *Anatolica* are endemic to *Anatolia* (Özhatay, Koyuncu, Atay, & Byfield, 1998). Saponins are glycosides of soapwort, which have surfactant properties and a polycyclic aglycone called sapogenin. One distinctive property of saponins is that they yield relatively stable, soap-like foam in aqueous solution.

Saponins are reported to reduce the palatability of livestock feeds because of their bitter taste; however, sugar is replaced with glucuronic acid in triterpenoid aglycone forms of saponins, making saponins taste like licorice. Saponins from the roots of *G. paniculata* and *G. arrostii* have been used as detergents and expectorant (Hostettmann & Marston, 1995). Traditionally, the roots of soapwort have not only been used for the preparation of remedies against coughs and ailments of the upper respiratory system, but also for the production of a variety of other products such as cleaning chemicals, film emulsion, in confectionery as a stabilizer of froth and as an ingredient in fire extinguishers. In Turkey, soapwort extract has been used to whiten halva, to prevent the separation of sesame oil from halva, to improve the textural properties of halva, and to increase the volume of halva (Turkish Food Codex, 2004).

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Commercial applications of soapwort saponins include 'drugs and medicines, precursors for hormone synthesis, adjuvants, foaming agents, sweeteners, taste modifiers and cosmetics' and natural antimicrobial agent againsts pathogens (Osbourn, 2003).

Egg white proteins play a significant role in foam formation in cakes. Large volumes of air are easily dispersed into the batter before baking. Heating egg foam expands the air bubbles trapped in cake batter, and the volume of cake increases immediately after the coagulation of egg proteins during baking. For foam-type cakes, the whipping properties of eggs usually determine the final volume, cell structure and tenderness of the products (Pyler, 1979). The better the whipping properties of eggs, the higher are the acceptabilities of cake appearance and texture (Arunepanlop, Morr, Karleskind, & Laye, 1996). Replacing egg white proteins with dairy or plant proteins in cake production influences the textural and physical properties of cakes (Arunepanlop et al., 1996; Lawson, 1994; Zhu & Damodaran, 1994).

In this study, we took advantage of the high foam-forming capacity of soapwort extract, and replaced egg white proteins partially with soapwort extract in the production of sponge cakes. In order to determine the effect of soapwort extract addition on the rheological and physical properties of cake batters, we also added water cake mixtures and determined similar properties of cakes batters. Using a sensory panel, we determined consumer liking for different sensory attributes of sponge cakes with soapwort extract.

2. Materials and methods

2.1. Materials

The roots of soapwort (*G. arrostii* var. *nebulosa*), all-purpose flour, sugar, fresh eggs, and baking powder were purchased from local markets in Denizli, Turkey. Water, purified by reverse osmosis, was used throughout the research.

2.2. Methods

2.2.1. Preparation of soapwort extracts

The roots of soapwort were manually broken into very small pieces with a hammer, and passed through a 2.5 mm sieve (AS 200 Basic model, Retsch, Haan, Germany). Soapwort root powder was mixed with pure water at a ratio of 1:10 (w/v) and extracted in a glass extractor for 6 h. Then, this mixture was cooled to room temperature, and it was passed through a filter paper (Selecta ∅125 mm Nr.589[5]). Final volume of the clarified extract was adjusted with water to a final concentration of 80 g/l. Appropriate amounts of this clarified extract were used in the sponge cake formulations.

2.2.2. Production of sponge cakes

Formulations presented in Table 1 were used to produce sponge cakes. Briefly, egg white, egg yolk and sugar were whipped to a cream in a kitchen aid robot with a mixer function (Prokit 444, Arzum Household Supplies, Istanbul, Turkey) at a maximum speed for 4 min. Then, flour and baking powder were added into the mixture, and it was whipped at medium speed for one minute. Finally, equal amounts of this batter (35 g) were poured into nonstick 6-cup muffin pans (ECHO), and baked at 170 °C for 35 min in an oven (Bosch HBT112 AEU). Sponge cakes were allowed to cool at room temperature. They were carefully taken out of the muffin pans and placed in plastic zipper bags, and the bags were stored in a dry and cool environment prior to analyses.

Table 1
Sponge cake formulation with water or soapwort extract

Cake sample *	Ingredient (% by weight)[A]		
	Egg white proteins	Soapwort extract	Water
Control	24.8	–	–
SE25	18.6	6.2	–
SE50	12.4	12.4	–
SE75	6.2	18.6	–
W25	18.6	–	6.2
W50	12.4	–	12.4
W75	6.2	–	18.6

[A] All samples contained 31.7% sugar, 31.7% flour, 11.3% egg yolk, and 0.5% baking powder by weight.
* In samples except control, egg white proteins were partially replaced with water or soapwort extract. For example, for SE25, 25% of egg white proteins in the control sample was replaced with soapwort extract.

Six different formulations, shown in Table 1, were used for the production of sponge cakes. To produce sponge cakes with soapwort extract, 25% (SE25), 50% (SE50) or 75% (SE75) of egg white proteins (by weight) were replaced with soapwort extract. In order to differentiate the effect of soapwort extract on the rheological properties of cake batters from the effect of water, 25% (W25), 50% (W50) or 75% (W75) of egg whites was replaced with water.

2.2.3. Analytical measurements

Specific gravity of cake batters was determined by the method of Lee and Hoseney (1982). Colour values (*L*, *a*, *b*) of cake batters and baked cakes were determined by Hunter Lab Mini Scan XE colorimeter (Reston, VA, USA). pH values of cake batters were monitored with a pH meter. Saponin content of soapwort extracts was determined gravimetrically, using the method of Lalitha, Seshadri, and Venkataraman (1987), modified by Battal (2002). Briefly, 75 ml of ether was added to the clarified soapwort extract (100 ml), and ether phase was discharged. Residual material was washed with 60 ml of butanol, and this was repeated five times. Butanol phases were collected in a flask. Then, butanol was evaporated with a rotary evaporator under vacuum at 40 °C until about 2 ml of extract were left in the flask. Twenty five millilitres of ether were added to the residual extract. Then, the ether phase was separated from methanol phase after centrifugation of the extract. Finally, the extract was completely dried in a desiccator prior to weighing the residue.

2.2.4. Rheological properties of sponge cake batters

Consistency coefficients and flow behaviour indices of sponge cake batters were determined by a viscometer (Brookfield Programmable DV-II+ Viscometer, Brookfield Eng. Labs. Inc., Stoughton, MA, USA). Briefly, batters were poured into a 600 ml beaker, and the aforementioned properties of cake batters were determined at room temperature with a spindle number 6. In order to determine the flow behaviour characteristics of sponge cake batters, the power-law model $\delta = K(\dot{\gamma})^n$, where δ is the shear stress (Pa), $\dot{\gamma}$ is the shear rate (s^{-1}), K is the consistency coefficient ($Pa.s^n$) and n is the flow behavior index (dimensionless), was used (Steffe, 1996).

2.2.5. Physical properties of sponge cakes

Specific volume of sponge cakes was determined by the ratio of cake volume to cake weight. The colour of cake crumbs and crusts (L, a, b) were determined by the Hunter Lab Mini Scan XE colorimeter. To determine the textural properties of cakes, volume, symmetry and uniformity indices and shrinkage values were determined by the method of AACC (Anonymous, 1972). This method takes the size of pans used for the cake production into account, and determines these values in terms of millimetre. Moisture contents of cakes were determined with a benchtop model drier at 100 °C (SMO 01, Scaltec Instruments, Heiligenstadt, Germany). Softness or hardness of cakes was determined by a penetrometer (ELE, Sweden) after 0, 24, 48 and 72 h of storage.

2.2.6. Sensory evaluation of sponge cakes

A panel of 36 subjects in the Department of Food Engineering (Pamukkale University, Denizli, Turkey) evaluated the sensory properties of cakes, and gave scores for colour, crumb cell structure, flavour, smell, chewiness, and sweetness on a hedonic scale from 1 (dislike extremely) to 7 (like extremely). The panel consisted of students, staff and faculty members (22 males, 14 females), and 36% of the subjects were between 18 and 25, 56% between 26 and 40 years old, and 8% older than 40 years. The samples were labelled randomly with three-digit numerical codes. During the panel session, subjects were instructed to rinse their mouths with water, and eat unsalted crackers before tasting each sample. Partitioned booths, equipped with daylight, were used for the panel.

2.2.7. Statistical analyses

Data were analyzed using the Statistical Analysis System software (SAS Institute, 1990). PROC GLM, with Duncan's multiple comparison test, was performed to determine significant differences at $\alpha = 0.05$.

3. Results and discussion

3.1. Sponge cake batters

Analytical measurement results of cake batters are given in Table 2. Specific gravity is usually determined by the ratio of cake batter weight to the weight of distilled water at the same temperature. Specific gravity indicates the ability of proteins to incorporate air into the batters, and it is related to the air cell size distribution in baked cakes (Arunepanlop et al., 1996). Replacing egg white proteins with soapwort extract up to 75% by weight (SE75), did not have any significant influence on the specific gravity of batters ($p > 0.05$). Air bubbles incorporated into the cake batters increased the volume of batter. This, in turn, decreased the weight of cake batters used for the determination of specific gravity.

Egg white proteins are essential in cakes for foam formation since they improve the dispersion of large volumes of air into the batter before baking. During baking, egg foam expands the air bubbles trapped in cake batter, and coagulation of egg proteins stabilizes the volume of cakes. Whipping of egg whites incorporates air bubbles into the batters. In our study, when egg whites were replaced with water in cake formulations, however, air bubbles could hardly get incorporated into the batters. Therefore, replacing egg white proteins with water yielded higher specific gravities for cake batters. When one quarter of the egg white proteins in control formulation were replaced with water (W25), specific gravity of cake batters increased slightly. However, replacing half of egg white proteins with water (W50) increased batter specific gravity significantly ($p < 0.05$). The reduction the volume of cakes can be observed as a result of the increased specific gravity.

Differences among the pH and colour values of cake batters with different formulations were insignificant ($p > 0.05$). Even though differences among Hunter L, a and b values for cake batters were statistically insignificant, we observed that cake batters prepared with distilled water

Table 2
Physical and rheological properties of sponge cake batters ($n = 3$)

Batter sample[A]	Specific gravity	pH	Hunter lab values			Consistency index (K, Pa. s^n)	Flow behaviour index (n)
			L	a	b		
Control	0.71^{c}	7.14	70.7	0.6	15.3	148.97^{a}	0.6526^{b}
SE25	0.74^{bc}	7.18	70.2	0.8	15.7	132.50^{ab}	0.6905^{ab}
SE50	0.75^{bc}	7.27	70.1	1.0	16.1	129.87^{ab}	0.6659^{b}
SE75	0.77^{abc}	7.25	69.7	1.1	16.0	112.23^{abc}	0.6684^{b}
W25	0.81^{abc}	7.18	69.2	1.3	16.7	104.67^{bc}	0.7147^{ab}
W50	0.88^{a}	7.22	68.2	1.5	17.4	89.33^{c}	0.7559^{a}
W75	0.85^{ab}	7.26	68.1	1.6	17.4	79.33^{c}	0.7185^{ab}

[A] Superscripts with different letters across the table show significant differences at $\alpha = 0.05$.

were darker in colour than the others. This may be due to the whitening properties of soapwort extract (Turkish Food Codex, 2004) in cake batters SE25, SE50 and SE75.

In term of rheological properties, all cake batters displayed a non-Newtonian flow behaviour ($0 < n < 1$ for shear thinning or pseudoplastic fluids) (Table 2). Addition of water to the cake mixture (W50) increased flow behaviour indices (n) of cake batters significantly ($p < 0.05$) whereas the effect of soapwort extract on n was insignificant ($p > 0.05$) in comparison to the n of control cake batter. The effect of replacing egg white proteins in control samples with soapwort extract on the consistency indices (K) of cake batters was statistically insignificant ($p > 0.05$). However, replacing egg white proteins with water reduced the consistency indices of cake batters significantly ($p < 0.05$). We observed that water addition made the cake batters thinner than control batters. Incorporation of air into the batters with water was hard to achieve. On the other hand, we did not observe this phenomenon in cake batters with soapwort extract. The reason may be the fact that saponins contain polar (water-soluble side chains) and nonpolar (sapogenin) molecules in their chemical structures, considering the ability to form foam. Saponin content of soapwort roots ($n = 3$) was 21 ± 8 ppm. In terms of the rheological properties of batters, egg white proteins in sponge cakes can be replaced with soapwort extract without altering consistency and flow behaviour indices of cake batter.

3.2. Sponge cakes

In terms of physical properties of sponge cakes, specific volume, crumb colour, crust colour, volume index, symmetry index, uniformity index and shrinkage value for each cake sample are shown in Table 3. Moisture contents of sponge cakes varied from 26.0% to 29.8%, and the differences among moisture contents were statistically insignificant ($p > 0.05$). In general, specific volumes of cakes with water were higher than those with soapwort extract. Although replacing egg white proteins with water reduced the specific volumes of sponge cakes, this reduction was also statistically insignificant ($p > 0.05$). The effect of replacing egg white proteins with soapwort extract in formulations on colour values of sponge cakes was statistically insignificant ($p > 0.05$).

The differences in the symmetry and uniformity indices and shrinkage values for all sponge cakes were less apparent; however, replacing egg white proteins with water generally reduced the volume indices of control sponge cakes (Table 3). Even though the volume indices for sponge cakes with soapwort extract were not different from those for control cakes, replacement of egg white proteins with water (especially 50%) reduced the volume indices of cakes.

Sponge cake is a foam-type cake because air bubbles are incorporated into batters prior to baking and foam is stabilized upon coagulation of foaming agent during baking. Dispersion of air bubbles in cake batters is usually generated by whipping egg white proteins in the formulations. Whipping properties of eggs usually play an important role for final products (Pyler, 1979). Replacing egg white proteins with dairy proteins influences the textural and physical properties of cakes (Lawson, 1994; Zhu & Damodaran, 1994). Studying the effect of partial replacement of egg white proteins with whey protein isolate on physical and sensory properties of angel food cakes, Arunepanlop et al. (1996) showed that full replacement of egg white proteins with whey protein isolates yielded cakes with undesired characteristics. Therefore, they partially replaced egg white proteins with whey protein isolate and used food additives such as xanthan gum, hydroxylmethyl cellulose and cupric sulfate to improve appearance, texture and sensory properties of angel cakes. Although we prepared sponge cakes in our study, we also observed that full replacement of egg white proteins with either water or soapwort extract resulted in cakes with inferior physical properties. In summary, egg white proteins in sponge cake formulations can be partially replaced with soapwort extracts without effecting physical properties of sponge cakes baked in conventional ovens.

3.3. Sensory evaluation of sponge cakes

The sensory results of sponge cakes showed that the effect of gender or its interaction with the amount of soapwort extract replacement on the sensory attributes of sponge cakes listed in Table 4 was insignificant ($p > 0.05$).

Table 3
Physical properties of sponge cakes ($n = 3$)

Cake sample[A]	Specific volume	Crumb colour			Crust colour			Volume index	Symmetry index[B]	Uniformity index	Shrinkage value
		L	a	b	L	a	b				
Control	4.31	67.3	1.6	21.3	50.3	11.7	20.8	106.0^{a}	−1.0	1.0	0.3
SE25	4.04	68.6	1.7	21.4	48.9	11.6	20.1	104.3^{ab}	−0.3	1.7	1.7
SE50	3.96	68.3	1.7	21.0	50.5	11.7	21.0	101.0^{ab}	2.0	1.3	1.0
SE75	3.93	67.9	2.0	21.4	52.2	10.9	21.3	92.7^{ab}	0.3	0.3	1.3
W25	3.35	68.5	1.6	21.4	50.8	10.8	20.1	105.0^{ab}	−2.0	2.0	0.0
W50	3.37	67.5	2.1	21.5	51.7	11.1	21.1	92.3^{b}	7.7	1.0	1.3
W75	3.41	67.0	2.2	21.4	50.7	11.6	21.1	94.0^{ab}	7.0	1.7	1.0

[A] Superscripts with different letters across the table show significant differences at $\alpha = 0.05$.
[B] Statistical analyses for symmetry and uniformity indices and shrinkage values were not run.

Table 4
Results of the sensory evaluation[A] and softness values for sponge cakes

Cake sample[B]	Cake colour	Crumb cell structure	Flavour	Smell	Chewiness	Sweetness	Overall	Penetrometer value (×0.1 mm)
Control	4.94	4.83	4.83	4.28	3.81[b]	5.03	4.56	25.0[b]
SE25	5.11	4.75	4.94	4.33	4.58[ab]	5.08	4.94	29.2[ab]
SE50	5.03	4.97	4.94	4.44	4.86[a]	5.19	5.00	31.6[ab]
SE75	5.06	4.81	5.00	4.22	5.33[a]	5.25	4.97	38.7[a]

[A] Scale of 1 (dislike extremely) to 7 (like extremely).
[B] Superscripts with different letters across the table show significant differences at $\alpha = 0.05$.

Table 5
The effect of storage time on softness of sponge cakes

Storage time (h)	Penetrometer value (×0.1 mm)
0	51.7[a]
24	27.1[b]
48	19.6[c]
72	18.7[c]

Superscripts with different letters across the table show significant differences at $\alpha = 0.05$.

Subjects liked the colour, crumb cell structure, flavour, smell and sweetness of all sponge cakes equally ($p > 0.05$) (Table 4). Vanilla, a typical ingredient in foam-type of cakes, is usually used to mask the smell of eggs in final products. In our study, subjects participating in the panel agreed that egg smell was strong in all cakes. One of the objectives in the sensory evaluation of sponge cakes was to find whether soapwort extract played any significant role in the smell of sponge cakes; therefore, the smell of sponge cakes were not masked with any food additive, such as vanilla. Overall, subjects liked all the cakes equally. On the other hand, based on the sensory scores, we found statistically significant differences only in the chewiness scores among the sponge cakes ($p < 0.05$) (Table 4). Sponge cakes prepared by replacing egg white proteins with soapwort extract (by 50% and 75% on weight basis, SE50 and SE75, respectively) received significantly higher chewiness scores than did control cakes ($p < 0.05$). Therefore, we can conclude that soapwort extract can be added to the formulation of sponge cakes for the purpose of improved chewiness of cakes.

Softness values of sponge cakes used in the sensory evaluation study are also shown in Table 4. Results similar to the chewiness values of sponge cakes were also observed in the textural analyses of cakes with a penetrometer. Replacing 75% of egg white proteins with soapwort extract (SE75) in the cake formulation made cakes softer than the control sample ($p < 0.05$). Penetrometer values decreased as cakes were stored at room temperature for 48 h ($p < 0.05$) (Table 5). Storage time longer than 48 h were unable to reduce softness.

4. Conclusion

This study showed that egg white proteins in the formulation of sponge cakes could be partially replaced with soapwort extract. Replacing egg white proteins with soapwort extract does not have any unfavourable influence on the rheological and physical properties of cake batters on the physical and sensory properties of sponge cakes. Moreover, results of the sensory panel showed that replacement of egg white proteins with soapwort extract in sponge cake formulations (up to 75%) improves chewiness of the baked cakes without altering sensory properties of cakes such as crumb cell structure, flavour, smell and sweetness. This improvement is most likely to develop from the saponin content of soapwort extract because saponins are known as foaming agents. In conclusion, it is possible to take advantage of the foam-forming ability of saponin-containing soapwort extract to improve rheological, physical and sensory properties of foods such as sponge cake.

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