

Evaluation of the Stability of Whipped Egg White

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Abstract

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An investigation was made into the effects of various egg white products and sweeteners on the stability and organoleptic properties of egg white foams. 12 foam products were prepared from egg white and sweeteners. The egg white was produced in the following forms: raw liquid egg white, pasteurised liquid egg white, liquid egg white treated at 55°C for 24 h, and spray-dried egg white powder. Three different sweeteners were used: sucrose, fructose-glucose syrup, and fructo-oligosaccharide syrup. The storage stability, firmness, adhesiveness based on the texture profile analysis, and organoleptic properties of the foams were evaluated. The flow curves of raw materials were also determined by means of a rotational viscometer. The results indicated that sucrose among the sweeteners and egg white powder among the egg white products are the most suitable for producing egg white foam and enhancing its stability. However, liquid egg white heat treated at low temperature also proved to be an appropriate choice for making stable egg white foams for the confectionery industry.

Keywords: egg white foam; heat treatment; foam stability; texture, rheology

Abbreviations

RL – raw liquid egg white (homogenised liquid egg white); EP – egg white powder (spray-dried liquid egg white); LT – liquid egg white treated at lower temperature (homogenised liquid egg white maintained at 55°C for 24 h); PL – pasteurised liquid egg (homogenised liquid egg white treated at 66°C for 4–5 min); S – sucrose; F – fructo-oligosaccharide syrup; I – Isosweet 111 (42% fructose-58% glucose syrup)

Confectionery products made of egg white foam and sugar (e.g. meringue and angel food cake) are popular due to their specific texture properties and good appearance. In some countries, including Hungary and Germany, there exists a special product called “Négercsók”, which is made in egg white to sugar ratio 1:5 and is covered with a thin layer of chocolate and served on wafer. The microbiological stability of the raw materials is primarily important because they are processed without heat treatment. These products have a short shelf

life, and another consideration is recent changes in peoples' dietary habits. Consumers prefer food products without artificial additives (i.e. preservatives, artificial sweeteners, etc.).

Nowadays, food manufacturers (e.g. cookie factories and confectioneries) prefer ready-to-use liquid egg products to whole eggs. These products are more favourable because the user does not have to deal with breakage or storage of egg shells infected with faeces (YADAV & VADEHRA 1977). Using an appropriate heat treatment such as pas-

teurisation (5–10 min at 58–60°C) reduces viable bacterial count (PALUMBO *et al.* 1996; SCHUMAN & SHELDON 1997; FRONING *et al.* 2002). Spray-drying is suitable for drying liquid eggs to obtain egg powder with 5% moisture content in which micro-organisms are not able to grow – or even a reduction of bacterium count can be achieved with certain bacteria, however, changes in functional properties have been observed (LECHEVALIER *et al.* 2007). A recent alternative is a protracted treatment of liquid eggs (at least 1 h) at 53–55°C. At this temperature (i.e. below 57°C), conalbumin does not coagulate and the temperature is below that generally used in the conventional pasteurisation procedure (NÉMETH *et al.* 2010a). According to our previous research, this method results in a product with excellent microbial stability and viscosity similar to pasteurised liquid egg white (NÉMETH *et al.* 2010b).

Egg white has good foaming properties due to the fact that all of its protein components have different roles in foaming (ALLEONI 2006). Ovalbumin (SMITH & BACK 1965; DU *et al.* 2002), glucoproteins such as ovomucin (YANG & BALDWIN 1995; OMANA *et al.* 2010), and globulins (MACDONNELL 1955) play different roles in foam stabilisation. Changes in functional properties of these egg proteins may result in detrimental changes in organoleptic or functional properties of egg white products. This explains why an appropriate preservation technology is needed.

Sucrose is known to have a positive effect on the foaming properties of this complex system (KINSELLA 1981; DAMODARAN 2005; LOMAKINA & MIKOVA 2006; RAIKOS *et al.* 2007). However, consumers need products prepared with sweeteners having more favourable nutritional properties than sucrose. Such sweeteners include fructose-oligomers that are not absorbed and can be considered ballast materials. In the large intestine, fructo-oligosaccharides serve as a source of carbon and nutrients for the bifidogenic bacteria in the bowels (RAO 2001; ROBERFROID 2002; BIEDRZYCKA & BIELECKA 2004; VAN DE WIELE *et al.* 2004; MACFARLANE *et al.* 2006), and are converted to lactate, short-chain fatty acids (acetate, propionate, butyrate) and gas in a manner similar to other dietary fibres. As a consequence of fermentation, their calorific value is very low: 2 kcal/g (BORNET *et al.* 2002). However, the effect of these sweeteners on the functional properties of egg white is not yet well-known.

Foam properties change depending on the equipment and whipping method, so it is quite difficult to compare the properties of foams made in different laboratories (STADELMAN & COTTERILL 1995).

The objective methods used for evaluating the foam properties are measuring the surface tension and thermal properties by differential scanning calorimetry (TALANSIER *et al.* 2009.) The functional quality of foams can be characterised by oscillatory rheological methods measuring their elasticity (MLEKO *et al.* 2007; TALANSIER *et al.* 2009), and by texture analysing methods based on immersing a specific measuring bob into the foam (ROSSI *et al.* 2010). The foam stability can be evaluated by measuring the leaking of whipped egg white during a given time (STADELMAN & COTTERILL 1995; TALANSIER *et al.* 2009; ROSSI *et al.* 2010).

The purpose of our work was to evaluate the effects of various sweeteners and preservation technologies on the rheological properties and foam stability of egg white. The influence of the addition of new components on organoleptic properties was also investigated.

MATERIAL AND METHODS

Material. The experiments included four types of egg white product (Capriovus Kft., Szigetcsép, Hungary): raw liquid egg white (homogenised liquid egg white) – RL; egg white powder (spray-dried liquid egg white) – EP; liquid egg white treated at lower temperature (homogenised liquid egg white maintained at 55°C for 24 h) – LT; pasteurised liquid egg (homogenised liquid egg white treated at 59°C for 5 min) – PL. All of the egg white products originated from the same batch and had the same protein content ($11 \pm 0.3\%$). Egg powder was dissolved in water (10 g egg powder in 73 ml water) before use.

In addition, sucrose, fructo-oligosaccharide syrup (Frutalose® L85; Sensud, Roosendaal, The Netherlands), and Isosweet 111 (42% fructose-58% glucose syrup; KUK-Hungária Kft., Győr, Hungary) were used as sweeteners. As for the additives, carboxymethyl-cellulose: CMC (Újvilág MGÉSZ, Abony, Hungary) and commercially available dietary citric acid were used.

Sample preparation. By combining egg white products and sweeteners, 12 egg white foams were produced with the same dry material content as follows. 83.5 g liquid egg white mixed with 93 g

sucrose and 1.4 g citric acid was whipped manually with an egg-whisk at a constant shear rate for ten minutes. The syrup was prepared separately: 235 g isosweet and 200 g sweetener were heated together to 85% Brix value (Brix value was measured using a digital refractometer Atago PR-301). The syrup was added to the foam while stirring continuously in order to reduce heat denaturation of egg white proteins. Then 1.5 g CMC was added, and the foam was whipped for 5 minutes.

The foam stability evaluation and texture profile analysis of the foam samples prepared were performed, and this was followed by organoleptic testing of the 5 best quality foams.

For rheological tests, sample solutions were prepared according to the combinations described above, using 86 g sweetener and 14 g egg white product for each sample. Each egg white product was tested without the sweetener as well.

Rheological test. Rotational rheological tests were performed using a Physica MCR 51 rheometer (Anton-Paar Hungary Kft., Veszprém, Hungary), with the measurement system CC 27 (cylinder 27 mm in diameter) and the measuring bob with paddles type ST24 -2V-2V-2D. The flow curves of the sample solutions were determined at 20°C in controlled shear rate mode at 100–1000 1/s shear rate interval. Twenty points were recorded for each flow curve during the measuring time of 80 second. All samples were measured three times in the same way.

The Herschel-Bulkley model was applied to various flow-curves to quantify the parameters of flow-curve:

$$\tau = \tau_0 + K \times \dot{\gamma}^n$$

where:

τ – shear stress (Pa)

τ_0 – yield stress (Pa)

K – consistency index (Pa·s)

$\dot{\gamma}$ – shear rate (s⁻¹)

n – power-law index

Foam storage stability test. The freshly made foams were poured into 50 ml measuring cylinders covered with parafilm and stored at room temperature for 18 days. The amount of liquid (ml) collected at the bottom of the cylinders was recorded every day. The so called leaking curves of each product were obtained by recording the fluid level as a function of storage time.

Texture profile analysis. The texture of egg foams was characterised with the texture analyser (LFRA

4500 Texture Analyser; Brookfield, Middleboro, USA) equipped with the probe, type TA43 (plastic ball 25.4 mm in diameter). The data were recorded and the analysis of the texture profile was performed by using TexturePro Lite v1.1 Build 4 software. The dimensions of certain texture parameters are given in the default form provided by the software.

The test parameters were: total cycles 2, test speed 4 mm/s, target value 20 mm (distance reached by the test piece in the sample). Based on the texture profile load (g) in function of time (s), firmness (g) (maximum deformation force during the first mastication cycle), and adhesiveness (g·s) (amount of work required to pull the compressing plunger away from the sample) were determined. All samples were measured in triplicate.

Sensory analysis. Prior to this analysis, samples were prepared again according to the recipe, and after refrigeration, they were served on wafers. The organoleptic properties were evaluated by a sensory panel consisting of 23 trained panelists using a 100-point scoring system. As the maximum, forty points could be given for the texture and taste of foams while ten points for the odour and total impression. After-taste was also evaluated using a hundred points scale.

Statistical analysis. Statistical analysis was performed using Statistica Vers. 9 (StatSoft Inc., Tulsa, USA) software. The differences between the firmness and adhesiveness results of consecutive samplings during storage were evaluated by Student *t*-test at 95% confidence.

RESULTS AND DISCUSSIONS

Rheological test

The flow-curves of the egg white samples made with sweeteners are shown in Figure 1. When viscosity increases, the stability of egg white foams increases as well (STADELMAN & COTTERILL 1995).

Among egg white products, raw liquid egg white had the highest viscosity because its protein structure was not damaged by the heat treatment. Heat treated liquid egg whites had a lower viscosity, and their flow curves had similar shapes and showed similar values. The shear stress of raw liquid egg white (RL) increased more slowly beyond the shear rate 700 s⁻¹ suggesting that the flow resistance decreased at a high deformation rate due to the orientation of egg white proteins.

The addition of sweeteners increased the viscosity of egg white products. Viscosity was increased at the highest rate by sucrose and at the lowest rate by the addition of Isosweet.

The shear stress of the samples made with sucrose in terms of deformation rate was considerably higher compared to those of other samples, which means that viscosity can be dramatically increased by adding sucrose. The viscosity of the samples prepared with Isosweet was lower compared to those made with other sweeteners.

Rheological parameters calculated from the Herschel-Bulkley model are shown in Table 1. Based on the correlation coefficient ($R^2 > 0.99$), the model is considered to be appropriate for each sample.

The power law index (n) showed a value of around 1 for the samples made with sucrose indicating that the shear stress uniformly increased as a function of the shear rate, and viscosity was constant beyond the yield stress. The n value of raw liquid egg white combined with sucrose was lower than 1 (0.6), indicating shear thinning rheological behaviour, i.e. the slope of the flow curve decreases by increasing the deformation rate. That may be

caused either by the alignment of the protein chains in the direction of the shear force, or by mechanical damage during the measurement. The n value of other samples was above 1, in other words, they showed shear thickening, dilatant behaviour. This can be explained by the fact that these samples contained a relatively small amount of fluid. There is increasingly greater friction between protein molecules with the increasing deformation rate, thus it is more difficult to force the samples to flow; and a higher force is required to maintain the specific deformation rate.

The higher is the observed consistency index or apparent viscosity (K), the greater stability of whipped egg white is to be expected (STADELMAN & COTTERILL 1995). The addition of sweeteners increased viscosity in all egg white products. Viscosity of the samples made with sucrose showed very high values compared to the other products; the highest value in the sample was obtained with RL (more than 120 000 mPa·s); the lowest viscosity was observed in the samples made with Isosweet.

Among liquid egg whites the raw liquid appeared to be the best as the protein chains in it were

Table 1. Rheological parameters (mean and standard deviation) of egg white liquid products with and without sweeteners calculated from Herschel-Bulkley model

Value	τ_0 (Pa)	K (mPa·s)	n	R^2
EP.	0.00	5.38 ± 0.89	1.40 ± 0.02	0.99 ± 0.001
EP.S.	747.44 ± 140.41	10 303.33 ± 6 596.7	0.94 ± 0.08	0.99 ± 0.001
EP.F.	1.16 ± 2.69	24.14 ± 5.43	1.35 ± 0.01	0.99 ± 0.001
EP.I.	0.00	13.48 ± 2.07	1.39 ± 0.02	0.99 ± 0.00
LT.	0.00	5.62 ± 2.60	1.39 ± 0.05	0.99 ± 0.003
LT.S.	472.35 ± 55.00	5 722.50 ± 3 902.12	1.02 ± 0.08	0.99 ± 0.00
LT.F.	12.82 ± 0.33	62.45 ± 4.36	1.23 ± 0.11	0.99 ± 1.00
LT.I.	0.00	10.90 ± 0.05	1.41 ± 0.004	0.99 ± 0.00
RL.	0.00	72.67 ± 20.34	1.15 ± 0.05	0.99 ± 1.00
RL.S.	0.00	122 210.00 ± 13 757.58	0.60 ± 0.01	0.99 ± 0.00
RL.F.	0.00	17.08 ± 0.97	1.42 ± 0.01	0.99 ± 0.00
RL.I.	0.00	7.87 ± 0.29	1.47 ± 0.003	0.99 ± 0.00
PL.	0.00	4.63 ± 1.06	1.43 ± 0.03	0.99 ± 0.001
PL.S.	1 495.86 ± 172.52	17 205.00 ± 7 085.36	0.92 ± 0.06	0.99 ± 0.001
PL.F.	0.00	11.56 ± 0.72	1.44 ± 0.01	0.99 ± 0.00
PL.I.	0.00	11.33 ± 0.86	1.42 ± 0.01	0.99 ± 0.00

EP – egg white powder; LT – long term heat treated egg white liquid; RL – raw egg white liquid; PL – pasteurised egg white liquid; S – sucrose; F – fructo-oligosaccharide syrup; I – Isosweet (fructose-glucose syrup); τ_0 – yield stress (Pa); K – consistency (mPa·s); n – power law index; R^2 – correlation coefficient between measured

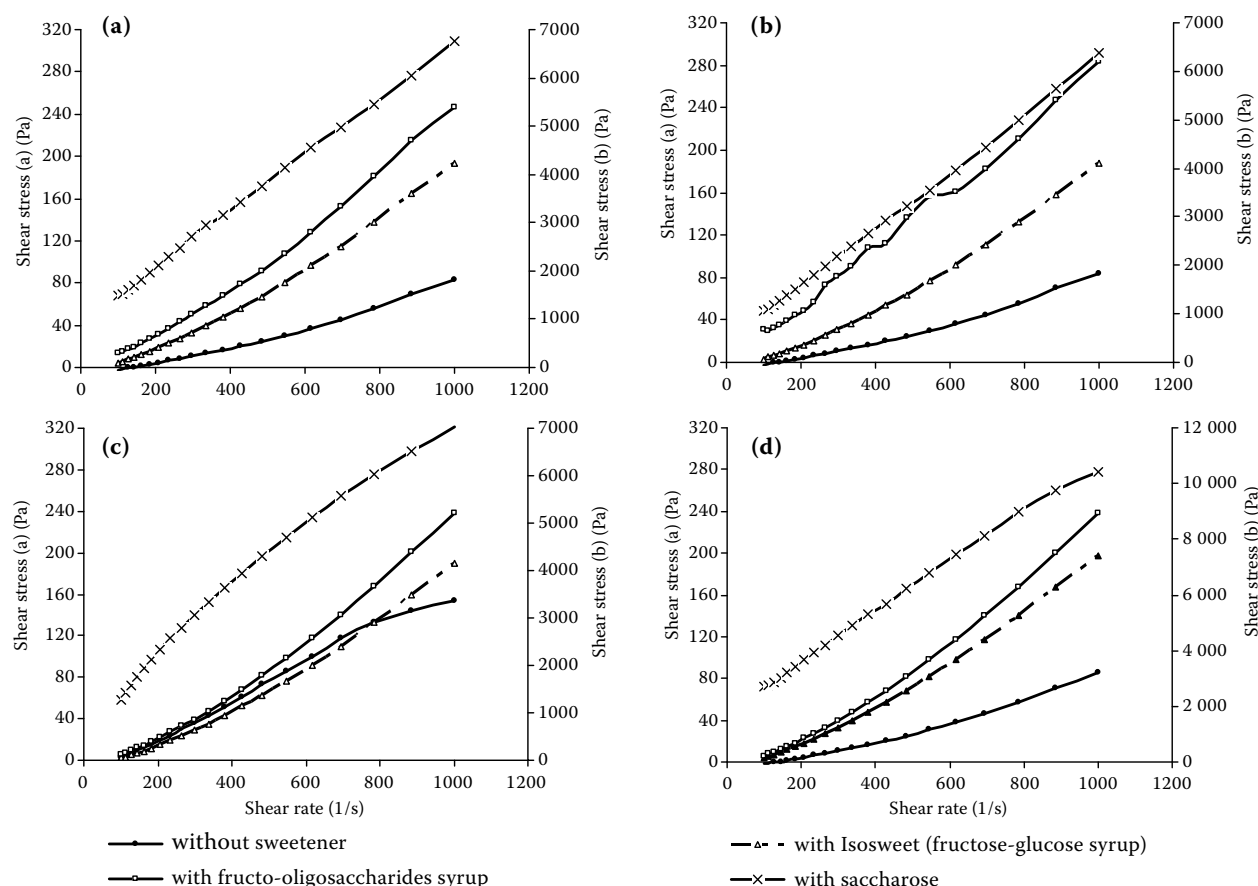


Figure 1. Flow curves of liquid egg white products in samples made from egg white powder (a); in samples made of liquid egg white treated at lower temperature (b), in samples made of raw liquid egg white (c), and in pasteurised liquid egg white (d)

less severely damaged because of the lack of heat treatment after homogenisation.

Except for RL, all samples made with sucrose revealed the yield stress indicating plastic behaviour, i.e. a certain deformation force is needed to make these samples flow. For this reason, sucrose has to be added to egg white foams in parts, in order not to destroy air bubbles with strong whipping.

Stability of egg foams

The results of the storage stability experiments (Figure 2) provide information on the shelf-life, which is one of the most important features of foams.

The fluid level increased with time in each sample except foam EP.S, where no elevation of the fluid level was observed in the course of experiment (Figure 2a). In foam samples RL.S and RL.I the fluid level elevation started after approx. 1 week (Figure 2c).

With each egg product, the foams made using sucrose lost the lowest amount of fluid except for the foams made of LT where the product made with Isosweet proved to be the most stable.

RL.S and RL.F samples lost a small amount of fluid and appeared to be promising while the egg foam produced with fructose syrup lost a large amount of fluid during the entire testing period.

Foams made of PL lost a considerable amount of fluid compared to other foams. PL.S showed promising results with moderate leakage, and PL.F started to lose fluid after Day 5. The PL.I. sample produced large bubbles and had completely collapsed by the end of the test period.

Texture analysis

Firmness and adhesiveness of egg white foams freshly made and stored for 3 weeks at room temperature are shown in Table 2.

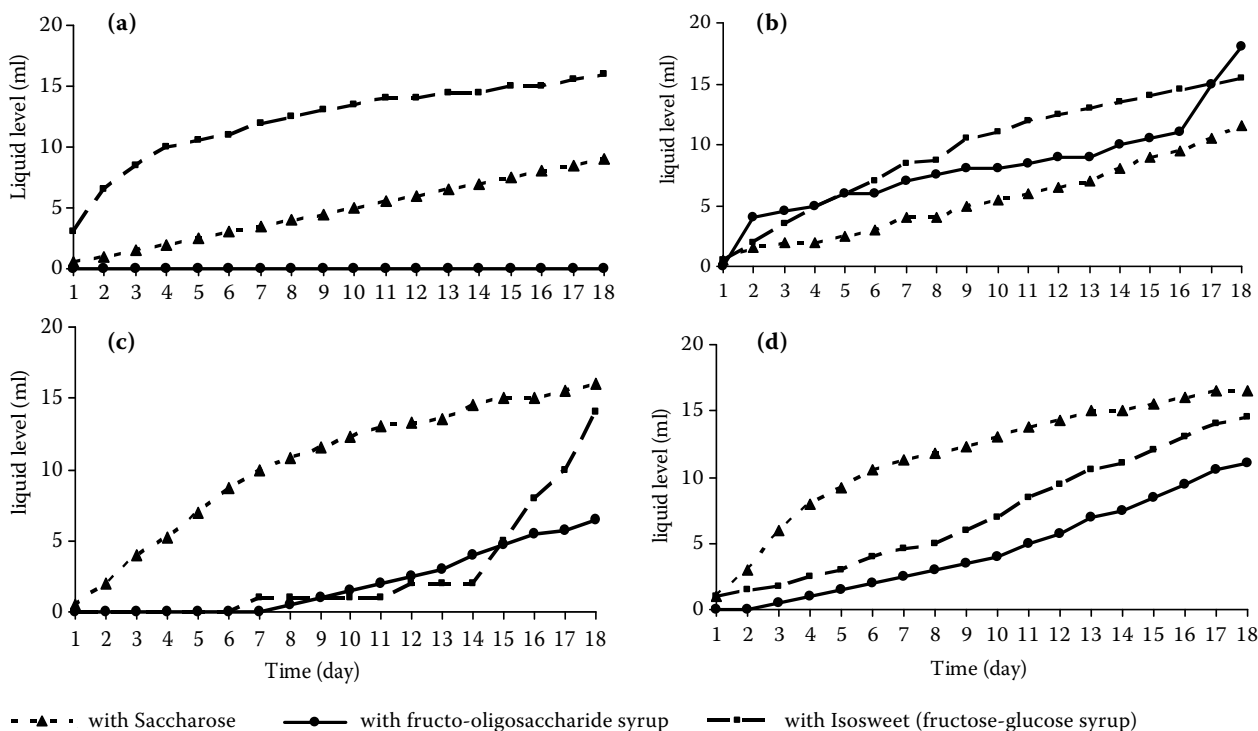


Figure 2. Fluid loss curves of reconstituted egg powder (a), liquid egg white treated at lower temperature (b), raw liquid egg white (c), and pasteurised liquid egg white (d) samples

Texture of fresh foams

In terms of all egg products tested, the highest firmness values were found in the samples made with sucrose, followed by the foams made with fructo-oligosaccharide syrup and Isosweet. A very high value was observed in RL.S (138.5 g) and EP.S (100.3 g) products. This can be explained by the fact that the functional properties of egg white components did not change in raw liquid egg white due to the absence of heat treatment and drying. The firmness values of other products ranged between 42.67 and 78.5 g. The lowest values (30.5 and 24.17 g) were found in the samples made of PL.

The adhesiveness values showed tendencies similar to the firmness values.

The adhesiveness of the samples made with sucrose proved to be the highest. The RL.S (−420.16 g·s) and PL.S (301.28 g·s) showed the best results. The adhesiveness of the other samples ranged between −100 g·s and −200 g·s. The lowest values were measured in the reconstituted egg white powder samples with −53.33 g·s and −36.84 g·s, respectively.

In conclusion, based on the texture testing, the addition of sucrose improves and that of Isosweet deteriorates the quality of egg white foams.

Changes in firmness during storage

The foam samples made of EP were the firmest after one week, followed by a decrease, with the exception of the samples made with sucrose, whose firmness values did not show any significant change. The firmness values of the samples made of liquid egg maintained at 55°C showed a uniform increase.

Among the foams made of RL, the sample made with sucrose was different from the other two samples. In this one sample, the initial foam was relatively firm and the firmness value decreased while in the other two samples the firmness values constantly increased from Day 0. After Week 3, the foam made with sucrose was the most stable.

In foams made from PL, a definite increase was observed until the end of Week 1 in all three samples, followed by a decrease in the firmness values of the foam made with Isosweet, and a continuous increase at a lower rate for the other two samples.

Changes in adhesiveness during storage

The adhesiveness of egg white foams started to decrease after a transient increase as a function of

Table 2. Hardness and adhesiveness of egg white foams made of combinations of different egg white products and sweeteners ($\bar{x} \pm \text{SD}$)

Sweetener	Time (week)	Hardness (g)	Adhesiveness (g·s)	Hardness (g)	Adhesiveness (g·s)
		egg white powder		raw egg white liquid	
S	0	103 ± 2.6 ^a	−301 ± 9.9 ^a	139 ± 1.9 ^a	−420 ± 14 ^a
	1	99 ± 3.7 ^a	−266 ± 26 ^a	83 ± 2.1 ^b	−224 ± 11 ^b
	2	109 ± 3.6 ^a	−254 ± 5 ^a	91 ± 1.1 ^c	−299 ± 6. ^c
	3	92 ± 11 ^{a,b}	−209 ± 16 ^a	101 ± 5.2 ^d	−311 ± 12 ^c
F	0	54 ± 2.9 ^a	−131 ± 11 ^a	51 ± 1.7 ^a	−119 ± 7.2 ^a
	1	103 ± 5.5 ^b	−221 ± 20 ^a	74 ± 3.5 ^b	−212 ± 4.3 ^b
	2	91 ± 4.4 ^c	−179 ± 1.3 ^a	81 ± 1.5 ^b	−224 ± 14 ^b
	3	58 ± 7.9 ^{d,a}	−92 ± 4.0 ^b	81 ± 0.8 ^b	−195 ± 13 ^b
I	0	79 ± 4.6 ^a	−222 ± 25 ^a	42 ± 0.6 ^a	−98 ± 4.3 ^a
	1	125 ± 8.6 ^b	−409 ± 60 ^b	118 ± 8.6 ^b	−314 ± 52 ^b
	2	105 ± 5.0 ^c	−324 ± 60 ^b	87 ± 8.7 ^c	−209 ± 46 ^b
	3	151 ± 5.7 ^d	−261 ± 34 ^{b,a}	82 ± 4.9 ^c	−174 ± 21 ^b
		long term heat treated egg white liquid		pasteurized egg white liquid	
S	0	68 ± 0.6 ^a	−185 ± 6.0 ^a	43 ± 3.7 ^a	−90 ± 14 ^a
	1	77 ± 1.2 ^b	−203 ± 22 ^a	83 ± 1.7 ^b	−219 ± 4.4 ^b
	2	88 ± 2.3 ^c	−235 ± 29 ^a	99 ± 0.7 ^c	−265 ± 20 ^c
	3	81 ± 5.4 ^c	−204 ± 35 ^a	106 ± 1.7 ^d	−261 ± 43 ^c
F	0	41 ± 1.7 ^a	−96 ± 8.0 ^a	31 ± 3.6 ^a	−53 ± 13 ^a
	1	85 ± 0.6 ^b	−244 ± 13 ^b	79 ± 2.1 ^b	−230 ± 11 ^b
	2	79 ± 3.4 ^b	−189 ± 17 ^c	83 ± 2.9 ^b	−232 ± 5.7 ^b
	3	74 ± 9.0 ^b	−167 ± 43 ^{c,a}	83 ± 4.9 ^b	−228 ± 13 ^b
I	0	45 ± 1.4 ^a	−102 ± 1.8 ^a	24 ± 0.6 ^a	−37 ± 2.7 ^a
	1	85 ± 0.6 ^b	−244 ± 1.0 ^b	85 ± 3.1 ^b	−137 ± 22 ^b
	2	92 ± 0.4 ^c	−266 ± 5.1 ^b	49 ± 8.1 ^c	−84 ± 6.1 ^c
	3	92 ± 0.4 ^c	−270 ± 14 ^b	32 ± 7.0 ^{c,a}	−29 ± 9.7 ^{d,a}

S – sucrose; F – fructo-oligosaccharide syrup; I – Isosweet (fructose-glucose syrup); \bar{x} – mean; SD – standard deviation; ^{a–d}the same letter indicates that there is no significant difference at 95% confidence between the indicated and previous data

time. The foam RL.S was sticky when it was fresh and after a significant decrease its adhesiveness started to increase slowly from Week 2. The adhesiveness values of the samples made with sucrose were the highest even after 3 weeks.

It was noted that if the firmness and adhesion values of the samples made from the same type of liquid egg their absolute values showed a similar tendency. Thus it was characteristic of the foams that the greater firmness values they had, the more stable they were, the better their adhesion, i.e. the more they were. One reason is that they have a

high sugar content leading to increased egg white viscosity and foam stability.

Organoleptic analyses

The results of organoleptic analyses are summarised in Table 3. All of the parameters (taste, odour, texture, total impression) were evaluated by high scores. Based on the results, no significant organoleptic differences occurred in the taste, texture, and odour of the samples made from various

Table 3. Organoleptic quality of egg white foams made of different egg white products and sweeteners

		EPS.	RL.S.	PL.S.	EPI.	LT.I.
Odour	\bar{x}	6.13	6.47	6.27	6.47	6.33
	SD	2.28	2.10	1.87	2.29	1.99
Taste	\bar{x}	29.67	31.38	29.95	29.95	31.00
	SD	6.37	5.77	4.68	6.58	6.44
Texture	\bar{x}	30.67	30.38	30.67	31.43	31.71
	SD	5.40	6.06	5.88	4.77	5.74
Total impression	\bar{x}	7.48	7.09	7.10	7.14	7.08
	SD	1.50	1.51	1.34	1.58	1.64
After-taste	\bar{x}	34.10	30.95	29.43	30.45	38.76
	SD	32.47	29.69	26.48	31.54	30.55
Overall acceptability	\bar{x}	72.83	76.52	73.80	74.87	76.80
	SD	11.13	8.50	8.33	13.94	11.42

EP – egg white powder; LT – long term heat treated egg white liquid; RL – raw egg white liquid; PL – pasteurised egg white liquid; S – sucrose; I – Isosweet (fructose-glucose syrup)

components. No unpleasant after-tastes could be identified as indicated by high standard deviations.

CONCLUSIONS

It was established that the best foam is that made of egg powder with sucrose since no fluid loss was observed during the storage experiments. It was the most stable when fresh, and it showed the highest viscosity in the rheological test.

Liquid egg white treated at a lower temperature (homogenised liquid egg white maintained at 55°C for 24 h) proved to be a good alternative for pasteurised egg white liquid for producing confectionery foams. Fructo-oligosaccharide syrup seems to be suitable for replacing a certain amount of sucrose, thus decreasing the energy value and increasing the nutritional value of the confectionery products made from egg white foam.

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