Factors Influencing Egg White Foam Quality

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Abstract

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The work was targeted on the study of egg white foam forming, including the influence of pH, aluminium ions, xanthan, maltodextrin, and phosphates on the whipping and stability of egg white foams. The whipping was studied with non pasteurised and pasteurised egg white using the blender with planet motion. Both types of egg white formed good foam in the acid area (pH below 4.5) and at neutral pH. Aluminium ions had a positive effect on the foam volume and stability, especially with the non pasteurised egg white. The addition of maltodextrin or saccharose decreased the foam volume but increased the foam stability. The addition of natrium pyrophosphate or natrium hexametaphosphate had a positive effect on the volume, density, and stability of foam. Foams with hexametaphosphate were applied into confectionary products.

Keywords: egg white; foam characteristics; acidity; aluminium ions; natrium pyrophosphate; natrium hexametaphosphate

The formation of foam belongs to the most important properties of hen egg white. The egg white is used in many branches of food industry, the formation of foam is needful especially in confectionery. The quality of egg white and egg white foams has been decreasing in last years. The objective of this work was to improve the whipping and stability of egg white foams. The quality and stability of foams have been evaluated by measuring the foaming attributes of egg white (index of whipping, index of foam durability, foam density, overrun, air phase).

The foam is a two-phase system in which air forms the dispersed phase and the surface phase is formed by a thin layer of denaturated proteins (Ternes *et al.* 1994). The proteins of egg white denature mechanically by whipping. Protein molecules include hydrophilic and hydrophobic groups. The hydrophilic groups are directed into the liquid phase and the hydrophobic groups into the air phase. During whipping stereometric changes occur due to that the hydrophobic groups stand up on the surface, the surface energy and surface tension decrease, and these effects influence the formation and stability of foam (Lomakina & Míková 2006a). Some proteins precipitate and form thin film surrounding the air bubles. After the creation of foam, the air from the inner layers with higher presure diffuses and causes cracking of the film formed by denaturated proteins. Between the bubbles some holes are shaped in which flows water and the foam liquefies (Lomakina & Míková 2006a).

Johnson and Zabik (1981) showed that egg white globulins had the best effect on the foam formation. Ovoalbumin, ovotransferrin, lysozym, ovomucoid, and ovomucin as well as their interac-

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tions also participate either on the foam formation or its stabilisation.

The factors influencing the formation and stability of egg white foam are: hen age, egg age, storage conditions, speed and time of whipping, temperature, pasteurisation, pH, dry matter, presence of egg yolk or lipids, salt, sugar, stabilisers and surface active compounds, metal ions, and proteolytic enzymes (Hata *et al.* 1997; Hammershøj & Qvist 2001).

Nakamura and Sato (1964) obtained a great foaming capacity at the neutral and acidic pHs except at the exceedingly acidic pH (pH 1.0). The foam stability was the highest at pH 8.6, the pH of the natural egg white, and decreased with changing pH. With an aqueous egg white solution, Hammershøj and Larsen (1999) established that the foam overrun was the highest at pH 4.8 and the lowest at pH 10.7. The foam stability against drainage was the best at pH 7.0 after 30 minutes.

An inhibition effect on the whipping properties was caused by the addition of sucrose, lactose, dextrose, and maltose, especially the last three (Yang & Baldivin 1994). The addition of glycerol, sorbitol or several other chemicals which increase the egg white viscosity improves the foam stability but reduces the foaming ability (Hatta *et al*. 1997).

The assumption that metalic cations may affect the functional performance of egg white foams was based on the ability of ovotransferrin to react with many polyvalent cations including aluminium, copper, iron, and zinc, forming with them complexes with an increased heat stability. Cotterill *et al*. (1992) examined the role of these ions on the foaming properties of spray-dried egg white before and after the heat treatment at 54°C for 10 days. Some significant differences in the foam volumes ocurred between both the unheated and heated spray-dried egg white samples. The most effective was Cu^{2+}, the least effective was Zn^{2+}. Phillips *et al.* (1987) showed that egg white protein and fresh egg albumen with 1mM $CuSO_4$ formed more stable foams.

Phosphoric and citric acids have also affinity for ovotransferrin. Therefore, the addition of their salts also increases the denaturation temperature of ovotransferrin, improving the foaming ability of egg white on pasteurisation (Nakamura *et al.* 1979). Trisodium phosphate and other phosphates are also active against Gram negative bacteria (Corry *et al.* 1995).

MATERIAL AND METHODS

The whipping was studied with non pasteurised and industrially pasteurised egg white (Zaruba a.s., České Budějovice, Czech Republic). Egg white was stored at 4°C and was tempered before whipping at 20°C. For the assessment of the whipping methods and foam formation, a blender with planet motion (Kitchen Aid, Ohio, USA) was used. The whipping was carried out at the speed grade 3 for 3 minutes. For the improvement of the foam formation and foam durability preservation, the impacts of acidity (pH) and various additives such as aluminium sulfate (Penta, Prague, Czech Republic), saccharose, maltodextrin (Barentz, Klatovy, Czech Republic), natrium pyrophosphate (Lachema, Brno, Czech Republic), and natrium hexametaphosphate (Dorapis, Prague, Czech Republic) were observed. All additives were alternatively added to non pasteurised egg white and to egg white after pasteurisation. Aluminium salt was added as a solution in milk acid (8.3 g $Al_2(SO_4)_3{\cdot}8H_2O$ was dissolved in 100 g 25% milk acid). The other additives were applied in the powder form. pH of egg white was adjusted with saturated solution of citric acid and 1M sodium hydroxide, respectively.

For the evaluation of foams the following characteristics were used:

$$\text{Index of whipping: } I_W = \frac{V_F}{V_{EW}} \times 100 \quad (\%)$$

$$\text{Index of foam durability: } I_D = \frac{V_F - V_{LEW}}{V_{EW}} \times 100 \ (\%)$$

$$\text{Specific density: SD} = \frac{m_{100F}}{V_{100F}} \quad (\text{g/ml})$$

$$\text{Overrun: } O_R = \frac{m_{100EW} - m_{100F}}{V_{100F}} \times 100 \quad (\%)$$

$$\text{Air phase: } A_P = \frac{O_R}{O_R + 100}$$

where:

V_F – foam volume (ml)
V_{EW} – egg white volume (ml)
V_{LEW} – volume of liquid egg white 30 min or 60 min after whipping (ml)
m_{100F} – weight of 100 ml foam (g)
V_{100F} – volume of 100 ml foam (ml)
m_{100EW} – weight of 100 ml egg white

All measurements were performed in two parallel assessments.

RESULTS AND DISCUSSION

Influence of pH

The acidity of egg white expressed as pH value had a strong influence on the volume (Figure 1) and durability of egg white foam. The largest volume and the lowest drain were observed with both non-pasteurised and pasteurised egg white in the acid area at pH 4, where most of the egg white proteins have isoelectric points, and near the neutral area at pH 7 with non-pasteurised egg white and pH 6.5 with pasteurised egg white. The worst whipping quality of non-pasteurised and pasteurised egg white was observed at pH 5 and in the pH range from 7.5 to 8.5 which corresponds to common pH of egg white. These results are in contradiction with the findings by Nakamura and Sato (1964), who reported that the foam stability was the highest at pH 8.6. Based on our results, acidification of egg white before pasteurisation to pH value approximately 6.8 is recommended.

Influence of aluminium ions.

Metal cations can be bound to form strong complexes with ovotransferrin. Ovotransferrin is contained in egg white in the amount of about 13%, it significantly contributes to the foam formation but its denaturation starts at a low temperature (53°C). Even a mild thermal treatment, e.g. pasteurisation of egg white, may cause damage of the functional properties, which is important in view of ovotransferrin having the best foaming ability of all egg white proteins. However, complex binding with metal cation improves the protein resistance towards thermoinduced denaturation and proteolysis (Mennicken & Waterloh 1997).

Aluminium sulphate was used for the ovotransferrin stabilisation since the complex with aluminium is colourless. The addition of aluminium sulphate to acidified non pasteurised egg white had a positive effect on the foam characteristics, especially the volume and durability (Table 1, Figures 2 and 3). The addition of aluminium sul-

Table 1. The influence of aluminium ions on egg white foam characteristics – non pasteurised egg white

c_{Al} (g/100 g)	I_W (%)	$I_D^{30'}$ (%)	$I_D^{60'}$ (%)	SD (g/ml)	O_R (%)	A_P (1)
0.0000	625.00	595.00	609.00	0.174	486.065	0.829
0.0002	600.00	571.00	582.50	0.174	474.015	0.826
0.0003	625.00	596.00	608.50	0.167	498.941	0.833
0.0007	625.00	597.75	608.75	0.160	522.582	0.839
0.0013	662.50	633.50	646.50	0.163	512.145	0.837
0.0024	675.00	648.00	658.50	0.161	521.308	0.839
0.0034	700.00	678.00	682.50	0.155	546.459	0.845
0.0044	700.00	681.25	681.50	0.154	550.022	0.846
0.0050	687.50	671.50	666.00	0.153	550.352	0.846

c_{Al} – aluminium ions concentration; I_W – index of whipping; $I_D^{30'}$, $I_D^{60'}$ – index of foam durability at drain of 30 min or 60 min; SD – specific density; O_R – overrun; A_P – air phase

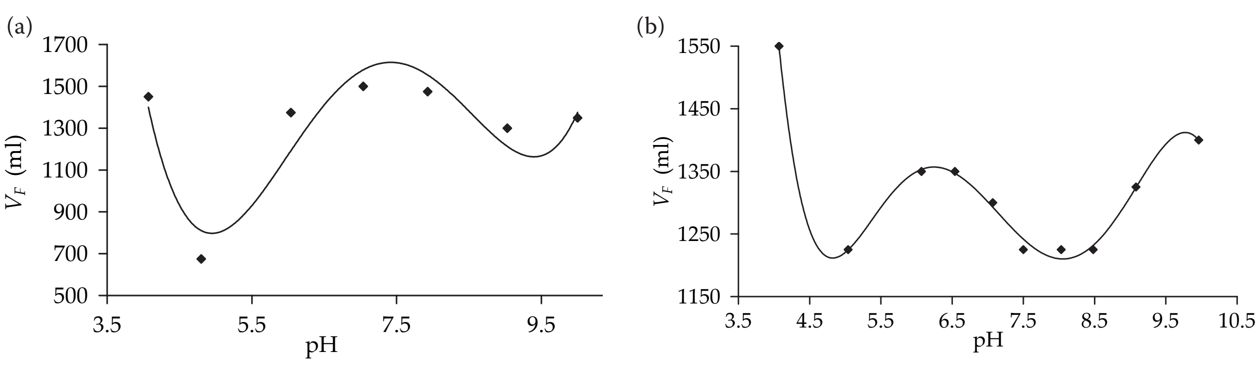

Figure 1. Dependence of foam volume on pH (a) non pasteurised and (b) pasteurised egg white

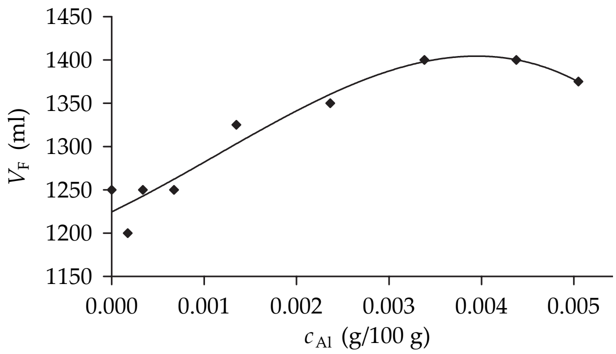

Figure 2. Dependence of foam volume on aluminium ions concentration – non pasteurised egg white

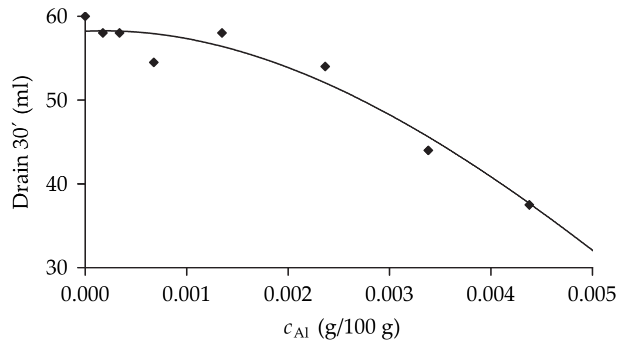

Figure 3. Dependence of drain (30 min) on aluminium ions concentration – non pasteurised egg white

phate to pasteurised egg white had no effect on the foam volume which means that ovotransferrin was denaturated during pasteurisation and was not able to form a complex any more. However, the durability of the foam from pasteurised egg white moderately increased after the addition of aluminium sulphate. Our results specified the conditions for aluminium salt utilisation (Mine 1995). The concentration of aluminium ions of 0.0044 g in 100 g of non pasteurised egg white was chosen as the best one and used in the industrial applications with a good effect.

Influence of saccharose and maltodextrin

Saccharose and maltodextrin in low concentrations (up to 3%) were used to increase the dry matter content of egg white since the low content of the dry matter in egg white is one of the reasons for a poor quality of foam. The best concentration of egg white dry matter for whipping is 14.4 ± 0.2% (Lomakina & Mikova 2006b). The addition of saccharose to non-pasteurised egg white decreased the foam volume at all concentrations observed. Higher concentration of saccharose

Table 2. Influence of Na pyrophosphate on foam characteristics – pasteurised and non pasterised egg white

c_{NaPP} (g/100 g)	I_W (%)	$I_D^{30´}$ (%)	$I_D^{60´}$ (%)	SD (g/ml)	O_R (%)	A_P (1)	pH
Pasteurised							
0.0000	625.00	596.25	607.00	0.159	535.910	0.843	9.04
0.5002	625.00	593.75	606.00	0.160	530.062	0.841	9.18
1.0002	650.00	615.75	633.50	0.156	545.228	0.845	9.22
1.5001	625.00	589.75	609.00	0.159	532.058	0.842	9.25
2.0000	612.50	576.50	594.50	0.169	494.564	0.832	9.28
2.5002	562.50	525.50	549.00	0.180	457.961	0.821	9.29
3.0003	537.50	49950	520.00	0.186	442.685	0.816	9.30
Non pasteurised							
0.0000	700.00	679.25	681.50	0.153	551.794	0.847	8.92
0.5002	725.00	707.75	707.00	0.147	580.779	0.853	8.96
1.0000	750.00	730.00	731.00	0.149	571.712	0.851	9.04
1.5003	725.00	704.50	706.75	0.157	538.513	0.843	9.10
2.0002	537.50	506.00	521.75	0.199	403.025	0.801	9.18

c_{NaPP} – Na pyrophosphate ions concentration; I_W – index of whipping; $I_D^{30´}$, $I_D^{60´}$ – index of foam durability at drain of 30 min or 60 min; SD – specific density; O_R – overrun; A_P – air phase

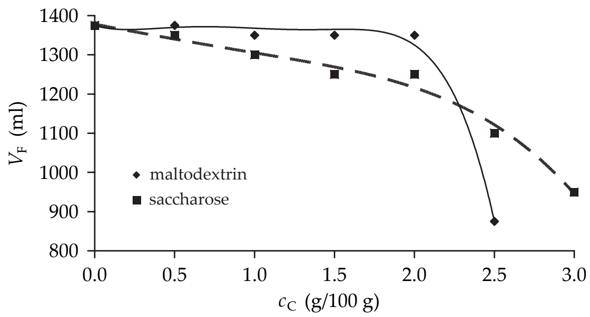

Figure 4. Dependence of foam volume on saccharose and maltodextrin concentration – non pasteurised egg white

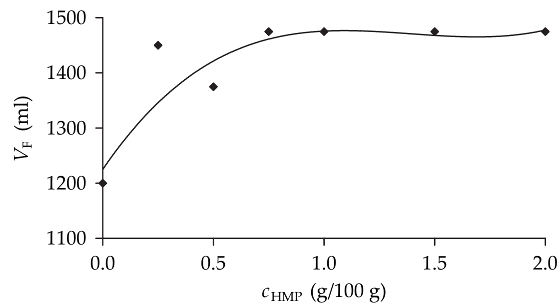

Figure 5. Dependence of foam volume on Na hexametaphosphate concentration – non pasteurised egg white

causes a delay of the foam formation and inhibition of whipping properties (Trziszka 1994; Yang & Baldivin 1994). The addition of maltodextrin had no effect on the foam volume up to 2% while higher concentrations decreased the foam volume (Figure 4). The durability of foam increased at concentrations of both saccharose and maltodextrin above 2%. The addition of saccharose or maltodextrin had no effect on the volume of foam from pasteurised egg white, but the durability of foam increased with increasing saccharose or maltodextrin concentrations.

Influence of natrium pyrophosphate

Na pyrophosphate increases pH of egg white. Because at pH higher than 9.5 the volume of foam escalated, the influence of Na pyrophosphate was tested. The results are presented in Table 2.

The characteristics of foams from both non pasteurised and pasteurised egg white were moderately better at Na pyrophosphate concentration 1% but the improvement was not significant. Higher concentrations of Na pyrophosphate lowered the quality of foams. This compound has pH > 12 at concentration 8% and is active against Gram negative bacteria (Corry *et al.* 1995).

Influence of natrium hexametaphosphate

The addition of Na hexametaphosphate decreased pH within the limits 9.1 (blank) to 6.7. Na hexametaphosphate significantly improved the foam characteristics of non-pasteurised egg white (Table 3, Figure 5). In the concentration range of 0.75% to 2.0%, the volume of foam increased by about 23%, and the drain after 30 min. decreased by about 64%. For the industrial application, the concentration of Na hexametaphosphate 0.75 g in 100 g of non-pasteurised egg white was chosen as the best. In the case of pasteurised egg white, the observed effect was not so impressive. The foam volume reached maximum at the concentration of Na hexametaphosphate 0.5%, at higher concentrations it decreased again. The drain decreased with increasing concentration of Na hexametaphosphate.

Table 3. Influence of Na hexametaphosphate on foam characteristics – non pasteurised egg white

c_{HMP} (g/100 g)	I_W (%)	$I_D^{30'}$ (%)	$I_D^{60'}$ (%)	SD (g/ml)	O_R (%)	A_P (1)	pH
0.0000	600.00	575.25	584.00	0.172	479.522	0.827	9.14
0.2501	725.00	710.00	707.25	0.149	572.083	0.851	8.33
0.5001	687.50	680.50	672.25	0.148	576.450	0.852	7.64
0.7501	737.50	730.50	723.75	0.140	612.147	0.860	7.35
1.0000	737.50	728.50	721.50	0.142	604.867	0.858	7.14
1.5000	737.50	728.50	722.50	0.144	591.991	0.855	6.87
2.0000	737.50	722.50	718.00	0.148	574.594	0.852	6.71

c_{HMP} – Na hexametaphosphate ions concentration; I_W – index of whipping; $I_D^{30'}$, $I_D^{60'}$ – index of foam durability at drain of 30 min or 60 min; SD – specific density; O_R – overrun; A_P – air phase

CONCLUSION

In conclusion, the quality of egg white foam for utilisation in confectionery can be improved by the adjustment of pH or by application of additives referred above. The results of this work are employed in the egg processing industry.

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