

Evaluation of Egg Albumen Foaming Capacity by an Automated Method

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Abstract

The optimal conditions for egg albumen foaming were settled using an automated device for foam testing. The method is based on stirring albumen sample in a transparent column at 6000 rpm for 240 seconds and obtaining the appropriate volume of foam. The method was applied for testing the storage time effect (0- 28 days) on albumen foaming properties for shell eggs. At 14 days of storage the foaming capacity registered a positive correlation with albumen weight, and negative correlations with albumen height and Haugh units.

Keywords: egg, foaming capacity, storage time.

1. Introduction

Eggs are characterized by quality parameters as their shape, the aspect of yolk and albumen (consistency, pH, color, dimensions etc.), and the shell thickness and its strength. The egg albumen is also characterized by many methods in relationship with its properties. Egg albumen can be coagulated, but has excellent foaming properties that could be correlated with hen diet or age, with egg freshness, pH values, protein concentration, and contaminative egg yolk [1]. Egg albumen is widely used as an excellent foaming agent in a variety of bakery products, such as cakes, cookies, mousses, meringues and other desserts based on its excellent foaming properties [2].

The methods for foaming are mainly based on whipping or bubbling, that means introducing of air into the solution of albumen protein molecules and forming bubbles, due to intermolecular interactions. The nature and type of the method influence the foaming characteristics. In methods

like whipping and mixing, vigorous agitation of the liquid with gas incorporates air into the liquid bulk. A higher whipping speed resulted in not just a higher foam-volume fraction, but with smaller foam bubbles and also with a higher liquid fraction in the foam [3]. Another common method of foam formation is the bubbling technique in which air is introduced through a nozzle or injector into liquid bulk in order to produce fine bubbles and achieve a better control over the size distribution of bubbles [4].

The freshness of eggs is a relevant index used in the food industry and in culinary applications. It gradually decreases with egg aging due to an extended shelf time storage. Among many methods for evaluation of egg freshness we can mention the Haugh unit determination (HU), the air cell size, the yolk index, and specific gravity.

The aim of the present paper is to propose and use an automated method for albumen foaming based on whipping in a column connected to sensors for foam height and controlled by dedicated software. The method was used to examine the effects of

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storage time of shell eggs on foaming properties of the albumen and next, to evaluate if there are any possible correlation between foaming properties and some of the albumen physical indicators that were also measured.

2. Materials and methods

The automated method for determination of albumen foaming capacity

The foaming method was applied using Dynamic Foam Analyzer – DFA100 (Krüss GmbH). This device enables the foaming behavior of the albumen samples and decay of the foam column to be investigated. Liquid sample is placed in a transparent measuring column which is located between a linear LED panel and a line sensor. The foaming action is produced by a stainless stirrer located in the base of the column. The line sensor measures the light transmitted through the measuring column over its full height. Two phase boundaries, liquid/foam and foam/air, are detected using the measured differences in light intensity. A special software measures time and calculates the foam volume and other indicators for the foam quality.

In our investigation we varied the stirrer speed and the stirring (foaming) time in order to obtain a maximum foam volume. A total of 180 eggs from layer hens were allocated for albumen samples testing (15 eggs for each test, accordingly to 4 varied times and 3 speed values on foaming) as presented in Tables 1a and 1b. The eggs were selected to be equal in dimensions and weight, as much possible. Before testing the eggs were maintained at room temperature ($21.55\text{ }^{\circ}\text{C} \pm 2.62$). Each egg was carefully broken, the albumen was very well separated from yolk and the chalaze were discarded. The same albumen volume was measured for each foam test and introduced in the basement of the device transparent glass column. The column walls must be clean and dry without sample or dirt. The stirring conditions (speed; time; data collection of foam height at 4 frames per minute and of foam decay at 10 frames per minute) were programmed. The stirring was started as well the automated collecting of data. The foaming results were presented by the software as a graphic or as a table with details of height and volume variations in time, for foam and for liquid part of the sample. These steps of software working are

illustrated in Figure 1. The results are saved as Excel file for each sample.

Calculation of albumen foaming capacity (FC) and foam stability (FS)

The following formula were used for:

$$\text{FC} = (\text{V} / \text{Vi}) \times 100 (\%)$$

$$\text{FS} = (\text{Vt} / \text{V}) \times 100 (\%)$$

where:

FC is the foaming capacity,

FS is the foam volume stability,

V is the volume of foam after stirring,

Vi is the volume of initial liquid albumen used for foam preparation,

Vt is the volume of foam measured over time (30 min.) after foam preparation.

Application of foaming method for characterization of storage shell eggs

A total of 30 eggs were collected from a hen-flock at hen age of 64 weeks. They were raised in 3-tier battery cages in a controlled household for temperature ($22.44\text{ }^{\circ}\text{C} \pm 1.85$), humidity ($45\% \pm 1.02$) and ventilation ($27.4\% \pm 10.86$). Feeds and water were offered ad libitum. The hens' diet contained 180 g/kg crude protein and 2850.00 kcal/kg metabolizable energy per kg of diet and was based on corn (39% of total diet ingredients), wheat (20%) and soybean meal (26.3%). First after eggs collecting, 10 eggs were evaluated for qualitative parameters and foaming capacity using the automated method, and also for foam stability over 30 min. The other eggs were stored at room temperature ($21.55\text{ }^{\circ}\text{C} \pm 2.62$) and also 10 of them were evaluated at 14 days of storage and the last ones at 28 days of storage.

Determination of eggs' physical qualitative parameters

The weight of whole egg and its components (albumen, yolk, and shell) were measured using a Kern EW6000-1M Electronic Balance. The egg shape index is calculated after measuring with a caliper. The egg freshness (albumen height, yolk diameter and Haugh unit calculation), were measured using a Digital Egg Tester DET-6500 (NABEL Co., Ltd., Kyoto, Japan). Albumen pH was measured immediately after breaking the egg using a calibrated portable pH meter (pH 5 Food waterproof tester, XS Instruments, Italy).

Statistical analysis

Data on all physical parameters and FC, respectively FS, were analyzed using the ANOVA by Minitab software (version 17, MinitabR Statistical Software) with main effect storage time. Simple regression coefficients of the storage time on albumen weight or height, Haugh units, albumen pH and FC, also and FS, were calculated. Probabilities of less than 0.05 were considered significant, and less than 0.01 very significant.

3. Results and discussion

Results for the parameters of the albumen foaming method

As it is presented in Table 1a the highest foam volume for the albumen sample was obtained for speed value 6000 rpm after 240 seconds. In Table 1b is presented foaming capacity that also indicated the highest values for these conditions of stirring. We considered that 240 seconds is enough for producing foam as in the literature the indicated time for whipping (using beater mixer method for albumen foaming) was around 5 minutes [5, 6]. Also, it is important to avoid overbeating which is characterized by decrease in foam firmness. A time of 4 minutes stirring is sufficient to produce optimum foam, and an extended time more than 4 minutes could reduce the foamability. In the same idea, of obtaining maximum foam but also to be stable/firm, the stirring speed of 6000 rpm was chosen to produce foam without rapid breakdown after the stirring is stopped (not measured, only by visual observation).

Table 1a. Albumen foam volume (ml) by varying stirring parameters at Dynamic Foam Analyzer – DFA100

	Speed time (seconds)			
	180 s	210 s	240 s	300 s
<i>Stirrer Speed value</i>				
5200 rpm	48.9±1.6	48.4±1.4	54.7±1.4	53.9±1.5
6000 rpm	46.5±1.4	49.9±1.5	57.3±1.6	57.4±1.7
7000 rpm	53.5±1.6	54.7±1.7	53.2±1.8	54.0±1.6

n = number of samples per group of foaming conditions (n=15);

Table 1b. The resulted albumen foaming capacity (%) after varying stirring parameters at DFA100

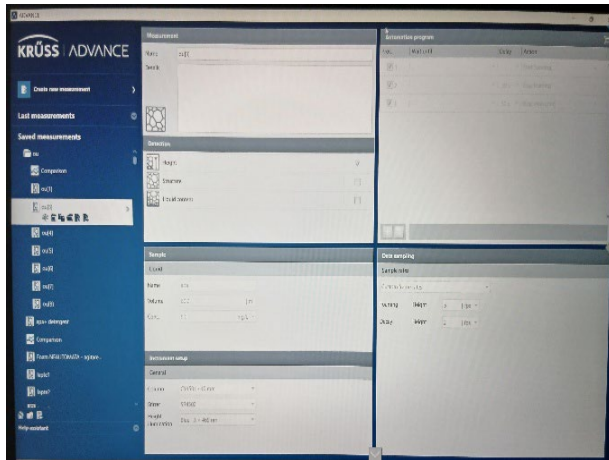
	Speed time (seconds)			
	180 s	210 s	240 s	300 s
<i>Stirrer Speed value</i>				
5200 rpm	222.33 ±7.54	220.67 ±6.60	241.67 ±6.60	239.00 ±7.07
6000 rpm	214.33 ±6.60	225.67 ±7.07	250.33 ±7.54	250.67 ±8.01
7000 rpm	237.67 ±7.55	241.67 ±8.02	236.67 ±8.49	239.33 ±7.54

n = number of samples per group of foaming conditions (n=15);

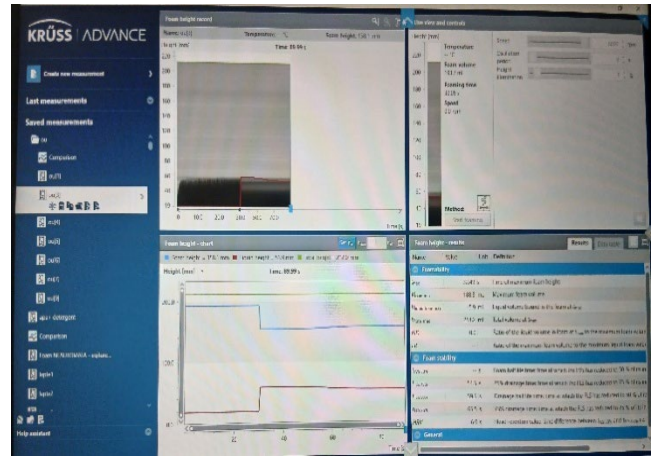
Results for storage shell eggs– the foaming properties

The automated method presented above was applied on testing the foaming properties (FC and FS) for stored shell eggs. The tests were done on initial time (0 days), 14 days and 28 days of storage. The results of the FC - foaming capacity - showed a gradually decreasing as the time storage was increasing (Figure 2). These data confirm previously observations of Hayakawa *et al.*, 1983, [7], where foamability of total homogenized egg albumen was found to decrease with increasing storage time up to 23 days at both 5 and 19 °C, or data of Sokołowicz *et al.*, 2023, [8], who observed that after 28 days of storage, the foaminess of the egg white and the stability of the foam were lower than at the first evaluation date. Our obtained data were lower than others reported in the literature [8, 9] or larger, e.g. Hammershoj *et al.*, 2001, [10]. This may be due to differences in the methods used to create foams or in the calculation of the foamability. As presented by other authors the albumen foaming properties seem to be affected by the housing system for layer hens [9] or by hen age [10] when only the thin fraction of albumen decreased in foamability as the hen age raised.

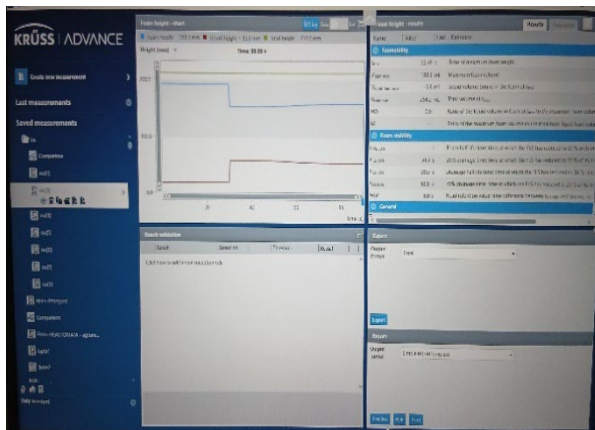
Step 1 (selecting the stirrer and the data recording in frames per seconds or minutes for foaming and decay)



Step 2 (recording the foam height during stirring and after stopping)



Step 3 (exporting the calculated results as Excel file)



Step 4 (chart results for foam and liquid albumen heights)

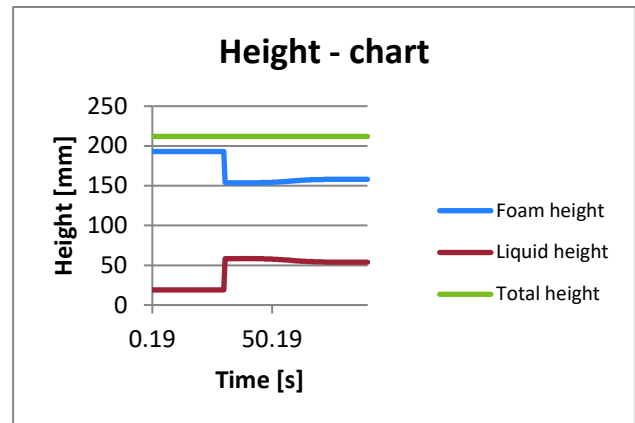


Figure 1. Using the software ADVANCE for DFA100 in 4 steps for setting foaming parameters and recording the results

The FS - foam stability - data, as presented in Figure 3, indicated that the stability was relative constant for a period of 14 days of storage time, after that it decreased. Our foam stability values were higher than that of Hammershoj, *et al.*, 2001, [10], or Alamprese *et al.*, 2012, [9], because they used extended time for measuring stability (60 min. or 120 min.). The decreasing tendency was also registered by [10] for 90 min. of stability, for eggs stored 14days at 4 °C; the author used foam liquid drainage as a function of stability and it was increasing with storage time at 4°C, due especially to thin albumen fraction. Also, Sokołowicz *et al.*, (2021 and 2023), [11, 8], presented that FS was reduced as the storage time was extended to 28 days. So, it can be concluded that storage time had a great influence on the albumen foaming properties.

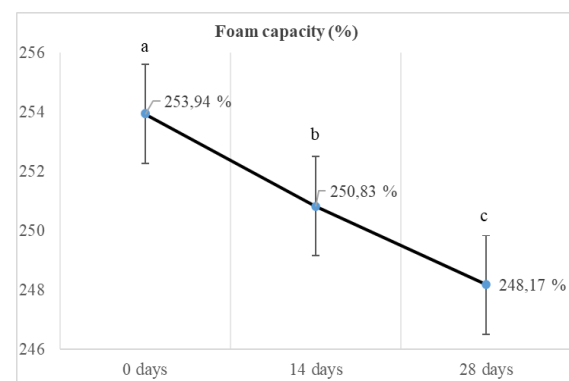


Figure 2. Evolution of foaming capacity (FC) with shell eggs storage time

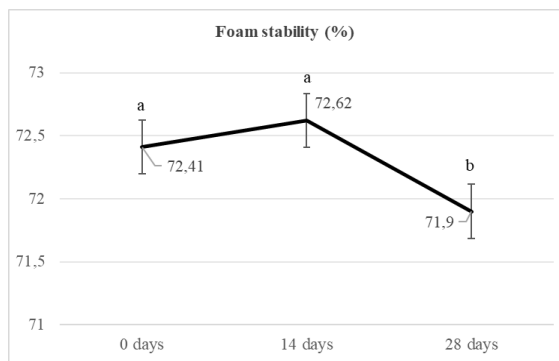


Figure 3. Evolution of foaming stability (FS) with shell eggs storage time

Results for storage shell eggs - the physical qualitative parameters

When eggs are stored, notable changes occur in the physical parameters, both for albumen and yolk. In **Table 2** data for the physical parameters of stored shell eggs at 21.55°C, especially for albumen, are

presented. The testing time intervals were the same as for the foaming properties.

It can be observed that whole egg weight and the egg shape index are not influenced by the storage time. But the albumen weight and height are decreasing at 28 days. Accordingly, the Haugh units (HU) are also decreasing at 28 days from higher HU values that indicate fresher eggs with firmer albumen, to lower values for stored eggs. The freshness rank at 28 days of storage indicated 66.67% class A and 33.33% class AA eggs. The reduction of albumen height during storage and also the affected Haugh unit score, were similarly as reported by [12] or [13]. Storage time had also an effect on the albumen pH which increased over 9 as a natural phenomenon reported in the literature [14-18]. At 14 days of storage albumen pH was significantly increased (9.23) by comparison with initial time (8.81); at 28 days the pH was high (9.25), but the same as for 14 days of storage.

Table 2. The effect of storage time on shell eggs

Parameters	Storage time			SEM	p-Value
	0 days	14 days	28 days		
Egg shape index (SI)	87.72	87.81	86.00	1,19	0,493
Whole egg weight (g)	63.37	63.08	62.98	0.512	0.861
Albumen weight (g)	39.68 ^a	39.35 ^a	37.48 ^b	0.439	0.006
Albumen pH (value)	8.81 ^b	9.23 ^a	9.25 ^a	0.036	0.0001
Albumen height (mm)	6.92 ^a	6.26 ^a	5.23 ^b	0.191	0.0001
Haugh unit HU (value)	82.30 ^a	79.85 ^a	69.38 ^b	1.910	0.001
Freshness					
class AA (HU > 72)	100	100	33.33		
class A (60 < HU < 72)	-	-	66.67		
class B (31 < HU < 59)	-	-	-		
class C (HU < 30)	-	-	-		

where: 0, 14 and 28 days are storage time periods; n = number of samples per period (10); SEM, standard error of the mean; ^{a-b}Mean values within a row having different superscripts are significantly different at p ≤ 0.05.

Correlations between albumen physical parameters and foaming properties

In Table 3 are presented correlations between albumen physical parameters and FC, and also FS. The most obvious significant correlation was found between HU and albumen height, at each tested time of storage (0.996 at 0 days; 0.832 at 14 days; 0.997 at 28 days of storage). Only at 28 days was observed a significant correlation between albumen pH and albumen weight (0.871); the pH was also in correlation with albumen height and HU. Also, for 28 days the albumen weight and height were appreciative negative correlated and consequently correlated with HU.

The resulted correlations for foaming properties are fluctuating during the storage time. At 0 days of storage, only the FS had appreciative correlations with albumen height (0.764) and HU (0.749). At 14 days the FC registered a positive correlation with albumen weight (0.735), and negative correlations with albumen height (-0.788) and HU (-0.692). The albumen height is mentioned also by [10], to influence the albumen foaming, along with protein composition, especially ovomucin. More, Kreuzer et al. (1995) [19] found indications of albumen height being related to foaming properties for albumen height variations between different hen lines.

For 28 days storage time there were weak correlations between foaming properties and indicators for egg freshness as just to be mentioned HU correlation of 0.490 with FC, and 0.408 with FS. The albumen pH had very weak correlations with FC and FS even it is known that foaming is also influenced by environmental factors like ionic strength or pH as presented by [20] or [21] who

demonstrated that large variations in pH values affect albumen foaming performances. The explanation is while the albumen pH increases to 9, the *n*-ovalbumin is transformed into the less hydrophobic *s*-ovalbumin; the cohesive film on the air-water interface is disturbed and determine the foam to become less stable [21].

Table 3. The Pearson correlation between albumin qualitative physical parameters and FC and FS

Storage time	Parameters					
	Albumen pH	Albumen weight	Albumen height	Haugh units, HU	Foam capacity	Foam stability
0 days						
Albumen pH	1					
Albumen weight	-0.463	1				
Albumen height	0.288	-0.101	1			
Haugh units, HU	0.240	-0.113	0.996**	1		
Foam capacity	0.520	-0.294	0.215	0.184	1	
Foam stability	0.524	-0.467	0.764	0.749	-0.097	1
14 days						
Albumen pH	1					
Albumen weight	-0.063	1				
Albumen height	0.266	-0.164	1			
Haugh units	-0.111	-0.485	0.832	1		
Foam capacity	0.255	0.735	-0.788	-0.692	1	
Foam stability	-0.156	-0.498	0.075	0.453	-0.539	1
28 days						
Albumen pH	1					
Albumen weight	0.871*	1				
Albumen height	-0.669	-0.792	1			
Haugh units	-0.624	-0.767	0.997**	1		
Foam capacity	0.203	-0.273	0.448	0.490	1	
Foam stability	-0.113	-0.456	0.366	0.408	0.601	1

*Correlation is significant at the 0.05 level

**Correlation is significant at the 0.01 level

Good correlations were registered for albumen weight to albumen height (-0.792) and to HU (-0.767) but are logical because of their relationship.

4. Conclusions

In this paper we presented an automated method of albumen foaming using a special device. The method is easy to use and permit also the foam stability measuring.

For stored eggs the albumen FC showed a gradually decreasing until 28 days of storage. The albumen

FS was relatively constant for 14 days of storage but was decreasing as the storage time is increasing. After testing the foaming properties in correlation with eggs physical parameters we found that at 0 days of eggs storage, only the FS had appreciative correlations with albumen height and HU. At 14 days of storage the FC registered a positive correlation with albumen weight, and negative correlations with albumen height and HU. For 28 days storage time there were weak correlations between foaming properties and HU as indicator for egg freshness.

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