

Sonication effect on foam properties of egg white

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Abstract

The aim of this study was to determine the effect of ultrasound treatment on foaming properties of egg white. The samples were sonicated at 20/40 kHz and 180/300 W equipment power (3.7/6.9 W absorbed power) for 30, 45 and 60 minutes. Foam capacity had been increased by 25% due to sonication at 40 kHz and 6.9 W absorbed power for 60 minutes. This phenomenon may be caused by the homogenisation effect of ultrasound and protein exposure of hydrophobic groups that improve the adsorption of protein onto the air/water interfacial molecules. It is found that frequency and duration of the treatment have no significant impact on the changes in foam capacity, only the absorbed power. On the other hand, foam stability had been decreased during the ultrasonic treatment. We can assume that sonication decreases the potential difference between the dispersed particles and the dispersion medium and this may be the cause of the collapse of the foam structure due to ultrasound treatment. In this case frequency, treatment time, and the absorbed power had a significant effect on the stability.

1. Introduction

Egg white possesses multiple functional properties, such as foaming, gelling and emulsifying and widely used in the food industry (Singh & Ramaswamy, 2015). Due to the excellent foaming properties it is a common ingredient in cakes and desserts. To provide a desirable texture and quality in such food products it is crucial for the food industry to improve the foaming properties of egg white (Duan et al., 2017).

The foaming formation is mostly influenced by the structure of the contained proteins. During the industrial thermal processes these proteins can be altered, leading to undesirable functionality loss (Chen & Ma, 2020). Using ultrasound treatment offers an application for the food industry to modify the functional properties of food proteins in a more favorable direction.

There are studies dealing with the topic of the effect of ultrasound treatment on foaming properties of egg white, but there are some conflicting observations.

Arzeni (Arzeni et al., 2012) found that sonication egg white on 20 kHz and 750 W equipment power (4.7 W absorbed power) for 20 minutes can alter the foaming properties. In the study they concluded that the foam capacity and the stability were decreased due to the treatment.

On the other hand Stefanivic (Stefanovic et al., 2017) reported that the foaming stability and foaming capacity had been increased due to sonication on 20 kHz and 34 W absorbed power for 2-20 minutes. In Gelvez-Ordenez (Gelvez-Ordenez et al, 2009) study it is reported that sonication on 40 kHz and 80 W for 5-10 minutes enhances the foam capacity, but the same treatment for 15 minutes resulted in a decreasing capacity. They also found that the foam stability had been decreased during the sonication regardless of the treatment time.

This is in good accordance with Sheng study (Sheng et al., 2018). They concluded that sonication (20 kHz, 90, 120, 240, 360 and 480 W equipment power for 10 minutes) significantly improved the foaming ability with a slight decline in foaming stability.

In these studies, they using different ultrasound treatment parameters that can cause these conflicting observations. Although, they agree that sonication has a significant effect on the foaming properties of egg white and it seems depending on the treatment parameters the foaming properties can have an increasing or a decreasing trend.

The purpose of this study is to inspect the sonication effect on the foaming properties of egg white to take a stand on this topic and determine the importance of the treatment parameters on these properties changes, that may give an explanation of the cause of the previous diverse findings.

2. Materials and methods

2.1 Egg white samples

A total of 7 liters of egg white were used for this experiment, provided by Capriovus Kft. (Szigetcsép, Hungary). The product was made of „A” classified (589/2008/EC regulation) homogenized and pasteurised fresh hen eggs. The egg white samples were stored at 0-4 °C in 1 L jugs before the measurement.

2.2 Ultrasound treatment

To determine the effect of ultrasound treatment on foaming properties an ultrasonic bath (HBM Machines, Netherlands) was used. The equipment is capable of delivering up to 300 W of power at 20/40 kHz frequency. Depending on the applied treatment parameters the samples were separated into 4+1 groups depending on the frequency and equipment power (Table 1). These groups (except control group) were separated into 3 more subgroups based on the duration of the treatment.

Table 1.: Sample groups by treatment parameters

Group	Frequency	Power	Duration
A	20 kHz	180 W	30, 45, 60 min
B	40 kHz	180 W	30, 45, 60 min
C	20 kHz	300 W	30, 45, 60 min
D	40 kHz	300 W	30, 45, 60 min
K	-	-	-

After homogenization 180 ml of egg white was poured into 200 ml glass container for each group. To ensure sonic conductivity the ultrasonic equipment was filled up with 16 L of tap water and the containers were put into this media. In order to avoid thermal impact on foaming properties an external cooling system was built to keep the temperature at low (18°C) temperature during the whole treatment. Untreated samples were subjected to the same temperature conditions as the sonicated ones.

The power, absorbed by the samples was measured in a preliminary experiment according to the heat increasing rate (Nagy et al., 2021).

2.3 Determination of foaming properties

For assessing foaming properties, foam capacity and foam stability were measured. 30 ml of egg white sample were poured into 150 ml beaker. The mass of the samples were measured by a digital scale (Radwag, WLC 2/2a) with 0.01 g readability. The samples then were whipped in the beaker with a hand mixer (Bosh MFQ36400, 450 W) on the highest rotational speed (~1300 rpm) at room temperature for 5 minutes. After whipping, the propeller was immediately removed

from the beaker and the height of the foam were measured. The volume of the foam were calculated by the following equation:

$$V = \pi * r^2 * h$$

, where V is the volume of the foam, r is the radius of the beaker and h is the height of the foam. In order to determine the foam stability a glass funnel was attached to the beaker and turned upside down (g) to separate the defoamed liquid egg white. After 1 hour, the mass of obtained the defoamed egg white was measured. The samples were measured in triplicates.



Figure 1.: Measurement setting to determine foam stability

2.4 Data analysis

In order to evaluate the effect of each treatment parameter on foam capacity and foam stability ANOVA is one of the mostly used method. However, the observed data is not normally distributed, which is crucial for such statistical test. Alternatively, Kruskal-Wallis test is a non parametric test that can be used if the data does not have normal distribution. The null hypothesis of this test is that the median of the studied groups are the same. In other words, it can be tested whether there is a difference between the medians of the populations belonging to each compared groups.

The statistical analysis was carried out using SPSS statistics 25 (IBM, Armonk, New York, United States of America).

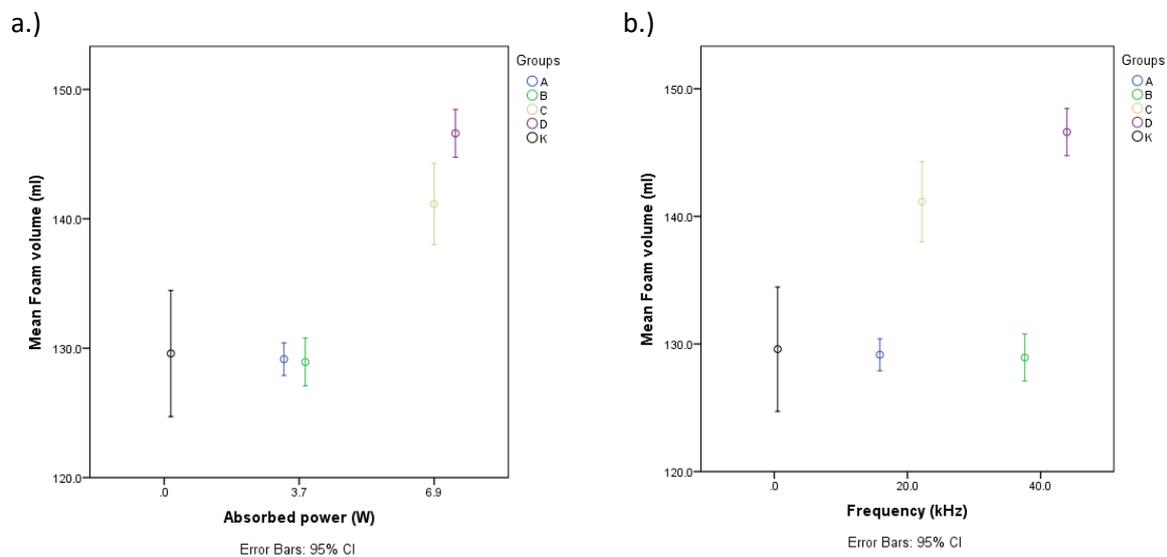
3. Results and discussion

The data shows that whipping the egg white results on average 4 times of foam in volume. The highest observed volume was 149.23 ml, which was from egg white treated at 40 kHz and 300 W for 60 minutes. Compared to control groups this means that sonication at this level can enhance the foam capacity by 25%.

Based on the graphical analysis of the volumes (Figure 2) it can be said that the frequency and the duration of the treatment does not affect the foaming capacity significantly. Although, the higher absorbed power results visibly more foam.

The significance levels, according to Kruskal-Wallis test (frequency - 0.354, duration - 0.403, and absorbed power - 0.000) also support that the only parameter that affects the foam capacity is the treatment power.

These results are in a good accordance with studies reporting that ultrasound can enhance the foam capacity (Jambrak et al., 2008; Stefanovic et al., 2017). This phenomenon can be due to the homogenisation effect of ultrasound and this treatment leading also to protein exposure of hydrophobic groups that improve the adsorption of protein onto the air/water interfacial molecules (Mirmoghtadaie et al., 2016).



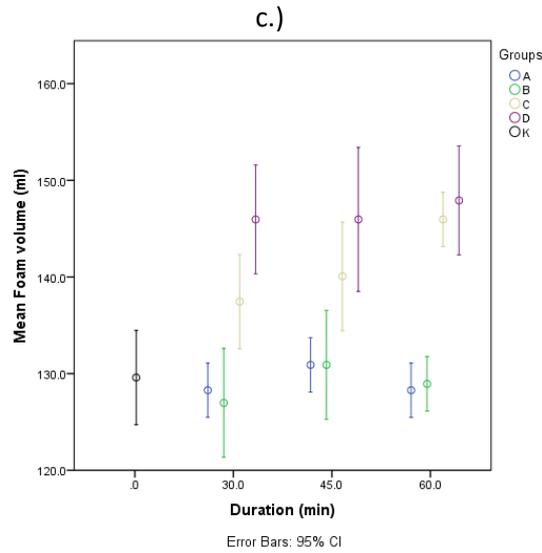
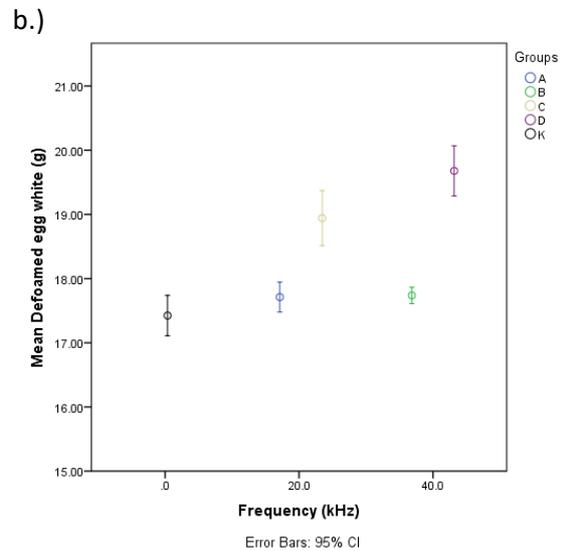
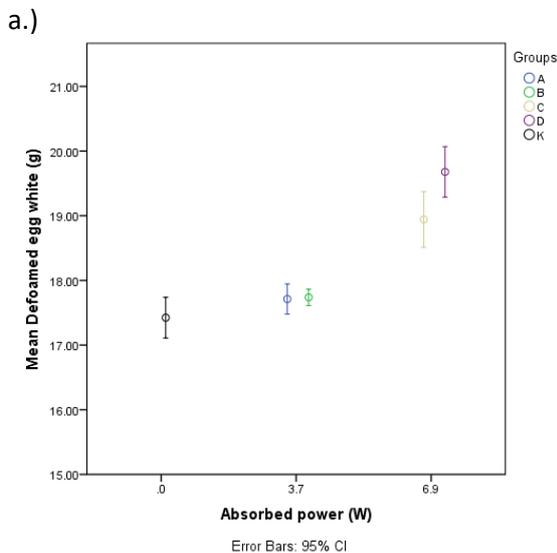


Figure 2.: Foam volume (ml) by absorbed power (a), frequency (b) and duration of the treatment (c). (A - 3.7 W absorbed power and 20 kHz frequency; B - 3.7 W absorbed power and 40 kHz frequency; C - 6.9 W absorbed power and 20 kHz frequency; D - 6.9 W absorbed power and 40 kHz frequency)

In case of foam stability, data showed a decreasing trend due to sonication. Similarly to foam capacity, graphical analysis showed that the frequency and the duration of ultrasound treatment has no effect on this property, but the absorbed power. The Kruskal-Wallis test, however showed that the frequency (0.026) and the duration (0.038) of the sonication treatment, besides the absorbed power (0.000), has significant effect on foam stability.

These results also supports the observation of previously reported studies (Chen et al., 2019; Sheng et al., 2018)

According to Stefanovics (2017) the foaming stability have a linear relationship with the zeta potential of the egg white. We can assume that the sonication decrease the potential difference between the dispersed particles (air) and the dispersion medium (egg white) and this may be the cause of the collapse of the foam structure due to ultrasound treatment.



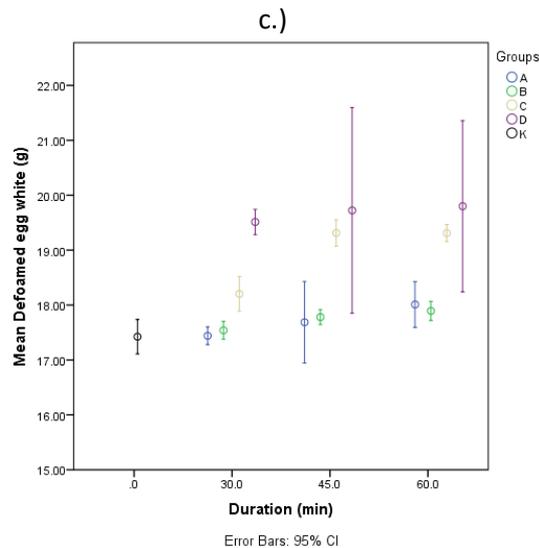


Figure 3.: Defoamed egg white (g) by absorbed power (a), frequency (b) and duration of the treatment (c) (A - 3.7 W absorbed power and 20 kHz frequency; B - 3.7 W absorbed power and 40 kHz frequency; C - 6.9 W absorbed power and 20 kHz frequency; D - 6.9 W absorbed power and 40 kHz frequency)

Conclusion

In this study the effect of ultrasound on the foam properties of egg white was examined. Foam capacity had been enhanced due to the sonication and a 25 % increase was observed in the case of 40 kHz and 300 W treatment with 60 minutes duration compared to control group samples. The foam stability however, decreased that may be caused by the changes in zeta potential of the egg white. In both cases the power of the sonication had the most impact on the changes and the frequency and duration had only affected the foam stability significantly.

The results supplied information about the applicability of ultrasound treatment in foam formation to achieve a better foam structure in the field of food processes.

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