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THE EFFECT OF ULTRASONIC TREATMENT ON SOME FUNCTIONAL PROPERTIES OF EGG WHITE

Efecto del Tratamiento con Ultrasonido sobre Algunas Propiedades Funcionales de la Clara de Huevo

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ABSTRACT

This work studied the effect of treatment with a high frequency ultrasound bath (40 kHz and a power of 80 W.) on the pH, foaming capacity and stability of the foam of the white of hens eggs (sample 1/120 hours post laying and sample 2/24 hours post laying). Exposure time was at varied intervals of 0, 5, 10 and 15 mins at 20°C. The samples were stored in refrigeration at 4°C for 3 days. The comparative study of the data was carried out using variance analysis(ANOVA) and surface response analysis (RSA); where it was found that the pH did not show any significant changes(P<0.05) due to the effect of the treatment and remained during storage. On the other hand, the results showed that treatment with ultrasound for ten minutes increased the foaming capacity by 15.84 and 13.07% in samples 1 and 2, respectively. However, the stability of the foam in both samples was seen to diminish by 13.89 and 8.50%.

Key words: Ultrasound, egg whites, pH, foam, stability.

RESUMEN

En este trabajo se estudió el efecto del tratamiento con un baño de ultrasonido de alta frecuencia (40 kHz y una potencia de 80 W) durante 0; 5; 10 y 15 min. / 20°C, sobre el pH, capacidad espumante y estabilidad de la espuma de la clara de huevos de gallina (muestra 1/ 120 horas pos-postura y muestra 2/ 24 horas post-postura). Las muestras fueron almacenadas en refrigeración a 4°C durante 3 días. El estudio comparativo de los datos se realizó por análisis de varianza (ANOVA) y superficie de respuesta (RSA); donde se encontró que en el pH no presentó cambios significativos (P<0,05) por efecto del tratamiento y de igual manera se mantuvo durante el tiempo de almacenamiento. Por otro lado se observó que el tratamiento con ultrasonido durante 10 mins aumentó la capacidad espumante en un 15,84 y 13,07% en las muestras 1 y 2, respectivamente. Sin embargo, la estabilidad de la espuma de estas muestras se vio disminuida en un 13,89 y 8,50%.

Palabras clave: Ultrasonido, clara de huevo, pH, espuma, estabilidad.

INTRODUCTION

The hens egg (*Gallus domesticus*) is a rich, well-balanced source of essential nutrients for the human diet composed of fatty acids, iron, phosphorus, trace minerals, vitamins A, B6, B12, D, E, and K, plus proteins of high biological value [17, 18]. It is one of the most consumed foods worldwide and is thus an important commodity in international trade. Consequently, the egg industry is a decisive segment of the food market, with a large supply of egg derivatives, such as, dried, frozen and liquid egg-products, being used as ingredients in food formulations or food services.

Protein (albumen) is the major component of egg white (9.7-10.6% w/v). The carbohydrates (which account for 0.5-0.6% w/v of the egg white) exist either in the free form or combined with protein. Glucose (at 0.5%) accounts for about 98% of the total free carbohydrates. The amount of lipid in the egg white is negligible (0.01%) compared with the amount present in the yolk (4%) [15].

Hen's egg white proteins have been extensively utilized as ingredients in food processing, because egg white proteins possess multiple functional properties (*e.g.* foaming, emulsification, heat setting and binding adhesion). These proteins are desirable ingredients in many foods, such as; bakery products,

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meringues, meat products and cookies. Investigations into the physicochemical characteristics of these proteins have aided the elucidation of their structure-function relationships for the benefit of food technologists [2, 12].

High-intensity ultrasound causes the physical disruption of the material to which it is applied and promotes certain chemical reactions. The current uses of high- intensity ultrasound are cleaning, liquid degassing, homogenization and welding. The possible effects of high-intensity ultrasound in food processing include the disruption of microorganisms and enzymes, generation of dispersion and emulsion or promotion of certain chemical reactions; thus high-intensity ultrasound is considered to be a potential unit operation of nonthermal food processing [7].

Response surface analysis (RSA) has been used to optimize processing parameters improving the quality of many products, including the crispness of banana chips [11]. Sumiri gel texture [1], and the enzymatic maceration palm hearts [13]. Using RSA, the processor can determine how various processing conditions, within the constraints of their equipment, will affect a variety of functional properties of their product in a wide range of processing conditions. Using this information, a processor can deliver a higher quality product to the consumer.

The aim of this study was to research the effect of treatment ultrasound bath on the functional properties of egg white using the RSA to predict the behavior of some of these properties based on the duration of the treatment and storage times.

MATERIALS AND METHODS

Hens egg

The hens eggs (sample 1/ 120 hours post laying and sample 2/ 24 hours post laying) were purchased from local supermarkets in Pamplona, Northern Santander, Colombia. The egg was broken and separated by hand. The egg white was separated from the egg yolk and the shell was removed.

Sample preparation

The egg whites (EW) were put into 25 ml cellulose tubes (22 mm in diameter, Talsa, Colombia), packed in polyethylene plastic packs and vacuum sealed (95% vacuum, Encovac 1500, Germany) to avoid any direct contact with the treatment medium.

Treatments

The high frequency ultrasound bath treatment equipment is of 40 kHz and a power of 80 Watts, fed by 120 V ± 10%, of AC to 60 Hz. / 1.91 L. (Branson, 100, USA). The equipment possesses a control, type PID (Proportional Derivative Integral) which allows the working temperature to be controlled to a precision of ± 2°C. The samples were submitted to the high intensity ultrasound treatment to times of 5, 10 and 15 minutes at a temperature of 20°C. The treated samples were stored in refrigeration (4°C) for three days, to avoid alterations in the later analyses; these samples were compared with a control sample which was kept in the same conservation conditions.

Analysis

pH

The pH of the EW was determined by a laboratory pH meter (HI1208, Hanna Instruments, Italy) samples treated with high intensity ultrasound and control samples for three days.

Foaming Property

The foaming property is expressed by foaming power [% Overrum]. EW foam was prepared by beating EW using a mixer equipped with double whipping beaters (Samurai, Colombia). 100 ml. of EW was added into a bowl and beaten for 5 mins at maximum velocity which was specified as an “egg whipping speed”. Then the foam produced was gently placed in the weighing boats (25 mL), avoiding the formation of air pockets, and any excess foam was scraped off the top of the weighing boat using a spatula. The efficiency of foam production was expressed in terms of % Overrun [8, 14]. This property was analyzed over a time period of three days.

$$\%Overrum = \frac{(wt\ 25\ ml\ EW) - (wt\ 25\ ml\ foam)}{(wt\ 25\ ml\ foam)} * 100$$

Foam stability

Foam stability was determined by monitoring the drainage of foam at ambient temperatures. The foam was put into a 5 ml pipette with a tip diameter of 5.0 mm and the weight of the drained foam was measured. The foam stability was calculated by the ratio of the remaining foam after 20 mins. Of drainage time [8, 14]. This property was analyzed over three days.

$$\%\ stability = \frac{(wt\ foam) - (wt\ drained\ foam)}{wt\ foam} * 100$$

Each measurement for the calculation of % Overrun and% Stability was repeated three times and the average values were reported.

Statistical Analysis

The EW experiments were performed in triplicate and the resulting data was analyzed using the General Linear Models Procedure of Statistics Analysis System (SAS, USA). The differences between means were compared using Studen-Newman-Keuls’s multiple range test with a significance of P<0.05. The response surface analysis (RSA) model, included storage time, treatment intensity and foam capacity and stability data. The RSA model may include quadratic effects and any or all interactions of the treatment effects and storage time.

RESULTS AND DISCUSSION

pH

TABLE I shows when the EW is treated by ultrasound bath; it did not show any significant changes (P<0.05) for three days, and maintained its pH. This was possibly due to the fact that the redistribution of charged groups is reflected by changes in velocity of ultrasound. In order to interpret such velocity measurements numerous studies of simple molecules are required in order to clarify the role of the various groups with the aim of studying the possible mutual interaction between such groups on the surface of the macromolecule [16].

Foaming capacity

The FIG. 1 shows the effect of time in the treatment of the foaming capacity. All the samples treated with a high frequency ultrasound bath treatment increased their foaming capacity compared to the non-treated samples.

As a result, the samples treated on the first day for 15 mins to see if the foaming capacity reduced, appeared to be statistically different (P<0.05) compared with those treated for 5 and 10 mins; but this foaming capacity was recovered in the following days.

In fresh EW (sample 2) the increase of the foaming capacity is statistically different (P<0.05) with each treatment. However, the sample 1 didn't present the same tendency.

These results may be explained according to studies carried out by Guzey *et al*. [9] which show that aqueous Bovine Serum Albumin (BSA) solutions ($3x10^{-4}$ M) treated with high-intensity ultrasound at an intensity of 20 Wcm^2 for up to 45 minutes resulted in the formation of a structural intermediate of the native BSA molecule. These authors found that by increasing sonification time the helical content of BSA increased from 61.1 to 74.5%, this indicates an increased degree of order in the protein molecule changes. In the same way, it showed that aqueous BSA increased the rate of absorption and surface hydrophobicity without any decrease in the helical content. This suggests that protein molecules might be undergoing a molecular orientation due to sonification. Possibly, ultrasound treatment exposes some of the native hydrophobic groups in the protein molecule, which would increase the surface hydrophobicity of the molecule and thus, the absorption rate at the air-water interface. Another explanation is that protein monomers after sonification might be forming dimers through their exposed free thiol groups. Dimerization of BSA after ultrasound treatment was also suggested by Hess and co-workers in 1964 as a result of ultrasound treatment with BSA [10]. They found an increase in the molecular weight from BSA from 66 kDa to 110 kDa using light scattering.

Response Surface Analysis (RSA)

The application of RSA when studying the foaming capacity shows an increase in both the storage time and ultrasound treatment time, which elevated the foaming capacity. This tendency is independent of both fresh EW and old EW.

The response superface analysis showed for sample 1 the FIG. 2 (equation No. 1). In this model the maximum percentage predicted with a significant (P< 0.05) increase in the foaming capacity on the overrum in the EW was at 10 mins in 15.84% on day three, compared to the non treated sample.

TABLE I

EFFECTS OF ULTRASONIC TREATMENT AND STORAGE TIMES ON pH. SAMPLES 1 AND 2 / EFECTOS DEL TRATAMIENTO POR ULTRASONIDO EN EL TIEMPO DE ALMACENAMIENTO DEL PH. MUESTRA 1 Y 2.

Sample 1			
Treatment	pH		
	Day 1	Day 2	Day 3
0	8,0±0,1	8,3±0,1	8,5±0,1
5	8,0±0,1	8,0±0,2	8,1±0,1
10	8,2±0,1	8,3±0,1	8,3±0,2
15	8,0±0,2	8,3±0,1	8,3±0,1
Sample 2			
Treatment	pH		
	Day 1	Day 2	Day 3
0	7,5±0,1	7,3±0,1	8,0±0,1
5	7,7±0,1	7,7±0,1	7,8±0,2
10	7,8±0,1	7,8±0,2	7,8±0,1
15	7,9±0,2	7,9±0,1	7,9±0,2

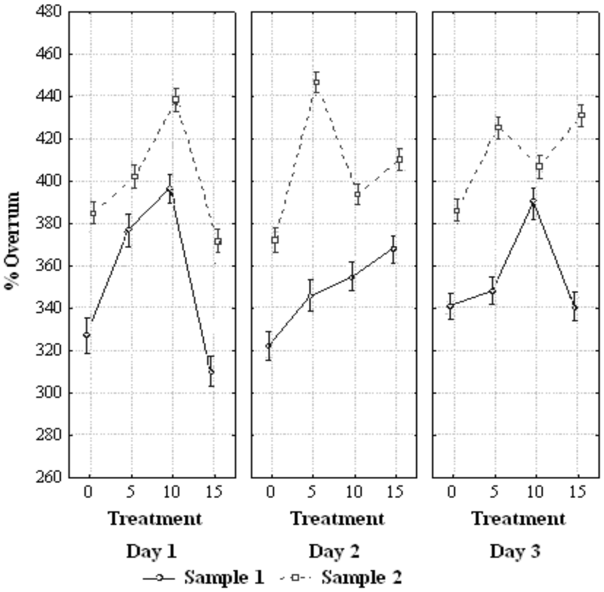

FIGURE 1. EFFECTS OF ULTRASONIC TREATMENT AND STORAGE TIMES ON FOAMING CAPACITY/ EFECTOS DEL TRATAMIENTO POR ULTRASONIDO EN EL TIEMPO DE ALMACENAMIENTO Y LA CAPACIDAD ESPUMANTE.

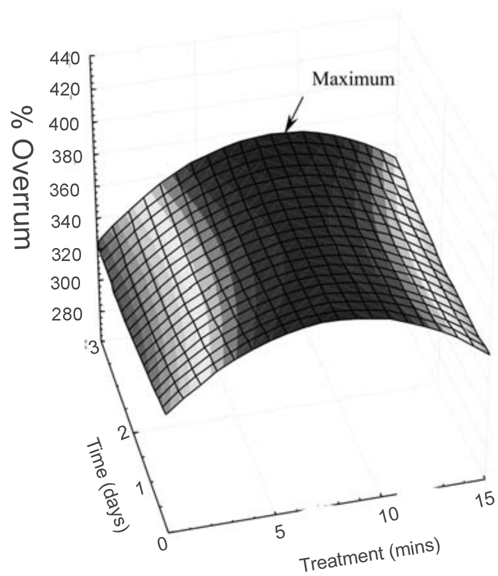

FIGURE 2. RESPONSE SURFACE ANALYSIS OF THE FOAMING CAPACITY. SAMPLE 1/ ANALISIS POR SUPERFICIE DE RESPUESTA DE LA CAPACIDAD ESPUMANTE. MUESTRA 1.

Equation Nº 1:

$$\%\ Overrum = 356.1889 + 9.7044X - 28.7167Y - 0.6778X^2 + 0.74XY + 6.0833Y^2$$

When X= treatment and Y= time

The FIG. 3 shows the response surface model for sample 2. It can be seen that on the third day the samples treated for ten minutes present overrum of 13.07% greater than the

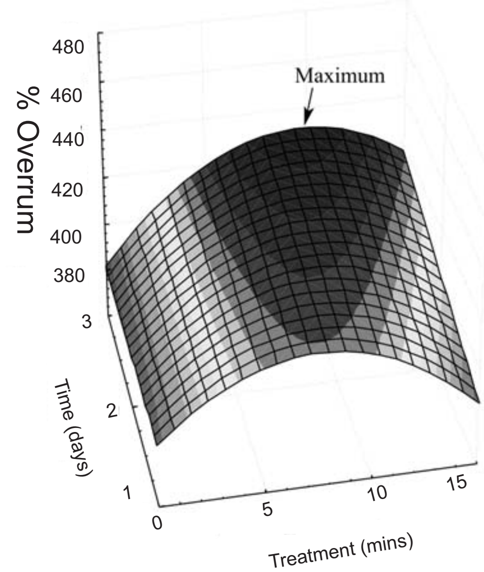

FIGURE 3. RESPONSE SURFACE ANALYSIS OF THE FOAMING CAPACITY. SAMPLE 2/ ANALISIS POR SUPERFICIE DE RESPUESTA DE LA CAPACIDAD ESPUMANTE. MUESTRA 2.

non-treated samples. This behaviour can be predicted by equation Nº 2 and this value is significantly lower ($P<0.05$) than in sample 1. Treated under the same conditions.

Equation Nº 2:

$$\%\ Overrum = 388.4722 + 6.7278X - 2.7667Y - 0.5278X^2 + 1.18XY + 0.1667Y^2$$

Foaming stability

The foaming stability in fresh EW is diminished by ultrasound treatment but is maintained over time for both fresh EW and old EW. Foam consists of a condensed continuous phase (liquid as in whipped cream and ice cream or solid as in bread) and a gaseous dispersed phase [5, 6]. Globular proteins are widely used in the food industry to facilitate the formation and stabilization of foam [3].

The quality attributed to foam, such as, appearance, texture and stability, are determined by the size and concentration of the gas bubbles distributed throughout the continuous phase [3]. Protein molecules rapidly absorb the surfaces of freshly formed bubbles, reducing interfacial tension. Once the surface of the gas bubbles are absorbed, protein molecules protect them from merging with each other by generating repulsive forces between the bubbles, e.g., electrostatic, steric and hydration repulsion. Many globular proteins undergo conformation changes after they have absorbed the surface of a bubble promoting the formation of intermolecular protein-protein interactions; often occurring through hydrophobic and disulfide bonds. As a result of these protein interactions, the membrane surrounding the gas bubbles becomes highly viscoelastic and resistant to deformation [4].

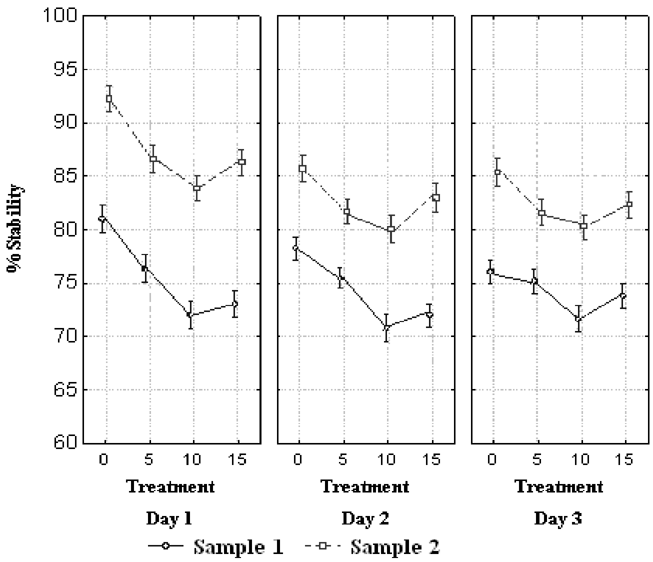

FIGURE 4. EFFECTS OF ULTRASONIC TREATMENT AND STORAGE TIME ON THE FOAMING STABILITY/ EFECTOS DEL TRATAMIENTO POR ULTRASONIDO EN EL TIEMPO DE ALMACENAMIENTO Y LA ESTABILIDAD DE LA ESPUMA.

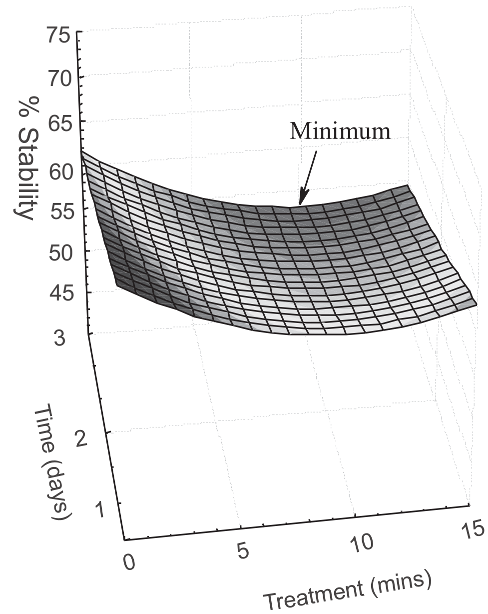

FIGURE 5. RESPONSE SURFACE ANALYSIS OF THE FOAMING STABILITY. SAMPLE 1/ ANÁLISIS POR SUPERFICIE DE RESPUESTA EN LA ESTABILIDAD DE LA ESPUMA. MUESTRA 1.

Response Surface Analysis

The surface response analysis showed that foaming stability is dependent on the age of the hen's egg. The foaming is more stable when hens eggs are fresh.

The response surface model of sample 1 and 2 is shown in (FIG. 5 and 6). The foaming stability for sample 1 is less than the samples treated for 10 minutes and in all treatments diminishes with time. In sample 2 the foaming stability also diminishes with the treatment but to a lower proportion than sample 1. The behaviour of these samples can be predicted by equations 3 and 4, respectively.

Equation Nº 3:

$$\%\boldsymbol{Stability} = \mathbf{73{,}1833 - 1.4633X - 5.35Y + 0.076X^2 - 0.0533XY + 0.5Y^2}$$

Equation Nº 4:

$$\%\boldsymbol{Stability} = \mathbf{93.7833 - 1.81X - 5.95Y + 0.1033X^2 + 0.0267XY + 0.6667Y^2}$$

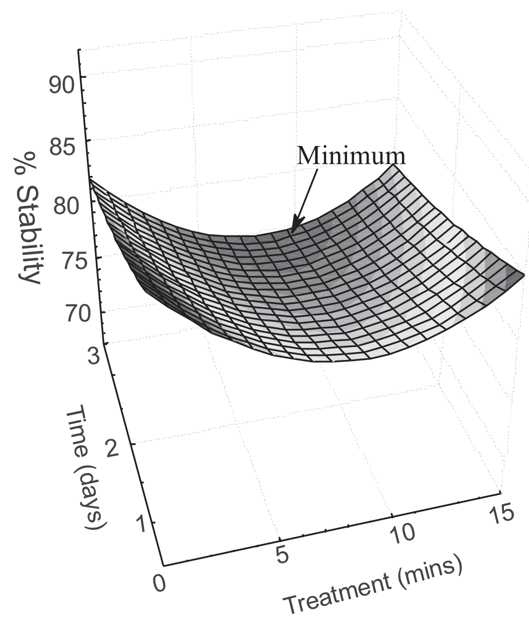

FIGURE 6 RESPONSE SURFACE ANALYSIS OF THE FOAMING STABILITY. SAMPLE 2/ ANÁLISIS POR SUPERFICIE DE RESPUESTA EN LA ESTABILIDAD DE LA ESPUMA. MUESTRA 2.

CONCLUSIONS

Treatment with ultrasound increases the foaming capacity of both fresh and old egg white, although this increase is not proportional to the treatment time but increases during storage. The highest increase was found in samples treated for 10 minutes and stored for three days. However, the stability of the foam formed under these conditions in the treated samples showed less stability.

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