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Effects of ultraviolet and ultrasound treatments applied before the storage period on egg quality characteristics

Ozlem Varol Avcilar[1] • Ebrunur Yilmaz[2]

[1] Department of Nutrition and Dietetics, Faculty of Health Sciences, Osmaniye Korkut Ata University, Osmaniye, Türkiye
[2] Institute of Graduate Education, Hasan Kalyoncu University, Gaziantep, Türkiye

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Correspondence: Ozlem Varol Avcilar
E-mail: ovarolavcilar@osmaniye.edu.tr

Abstract
Egg is an important source of animal protein with its nutritional substances. These nutritional substances and the quality characteristics of the egg are affected by the physicochemical changes with the effect of various factors during storage. Different studies have been carried out to preserve the quality values of eggs during storage. In these studies, Ultraviolet applications were mostly used for the sanitation of eggs, while Ultraviolet applications were made to determine the internal quality of the egg without breaking the shell. The aim of this study is to determine the effects of ultraviolet and ultrasound applications applied before storage to the quality characteristics of the eggs collected from laying hens. Eggs collected in the morning were subjected to ultraviolet and ultrasound treatments before storage and stored for 28 days in an environment of 20°C and approximately 60% humidity. The applied treatments made a significant difference between the groups in egg shell thickness ($p < 0.01$), albumen weight ($p < 0.01$) and yolk dry matter value ($p < 0.01$). Storage time, on the other hand, made significant changes between groups on weight loss, shell breaking strength, albumen and yolk quality characteristics. The interaction of applications and storage time was statistically significantly in weight and height of albumen, Haugh unit and dry matter of yolk. As a result, the effects of processes such as ultraviolet and ultrasound applied to eggs, especially on egg shell thickness, reveal the importance of application time and application amount in such studies.

Keywords: Egg, Quality changes, Storage time, Ultrasound, Ultraviolet

INTRODUCTION

The laying hen industry is invaluable for producing the cheapest and best quality protein source. Egg is among the indispensables of low-calorie diets with its antioxidant properties and some essential amino acids. It also strengthens the immune system and protects against diseases (Benede and Molina, 2020; Puglisi and Fernandez, 2022).

When the egg is first taken from the chicken, it cannot carry the characteristics it has until consumption. In particular, the factors (care and feeding conditions, oviposition time, genetic structure, age, temperature, huminity, storage time etc.) that cause changes in internal and external quality can show their effects both during and after the production stage and cause changes until the consumption stage. Extending the shelf life of the egg by maintaining its quality properties increases the value of this animal food (Onbaşılar and Avcılar, 2011; Lou et al., 2020; Tabib et al., 2021; Sarıyel et al., 2022).

During storage, changes in egg internal quality can be observed as a result of increase in albumin pH, thinning of albumin thickness, liquefaction and evaporation of water. Due to the increase in pH, carbon dioxide loss occurs from the shell (Kumari et al., 2020).

The long storage period of the egg may cause the breakdown of fat and proteins in its structure, and the release of ammonia and sulfur components. This results in the formation of undesirable taste and odor (Brodacki et al., 2019). The less the processes to be applied to the egg change the internal and external quality during the storage period, the better the quality properties for both the consumer and the products to be processed will be preserved, as deterioration will be prevented.

In the researches, various methods were applied after the eggs were collected in order to preserve the quality characteristics of the eggs and to extend the shelf life. Some of these methods are; coating of eggs with various substances (zein (Caner and Yüceer, 2015), soy proteins (Xie et al., 2002), mineral oils (Jirangrad et al., 2010), chitosan (Bhale et al., 2003)) and ultraviolet applications (UV) (Mehdizadeh et al., 2015; Melo et al. 2019; Cassar et al. 2021).

It is mostly used in egg sanitation processes such as ultraviolet applications other sanitation aids (chlorine, hydrogen peroxide, quaternal ammonium cation, etc.) in the egg industry (Al-Ajeeli et al., 2016).

Turtoi and Borda (2014) in their study on the decontamination of eggshell by the application of ultraviolet light, stated that compared to chemical disinfectants, clean and recently contamination eggshells resulted as significant reduction in the bacterial population. In a study in which UV applications used in chicken breeding were compiled, it was reported that ultraviolet-A light had positive effects on reducing fear and stress responses, but in some studies, it significantly increased feather pecking due to age in the production phase (Rana and Campell, 2021).

Ultrasound procedures applied to the egg have been studies on determining and improving the internal quality of the egg. In a study, ultrasonic waves (frequency of 150 kHz) were used to determine the internal quality of the egg without damaging the egg shell, and it was stated that it could be used to provide information about the freshness of eggs stored for 3 weeks (Aboonajmi et al., 2010).

According to Sert et al. (2011) in their studies where they applied 35 kHz ultrasound to eggs at different times (5, 15, 30 min); detected high specific weight, shell strength, albumen height, and Haugh unit in eggs that were subjected to ultrasound. It was stated that egg quality was significantly improved by ultrasonic treatment ($p < 0.01$). Caner and Yüceer (2014) reported that the application of 300 W and 400 W ultrasound improved the internal quality of fresh eggs during storage. It has been stated that it affects the shell strength negatively. Yüceer end Caner (2020) used different methods (ozone, ultrasound and coating with shellac and lysozyme-chitosan) to preserve the freshness of eggs during storage. It has been stated that ultrasound application has a positive effect on the preservation of the internal quality of the egg after storage.

In this study, it was aimed to determine the effects of ultraviolet and ultrasound treatments applied to before storage on egg external and internal quality characteristics at the same temperature and humidity levels during storage.

MATERIALS AND METHODS

Materials

In the research, eggs were obtained from a private enterprise in December 2021. A total of 300 egg were collected from 34 weeks old Nick-Brown layer hybrids. Eggs were collected in the morning (10:00-11:00). While collection process, the poultry house temperature was measured as 22 °C and the humidity is 60%. It was known that animals were given standard layer feed during the laying period. Precaution was taken to ensure that the eggs were not broken, dirty and different size. The eggs were brought to the laboratory where they would be stored for 28 days. Collected eggs were weighed (Pioneer Ohaus, USA) and divided into three groups (control (non-treatment), ultraviolet treated, ultrasound applied). Eggs were kept at 22 °C and 60% humidity until the last day of storage. To determine the quality characteristics of the eggs, 10 eggs from each group were examined on the 1st, 7th, 14th, 21st and 28th days. During storage, egg weight, egg weight loss, shell breaking strength, shell thickness, shell weight, albumen measurements (length, width, height, ph), yolk measurements (diameter, weight, height, ph), albumen and yolk index values, and Haugh unit value has been determined.

Applications

UV-C Irradiation application: For this process, the eggs were placed in a closed system UV device (BLX-254, France) with a metal flat tray of 10 eggs at a time. Eggs were exposed to UV lamps (5 x 8 W, 254 nm tube) for 3 minutes. UV area was 20 x 50 cm^2. Eggs were stored in the same environment with other groups throughout store time.

Ultrasonic Application: Ultrasonic water bath (Ultrasound HD Selecta, Spain) was used for this process. Each time 8 eggs were placed in the basket apparatus of the device and immersed in distilled water at 24°C, and ultrasound (120 W 10 min) was applied (modification Yuceer and Caner, (2020)). Afterwards, the eggs were dried and stored in the same environment as the other groups.

Egg Quality Analysis

Eggshell breaking strength;

10 eggs from each group were used to determine

the breaking strength of the eggshell. The CT3 Texture Analyzer (BrookfieldEngineering Labs Inc., Middleborough, MA, USA) device was used to measure this. For analysis, the eggs were conveniently placed under the piercing apparatus of the device. Force was applied to make hole in the top and bottom eggs parts. Probe model TA39. Test speed was 5mm/s.

The internal and external egg quality;

In order to determine the internal and external quality characteristics of the eggs, firstly, it was broken on a flat surface. Egg shell thickness was measured from 3 different points (top, bottom and equatorial) and averaged. Some properties of albumen (length, width, height) and yolk (diameter, weight and height) were measured with an electronic digital vernier caliper (Insize, 1183-150A, Chine). These values were used to calculate the yolk index [(yolk height / yolk diameter) x100], albumen index [(albumen height / (average of albumen length and albumen width)/2 x 100] and Haugh unit (HU) value (Haugh unit (HU); [100 x log (H + 7.57 - 1.7W0.37), where H is albumen height and W is egg weight] (Yalçın et al. 2014).

In addition, after the albumen and yolk were brought to a homogeneous form, the dry matter values were calculated by using a digital refractometer (A. Krüss Optronic, Germany). pH measurements (Thermo Scientific Orion 2 Star, Singapore) were also made on specimens.

Statistical analysis

Distribution, the homogenity of variance of data, was analysed. Two-way ANOVA determined the effects of applications and storage period on egg properties. Tukey test was used to check the significance of the difference between the groups. The statistical analysis was performed by means of the SPSS Statistics 23.0 package software. $p < 0.05$ was taken into account statistically (Dawson and Trapp, 2001).

RESULTS

In Table 1, egg weight losses and shell quality characteristics of the groups are given. While there was no difference in weight loss among UV, Ultrasound and control groups, it was observed that the weight loss increased as the storage time increased ($p < 0.001$). The highest weight loss was determined as 2.60 g on the 28th day. Although the eggshell breaking strength was determined as the highest value (4.056 kg/cm^3) in the upper part of eggs the ultrasound group, as there is no statistical difference was observed between the groups. There was no difference between the eggshell breaking strength in the upper part of eggs the groups in the storage time. While there was no difference between the treatment groups in the breaking force values applied to the lower pole of the eggs, it was determined that 3.539 km/cm^2 on the 1st day, 3.631 kg/cm^2 on the 21st day and 3.152 kg/cm^2 on the 28th day during the storage period. According to these values it was concluded that this difference was statistically significant ($p < 0.05$).

It was determined that the highest shell thickness was in the control group (0.48 mm) the lowest shell thickness was in the ultraviolet applied group (0.44 mm), and this difference was significant ($p < 0.01$). Although the highest shell thickness was determined on the 21st day, the storage time did not make a significant difference in terms of this value. Shell weight was a value that was not affected by both the application processes and the storage time ($p > 0.05$).

Table 1. Effects of UV, Ultrasond and storage period on egg weight loss and shell quality of eggs.

Treatments	Storage period (day)	Initial egg weight (g)	Weight loss (g)	Breaking strength (top) (kg/cm^2)	Breaking strength (bottom) (kg/cm^2)	Shell thickness (mm)	Shell weight (g)
UV		61,25	1,41	4,031	3,494	0,44^A	7,37
Ultrasond		61,64	1,41	4,056	3,395	0,45^A	7,49
Control		59,47	1,41	4,027	3,340	0,48^B	7,27
	1		0,15^a	3,926	3,539^{bc}	0,44	7,39
	7		0,83^b	4,183	3,419^{abc}	0,46	7,58
	14		1,45^c	3,953	3,308^{abc}	0,46	7,29
	21		2,04^d	4,286	3,631^c	0,47	7,37
	28		2,60^e	3,844	3,152^a	0,45	7,25
					P		
Treatment			NS	NS	NS	**	NS
Storage period			***	NS	*	NS	NS
Interaction			NS	NS	NS	NS	NS

n=10. Values were shown as mean. ^{a,b,c,d,e}: The difference among means carrying different letters in the same column was statistically significant ($p < 0.05$). ^{A,B}: With in treatments grups, values with the same superscript do not significantly differ ($p < 0.05$).
NS: $p > 0.05$; *: $p < 0.05$; **: $p < 0,01$; ***: $p < 0,001$

Albumen weight was determined as the highest in the ultrasound group (37.22 g) and the lowest in the control group (35.29 g) in the treated eggs (p <0.01). During the storage period, albumen weight decreased gradually (p <0.001) and it was measured as 38.70 g on the 1st day and 34.74 g on the 28th day (Table 2). Albumen pH values were similar between the treated groups. It was observed that this value increased gradually during the storage period and reached the highest value on the 28th day (9.54) (p <0.001). While no difference was observed between the treated groups in terms of albumen height values (p >0.05), it was determined that the highest numerical value was in the group treated with ultraviolet (5.46 mm). Moreover, it was found that as the storage time increased, the albumen height value decreased statistically significantly (p <0.001).

While there was no difference in albumen length and width measurements in the treated egg groups (p >0.05), it was determined that these values increased significantly as the storage time extended (p <0.001). There was no difference in Haugh unit and albumen dry matter values in the treated egg groups. It was determined that the haugh unit value decreased (p <0.001) and albumen dry matter value increased (p <0.001) as the storage time increased.

When the egg albumen quality values were examined, it was determined that there was a statistically significant interaction between the processes applied to the eggs and the storage time (p <0.05), this interaction in the albumen weight, albumen height and Haugh unit respectfully.

In egg yolk quality values, it was determined that the treatments applied to the eggs did not generally differ between the groups (Table 3). It was determined that only the difference in egg dry matter value was significant (p <0.01) and this difference was due to the control group (46.18%). As the storage time increased, the egg yolk; diameter, weight and pH value increased (p <0.001); it was determined that the yolk height (p <0.05), yolk index (p <0.001) and dry matter amount (p <0.001) decreased.

DISCUSSION

Egg, which contains many essential amino acids in its structure and carries valuable elements for the emergence of a living thing, takes its place as an ingredient in the preparation of consumer products and most foods prepared in different ways in many countries without any limitation.

The nutrients and quality characteristics of the egg may change during the storage of the egg. The temperature, humidity and storage time of the environment during storage are among the effective factors in the formation of these changes. In order to reduce the negative effects of these factors, studies on the effects of processes that do not require heat (Sert et al. (2011); Caner and Yüceer (2014); Mehdizadeh et al., 2015; Melo et al. 2019; Cassar et al. 2021).

In the study, it was determined that the ultrasound and ultraviolet applications applied to the eggs did not make any difference between the groups on egg weight loss, shell breaking strength and shell weight. It was determined that only shell thickness was lower in the treated groups compared to the control.

It can be thought that the thickness of the shell will decrease because the processes applied to the egg damage the shell surface (cuticle layer). However, it is

Table 2. Effects of UV, Ultrasond and storage period on albumen quality and Haugh unit of eggs.

Treatments	Storage period (day)	Alb. weight (g)	Alb. pH	Alb. height (mm)	Alb. length (mm)	Alb. width (mm)	Alb. index	Haugh unit	Alb. dry matter (%)
UV		$36{,}83^{B}$	9,31	5,46	112,42	93,12	5,86	70,65	15,55
Ultrasond		$37{,}22^{B}$	9,32	5,28	115	92,57	5,5	67,97	15,5
Control		$35{,}29^{A}$	9,31	5,04	110,64	89,01	5,54	68,78	15,65
	1	$38{,}70^{c}$	$8{,}84^{a}$	$7{,}76^{d}$	$82{,}86^{a}$	$69{,}27^{a}$	$9{,}96^{c}$	$88{,}55^{d}$	$14{,}84^{a}$
	7	$37{,}66^{b}$	$9{,}42^{b}$	$5{,}68^{c}$	$109{,}59^{b}$	$81{,}08^{b}$	$6{,}03^{b}$	$73{,}42^{c}$	$15{,}61^{b}$
	14	$35{,}70^{a}$	$9{,}29^{c}$	$4{,}86^{b}$	$119{,}86^{c}$	$95{,}81^{c}$	$4{,}57^{a}$	$67{,}12^{b}$	$15{,}47^{bc}$
	21	$35{,}45^{a}$	$9{,}49^{bd}$	$4{,}07^{a}$	$124{,}72^{d}$	$107{,}70^{d}$	$3{,}60^{a}$	$58{,}80^{a}$	$15{,}80^{b}$
	28	$34{,}74^{a}$	$9{,}54^{d}$	-	-	-	-	-	$16{,}11^{bd}$
					P				
Treatment		**	NS	NS	NS	NS	NS	NS	NS
Storage period		***	***	***	***	***	***	***	***
Interaction		*	NS	*	NS	NS	NS	*	NS

n=10. Values were shown as mean. , a, b, c, d: The difference among means carrying different letters in the same column was statistically significant (p <0.05). A, B:With in treatments grups, values with the same superscript do not significantly differ (p<0.05). NS: p >0.05; *: p<0.05; **: p<0,01; ***: p<0,001

Table 3. Effects of UV, Ultrasond and storage period on yolk quality of eggs.

Treatments	Storage period (day)	Yolk weight (g)	Yolk pH	Yolk height (mm)	Yolk diameter (mm)	Yolk index	Yolk dry matter (%)
UV		15,44	6,29	14,61	41,35	35,60	46,78^{B}
Ultrasond		15,58	6,31	14,49	41,42	35,72	46,76^{B}
Control		15,41	6,30	14,24	41,88	34,40	46,18^{A}
	1	14,47^{a}	6,12^{a}	14,60^{ab}	38,47^{a}	38,42^{b}	48,53^{c}
	7	15,29^{a}	6,17^{a}	15,30^{b}	39,62^{a}	38,66^{b}	46,92^{b}
	14	15,54^{b}	6,31^{b}	14,51^{ab}	42,21^{b}	34,50^{a}	46,43^{b}
	21	16,11^{b}	6,42^{c}	13,95^{a}	43,78^{c}	32,79^{a}	45,41^{a}
	28	15,96^{b}	6,47^{c}	13,88^{a}	43,68^{bc}	31,82^{a}	45,59^{a}
					P		
Treatment		NS	NS	NS	NS	NS	**
Storage period		***	***	*	***	***	***
Interaction		NS	NS	NS	NS	NS	**

n=10. Values were shown as mean. [a, b, c]: The difference among means carrying different letters in the same column was statistically significant (p <0.05). [A, B]:With in treatments grups, values with the same superscript do not significantly differ (p<0.05).
NS: p >0.05; *: p<0.05; **: p<0,01; ***: p<0,001

noteworthy that this thinning is not reflected in the shell breaking strength. Yan et al., (2014) stated that there is a correlation between eggshell thickness and breaking strength, and eggs with thin and homogeneous eggshells are stronger.

In a study done, it was stated that the application of ultrasound to the egg increased egg weight loss, unlike this study (Sert, 2011). In another study, it was stated that the egg shell strength was negatively affected in different levels of ultrasound application (300-400W) (Caner and Yuceer, 2014).

In this study, it was determined that the egg weight loss increased as the egg storage period increased. Weight loss occurs due to the loss of water and carbon dioxide in the albumen during storage (Yimenu et al., 2017). At the same time, it was determined that the breaking strength at the wide pole of the egg decreased due to the prolongation of the storage period. This may be caused by thinning of the shell surface, depending on the prolonged storage period.

Albumen properties are among the important factors in determining the internal quality. Albumen weight was determined to be the highest in the ultrasound group. In contrast, Albumen weight was determined as lowest in the control group. Yüceer end Caner, (2020) used different methods (ozone, ultrasound and coating with shellac and lysozyme–chitosan) to preserve the freshness of eggs during storage, and it was stated that ultrasound application positively affects the preservation of the internal quality of the egg after storage.

In the study, the albumen weight, height, index and Haugh unit values decreased as a result of the physico-chemical changes occurring in the internal structure of the egg as the storage period was prolonged. Increases in albumen length, width, pH and dry matter values were found similar to other studies. These changes may develop due to reasons such as prolongation of the storage period, loss of water and CO_2, and increase in the pH of the albumen (Kopacz and Drazbo 2018; Kumari et al., 2020; Sheng et al., 2020).

Many properties of the yolk, which was a valuable part of the nutritional diversity of the egg, were not affected by the ultrasound and ultraviolet treatments applied in this study, and had similar values with the control. It was determined that only the differences in the amount of yolk dry matter were significant. Depending on the processes applied, changes in the egg internal quality and its effect on the transitions in the vitelline membrane may be effective these results (Kumarin et al., 2020).

It was determined that the storage period was effective on all yolk quality characteristics. The increase in vitelline membrane permeability with time may have caused changes in yolk quality characteristics. Similar results have been reported in other studies depending on the time storage period (Drabik et al., 2021; Tabib et al., 2021).

The interaction between the processing applied to the eggs and the storage period was statistically significant. This interaction was determined in the albumen weight, height, Haugh unit and the yolk dry matter value respectufuly. The albumen weight of the ultraviolet and ultrasound treatments was higher than the control group. Processes can reduce water loss by affecting the pores in the shell, and as a result, less weight loss may occur during storage.

CONCLUSION

As a result, in this study, it was determined that ultrasound and ultraviolet treatments applied to eggs are important in terms of some properties on both albumen and yolk quality values. The application time of the methods and the amount of application may be effective in the formation of these effects. Prolongation of the egg storage period caused changes in the internal egg quality. It is noteworthy that the interaction of both the processes applied to the egg and the storage time is mostly observed in the albumen values. Considering this interactions, future studies may bring up the use of these two methods in different ways.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

Study conception, design, data analysis, and writing of the manuscript were performed by Ö. Varol Avcılar. Material preparation and data collection were Ö. Varol Avcılar and E. Yılmaz. All the authors read and approved the final manuscript. All the authors verify that the Text, and Tables are original and that they have not been published before.

Ethical approval

Ethics committee approval is not required.

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Data availability

All data generated or analysed during this study are in cluded in this published article.

Consent for publication

Not applicable.

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