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A new original method for table eggs pasteurization using low levels of red laser irradiation

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Abstract

The objective of this original study was to determine the shelf life of table eggs using low levels of red laser irradiation as a new method of pasteurization through determination some quality, chemical and microbial characteristics of the eggs during refrigerator storage. This experiments were performed at the Laboratory of Laser, College of Engineering, University of Al-Nahrain using fresh eggs were collected from 31 weeks of age hens of commercial farms. Eggs were distributed into five treatments groups (40 eggs/ treatment), the first was control group (without irradiation), the other were distributed to the four irradiation levels which were 0.4, 0.8, 1.2^2 and 1.6mW/cm^2 respectively for 14sec duration of irradiation, then all eggs were stored in refrigerator for 1, 7, 14 and 28 days. The data obtained revealed that all treatments of red laser irradiation expanded shelf life of table eggs compared with control group, 1.2 and 1.6mW/cm^2 for 14sec duration of irradiation were the best for reduction the deterioration of egg quality parameters, chemical composition, also reduced the studied microbial counts groups during refrigerator storage to 28 days.

Keywords: Table eggs, Pasteurization, Red laser, Irradiation, Shelf life.

Introduction

Chicken eggs are very good nutritional, economical and easy to prepare food, it provide a well balanced source of nutrients for man of all ages (Matt *et al.,* 2009). Moreover, eggs have high quality proteins, low caloric value and ease of digestibility (Burley and Vadehra, 1989; Bufano, 2000). Eggs like milk and meat are perishable food which need quick cooling and refrigerator treatments during storage for keeping good quality (Stadelman and Cotterill, 1995). Storage revealed significant effect on loss percentage in egg weight, albumen and yolk pH (Bufano, 2000). Naturally occurring *Coliforms*, *Psychrophilic* bacteria, *Staphylococci*, *Fungi* (Yeast and Moulds) on the egg shell surface and in the egg contents will increased during storage, eggs remained fairly acceptable sensorial up to 10 days of storage at ambient conditions (Imai *et al.,* 1986; Jones, 2007).

Recently, there is no efficient and satisfactory technology available for pasteurizing shell eggs. The current technology uses batch hot water immersion or moistened hot air or both combined, which requires a very long time ranging in hours to complete and are not really energy efficient due to the poor thermal properties of the shell and the shell membrane though they are not really the focus of pasteurization and as a result they are not cost effective (Mermelstein, 2001). Also these treatments affect the functional properties of the egg components. Proteins are highly heat sensitive components of the egg. The functional properties like whipability, foamability, foam stability etc. which make the eggs an inevitable ingredient of various food products are severely affected by high temperatures. Also experimentally it is found that the egg yolk needs to be heated to a higher temperature than the albumen. This is possible by conventional heating only if the yolk and albumen are separated (the shell is broken). The existing method of pasteurizing the shell eggs results in overheating of the albumen and partially cooked eggs along the shell membrane (Hank *et al.* 2001; Sivaramakrishnan, 2007).

The term laser stands for Light Amplification by Stimulated Emission of Radiation. A laser is a device that emits a special form of light. The light is special because it consists of light waves of a single wavelength, in which all the waves reinforce one another. Low levels of red laser irradiation for fertilized poultry eggs has been reported to increase hatchability rate and improve chicks survival

(Bessarabov *et al*., 1986; Popov *et al*., 1984; Yakimenko *et al.,* 2002).

The aim of this original study was to determine the shelf life of table eggs using low levels of red laser irradiation as a new method of pasteurization through determination some quality, chemical and microbial characteristics of the eggs.

Materials and Methods

This experiment was carried out at the Laboratory of Laser, Department of Laser, College of Engineering, University of Al-Nahrain. Fresh eggs were collected from 31 weeks of age hens of commercial farms. The experimental eggs were irradiated prior to refrigerator storage. Laser light of < 5 W power and a wave length of 650 nm (red light) was generated using Red Laser Wave 084322 (Beijing Laser Wave Optoelectronic Technology Co., Ltd. China).

In our research eggs were distributed into five treatments groups (40 eggs/ treatment), the first was control group (without irradiation), the other were distributed into four irradiation levels which were 0.4, 0.8, 1.2 and 1.6mW/cm^2 respectively for 14sec duration of irradiation. The radiation was performed under darkened conditions and all eggs were stored in refrigerator for 1, 7, 14 and 28 days as eggs of experimental groups.

Eggs quality: All eggs were weighed using Sartorius digital balance and broken onto a flat surface where the height of the inner thick albumen and the upper point of yolk were measured with a height gauge (Ames micrometer, USA), yolk diameter measured with a Vernier caliper device according to the methods revealed by Stadelman and Cotterill (1995). Egg Haugh unit values were determined according to the formula:

$$HU = 100 \log (H + 7.57 – 1.7W^{0.37})$$

whereby: HU = Haugh units; H = thick egg white height (mm); W = egg weight (g) (Stadelman and Cotterill, 1995).

Yolk index values were determined by division yolk high values to yolk diameter values according to the formula revealed by Stadelman and Cotterill (1995) which 10 eggs were utilized per treatment after each storage periods.

Chemical analyses: The yolk was not separated from the albumen and both were homogenized using low speed magnetic stirrer and distributed into three replicates of glass beakers. Egg moisture, ash, protein, lipid and carbohydrates contents were carried out according to AOAC (1980), all these measurements were done in triplicates. Moisture determined by drying samples in conventional oven at 98^{o}C for 24hrs. Ash determined by ashing samples using muffle furnace oven at 600^{o}C for 6hrs. Lipid analysis was conducted on all samples using mixture of chloroform : methanol (1 : 1) and stirred for 20min. using magnetic stirrer for several rinsing times. Protein determined by the method of semi-microkjeldal determination of N% and the values obtained multiplied with 6.25 to calculate protein%. Carbohydrate was determined by subtracking moisture, ash, lipid and protein percentages from 100.

Microbial counts: At sampling, egg shell microbial load were eluted by rinse method in which two eggs (per replicate) were placed in sterile poly ethylene bags and carefully rinsed with 50 ml of sterile peptone water for 10 min., then several decimal dilutions were done using sterile peptone water in universal 10 ml screw caped bottles, *Psychrophilic*, *Coliform*, *Staphylococci* and *Fungi* (Mold and yeast) counts on egg shell were done by culturing 1 ml of each decimal dilutions on Nutrient agar, MacConkey agar, Staph. #110 agar and Saubroud agar plates respectively, according to Yousef and Carlstrom (2003), all these measurements were done in triplicates.

Statistical analysis: Data were analyzed by using the General Linear Model Procedure of SAS (2001). Means were compared by the Duncan's Multiple Range test at 5% probability (Steel and Torrie, 1980).

Results and Discussion

The data obtained revealed that all treatments of red laser irradiation expanded shelf life of table eggs compared with control group, 1.2 and 1.6mW/cm^2 for 14sec duration of irradiation were the best for reduction the deterioration of egg quality parameters (Table 1), chemical composition (Table 2), also reduced the studied microbial counts groups (Table 3) during refrigerator storage to 28 days.

Pasteurization is a process of heating food for the purpose of killing or eliminating harmful microorganisms such as bacteria, viruses, protozoa, molds, and yeasts (Lewis and Heppell 2000). Pasteurizing the eggs exhibit a better keeping quality and extended shelf life, it is a mild processing because the amount of chemical damage caused is a very small and the changes in the sensory characteristics are minimal. After pasteurization, the food must refrigerated till consumed. Food Safety and Inspection Service (FSIS) of the United States Department of Agriculture (USDA) recommends heating the egg white and the egg yolk to 57.5°C and 61.1°C respectively for at least 2.5min to ensure egg safety against Salmonella and other food borne pathogens (USDA, 2007).

There are 2 types of medical lasers: High power lasers and low power lasers. In summary for high power laser or hot laser the output of laser energy is between 3000 to 10000mW (milliwatt). It is usually used to solidify the bleeding and to cut the tissues, called laser knife or also known as surgical lasers, on the other hand, in low power laser or low level laser, the output is lower between 1 and 500mW. The power is low and will not damage the hydrogen bonds in the tissues, does not cause any change but the photochemistry effect.

Sometimes, low power laser is also called cold laser or soft laser. For our purposes we also call it therapeutic lasers or low level laser. At our clinic we only use low power lasers (Karu, 1988). Previously studies of low levels of red laser irradiation for fertilized poultry eggs has been reported to increase hatchability rate and improve chicks survival (Bessarabov *et al*., 1986; Popov *et al*., 1984; Yakimenko *et al.,* 2002; Ghalehkandi *et al*., 2014).

High temperature pasteurization is considered the best solution to the *Salmonella* problem in eggs, recently, there is no efficient and satisfactory technology available for pasteurizing shell eggs. The current technology uses batch hot water immersion or moistened hot air or both combined, which requires a very long time ranging in hours to complete and are not really energy efficient due to the poor thermal properties of the shell and the shell membrane though they are not really the focus of pasteurization and as a result they are not cost effective (Mermelstein 2001). Also these treatments affect the functional properties of the egg components. Proteins are highly heat sensitive components of the egg. The functional properties like whipability, foamability, foam stability etc. which make the eggs an inevitable ingredient of various food products are severely affected by high temperatures. Also experimentally it is found that the egg yolk needs to be heated to a higher temperature than the albumen. This is possible by conventional heating only if the yolk and albumen are separated as the yolk is concentric within the albumen in a shell egg (i.e. only if the shell is broken). The existing method of pasteurizing the shell eggs results in overheating of the albumen and partially cooked eggs along the shell membrane (Hank *et al.,* 2001).

Table (1): Effect of red laser irradiation levels on egg quality parameters during refrigerator storage.

Parameters	Storage Periods (Days)	Laser levels (mW/cm^2) treatments				
		Control	0.4	0.8	1.2	1.6
Egg weight	1	62.5 ±0.81^{b}	62.4 ±0.77^{a}	62.5 ±0.72^{a}	62.3 ±0.77^{a}	62.4 ±0.80^{a}
	7	61.4 ±0.75^{b}	61.9 ±0.82^{a}	61.8 ±0.79^{a}	62.0 ±0.72^{a}	62.0 ±0.73*
	14	61.0 ±0.75^{b}	61.6 ±1.77^{a}	61.4 ±0.78^{a}	61.5 ±0.78^{a}	61.5 ±0.86*
	28	59.3 ±0.78^{c}	60.0 ±0.82^{b}	60.1 ±0.76^{b}	60.7 ±0.82^{a}	60.8 ±0.73^{a}
Haugh unit	1	90.8 ±1.62^{a}	90.9 ±1.66^{a}	91.2 ±1.61^{a}	91.2 ±1.63^{a}	90.8 ±1.65^{a}
	7	88.6 ±1.65^{a}	89.8 ±1.65^{b}	90.2 ±1.64^{bc}	90.2 ±1.64^{bc}	90.5 ±1.63^{c}
	14	86.6 ±1.63^{a}	87.7 ±1.67^{b}	88.0 ±1.64^{bc}	88.7 ±1.61^{c}	88.9 ±1.63^{c}
	28	83.7 ±1.62^{a}	85.8 ±1.64^{b}	86.2 ±1.62^{c}	87.2 ±1.64^{d}	87.5 ±1.64^{d}
Yolk index	1	0.44 ±0.03^{a}	0.44 ±0.02^{a}	0.45 ±0.02^{a}	0.44 ±0.03^{a}	0.45 ±0.03^{a}
	7	0.42 ±0.04^{a}	0.43 ±0.03^{ab}	0.43 ±0.02^{ab}	0.44 ±0.04^{b}	0.44 ±0.03^{b}
	14	0.41 ±0.04^{a}	0.42 ±0.04^{b}	0.42 ±0.03^{b}	0.43 ±0.04^{c}	0.43 ±0.03^{c}
	28	0.38 ±0.03^{a}	0.40 ±0.03^{b}	0.40 ±0.04^{b}	0.42 ±0.03^{c}	0.42 ±0.02^{c}

Values (Mean± SE) with different superscripts in a row differ significantly ($P<0.05$).

Table (2): Effect of red laser irradiation levels on egg chemical composition during refrigerator storage.

Parameters (%)	Storage Periods (Days)	Laser levels (mW/cm^2) treatments				
		Control	0.4	0.8	1.2	1.6
Moisture	1	72.1 ±1.73[a]	72.2 ±1.75[a]	72.2 ±1.72[a]	72.2 ±1.72[a]	72.2 ±1.73[a]
	7	71.5 ±1.75[b]	71.8 ±1.72[a]	71.8 ±1.72[a]	71.9 ±1.80[a]	71.9 ±1.77[a]
	14	70.5 ±1.78[c]	70.9 ±1.76[b]	71.4 ±1.81[b]	71.4 ±1.79[a]	71.6 ±1.82[a]
	28	67.6 ±1.75[c]	68.2 ±1.81[b]	68.8 ±1.82[b]	69.0 ±1.82[a]	69.2 ±1.80[a]
Ash	1	1.13 ±0.02[a]	1.14 ±0.03[a]	1.13 ±0.02[a]	1.12 ±0.02[a]	1.14 ±0.02[a]
	7	1.14 ±0.02[a]	1.14 ±0.02[a]	1.14 ±0.02[a]	1.13 ±0.02[a]	1.13 ±0.02[a]
	14	1.15 ±0.02[a]	1.14 ±0.03[a]	1.14 ±0.02[a]	1.14 ±0.03[a]	1.14 ±0.03[a]
	28	1.16 ±0.03[a]	1.15 ±0.02[a]	1.14 ±0.02[a]	1.14 ±0.03[a]	1.14 ±0.02[a]
Protein	1	12.45 ±0.80[a]	12.42 ±0.82[a]	12.42 ±0.86[a]	12.43 ±0.84[a]	12.46 ±0.83[a]
	7	12.50 ±0.83[a]	12.46 ±0.84[ab]	12.46 ±0.84[ab]	12.44 ±0.85[b]	12.43 ±0.84[b]
	14	12.52 ±0.84[a]	12.48 ±0.85[b]	12.47 ±0.85[b]	12.45 ±0.85[b]	12.45 ±0.83[b]
	28	13.59 ±0.85[a]	13.50 ±0.82[b]	13.51 ±0.85[b]	13.48 ±0.84[c]	13.47 ±0.83[c]
Lipids	1	13.17 ±0.73[a]	13.11 ±0.69[a]	13.11 ±0.71[a]	13.11 ±0.69[a]	13.15 ±0.74[a]
	7	13.70 ±0.74[a]	13.45 ±0.74[b]	13.44 ±0.71[b]	13.38 ±0.73[b]	13.39 ±0.71[b]
	14	15.83 ±0.74[a]	14.33 ±0.72[b]	13.83 ±0.74[c]	13.86 ±0.77[c]	13.66 ±0.73[c]
	28	16.47 ±0.73[a]	15.99 ±0.75[b]	15.38 ±0.72[c]	15.22 ±0.76[c]	15.03 ±0.74[c]
Carbohydrates	1	1.15 ±0.47[a]	1.13 ±0.48[a]	1.14 ±0.43[a]	1.14 ±0.46[a]	1.15 ±0.46[a]
	7	1.16 ±0.44[a]	1.15 ±0.47[a]	1.16 ±0.47[a]	1.15 ±0.46[a]	1.15 ±0.44[a]
	14	1.16 ±0.46[a]	1.15 ±0.47[a]	1.16 ±0.45[a]	1.15 ±0.46[a]	1.15 ±0.47[a]
	28	1.18 ±0.48[a]	1.16 ±0.45[a]	1.17 ±0.47[a]	1.16 ±0.47[a]	1.16 ±0.46[a]

Values (Mean± SE) with different superscripts in a row differ significantly ($P<0.05$).

Table (3): Effect of red laser irradiation levels on egg some microbial counts during refrigerator storage.

Microbial groups (cfu/egg)	Storage Periods (Days)	Laser levels (mW/cm^2) treatments				
		Control	0.4	0.8	1.2	1.6
Psychrophilic	1	89×10^5 ±22.0[a]	56×10^4 ±26.5[b]	60×10^3 ±21.2[c]	42×10^2 ±21.0[d]	21×10^2 ±22.4[d]
	7	112×10^5 ±27.5[a]	80×10^4 ±24.9[b]	58×10^4 ±27.3[b]	48×10^2 ±24.3[c]	25×10^2 ±24.6[c]
	14	90×10^6 ±29.4[a]	128×10^4 ±21.1[b]	136×10^4 ±24.4[b]	88×10^2 ±27.8[c]	54×10^2 ±25.0[c]
	28	141×10^6 ±25.1[a]	117×10^5 ±27.5[b]	87×10^5 ±26.4[b]	52×10^c ±23.7[a]	67×10^c ±25.3[a]
Coliform	1	41×10^3 ±15.7[a]	41×10^2 ±18.8[b]	< 10 ±0.0[c]	< 10 ±0.0[c]	< 10 ±0.0[c]
	7	89×10^3 ±20.2[a]	49×10^2 ±18.7[b]	27×10^2 ±17.2[c]	< 10 ±0.0[d]	< 10 ±0.0[d]
	14	35×10^4 ±19.5[a]	56×10^3 ±20.6[b]	69×10^2 ±19.7[c]	68×10^2 ±19.2[d]	35×10^2 ±17.8[d]
	28	123×10^4 ±20.7[a]	114×10^3 ±20.5[b]	53×10^3 ±19.3[c]	22×10^3 ±18.3[d]	96×10^2 ±20.1[d]
Staphylococci	1	37×10^3 ±22.3[a]	39×10^2 ±20.4[b]	< 10 ±0.0[c]	< 10 ±0.0[c]	< 10 ±0.0[c]
	7	105×10^3 ±21.7[a]	21×10^3 ±24.3[a]	15×10^2 ±25.7[b]	6×10^2 ±20.5[b]	5×10^2 ±21.1[b]
	14	58×10^4 ±25.3[a]	77×10^3 ±25.9[b]	89×10^2 ±26.2[c]	70×10^2 ±23.6[c]	44×10^2 ±26.3[c]
	28	156×10^4 ±24.4[a]	35×10^4 ±25.5[b]	58×10^3 ±24.5[c]	34×10^3 ±24.3[c]	112×10^2 ±24.6[c]
Fungi	1	15×10^2 ±8.1[a]	8×10^2 ±7.7[a]	< 10 ±0.0[b]	< 10 ±0.0[b]	< 10 ±0.0[b]
	7	88×10^2 ±7.9[a]	19×10^2 ±8.1[a]	< 10 ±0.0[b]	< 10 ±0.0[b]	< 10 ±0.0[b]
	14	64×10^3 ±8.4[a]	140×10^3 ±8.6[a]	57×10^2 ±7.7[b]	38×10^2 ±7.5[b]	2×10^2 ±7.3[b]
	28	98×10^4 ±8.8[a]	23×10^4 ±8.9[a]	76×10^3 ±8.4[b]	34×10^3 ±8.0[ab]	99×10^2 ±8.2[b]

Values (Mean± SE) with different superscripts in a row differ significantly (P<0.05).

Conclusion

This original study using low levels of red laser irradiation as a new method of pasteurization table eggs revealed that all treatments of red laser irradiation expanded shelf life of table eggs compared with control group and we recommended the using of 1.2 and 1.6mW/cm^2 for 14sec duration of irradiation for reduction the deterioration of egg quality parameters, chemical composition, and microbial counts during refrigerator storage up to 28 days.

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