Irradiation of Shell Egg on the Physicochemical and Functional Properties of Liquid Egg White

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Summary and Implications

The effect of irradiation of shell eggs on the physiochemical and functional properties, and color and textural parameters of liquid egg white during storage were determined. Shell eggs were irradiated at 0, 2.5, 5, or 10 kGy using a linear accelerator. Viscosity, pH, turbidity, foaming properties, color, and volatile profile of liquid egg white, and color and texture properties of cooked egg white were determined at 0, 7, and 14 days of storage. Irradiation increased the turbidity but decreased viscosity of liquid egg white. Foaming capacity and foam stability were not affected by irradiation at lower dose (2.5 kGy), but were deteriorated at higher doses ($\geq$ 5.0 kGy) of irradiation. Sulfur-containing volatiles were generated by irradiation and their amounts increased as the irradiation dose increased. However, the sulfur volatiles disappeared during storage under aerobic conditions. Lightness (L^* value) and yellowness (b^* value) decreased, but greenness ($-a^*$ value) increased in cooked egg white in irradiation dose-dependent manners. All textural parameters (hardness, adhesiveness, cohesiveness, chewiness, and resilience) of cooked egg white increased as the irradiation dose increased, but those changes were marginal. Our results indicated that irradiation of shell egg at lower doses (up to 2.5 kGy) had little negative impact on the physiochemical and functional properties of liquid egg white, but can improve the efficiency of egg processing due to its viscosity-lowering effect. Therefore, irradiation of shell eggs at the lower doses has high potential to be used by egg processing industry to improve the safety of liquid egg without compensating its quality.

Introduction

Shell eggs and egg-containing products were responsible for 80% of Salmonellosis of which food sources are confirmed from 1985 to 1999. In addition, a nationwide outbreak of *Salmonella* Enteritidis (SE) infection associated with shell eggs caused over 1,900 foodborne illness and led to a recall of 500 million eggs in 2010. Due to the significance of egg-related *Salmonella* infection, the FDA implemented a new egg safety regulation named 'Egg Safety Final Rule' in 2009 to prevent s*almonella* contamination of shell eggs during production, transportation, and storage.

Salmonella contamination can occur on the outer shell as well as internal contents such as egg yolk and white. *Salmonella* on the shell may penetrate into the inside of eggs via the cracks and contaminate the internal contents. In addition, direct contamination of internal contents can occur from the infected reproductive organs before laying eggs. Washing can eliminate *Salmonella* on the surface of shell eggs, but are not effective on the *Salmonella* in the internal contents of eggs. Recently, in-shell pasteurization processes at a low temperature (~55°C) have been used to reduce *Salmonella* in shell eggs, but they need extended time to achieve a 5-log reduction of *Salmonella*.

Irradiation is one of the most effective non-thermal pasteurization technologies and may be the most suitable to destroy *Salmonella* contaminated in the internal contents of shell eggs. Irradiation is very effective in controlling *Salmonella* and other foodborne pathogens that contaminate shell eggs internally and externally. However, irradiation can also cause significant changes in functional properties of egg white due to the oxidation of egg components by hydroxyl radicals produced through the radiolysis of water. Free radicals can cause fragmentation, aggregation, and cross-linking of protein molecules, and induce changes in physicochemical and functional properties such as viscosity, foaming, binding, emulsification, thermal gelation, and thickening properties of egg white. Changes in physicochemical and functional properties of egg white can significantly influence the quality of many food products using egg as an ingredient. Yet, the effect of irradiation on physicochemical and functional properties of egg white is still controversial. Several studies showed that irradiation caused oxidation of egg components such as proteins, polyunsaturated fatty acids, cholesterols, and carotenoids, deteriorated internal and sensory quality, changed color, and decreased the viscosity of egg white. On the other hand, other studies indicated that low-dose irradiation (1.5-2.5 kGy) did not cause substantial changes in physicochemical and functional properties of shell eggs and egg products.

The objective of this study was to investigate the effect of irradiating shell eggs on the physiochemical and foaming properties of liquid egg white during storage. In addition, changes in color and texture properties of cooked egg white made from irradiated liquid egg white were determined.

Materials and Methods

- A total of 1,440 fresh shell eggs were irradiated at 0, 2.5, 5, and 10 kGy using a Linear accelerator.
- Egg white was separated and stored in a refrigerator at 4°C up to 14 days.

- A part of egg white was placed in cellulose casings and cooked in boiling water for 18 min to produce cylinder-shape sticks.
- Viscosity, pH, turbidity, foaming properties, color, and volatile profile of liquid egg white, and color and texture properties for cooked egg white were determined at 0, 7, and 14 days of storage.

Results

- The turbidity of liquid egg white was increased by irradiation probably due to decreased solubility of egg white proteins.
- Irradiation decreased the viscosity of liquid egg white in an irradiation dose-dependent manner because irradiation degraded major protein molecules such as ovomucin, conalbumin, ovalbumin, and ovotransferrin in egg white.
- The watery characteristics of irradiated egg white can increase the flow of liquid egg white in egg processing facilities and improve equipment efficiency.
- Low-dose irradiation (≤ 2.5 kGy) had little effect, but higher-dose irradiation (≥ 5 kGy) had negative impact to the foaming capacity and foam stability of liquid egg white.
- Low-doses irradiation (≤ 2.5 kGy) of shell egg can be used to improve the safety of liquid egg white without deteriorating its foaming capacity and stability.
- The amounts of total volatile compounds in liquid egg white significantly increased as irradiation doses increased. The amounts of benzene, toluene, and hexanal in liquid egg white increased by irradiation and some
- Many sulfur-containing volatiles including methanethiol, dimethyl sulfide, methylthio ethane, ethanethioic acid, dimethyl disulfide, and dimethyl trisulfide were generated by irradiation, and their amounts increased as the irradiation dose increased. Dimethyl disulfide was the major sulfur volatiles produced by irradiation, and methanethiol, dimethyl sulfide, and methylthio ethane appeared at higher dose irradiation (≥ 5 kGy). However, irradiation of shell egg may not influence odor if the liquid egg white is stored for 1-2 weeks under aerobic conditions before use.
- Although significant changes in color can be detected by the instrument, they were not detectable by human naked eyes.
- All textural parameters (hardness, adhesiveness, cohesiveness, chewiness, and resilience) of the cooked egg white sticks from non-irradiated control at Day 0 were not different from those from irradiated at 2.5 and 5 kGy (except adhesiveness for those at 5 kGy), but were significantly lower than those from irradiated at 10 kGy ($P < 0.05$). However, all values of textural parameters, except cohesiveness, tended to increase as irradiation dose increased.

Conclusion

Irradiation of shell eggs caused substantial changes in turbidity, viscosity, foaming properties (when dose >2.5 kGy), and volatile profiles of egg white due to oxidative changes in egg white proteins, and the extents of the changes were irradiation dose-dependent. However, the foaming properties of liquid egg white were minimal when the shell eggs were irradiated at lower dose (2.5 kGy). The viscosity of egg white changed dramatically by irradiation even at low dose (≤ 2.5 kGy). Because of viscosity-lowering effect, irradiation of shell eggs at lower doses can improve efficiency of egg white processing by facilitating separation of egg yolk and white, flow of liquid egg white through pipelines, mixing it with other ingredients, spray-drying, etc. without deterioration of physicochemical and functional properties in egg white. In addition, irradiation of shell eggs can reduce microbial loads in liquid egg white. Therefore, low dose irradiation of shell egg could be beneficial for egg processing industry and the safety of food products that use liquid egg white can be improved.

Table 1. Turbidity, viscosity, and foam stability of irradiated liquid egg white with different irradiation doses and their changes during storage[1]

	Irradiation dose (kGy)			
Storage	0	2.5	5	10
Turbidity				
Day 0	0.59^{d}	0.94^{cy}	1.33^{bz}	2.07^{ay}
Day 7	0.57^{d}	1.04^{cx}	1.44^{by}	2.13^{ax}
Day 14	0.55^{d}	1.07^{cx}	1.48^{bx}	2.16^{ax}
Viscosity (cP[2])				
Day 0	26.4^{ay}	20.0^{by}	19.2^{cz}	16.8^{dy}
Day 7	29.6^{ax}	19.8^{by}	20.0^{by}	17.0^{cy}
Day 14	30.2^{ax}	21.4^{bx}	21.6^{bx}	21.6^{bx}
Foaming capacity (g/mL foam)				
Day 0	0.118^{c}	0.125^{cy}	0.176^{ax}	0.155^{b}
Day 7	0.131^{c}	0.142^{bx}	0.142^{by}	0.155^{a}
Day 14	0.124^{b}	0.130^{by}	0.160^{ax}	0.152^{a}
Foam stability (mL drainage)				
Day 0	23.7^{c}	25.9^{c}	56.5^{ax}	39.3^{bx}
Day 7	19.3^{d}	27.1^{b}	23.1^{cy}	30.2^{ay}
Day 14	16.2^{c}	22.4^{b}	32.1^{ay}	28.8^{ay}

[1]Means with different letters (a-d) within the same row are significantly different ($P < 0.05$).
Means with different letters (x-z) within the same column are significantly different ($P < 0.05$).
SEM = standard error of the means. n = 4.
[2]cP = centipoise.

Table 2. Volatiles profiles of liquid egg white with different irradiation doses and their changes during storage[1]

	Irradiation dose (kGy)											
	Day 0				Day 7				Day 14			
Compound	0	2.5	5	10	0	2.5	5	10	0	2.5	5	10
Acetaldehyde	0	256	0	181	-	-	-	-	-	-	-	-
Methanethiol	0^{b}	0^{b}	213^{b}	1367^{a}	-	-	-	-	-	-	-	-
Pentane	0^{d}	245^{c}	317^{b}	495^{a}	0	0	0	34	-	-	-	-
2-Propanone	0	1932	689	154	-	-	-	-	-	-	-	-
Dimethyl sulfide	0^{c}	75^{c}	296^{b}	808^{a}	-	-	-	-	-	-	-	-
2-Methyl propanal	0^{d}	3217^{c}	4246^{b}	7302^{a}	0^{d}	1380^{c}	2245^{b}	4078^{a}	0^{b}	0^{b}	0^{b}	741^{a}
Hexane	1412^{b}	3337^{a}	3255^{a}	588^{c}	353^{b}	892^{a}	694^{a}	0^{c}	5949^{b}	4482^{b}	6068^{b}	10703^{a}
Methylthio ethane	0^{b}	0^{b}	0^{b}	302^{a}	-	-	-	-	-	-	-	-
Ethyl acetate	160	437	218	311	-	-	-	-	-	-	-	-
Benzene	347^{d}	988^{c}	1989^{b}	5838^{a}	0^{d}	103^{c}	563^{b}	2438^{a}	-	-	-	-
3-Methyl butanal	0^{d}	5549^{c}	7868^{b}	13783^{a}	0^{d}	1799^{c}	3050^{b}	5633^{a}	0^{b}	0^{b}	213^{b}	1075^{a}
2-Methyl butanal	0^{d}	3849^{c}	5958^{b}	10930^{a}	0^{d}	1408^{c}	2609^{b}	5015^{a}	0^{b}	0^{b}	177^{b}	1048^{a}
Heptane	0^{d}	157^{c}	200^{b}	314^{a}	-	-	-	-	-	-	-	-
Ethanethioic acid	0^{c}	513^{b}	718^{b}	1610^{a}	-	-	-	-	-	-	-	-
Pentanal	71^{b}	430^{a}	282^{a}	315^{a}	-	-	-	-	-	-	-	-
Dimethyl disulfide	0^{d}	5729^{c}	9017^{b}	14000^{a}	0^{d}	1261^{c}	2363^{b}	3772^{a}	-	-	-	-
Toluene	278^{d}	7943^{c}	13615^{b}	21857^{a}	0^{d}	1872^{c}	3943^{b}	7490^{a}	0^{b}	1099^{ab}	1412^{ab}	2497^{a}
Hexanal	414^{b}	850^{a}	852^{a}	864^{a}	-	-	-	-	-	-	-	-
Nonane	131^{b}	156^{a}	168^{a}	171^{a}	-	-	-	-	-	-	-	-
Dimethyl trisulfide	0^{b}	40^{b}	180^{a}	246^{a}	-	-	-	-	-	-	-	-
Total	3214^{d}	36120^{c}	50088^{b}	81445^{a}	353^{d}	8716^{c}	15470^{b}	28566^{a}	5949^{b}	5582^{b}	7872^{b}	16460^{a}

[1]Means with different letters (a-d) within the same row with same storage day are significantly different ($P < 0.05$). SEM = standard error of the means. n = 4. Unit = total ion counts × 10^{4}.

"-" indicates that compounds were not detected.