

CHANGES OF HEN EGGS AND THEIR COMPONENTS CAUSED BY NON-THERMAL PASTEURIZING TREATMENTS I. GAMMA IRRADIATION OF SHELL EGGS

L. MÉSZÁROS^a, K. HORTI^b and J. FARKAS^{b,c,*}

^a National Office of Food Safety, H-1035 Budapest, Miklós tér 1. Hungary

^b Department of Refrigeration and Livestock Products' Technology, Corvinus University of Budapest,
H-1118 Budapest, Ménesi út 45. Hungary

^c Central Food Research Institute, H-1022 Budapest, Herman Ottó út 15. Hungary

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Shell eggs have been irradiated with increasing radiation doses in the 0.5–3.0 kGy dose range and various non-microbiological changes, important from the point of view of consumer quality, have been estimated. Dose-dependent changes in the flow behaviour of egg white and brittleness of the yolk membrane in broken eggs, sensorial parameters of the raw and soft-boiled eggs, whippability and foam stability of the egg white were observed. Considering that a minimal dose of 1.5 kGy would be required for radiation inactivation of salmonellae and other, non-pathogenic bacteria, the quality of irradiated eggs upon such gamma radiation dose would not be equal in all parameters to those of the fresh shell eggs, however, changes in sensorial and functional properties at this dose level may be still acceptable, mainly for risk population and some industrial use.

Keywords: shell eggs, gamma irradiation, functional properties, sensorial properties

Besides being food in themselves, eggs have functional properties that do the job of many additives: foam, leaven, bind, thicken, coat, colour, emulsify and control of crystallization when various composite foods are prepared. On the other hand, leading sources of food infections in the epidemiological statistics are also eggs and foods prepared with eggs. Eggs are known as the commonest source of *Salmonella* food poisoning. In addition to this, since the late 1970s, *Salmonella* Enteritidis has emerged as the major cause of salmonellosis and in the late nineteen eighties, evidence came from various findings that certain phage types of *S. Enteritidis* cause human illness due to infection not only from contaminated carcasses and eggs of chicken, but also from the contents of intact eggs. (The microorganism is capable of growing in intact shell eggs at temperatures ≥ 10 °C.) Although the proportion of eggs infected trans-ovarian is

* To whom correspondence should be addressed.
Fax: +36-1-482 6321; e-mail: j.farkas@cfri.hu

low (ANON., 1989), it would be necessary to destroy the pathogenic bacteria eventually present in them prior to various utilizations of eggs or egg components. Even if boiled, the yolks of eggs are unlikely to reach temperatures sufficient to kill *S. Enteritidis* until about 7 minutes after cooking. In eggs infected in laboratory, the microbe was able to survive domestic cooking conditions that yield a runny yolk (ANON., 1989).

Heat pasteurization of liquid egg/egg product has been designed principally to control *Salmonella*. However, the egg components are quite sensitive to heat treatment, which may harm their functional properties. Thus, one may consider application of non-thermal pasteurization such as ionizing radiation treatment, or, for liquid egg products, high hydrostatic pressure processing (HHP) as treatments, which are known as treatments not causing heat damage and have been demonstrated as efficient means for destruction of vegetative bacteria contaminating foods. Since 2000, the Food and Drug Administration of the USA approved the use of up to 3 kGy ionizing radiation dose to reduce the level of *Salmonella* in shell eggs (FDA, 2000).

Pioneering studies on effect of ionizing radiation in salmonella control in egg products such as egg magma (PROCTOR et al., 1958) and frozen whole egg (BROOKS et al., 1958) demonstrated that the average dose required to achieve 10^7 -fold reduction in the number of salmonellae present was 2.5 kGy for *S. Typhimurium* and *S. Paratyphi*, and about 1.0 kGy for *S. Senftenberg*. SCHAFFNER and co-workers (1989) recorded D_{10} value of 0.26 kGy for *S. Enteritidis* in liquid whole egg at 19 °C. In a more recent work by CABO VERDE and co-workers (2004), D_{10} values in whole eggs varied between 0.31–0.26 kGy and 0.20–0.18 kGy in case of *S. Typhimurium* and *S. Enteritidis*, and between 0.20–0.18 kGy and 0.07–0.09 kGy in case of *Campylobacter coli* and *C. jejuni*, for shell egg and yolk+white, respectively. PONCE and co-workers (1998) and MORMUR and co-workers (1999) reported a decimal reduction time of 14.1 min for *Escherichia coli* and 8.2 min for *Listeria innocua* at 400 MPa and 20 °C in liquid whole egg. The latter authors observed 4–5 log cycles reduction of the viable counts of *S. Enteritidis* inoculated in liquid whole egg at 350 MPa, 15 min at 20 °C.

In order to develop proper non-thermal decontaminating technologies, one has to explore, however, those eventual side-effects, which may diminish some quality properties of the pasteurized product. Therefore, we have performed experiments to study changes induced by pasteurizing doses of gamma irradiation in shell eggs, and investigated the radiation- or HHP-induced changes in liquid egg yolk and liquid egg whites. The present paper will summarize and discuss our experiences with gamma irradiated shell eggs.

1. Materials and methods

1.1. Irradiation

Fresh shell eggs were bought at retail markets and irradiated with 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 kGy, resp., in the RH-gamma-30 type self-shielded ^{60}Co gamma irradiator of the Central Food Research Institute, Budapest.

1.2. Testing

Unirradiated and irradiated replicate eggs were broken individually into the metal cone of an Adams consistometer standing on a glass plate, which was put over a quadratic graph paper. After 30 s, the consistometer cone was lifted and the egg-spot formed was photographed from fixed distance after an additional time of 60 s. The surface covered by the broken eggs was determined planimetrically from the photographs, and considered as a measure of the flow behaviour of the egg white. The intactness of the yolk membrane was also observed.

Separated egg white and egg yolk were judged by a 10-member sensory panel for raw odour and clarity of egg white, and raw odour and colour of egg yolk by ranking coded samples from the seven dose levels including the control. The same panel evaluated the odour, taste, consistency and yolk colour of eggs boiled for four min.

Equal amounts (100 g) of pooled egg whites from the same dose level were whipped for 6 min with an electric kitchen machine and the foam volume and foam stability (time required until a liquid phase appeared in the foam) were determined.

2. Results and discussion

2.1. Consistency of raw egg white and membrane stability of egg yolk

Typical photographs of broken eggs from the control and 2 kGy batches, respectively, are shown in Fig. 1.

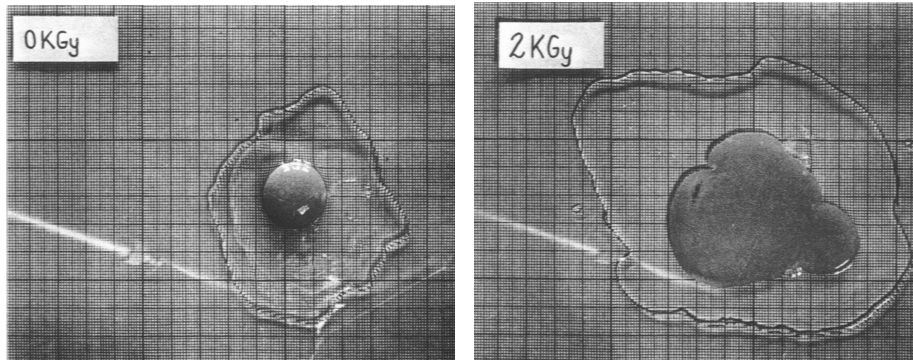


Fig. 1. A broken egg irradiated prior to breaking as compared to that of an untreated control

Mean values of the surface area covered by broken eggs and results of analysis of variance are given in Table 1.

Table 1. Surface area covered by broken raw eggs as a function of radiation dose (Number of replicates: 7)

Dose level (kGy)	Surface area in arbitrary units (planimetric estimation)	
	Mean value	95% confidence intervals for means
0	230 a*	185–275
0.5	370 b	325–415
1.0	367 bc	323–412
1.5	419 bcd	375–464
2.0	459 bcd	414–504
2.5	422 bcd	377–467
3.0	494 cd	449–539

* Means which do not differ significantly ($\alpha \leq 0.05$) from each other are followed by the same letter.

As can be seen from the above results, the flow behaviour of irradiated fresh eggs differed from that of the untreated ones already after 0.5 kGy dose. The egg white became progressively more running and the thick part of egg white became much thinner, similar to the effect of aging of eggs. The irradiated yolk ruptured more easily during the breaking procedure as the irradiation weakened the yolk membrane. Similar observations were reported by MCARDLE and DESROSIER (1955) and TUNG and co-workers (1970). Marked decrease in the viscosity of the egg white was also observed previously (MA, 1996), whereas PINTO and co-workers (2004) have shown that both irradiation (0.5–5 kGy) and heat pasteurisation (90 s at 57 °C) reduced the viscosity of egg white almost equally. For comparison, the U.S. minimum heat pasteurization requirement is 3.5 min at 60 °C (USDA, 1969).

2.2. Sensorial testing of raw eggs

The average sensorial ranks of raw albumen odour and the results of analysis of variance are given in Table 2. As can be seen, statistically significant differences (off-odour) of raw albumen were noted by the panel at 1 kGy or higher doses.

The results of visual evaluation of the clarity of egg white are shown in Table 3. The results show that the visual clarity of the egg white was decreased by irradiation even at 0.5 kGy dose level, because the yolk membrane ruptured more frequently at breaking the egg, and a part of yolk material diffused into the egg white in irradiated samples.

The rank scores of raw yolk odour and results of their statistical analysis are shown in Table 4. According to these observations, no significant differences in yolk odour were noted in the whole dose range investigated, however, the rank scores showed an increasing tendency as the radiation dose increased.

At 1 kGy or higher doses, the bright yolk colour tended to be slightly faded, however, the average ranks became statistically significantly higher than that of the control only at 3 kGy (Table 5). MA and others (1992) also noted that yolk colour was pale after irradiation.

Table 2. Raw albumen odour as a function of the radiation treatment of fresh shell eggs
(Number of panelists: 10)

Dose level (kGy)	Mean rank score	95% confidence interval for means
0	1.65 a*	0.65–2.65
0.5	3.35 ab	2.35–4.35
1.0	4.10 b	3.10–5.10
1.5	4.65 b	3.65–5.65
2.0	4.35 b	3.35–5.35
2.5	4.80 b	3.80–5.80
3.0	5.10 b	4.10–6.10

* Means which do not differ significantly ($\alpha \leq 0.05$) from each other are followed by the same letter.

Table 3. Clarity of raw albumen as influenced by the radiation treatment of fresh eggs
(Number of panelists: 10)

Dose level (kGy)	Mean rank score	95% confidence intervals for means
0	1.30 a*	0.63–1.97
0.5	3.00 b	2.33–3.67
1.0	2.85 b	2.18–3.51
1.5	3.85 bc	3.18–4.52
2.0	6.50 e	5.83–7.17
2.5	5.15 cd	4.48–5.81
3.0	5.35 de	4.68–6.02

* Means which do not differ significantly ($\alpha \leq 0.05$) from each other are followed by the same letter.

Table 4. Rank scores for odour of raw yolk as a function of irradiation of fresh eggs
(Number of panelists: 10)

Dose level (kGy)	Mean rank score*	95% confidence intervals for means
0	3.30	2.15–4.45
0.5	3.70	2.55–4.85
1.0	3.50	2.35–4.65
1.5	4.00	2.85–5.15
2.0	4.05	2.90–5.20
2.5	4.95	3.80–6.10
3.0	4.50	3.35–5.64

* No significant difference exists between any two means ($\alpha \leq 0.05$).

2.3. Sensory testing of soft boiled eggs

The rank scores for the odour of soft boiled eggs are shown in Table 6. A tendency for off-odour became statistically significant at 2–3 kGy dose levels.

Table 5. Rank scores for colour intensity of raw yolk as a function of irradiation of fresh shell eggs
(Number of panelists: 10)

Dose level (kGy)	Mean rank score	95% confidence intervals for means
0	2.80 ab*	1.79–3.81
0.5	2.15 a	1.14–3.16
1.0	4.60 bc	3.58–5.61
1.5	4.05 abc	3.04–5.06
2.0	4.00 abc	2.99–5.01
2.5	4.75 bc	3.73–5.76
3.0	5.65 c	4.63–6.66

* Means which do not differ significantly ($\alpha \leq 0.05$) from each other are followed by the same letter.

The rank scores for the taste of the soft-boiled eggs are shown in Table 7, which show a similar tendency for off-flavour as noted for smelling.

The rank scores of yolk colour of soft-boiled eggs are summarized in Table 8. It can be seen that the tendency of colour change as a function of irradiation dose was less pronounced in the soft-boiled eggs than in case of the raw egg yolk (see Table 5).

The rank scores of consistency of soft-boiled eggs (Table 9) do not show radiation-induced changes.

Table 6. Rank scores for odour of soft boiled eggs as a function of irradiation of raw eggs
(Number of panelists: 10)

Dose level (kGy)	Mean rank score	95% confidence intervals for means
0	2.60 a*	1.56–3.64
0.5	2.85 ab	1.81–3.89
1.0	4.50 abc	3.46–5.54
1.5	3.60 abc	2.55–4.64
2.0	5.05 c	4.00–6.09
2.5	4.55 abc	3.50–5.59
3.0	4.85 bc	3.80–5.89

* Means which do not differ significantly ($\alpha \leq 0.05$) from each other are followed by the same letter.

Table 7. Rank scores for taste of soft boiled eggs as a function of radiation treatment of raw eggs (Number of panelists: 10)

Dose level (kGy)	Mean rank score	95% confidence intervals for means
0	2.35 a*	1.25–3.44
0.5	3.25 ab	2.15–4.34
1.0	5.00 b	3.90–6.10
1.5	3.55 ab	2.45–4.64
2.0	4.90 b	3.80–6.00
2.5	3.80 ab	3.70–4.90
3.0	5.15 b	4.05–6.25

* Means which do not differ significantly ($\alpha \leq 0.05$) from each other are followed by the same letter.

Table 8. Rank scores for yolk colour of soft boiled eggs as a function of radiation treatment of raw eggs (Number of panelists: 10)

Dose level (kGy)	Mean rank score	95% confidence intervals for means
0	2.90 a*	1.90–3.90
0.5	3.85 a	2.85–4.85
1.0	3.75 a	2.75–4.75
1.5	4.05 ab	3.05–5.05
2.0	5.85 b	4.85–6.85
2.5	3.60 a	2.60–4.60
3.0	4.00 ab	3.00–5.00

* Means which do not differ significantly ($\alpha \leq 0.05$) from each other are followed by the same letter.

Table 9. Rank scores for consistency of soft boiled eggs as a function of radiation treatment of raw eggs (Number of panelists: 10)

Dose level (kGy)	Mean rank scores*	95% confidence intervals for means
0	3.95	2.78–5.11
0.5	4.50	3.33–5.66
1.0	4.90	3.73–6.07
1.5	3.05	1.88–4.21
2.0	3.50	2.33–4.67
2.5	3.60	3.33–5.67

* No significant difference exists between any two means ($\alpha \leq 0.05$).

2.4. Foam volume and foam stability

The foam volume and foam stability values were determined only in duplicate samples. The foam stability tended to decrease at 2 kGy or higher doses. The foam volume values did not show a clear trend as a function of radiation dose.

3. Conclusions

Considering the inactivation data referred to in the introduction, a minimal radiation dose of 1.5 kGy can be considered as a pasteurization/sanitization dose for shell eggs or liquid eggs. Such dose could significantly reduce the health hazard from eggs contaminated internally with *S. Enteritidis* until its eradication from laying flocks can be achieved. According to the observations reported earlier in this paper, the quality of such irradiated eggs is not equal in all parameters compared to that of the fresh shell eggs (PINTO et al., 2004), however, slight changes in sensorial and functional properties may be acceptable, mainly for risk population, catering and some industrial uses. Our observations in comparative studies on some radiation- and HHP-induced changes in liquid egg yolk and liquid egg white will be reported in an additional paper.

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References

- ANON. (1989): Memorandum of evidence to the Agriculture Committee inquiring on *Salmonella* in eggs. *PHLS Microbiology Digest*, 6 (1) 1–9.
- BROOKS, J., HANNAN, R.S. & HOBBS, B.C. (1958): The use of gamma radiation to destroy *Salmonella* in frozen whole egg. *Isotopes in Agr.*, 27, 374. (Ref.: GRIM & GOLDBLITH, 1965).
- CABO VERDE, S., TENREIRO, R. & BOTELHO, M.L. (2004): Sanitation of chicken eggs by ionizing radiation: HACCP and inactivation studies. *Radiat. phys. Chem.*, 71, 29–33.
- FDA (2000): Irradiation in the production, processing and handling of food. *FDA Federal Register*, 65 (141) 45280–45282.
- GRIM, A.C. & GOLDBLITH, S.A. (1965): Effect of ionizing radiation on the flavor of whole-egg magma. *Fd Technol.*, 19, 1594–1596.
- MA, C.Y. (1996): Effects of gamma irradiation on physicochemical and functional properties of eggs and egg products. *Radiat. phys. Chem.*, 48, 375.
- MA, C.Y., SAHASRABUDHE, M.R., POSTE, L.M., HARWALKAR, V.R., CHAMBER, J.R. & O'HARA, K.P.J. (1992): Gamma irradiation of shell eggs. Internal and sensory quality, physicochemical characteristics and functional properties. *Can. Inst. Fd Sci. Technol. J.*, 23, 226–232.
- MCARDLE, F.J. & DESROSIER, N.W. (1955): Influences of ionizing radiation on the protein components of selected foods. *Fd Technol.*, 7, 527–532.
- MOR-MUR, M., PLA, R., PONCE, E. & YUSTE, J. (1999): High pressure processing in poultry meat and egg products. -in: COLIN, P. & MULDER, R.W.A.W. (Eds) *Status and prospects of decontamination and preservation of poultry and egg products*. EUR 18830. COST Action 97, Pathogenic microorganisms in poultry and eggs. European Commission, Directorate-General, Science, Research and Development, Office for Official Publications of the European Communities, Luxembourg, pp. 117–123.
- PINTO, P., RIBERIO, R., SOUSA, L., CABO VERDE, S., LIMA, M.G., DINIS, M., SANTANA, A. & BOTELHO, M.L. (2004): Sanitation of chicken eggs by ionizing radiation: functional and nutritional assessment. *Rad. phys. Chem.*, 71, 35–38.
- PONCE, E., PLA, R., CAPELLAS, M., GUAMIS, B. & MOR-MUR, M. (1998): Inactivation of *Escherichia coli* inoculated in liquid whole egg by high hydrostatic pressure. *Fd Microbiol.*, 15, 265–272.
- PROCTOR, B.E., JOSLIN, R.P., NICKERSON, J.T.R. & LOCKHART, E.E. (1958) Elimination of *Salmonella* in whole egg powder by cathode ray irradiation of egg magma prior to drying. *Fd Technol.*, 7, 291.
- SCHAFFNER, D.F., HAMDY, M.K., TOLEDO, R.T. & TIFT, M.L. (1989) *Salmonella* inactivation in liquid whole egg by thermoradiation. *J. Fd Sci.*, 54, 902–905.
- TUNG, M.A., RICHARDS, J.F., MORRISON, B.C. & WATSON, E.L. (1970): Rheology of fresh, aged and gamma-irradiated egg white. *J. Fd Sci.*, 35, 812–814.
- USDA (1969): *Egg pasteurization manual*. ARS 74-78. Poultry Laboratory, Department of Agriculture, Albany, CA, Agriculture Research Service, United States.