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Functional properties of egg powder: effect of gamma irradiation

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Abstract

To determine the effect of gamma irradiation treatment on functional characteristics of whole egg powder, samples of egg powder (EP) was treated with 0, 5, 10 and 15 kGy doses of gamma irradiation. Foam stability (FS), foaming capacity (FC), oil holding capacity (OHC), water holding capacity (WHC), stability (ES), emulsifying activity (EA), emulsion and solubility of EP were determined. The un-irradiated EP samples exhibited a high functional property. The solubility, WHC, FS and EA were not affected, but OHC, FC and ES of egg powder were significantly increased by irradiation. According to the result, it was suggested that protein decompositions are the essential changes induced by irradiation and this protein decomposition may be the main reason for improving the FC, OWC, and ES of EP.

Keywords: Egg powder, Functional properties, Gamma irradiation, Storage

1. Introduction

Chicken egg and its derivatives (whole egg), egg yolk and egg white have well-known properties [1]. Besides being food, eggs are favourite food ingredients because of its functional characteristics of emulsifying, thickening, binding, foaming, coating and moisturizing which give desirable qualities and physical functional characteristics in the preparation of many kind of foods in which they are prepared [2-4]. These natural functional characteristics of whole egg were generally used in food preparation and in food processing industry such as desserts, confectioneries, puddings, bakery foods, bakery mixes, mayonnaise reformulated meat products, baby food, beverage and many convenience foods [5-8].

Current food production behaviour is towards less processed, natural food without additive and use of harmless preparation technologies. Therefore, new food preparation and processing techniques are needed to guarantee quality and safety of foodstuffs [9]. However, the properties of eggs are very delicate, it is significant that the processing method leads to many changes egg components, resulting in different functional properties [10,11]. Many procedures have been made to enhance foaming property of egg white by using high pressure or heat processing [12]. Irradiation treatment is comparable for heat-sensitive food products including eggs. While, highly reducing the prevalence of food-borne infection diseases, the temperature of the irradiated product is not increased and the changes in quality, property and nutrition value are negligence [13]. This treatment is used in different countries to processing eggs and egg products [14-16], but some issues remain to be tested. According to our bibliography, there is little information available on the influence of gamma irradiation treatment on the functional characteristics of dried eggs, especially when high doses of irradiation (up to 15 kGy) are used. Also, until now, no scientific study has been reported in Syria and region countries about the functional properties and the influence of gamma irradiation treatment on the functional characteristics of dried eggs. The objective of this study is therefore to determining the influence of gamma irradiation and drying on the functional characteristics of whole egg powder.

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2. Materials and Method

2.1. Sample preparation

Fresh and good quality eggs were purchased from Sidnaia poultry farms, in Damascus, Syria. The eggs were cleaned by dusting, washing to remove dirt and other undesirable material to avoid any contamination. They were carefully de-shelled and whole egg liquid obtained in a graduated cylinder. Whole egg liquid was mixed in a blender (WARING commercial blender model 32BL80 made in U.S.A) for 1-2 min, liquid egg was spread thinly (0.5-1.0 mm thickness) on tray and oven dried at 60 °C for 48 hours in a laboratory oven (MEMMERT model 600) to constant mass and kept to cool. The dried egg was scooped, milled and sieved with 60 mm mesh. Then the egg powder was weighed and packed into plastic films, labelled and identified with respective radiation doses for further investigation.

2.2. Irradiation treatment

Egg powder were irradiated with dose of 0, 5, 10 and 15 kGy, at room temperature, using a gamma source ^{60}Co (ROBO, Russa) at a dose rate of 7.775 kGy h^{-1}. The absorbed dose was monitored by alcoholic chlorobenzene dosimeter [6]. The irradiated and non-irradiated control samples of egg powders were kept for 12 months at ambient temperature (18-25 °C) under relative humidity (RH) of 50-70 %. Functional properties were determined on both samples (irradiated and un-irradiated) at 0, 6 and 12 months of storage.

2.3. Foaming properties determination

Foaming capacity (FC) and foam stability (FS) of EP was measured using the procedure described by Tan et al. [17]. Powder of whole egg was solved to 1:1 (v/v) with distilled water. A volume of 30 mL dilution was put into a 100 mL cylinder and mixed for 1 min with homogenizer (ULTRA TURRAX IKA T18 basic, made in Brazil) at 12000 rpm at 25 °C. Foam stability was expressed in term of percent liquid drainage comparing to initial liquid volume as a function of standing time for 60 min. The FC, FS and Drainage volume (DV) were calculated using the following equations [18]:

Foaming capacity (FC) (%) = (FV/ILV) X 100

Foaming stability (FS) (%) = (ILV – DV) / ILV X 100

Drainage volume (DV) (mL) = LVM – LVS

Where FV is the volume of foam, ILV is the liquid before foaming, DV is the volume of liquid drainage, LVM is the volume of liquid phase at t=60 min after foaming was finished and LVS is the volume of liquid phase at t=30 s after foaming was finished.

2.4. Water and oil absorption properties determination

Water holding capacity (WHC) and oil holding capacity (OHC) of the EP samples were determined by using the methods suggested by Shad et al. [19]. The whole egg (1 g) was mixed with distilled water (10 mL) in previously weighed tube for 30 minutes, and keeping at room temperature for 30 minutes, then the mixture was centrifuged at 3000 × g for 25 min (Laboratory centrifuges SIGMA model 6K15, made in Germany). The sold sediments were weighed after removal the supernatant portion. The determination of OHC was done by mixing 0.5 g of sediment with 5 mL sunflower in previously weighed centrifuge tube and treated further as mentioned for WHC. The OHC and WHC in term of percentage were calculated using the following equation:

WHC and OHC (%) = [(W2 – W1)/W0] X 100

Where W0 is the weight of the sample, W1 is the weight of centrifuge tube plus sample and W2 is the weight of the centrifuge tube plus sediments. WHC was expressed as g water held per g sample, and OHC was expressed in term g oil held per g protein sample.

2.5. Emulsification properties determination

Emulsion characteristics were determined using 10 mL samples of a 2% (w/v) suspension adjusted to pH value 7.0. These were homogenized using a homogenizer (ULTRA TURRAX IKA T18 basic, made in Brazil Ltds) at 2000 rpm for 2 min. This suspension was mixed with 10 mL of sunflower oil and the dilution was homogenized for 1 min. The emulsions were centrifuged (Laboratory centrifuges SIGMA model 6K15, made in Germany) in 15 mL graduated centrifuge tubes at 1200 × g for 5 min and emulsion volume was evaluated. Emulsifying activity (EA) was expressed in term of percentage indicated by emulsified layer volume of pure layer in the centrifuge tube. For determine the emulsion stability (ES), the emulsions were heated for 30 min at 80 °C, then cooled to room temperature and centrifuged at 1200 × g for 5 min. The ES was expressed in term of percentage represented by the remaining emulsified layer volume of the original emulsion volume [7].

2.6. Solubility determination

The solubility of dried whole egg powder can be assessed by the Haemin method. In the modification described by Sujata [20], 1 g of the powder (3 replicates for each test were used) was placed with 5 mL of 5 percentage sodium chloride solution (m/v) in Stoppard tube, which is then shaken thoroughly in a standardized way. The refractive index of the dispersed sample and of the salt solution are both measured. Solubility of egg powder was calculated as follows:

Haenni value = y = (N25D of sample soln-N25 of solvent) X 1000

Solubility = $(\log_{10} Y - 0.445)/ 0.01$

2.7. Statistical analysis

The four irradiation doses, three storage times with three replicates of each treatments were distributed in randomized design. The data were statistically evaluated by the one-way analysis of variance procedure (ANOVA) using special computer package (Abacus Concepts Inc, Berkeley, CA, USA, 1998). Data were expressed in the form of means ± standard deviation (SD) to compare mean values. The difference was of statistical significance at $p < 0.05$ [21].

3. Results and Discussion

3.1. Effect of gamma irradiation treatment on foaming properties of EP

The foaming properties are particularly important in the stability of foodstuffs such as ice cream and in bread production [2]. Food foams are related to the surface activity and film-forming capacities of specific protein molecular, which may be found in relatively low percentages. Foaming ability is depended on the rate at which the surface tension of the air-water interface decreases [12]. Egg, that is responsible for the foam formation, contains different proteins that can help to foam formation and stability: conalbumin and globulin contribute to the formation of foam and ovomucin and lysozyme to foam stability [4,12,16].

As indicated in Table 1, the apparent faming capacity of the samples treated with 0, 5, 10 and 15 kGy were 57.78, 43.33, 64.44 and 72.22%, respectively. As shown in Table 2, irradiation at 5 kGy significantly ($p<0.05$) decreased the percentage of foaming capacity (FC %). While, irradiation at 10 and 15 kGy significantly ($p<0.05$) increased the percentage of foaming capacity (FC %) of egg powder (EP). Our results are somehow in good agreement with those of Song et al. [22], Liu et al. [12], Yun et al. [23], and Farag et al. [5], who found that ability of the foam produced from egg significantly increased as irradiation increased. The increase of the foaming capacity observed in the case of irradiation with higher doses (10 and 15 kGy) may attributed to the homogenisation of gamma irradiation. Knorr et al. [33] reported that, ultrasound usually decomposes the protein and fat particles in liquid egg white more probably which may enhance the foaming capability of liquid egg white. Also, the higher foaming capability observed at 10 and 15 kGy was possibly due to an increase in protein net charge. This weakens hydrophobic interactions and increases protein flexibility, allowing them to more quickly spread the air-water interface, encapsulate air particles and increase foam formation [7]. The large foam volumes of irradiated egg white were caused by protein scission [5]. Clark et al. [24] indicated that irradiated egg had a remarkable increase in foam ability and stability and induced un-remarkable changes in secondary structure from a-helix to random structure improving some functional characteristics. Ma et al. [25] indicated that the foaming capacity was enhanced by irradiation due to the conformational changes of protein in egg white and increased surface hydrophobicity. In the contrary, Min et al. [26] reported that both foaming ability and foam stability of egg white were significantly decreased with the increase of irradiation dose due to the assurance changes of egg white protein, which increased surface hydrophobicity.

Foaming stability of egg powder of non-irradiated (control) and irradiated with gamma irradiation (5, 10 and 15 kGy) and storage (6 and 12 months) of egg powder is recorded in Table 1. As indicated in Table 2, the apparent faming stability of the samples treated with 0, 5, 10 and 15 kGy were 93.33, 93.67, 88.89 and 93.33%, respectively. The results show that there was non-significant ($p>0.05$) effect of gamma irradiation at 5, 10 and 15 kGy doses and storage for 6 and 12 months on foaming stability of

Table 1. Impact of gamma irradiation treatment and storage time on foaming properties of egg powder

Storage period /(Months)	**0**	**6**	**12**	**P-level**
Treatments		**Foaming capacity (FC %)**		
Control	**57.78±3.85^{bA}**	**61.11±1.93^{bA}**	**57.78±1.93^{aA}**	**0.2963**
5 KGY	**43.33±3.33^{cB}**	**48.89±1.93^{cAB}**	**56.67±5.77^{aA}**	**0.0183**
10 KGY	**64.44±3.85^{abA}**	**61.11±1.93^{bAB}**	**58.89±1.93^{aB}**	**0.1151**
15 KGY	**72.22±9.62^{aA}**	**65.56±1.93^{aAB}**	**60.00±3.33^{aB}**	**0.1168**
P-level	**0.0017**	0.0001	**0.7075**	
		Foaming stability (FS %)		
Control	**93.33±0.00^{aA}**	**94.44±3.85^{aA}**	**93.33±0.00^{aA}**	**0.7865**
5 KGY	**93.67±0.58^{aAB}**	**95.56±1.93^{aA}**	**92.22±1.93^{aB}**	**0.1107**
10 KGY	**88.89±5.09^{aAB}**	**94.44±1.93^{aA}**	**88.89±3.85^{aB}**	**0.0723**
15 KGY	**93.33±0.00^{aA}**	**92.22±1.93^{aA}**	**88.89±8.00^{aA}**	**0.7023**
P-level	**0.1451**	**0.4803**	**0.5233**	

^{abc} Means values in the same column not sharing a superscript are significantly different.
^{ABC} Means values in the same row not sharing a superscript are significantly different.
NS: not significant.

egg powder were detected. These results are in contrast with those of Farag [5] who reported that foaming stability are increased following gamma irradiation of shell egg. This increase in foam of irradiated egg was due to the partial denaturation of protein present at air water interface which forms an elastic film that stabilizes the foam [5]. Foam collapses by some principal mechanisms including bubble disproportionation, lamellae rupture – bubbles coalesce quickly and drainage – water around the bubbles as described by Lomakina and Mikova [27].

3.2. Effect of gamma irradiation on water and oil absorption properties of EP

The water and oil absorption qualities give some useful effect on the rheological, functional and baking properties of its products [2]. The WHC and OHC capabilities are prime functional characteristics of protein which related to the pore size and the charges on the protein components. The WHC of proteins plays an important role in the physical, chemical and sensory attributes of foods [5]. A range of WHC from 149.1 to 471.5% is suitable for the preparation of special foods such as soups, and some bakery products [19].

Table 2 shows the water holding capacity (WHC) changes of EP samples as affected by gamma irradiation. The mean WHC values of the EP were 258.34, 225.30, 258.19 and 254.51% for sample treated with 0, 5, 10 and 15 kGy, respectively. There were no significant differences (p>0.05) occurred in solubility of egg powder among the treatments (0, 5, 10 and 15 kGy) and storage periods (0, 6 and 12 months) of samples treated with 0, 5 and 15 kGy (Table 2). The contradictive findings that some studies demonstrated WHC changes while others did not may be attributed to changes occurring during post-irradiation storage. WHC of eggs was significantly diminished with increasing the ray at different dose levels of 2, 4 and 6 kGy [5]. The WHC is affected by some factors such as protein concentration, heating period and the temperature degree during gelation, pH value and ionic strength [18]. High WHC determines the hydrophilic nature and high hydrogen bonding of protein molecules [19]. The increase in WHC with irradiation may in part be due to irradiation-induced damage or degradation of complex components to simple molecules that have high affinity for water [28].

Table 2. Impact of gamma irradiation treatment and storage time on water-oil holding properties of egg powder

Storage period /(Months)	0	6	12	P-level
Treatments		**Water holding capacity (WHC %)**		
Control	**258.34±7.01^{aA}**	**203.21±29.97^{aB}**	**245.87±12.61^{abA}**	**0.0287**
5 KGY	**225.30±7.77^{aA}**	**225.53±23.73^{aC}**	**247.67±6.05^{abB}**	**0.1100**
10 KGY	**258.19±2.32^{aA}**	**196.90±3.00^{aC}**	**237.34±2.69^{bB}**	**0.0001**
15 KGY	**254.51±4.14^{aA}**	**215.81±30.60^{aB}**	**256.37±4.00^{aC}**	**0.0554**
P-level	**0.7892**	**0.5195**	**0.0767**	
		Oil holding capacity (OHC %)		
Control	**122.13±8.35^{cAB}**	**104.88±6.45^{aB}**	**134.53±11.31^{aA}**	**0.0185**
5 KGY	**145.93±7.60^{bA}**	**108.78±1.66^{aA}**	**139.50±10.45^{aB}**	**0.0020**
10 KGY	**163.86±9.64^{abA}**	**107.92±3.73^{aC}**	**131.58±17.76^{aB}**	**0.0031**
15 KGY	**158.77±5.39^{aA}**	**107.25±2.63^{aC}**	**126.72±10.14^{aB}**	**0.0003**
P-level	**0.0008**	**0.6829**	**0.6773**	

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Oil-holding capability (OHC) was higher in the irradiated EP (145.93, 163.86 and 158.77% for 5, 10 and 15 kGy, respectively) than in the control sample (122.13%). The high OHC in the irradiated samples was probably due to the present of nonpolar residue products in higher amount, which would lead to increase the contact surface and therefore improved OHC. Based on its OHC values, the irradiation would be the useful treatment for improving the structural interactions in foodstuff such as flavour retention and improvement the sensory characteristics. Our results confirmed by the data previously stated [29]. Anwar et al. [30] found that, irradiation at 10 and 20 kGy doses increased oil absorption of canola meals.

3.3. Effect of gamma irradiation on emulsification properties of EP

The emulsification characteristics of food materials are necessary for stability of the suspension of one liquid in another [2]. Emulsion properties of irradiated and un-irradiated EP were analyzed. To investigate emulsifying ability (EA), both irradiated and un-irradiated EP were mixed with corn oil. EA was similar between treatments (8.39 ± 0.65 for control samples to 9.05 ± 0.03 for the samples treated by 5 kGy) (Table 3). The slight increases were not significant (p>0.05), and could be regarded as not related to the irradiation treatment. This may be attributed to extensive denaturation of the most thermolabile egg proteins, which precipitated upon irradiation and were thus unavailable for stabilizing the emulsion. The comparatively higher EA of irradiated samples of EP makes it suitable to using it in food preparation like desserts, confectioneries, bakery foods, mayonnaise reformulated and other convenience foods [19]. The ability of a protein to aid the formation of an emulsion is related to its ability to attach to and stabilize the oil-water interface, the more the direct area that can be covered by the available protein, EA should be higher [31]. Proteins are supper surfactants in the preparation of food emulsions mainly (oil-water) as surface-active agent and favours resistance to coalescence [7].

The obtained results as shown in Table 3, indicates that the irradiation treatment used, had effect on emulsifying stabilities (ES) of the dried egg compo-

Table 3. Impact of gamma irradiation treatment and storage time on emulsifying properties of egg powder

Storage period /(Months)	0	6	12	P-level
Treatments		**Emulsifying activity (EA %)**		
Control	**8.39±0.65^{aB}**	**8.93±0.94^{aB}**	**13.15±1.59^{aA}**	**0.0118**
5 KGY	**9.05±0.03^{aB}**	**9.31±0.43^{aB}**	**13.70±0.63^{aA}**	**0.0017**
10 KGY	**8.84±0.39^{aB}**	**9.50±0.36^{aB}**	**14.10±0.56^{aA}**	**0.0004**
15 KGY	**9.03±0.00^{aC}**	**9.70±0.04^{aB}**	**14.42±0.14^{aA}**	**0.0001**
P-level	**0.1913**	**0.4121**	**0.3991**	
		Emulsifying stability (ES %)		
Control	**7.96±0.75^{bA}**	**5.23±0.62^{bB}**	**7.70±1.04^{bA}**	**0.0040**
5 KGY	**9.05±0.03^{aA}**	**5.84±0.61^{abB}**	**8.60±0.92^{abA}**	**0.0001**
10 KGY	**8.62±0.41^{abA}**	**6.05±0.35^{aB}**	**8.97±0.56^{abA}**	**0.0001**
15 KGY	**8.39±0.00^{abB}**	**6.25±0.35^{abC}**	**9.30±0.56^{aA}**	**0.0002**
P-level	**0.0705**	**0.1497**	**0.1594**	

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nents. The ES of 9.05, 8.62 and 8.39% for egg powder irradiated at dose of 5, 10 and 15 kGy, respectively, were higher than for non-irradiated control sample (7.96%).

3.4. Effect of gamma irradiation treatment on solubility of EP

The solubility of protein component is an important characteristic affecting the functional trend of proteins and their industrial application to food product preparation [32].

The solubility of egg powder varied between 43.33 ± 2.88% (control sample) and 46.17 ± 0.31% (irradiated sample with 15 kGy). No significant (p>0.05) differences occurred in solubility of egg powder among the treatments (0, 5, 10 and 15 kGy). Throughout storage periods, the solubility of both irradiated and control samples of EP decreased. The decrement was higher in the irradiated than those of non-irradiated control samples. After 12 months of storage, in gamma irradiated EP with doses of 5, 10 and 15 kGy solubility significantly (p<0.05) decreased. While, in the control samples of EP solubility slight and not significantly decreased. The solubility values determined for irradiated and non-irradiated EP samples in the current work is in contrast with that of Min et al. [26] and Liu et al. [12] who observed reported an increase in protein oxidation in egg white with an increase in the radiation dose. It has been suggested that irradiation induced changes and modification in some quality characteristics of egg white proteins [16]. This suggested that the increment of density in irradiated egg white could be attribute to the decreased solubility degree of egg white proteins. Both irradiated and non-irradiated egg powders exhibited high solubility, which might be due to variations in protein components, degrees of composition or decomposition of protein molecules, and the type of amino acid compositions [33]. Therefore, irradiated and un-irradiated EP could be used as a valuable supplement in many foodstuff preparations.

In present study the functional properties including foam stability (FS), foaming capacity (FC), oil holding capacity (OHC), water holding capacity (WHC), emulsion stability (ES), emulsifying activity (EA) and solubility of irradiated and un-irradiated EP were evaluated. These functional characteristics play an important role in the preparation of various food products [2,17]. Modifications in the characteristics of egg white

Table 4. Impact of gamma irradiation treatment and storage time on solubility (%) of egg powder

Storage period /(Months)	0	6	12	P-level
Treatments		**Solubility (%)**		
Control	**43.33±2.88^{aA}**	**41.82±1.19^{aA}**	**40.61±1.60^{aA}**	**0.3248**
5 KGY	**44.12±2.02^{aA}**	**42.02±1.24^{aAB}**	**40.01±0.62^{aB}**	**0.0331**
10 KGY	**45.06±1.79^{aA}**	**41.21±1.81^{aB}**	**39.17±0.37^{aB}**	**0.0078**
15 KGY	**46.17±0.31^{aA}**	**41.43±0.91^{aB}**	**40.22±0.36^{aC}**	**0.0001**
P-level	**0.3861**	**0.8732**	**0.3220**	

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^{ABC} Means values in the same row not sharing a superscript are significantly different.
NS: not significant.

protein can be the cause of some changes in foaming, emulsifying and gelling abilities [34]. The free radicals produced by irradiation may play an important role in changing functional characteristics of egg white, which in turn induces physical and chemical modification in the protein components [35]. Irradiation at medium doses has slightly improved the functional characteristics of both egg white and egg yolk [24,25,35-37]. The radiation-induced enhancement in the functional characteristics of egg and egg products may have been attribute to structural modifications of the proteins [37].

4. Conclusion

Based on our study it can be stated that the applied doses of gamma irradiation treatment that recommended for decontamination of dried food and ingredients, can enhance the safety properties of egg powder (EP) without the significant deterioration of their functional properties.

Compared to un-irradiated EP, irradiated EP had higher functional properties including solubility, oil holding capacity, foaming capacity and emulsifying properties. These changes are due to modifications on the protein structure during irradiation of EP. Irradiated EP may be favourable ingredient for preparation bakery and confectionary products. Therefore, the irradiated EP studied here is a promising alternative ingredient for preparing different foodstuff products such as desserts, puddings and some modified meat products.

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Compliance with Ethics Requirements. The author declares that he respect the journal's ethics requirements. The author declares that he has no conflict of interest.

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