The impact of alternative processing technologies on the quality of eggs and egg products

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Summary

The paper is a review of the late treatments proposed in the literature to improve shell egg sanitisation and egg product pasteurisation. In a first part, the recent opinions adopted by the European Food Safety Authority on the washing and cooling of table eggs, as possible methods to reduce the risk for consumers, are presented and discussed. In the second part, the effects of in-shell treatments of eggs, such as the cryogenic cooling, the microwave treatment, and the gamma irradiation are presented, as well as the effects on egg products of various processing technologies. In particular, gamma radiation and high-pressure processing are considered as tools for liquid egg pasteurisation, also taking into account the influence of such technologies on the composition, functionality, allergenicity, and physico-chemical characteristics of the final egg products.

Keywords: EFSA, egg, egg cooling, egg products, egg washing, gamma irradiation, high pressure, microwave heating.

Introduction

From consumer standpoint, safety is an implicit quality attribute of food. Thus, in order to maintain consumer confidence, food suppliers have the responsibility to make any effort to guarantee this important health and quality priority. When trying to reduce the risk of microbiological hazard in egg consumption, two complementary strategies can be accomplished: a) at farm level, avoiding the presence of pathogenic bacteria by suitable control measures; b) at packing centre or egg product industry, applying processing technologies able to reduce the microbiological risk to acceptable levels. In the field of current egg product manufacture, safety mainly relies on some traditional operations such as egg washing, pasteurisation, and cooling of the final product to 4 °C or below, whilst for table eggs, the control of pathogenic bacteria (e.g.. *Salmonella spp*.) is most effectively done by monitoring live hens directly at farm. In the recent years, some new technologies have been proposed, to be used alone or in combination with traditional treatments, for shell egg treatment and egg product pasteurisation. Some of these deserve consideration in this review, as well as other well established practices, such as table egg washing and cooling, currently used in a number of non European countries and that instead are still under discussion in EU. The increase in non-caged egg production where layers are more in contact with litter, manure and environmental bacteria, justify the growing interest for implementing technologies that might improve the microbiological safety of eggs (EFSA, 2005).

Table egg washing and cooling

The incidence of human salmonellosis in the EU was in 2006 of 31.1 reported cases per 100,000 inhabitants (EFSA, 2007). Table eggs are considered a primary source of salmonellosis, and egg washing has been proposed as a practical method to reduce salmonella and total bacterial load on shell eggs, with a direct effect on the so called horizontal transmission occurring after shell formation. Although egg washing, could have a chance to reduce the risk of salmonellosis (no epidemiological data on the public health effect of egg washing is available), washing of table eggs (class A eggs) is not allowed in the EU because of a possible microbiological risk associated with this practice when carried out under less than optimal conditions. In fact, contamination arises if strict control is not maintained over the wash and rinse water temperatures (Hutchinson et al., 2004). Among the drawbacks of table egg washing, damage to the cuticle generates some concern because it may favour trans-shell contamination, however modern methods of egg washing seems not to remove the cuticle from the egg shell (Kuhl, 2005).

Advantages and disadvantages, from a safety point of view, of using washing systems to sanitize table eggs were evaluated in an opinion prepared by the EFSA Scientific Panel on Biological Hazard (EFSA, 2005). The Panel concluded that any balancing between advantages and disadvantages needs to be related to a particular system of washing. If well done, there are clear advantages to egg washing although poor practices increase the risk of penetration of the egg by *Salmonella ssp*. Data regarding current egg washing practices indicates a bacterial reduction of 1-6 log10 units.

However, the reduction of bacterial load on egg surface will not prevent egg related diseases caused by microorganisms that are already present inside the eggs. Preventing *Salmonella spp*. infection, especially *S. enteritidi*s, in primary layer production will reduce the occurrence of *Salmonella spp*. in eggs, especially on the egg surface, and thereby reduce the risk associated with egg washing. Thus, in countries where salmonella prevalence in layers is very low, the risk of egg washing will also be lower.

According to the EFSA opinion briefly summarized above, the Commission stated that the egg washing practice, as performed in certain packing centres, can be sustained from a hygienic standpoint provided, *inter alia*, that a code of practice for egg-washing systems is developed (EU, 2007). So, class A eggs shall not be washed or cleaned except for Member States which, on 1 June 2003, authorised packing centres to wash eggs. These States (e.g. Sweden) may continue to authorise packing centres to wash eggs, but washed eggs may only be marketed in the Member States in which such authorisations have been issued (EU, 2007).

Egg refrigeration has been suggested as an additional control option applied along the food chain, preferably commencing at farm level, to reduce the incidence of salmonellosis in the human population (EFSA, 2009). In fact, cooling of table eggs at 7 °C or below limits the growth of pathogens, however cooling can prolong the survival of *Salmonella spp*. on the egg shell. Moreover, rapid cooling methods increases the likelihood of developing microcracks in the shell. Temperature fluctuation that causes water condensation on the egg shell must be avoided because this favours bacterial penetration through the shell. The Scientific Panel on Biological Hazards, was asked to give an opinion on egg cooling as a measure to reduce the risk for consumers through salmonella. The Panel concluded that not sufficient data are available to evaluate the occurrence of trans-shell penetration and growth of salmonella during processing and consequently to assess the related risk for consumers. A quantitative approach is needed taking into account all the factors contributing to the risk of salmonellosis, including consumer practices. Also an assessment of the efficacy of ongoing salmonella-reduction measures at farm level is needed (EFSA, 2009).

In the US, shell eggs packed for consumers must be kept at an ambient temperature not greater than 7.2 °C during transportation throughout storage (USDA, 1998). Current practices requires 7 to 10 days for packaged eggs to reach equilibrium when cooling from 40-45 °C (egg temperature after washing) to 7 °C in a refrigerated environment (Keener et al., 2000). To reduce this long cooling period, which may be a food safety concern, rapid cryogenic cooling techniques have been suggested (Curtis et al., 1995). These techniques that make use of N2 (-122 °C) or CO2 (-45 °C) can cool eggs to 7 °C in 15 min or less. They increase shelf life of shell eggs by modifying the gas composition of the air cell, with a significant reduction in the number of pathogenic microorganisms contained in the egg (Keener et al., 2000). By a reduction of albumen pH to values below 6.5, CO_2 cooling shows also an additional positive effect on Haugh units, an important quality criteria for egg grading in the US. However, compared to traditional cooling, an increase in cracked eggs are reported when eggs are subjected to gaseous N_2 and CO_2 cooling, while no difference is observed when liquid nitrogen is used (Jones et al., 2002).

Alternative shell-egg treatments

Different in-shell treatments to reduce bacterial load on the surface or inside shell eggs have been attempted with varying success. Gamma irradiation of shell eggs with increasing radiation doses in the range 0.5-3.0 kGy has demonstrated that a minimal dose of 1.5 kGy is required for the inactivation of salmonella and other non-pathogenic bacteria (Meszaros et al., 2006). Considering that gamma irradiation of any food commodity up to an overall average dose of 10 kGy presents no toxicological hazard (WHO, 1999), the treatments applied could be feasible from a safety standpoint, but the quality of irradiated eggs resulted not completely satisfactory. However, changes in sensory and functional properties of eggs treated with a dose of 1.5 kGy were still acceptable for populations exposed to risk and some industrial uses.

The microwave heating of shell eggs provides an opportunity for significant improvement of the current immersion pasteurisation that involves heating the eggs in a water bath at 60 °C for about 20-25 min (Dev et al., 2008). The Authors observed that the time to reach pasteurisation temperatures during in-shell heating of eggs by microwave ranged between 3.5 and 9 min for power density of 2.0-0.75 W g-1. No visible cracks or any deformations on the shell surface were observed. Although, microwave treatments have the potential for in-shell pasteurisation, the scaling up of the process to industrial scale requires more detailed investigations into other egg quality aspects. Actually, a task of the European research project RESCAPE is the up-scaling of a microwave treatment of shell eggs by modelling the lethality of this decontamination process and the impact of microwave treatment on the internal quality of eggs (SAFEHOUSE and RESCAPE, 2009). Within the same project, a hot-air pasteurisation prototype has also been designed and validated. Shell eggs subjected to a thermal cycle consisting of two treatments at 600 °C for 8 s spaced out by 32 s in cold air presented reduced shell contamination by more than 90%, without any egg quality deterioration. The gas plasma sterilisation seems also promising, producing reductions of 1 to 5 log10 cfu/eggshell, depending on treatment time (SAFEHOUSE and RESCAPE, 2009).

Alternative liquid-egg treatments

The dielectric properties (dielectric constant and loss factor) of liquid egg whites and whole eggs were studied by Wang et al. (2009) in order to acquire information necessary to design dielectric heating processes to preserve shelf-stable products. Dielectric heating, including radio frequency and microwave heating, can in fact potentially reduce processing time and improve heating uniformity of foods packed in container. This is possible because the heat is generated inside the food by conversion of alternating electromagnetic energy to thermal energy. The Authors observed that the thermal denaturation of liquid egg whites and whole eggs influenced the dielectric constants and dipole loss component of eggs, with differences in the loss factor between the different egg fractions at above 60 °C (Wang et al., 2009). These differences are outstanding because the loss factor determines the properties of the material to convert electric energy to thermal energy.

Gamma irradiation with 3 kGy dose at room temperature, followed by storage at 4 °C, of liquid egg white and yolk was able to destroy salmonella and *Staphylococcus aureus*, while reducing total plate count to values below 105 cfu/ml. A slight decrease in total carotenoids and protein solubility, and an increase in free fatty acids and peroxide value were observed for irradiated liquid yolk. Moreover, irradiation treatment with 3 kGy dose had no significant effects on the sensory appearance, colour and odour scores of liquid egg white and yolk (Badr, 2006). Gamma irradiation was also applied to liquid egg white to change the antigenic and allergenic properties of ovalbumin (Lee et al., 2005). Immunological analyses performed on a cake formulation prepared with egg white to which 10 and 20 kGy doses were applied indicated that gamma radiation increased the antigenicity of ovalbumin, but the allergenicity was decreased by irradiation and processing.

The great potential of high pressure (HP) processing in the food industry has been recently reviewed (Norton and Sun, 2008). This processing inactivates microorganisms, denatures proteins and extends food-product shelf life, with minor effects on flavour and nutritional value. HP treatments have been applied to inactivate different microorganisms inoculated in liquid whole egg. In particular, treatments at pressure above 400 MPa combined with temperature of 50°C were able to reduce *Salmonella enteritidis* count by 8 log10 units. Total bacterial count was also significantly reduced, and after 15 days of storage at 4 °C only 10 cfu/ml were detected (Guamis et al., 2005). Rheological properties are also deeply affected by HP, because with the application of high hydrostatic pressure the cold coagulation of egg components occurs, with possible interactions between protein and lipids when whole egg is treated (Ahmed et al., 2003). As a consequence of protein unfolding, the viscosity of HP-treated albumen increases, but foaming and gelling properties are retained; moreover the addition of NaCl prior to HP application prevents cold insolubilization or gel formation of albumen protein (Iametti et al., 1999). A ten fold dilution of egg white with 0.2 M TrisHCl at pH 7.6 and 8.8 before HP also prevented protein precipitation (Van der Plancken et al., 2007). An increase in the pressure level from 200 to 450 MPa produced a dramatic change in the linear viscoelastic behaviour of egg yolk dispersion, undergoing a sol-gel transition (Aguilar et al., 2007). However, the impact of HP on aggregation and network formation can be modulated by pH. The results carried out at different pH and protein concentrations confirmed the hydrophobic nature of pressure-induced aggregation of egg yolk proteins (Aguilar et al., 2007).

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