CO_2 MAP for the improvement of physico-chemical and technological properties of shell hen's albumen

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Abbreviated title: Quality of CO_2 packed eggs

Summary

Modified atmosphere packaging (MAP) is a widely used food storage technique that receives consumer perception as a natural and additive-free technique. The aim of this study was to compare some physico-chemical and technological properties of albumen of not-packed eggs (control) with that of eggs packed in high barrier plastic pouches, in air and in 100% CO_2 MA. Fresh eggs and egg samples during 28 days of storage were analysed for albumen pH and dissolved CO_2, Haugh unit (HU), texture of the coagulated albumen and crispness of meringues. Our research confirmed the beneficial effect of 100% CO_2 MAP on egg freshness maintenance. In addition our findings showed that the exposition of shell egg to CO_2 improved some technological performances of the albumen (e.g. meringue crispness), showing also high potentiality in order to modulate the hardness of coagulated albumen.

Keywords: shell eggs, modified atmosphere packaging, carbon dioxide, freshness, functional properties

Introduction

Various quality attributes of the albumen and yolk are lost with egg aging. This happens because eggs are breathable material and they allow moisture and CO_2 to permeate through the shell (Caner, 2005). The diffusion of CO_2 causes a sharp rise in pH especially in egg white. The albumen pH of a newly laid egg is between 7.5 and 8.8 and that of the yolk approximately 6. Of importance for egg processing is the fact that during egg shelf-life several properties change, such as egg white whipping behaviour and foam stability.

Heat coagulation is one of the most important functional properties of egg white. This phenomenon is a multi-stage process that plays a key role in determining the rheological and textural properties of products such as cakes, egg-based creams, confectionery and surimi seafood. The texture of heat coagulated albumen gel is also important in industrial processing of whole shell eggs for producing hard-boiled peeled eggs (HammershØj *et al.*, 2001).

In addition to coagulation, egg albumen proteins are responsible for different functional properties such as foaming, whipping, and viscosity building. While a model interface can be observed for hours or days to establish equilibrium, foam made with egg white proteins starts changing within minutes of formation (Foegeding *et al.*, 2006).

Conditions become more complex with foods such as meringue, angel food cake or nougat because stability must be maintained during additional processing. With meringue, the foam must show little expansion or collapse when heat-setting causes drying, and convert the foam from a liquid to a solid (Foegeding *et al.*, 2006).

The beneficial effects of storage in atmospheres enriched in CO_2 on the quality maintenance of fresh eggs are known from many years. In a recent work, we confirmed the efficacy of CO_2 to maintain the egg freshness during its shelf-life, applying modified atmosphere packaging (MAP) conditions with a MA of 100% CO_2 and a high barrier packaging material (Rocculi *et al.*, 2009).

In the present work, the attention was also focused on the changes of some technological properties (gel hardness, meringue crispness) of albumen of non packed eggs (control) and eggs packed in high barrier plastic pouches with two atmospheres (air, 100% CO_2) during 28 days of storage at 25°C.

Materials and methods

Raw material and sample preparation

Experiments were carried out on 1170 eggs of an average weight of 68.05 ± 4.23 g, obtained from Hyline brown hens of about 32 weeks age. Seventy plastic supports filled with eggs were packed in high barrier multilayer (PE-PA-PE) pouches commonly used for under vacuum packaging.

The following samples were prepared: Control (not packed); Air (packed in air) and CO_2 (packed in 100% CO_2). Fresh eggs and egg samples after 1, 2, 4, 8, 15, 21 and 28 days of storage at 25 ± 2°C were analysed for albumen pH and dissolved CO_2, Haugh unit (HU), texture of the coagulated albumen and meringue crispness.

Analyses

Three numbered eggs for package were broken by hand and on each egg HU was determined at 25°C. For HU evaluation, after egg weighting and breaking over a flat surface, the height of the thick albumen was measured at a distance of 1 cm from the yolk perimeter, with a micrometer attached to a tripod (resolution 0.1 mm).
The pH of egg white and yolk was measured at 25°C using a pH-meter mod. Cyberscan 510 (Lennox, Dublin, Ireland).
Dissolved CO_2 on egg albumen was determined according to the titration method of Keener *et al*. (2001).
The coagulation properties of egg albumen were determined with a similar method of that of HammershØj *et al*. (2001). Heat-coagulated albumen gels were prepared inserting about 40 g of gently mixed albumen into a cylindrical glass jar. The jars were closed with glass caps and submerged in a water bath at 90 ± 2°C for 30 min. From each jar, three cylindrical samples of coagulated albumen (diameter 15 mm, height 10 mm) were taken using a core borer and than subjected to texture profile analysis (TPA) using a texture analyser mod. HD500 (Stable Micro Systems, Surrey, UK) equipped with a 50-kg load cell and a cylindrical probe mod. P/25 (diameter 25 mm). Test speed was 0.5 mm s^{-1} and the samples were compressed twice to 50% of the original thickness (5 mm). Results were expressed as hardness (N), corresponding to the height of the force peak measured during the first compression cycle (HammershØj et al., 2001).

Hard meringues were prepared with a ratio of albumen:sugar of 1:2 and a whipping time of 8 min. To 120 g of albumen obtained from three eggs, icing sugar has been added at two times: 120 g to raw albumen and 120 g gently after 7 min of whipping. The whipping process was performed with a stand mixer mod. KSM90 (Kitchenaid, St. Joseph, USA) at the maximum speed for 2 min. Aluminium pans of 28 mL capacity (diameter 45 mm, height 60 mm) were then filled with fractions of about 11 g of raw meringue exactly weighted and cooked in an oven at 90 °C for 210 min. Texture analysis was performed at 23 ± 2 °C, about two hours after removing meringues from the oven. A three point bending rig mod. HDB/3PB was used. The following setting was applied: pre-test speed, 1.0 mm/s; test-speed, 1.0 mm/s; post-speed, 10 mm/s; data-acquisition, 200 pps; distance, 20 mm. As an index of crispness, linear distance (L_d) was determined, using the 'Linear Distance' function within Texture Expert Exceed software (Version 2.61, Stable Micro Systems, Ltd., Surrey, UK), on a plot force (F) in N versus distance (D) in mm (Gregson & Lee, 2003). Although a 'length' is calculated, distance units cannot be used as one axis has force units.

Results and discussion

In terms of pH (Fig. 1), the albumen of Control sample showed an increasing trend from the beginning to the end of the storage period caused by CO_2 loss trough the shell (Keener *et al.*, 2001). Starting from fresh eggs with an average pH value of 8.98, the albumen of the Control sample reached values of about 9.5 after 28 days of storage. The albumen of samples packed in air evidenced a similar increasing trend of pH until the fourth day of storage, while it maintained quite constant values of about 9.2 during the rest of the storage period. The use of 100% CO_2 was responsible for a fast and marked pH decrease (of more than two points) as a consequence of CO_2 solubilization in the albumen. Actually, the absorption of this gas by the egg content takes place until equilibrium is established between the surrounding headspace and the CO_2 concentration within the egg. Particularly the equilibrium between white and CO_2 resembles that between blood serum and this gas where the proteins react to the addition of acid by reversible combination with H^+. Looking at the pH behaviour of CO_2 packed sample, it seems that in our experiments this condition was reached after the eighth day of storage. Actually, in albumen egg fraction, the combined CO_2 is the aggregate of bicarbonate, carbamino and unknown forms in which CO_2 is bound to proteins (Thapon & Bourgeois, 1994). In terms of dissolved CO_2, Control and Air samples showed very similar values for all the storage period, fluctuating around the initial amount detected on fresh egg (from about 1.7 to 2.2 mg g f.w.$^{-1}$). As expected, the dissolved CO_2 of eggs packed in 100% CO_2 sharply increased just after one day of storage, maintaining values of about 3 mg g f.w.$^{-1}$ until the 15th day, decreasing slightly from the 15th to the 28th day. The average HU value of fresh eggs used for our experiment (Fig. 3) was about 70 that correspond to the one of a fresh, good quality egg (Caner, 2005). This value rapidly decreased for the Control sample, in agreement with previous investigation about quality modification of fresh eggs during storage (Jones *et al*., 2005). HU reduction is due to the decrease of thick albumen height. Multiple hypotheses for this phenomenon have been proposed, including the break down of the ovomucin-lysozyme complex, decreasing carbohydrate content of ovomucin and increasing pH during storage (Chen *et al*., 2005).

Fig. 1. pH values of the albumen of shell egg samples during 28 days of storage at 25 °C. Control (▲): not packed; Air (O): packed in air; CO_2 (◆): packed in 100% CO_2

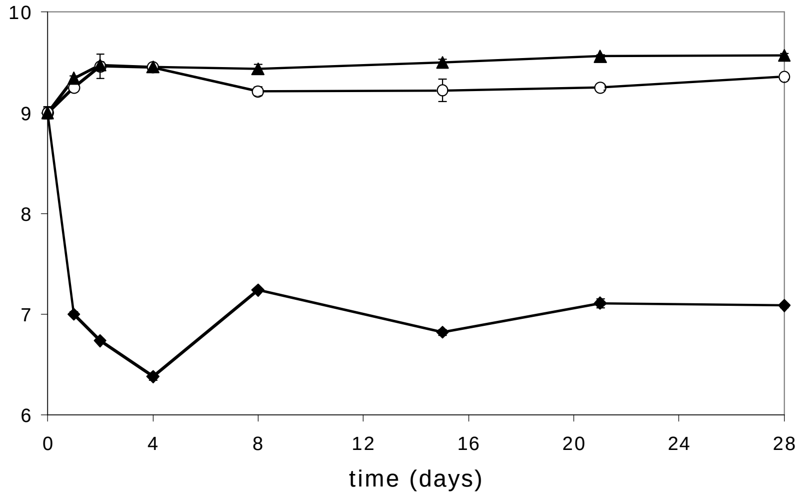


Fig. 2. Values of dissolved CO_2 (mg g f.w.$^{-1}$) in the albumen of shell egg samples during 28 days of storage at 25 °C. Control (▲): not packed; Air (O): packed in air; CO_2 (◆): packed in 100% CO_2

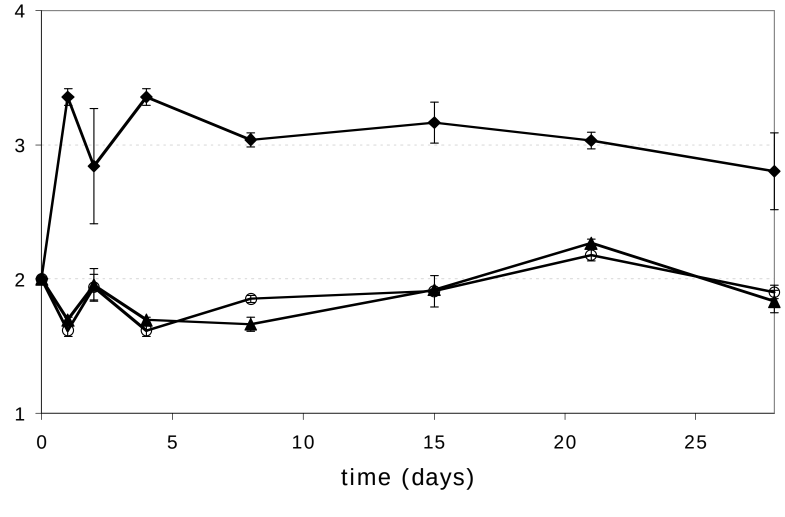


Fig. 3. Haugh unit (HU) values of shell egg samples during 28 days of storage at 25 °C. Control (▲): not packed; Air (O): packed in air; CO2 (◆): packed in 100% CO_2

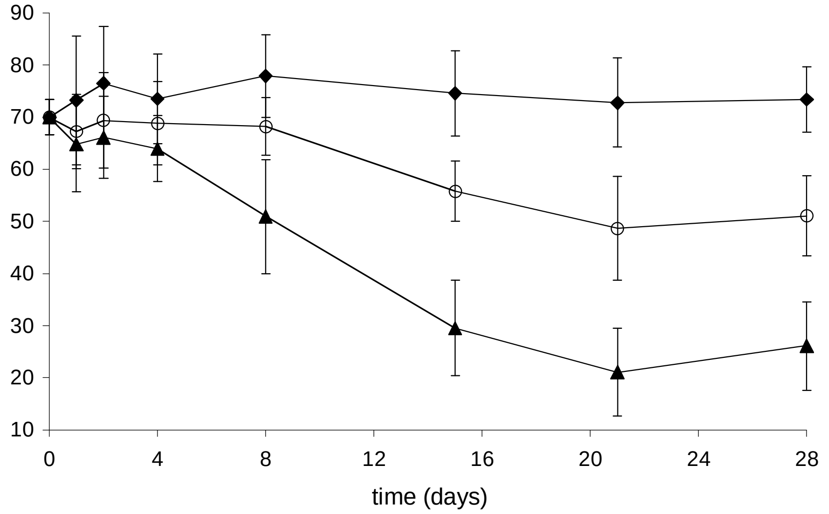
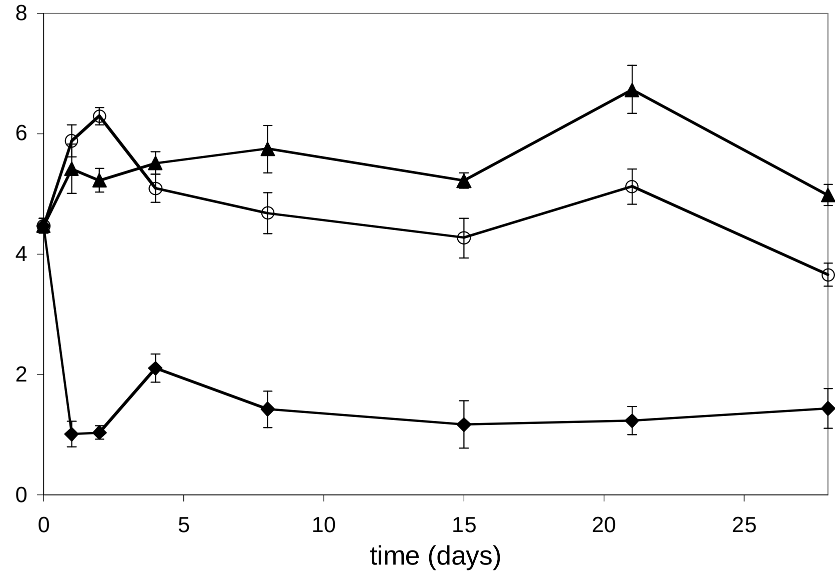


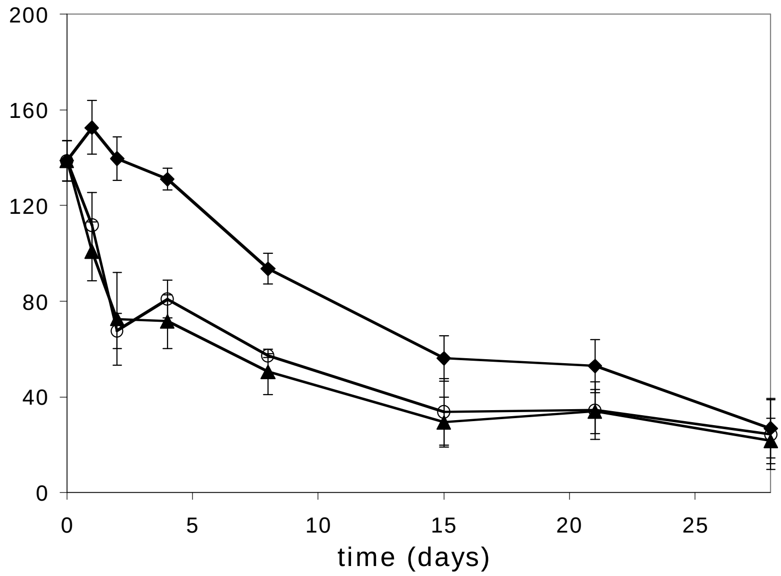
Fig. 4. Hardness (N) of coagulated albumen cylinders obtained from shell egg samples during 28 days of storage at 25°C. Control (▲): not packed; Air (O): packed in air; CO2 (◆): packed in 100% CO_2



On the basis of HU values, Caner (2005) classified eggs quality grade: grade A, HU > 55; B, 31 < HU < 54; C < 30. According to this author, after 8 days of storage the quality of eggs of Control sample shifted to B grade, reaching C grade after 15 days. Sample packed in air better preserved eggs in terms of HU compared with the Control, maintaining higher values of this parameter for all the storage period. Actually, this sample reached grade B only after 21 days of storage, while eggs packed in CO_2 sample maintained grade A for all the storage period. Indeed the HU behaviour of CO_2 sample did not show significant changes until the end of the experiment. In Fig. 4, the hardness behaviour of the heat coagulated albumen samples is reported. In general the values of hardness detected in our experiments are comparable with those obtained by HammershØj *et al*. (2001) on fresh eggs (from 4 to 7.5 N) laid by white Leghorn hens at different ages. The values of hardness for Control sample showed an increasing trend during the first height day of storage, maintaining the highest levels until the end of the experiment. This behaviour was probably due to the pH increase detected for this sample during storage (Rocculi *et al*., 2009). This firmness increase with increasing pH can be attributed to sulfhydryl-disulfide exchange, which was accelerated at pH 9. In this direction and in agreement with our results, Chang *et al*. (1999) showed that the hardness of albumen gel significantly increased ($P < 0.05$) as the adjusted pH increased from 7.5 to 10. A so intense modification of coagulated albumen hardness was not detected for samples packed in Air, that showed significantly lower values compared with the Control from the fourth day of storage that were not faraway from the initial value. A relation between pH and hardness response was observed also for CO_2 sample. Even in terms of hardness, the coagulated albumen of CO_2 sample evidenced a fast and marked reduction, reaching a value of 1.01 ± 0.13 after two days of storage, slightly increasing until the end of the experiment. As reported in previous investigations, this phenomenon was caused by the formation of a soft and puffy coagulum, due to the expansion of CO_2 during heating (Chang *et al*., 1999). According to this finding, from a visual examination of the heat coagulated albumen, while Control and Air samples had a typical compact structure, the one of CO_2 sample was very soft and puffy. Hermansson (1982) reported that at high pH, a fine and uniform gel matrix is formed with high gel strength, with small and water-binding pores. He also indicated that the net charge of proteins increased as pH increased, causing proteins to aggregate with low gel strength, thus forming a coarse network with large pores and minimal water-binding. HammershØj *et al*. (2001) stated that for food use of albumen gelling, the optimal texture was obtained with eggs stored for 14 days at 4°C because, due to the high CO_2 content, fresh albumen expands during heating and water-holding capacity is reduced. This happens also because the pH is closer to the isoelectric point of most albumen proteins. Further investigations of kind and amount of combined forms of CO_2 (e.g. aggregate of bicarbonate, carbamino, lipoids, unknown forms in which CO_2 is bound to proteins) present in the albumen of shell egg as a function of CO_2 partial pressure and storage time could clarify these aspects. For the production of foods such as meringue, foam stability must be maintained during formulation and additional processing. With this product, the foam must show little expansion or collapse when heat-setting causes drying, and converts the foam from a liquid to a solid (Foegeding *et al*., 2006). According to Gregson and Lee (2003), among the instrumetal parameters mental, one of the most useful for crispness assessment of crispy product like is the linear distance (L_d). In Fig. 5, L_d values detected on the different samples are reported. As happened for foam stability (data not reported), the crispness of meringue showed a decreasing trend for all the samples during storage.

Even this parameter was improved as a consequence of two days of eggs exposition to CO_2. While Control and Air samples showed very similar behaviour, crispness of meringue obtained with albumen of CO_2 sample was significantly the highest until 14-21 days of storage.

Fig. 5. Crispness (linear distance, Ld) of meringues prepared using albumen of shell egg samples during 28 days of storage at 25°C. Control (▲): not packed; Air (O): packed in air; CO2 (◆): packed in 100% CO_2



Conclusions

Our research confirmed the beneficial effect of 100% CO_2 MAP on egg freshness maintenance during storage. In addition our findings showed that the exposition of shell egg to this gas improved some technological performances of the albumen (e.g. meringue crispness), showing also high potentiality in order to modulate the hardness of coagulated albumen. From an industrial point of view, the application of this technology (e.g. with controlled atmosphere storage) could permit the substitution of more artificial, complicated, and expensive process commonly applied to change the albumen pH, in order to improve the quality characteristics of albumen based food products. In the optic of fresh shell eggs commercialization, CO_2 MAP eggs could represent a tailored innovative food product, with specific characteristics bound to its destination (e.g. fresh shell eggs special for meringue).

Acknowledgments

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