Time, temperature and moisture effects of dry-heating egg albumen powder in a fluidised bed

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Summary
The last 10-15 years the bacterial decontamination of dried egg albumen powder in the industry has traditionally been performed by hot room storage for several (7-15) days or by heating the powder at 80-90°C for ~24 hours during agitation of a vessel. Either method is time-, energy-, and storage capacity consuming.

We have examined the possible use of a fluidised bed as an alternative heat treatment process in order to pasteurise de-carbohydrated egg albumen powder. The fluidised bed process is performed within shorter time and requires less energy. The process parameters studied were temperature (90, 115, 130°C), time (0, 1, 3 h) and air relative humidity levels (~2, ~20%). The resulting bacterial count, egg albumen gel texture and water holding capacity (WHC), and surface hydrophobicity (S₀) were analysed.

All gel parameters analysed were affected as function of time and temperature in the fluidised bed. This could partly be explained by an increased surface hydrophobicity of the egg albumen proteins contributing in the gel network formation. Furthermore, the high temperature resulted in a sufficient reduction in bacterial count within the applied time-range. When process temperature was held constant and air relative humidity was high the resulting gel texture, WHC and S₀ increased significantly.

Introduction
One of the most significant properties of egg albumen is the ability to create a strong gel-network upon heating. Egg albumen gels are characterised as particulate gels that cold-set and are able to bind a high amount of water ~ 90% water/10% protein (Clark, 1992). The various processing steps in producing dried egg albumen powder reduces the gel textural properties compared with those of the initial raw egg albumen (Hammershoj et al., 2004). However, application of a dry heating process of the final spray-dried powder induces changes to the egg albumen powder, which was first reported by Kato et al. (1989) to be positive for the gel texture. Today, it is common that industrial processing of egg albumen powder includes a final dry-heating step in order to eliminate bacteria and improve functional properties. The usual methods for dry-heating are either hot room storage at 67-80°C for several (7-15) days (Baron et al., 2003; Mine, 1996) or heating the powder at 80-90°C for ~24 hours during agitation (Hammershoj et al., 2004). Either method is time-, energy-, and storage capacity consuming.

To minimise these parameters in the dry-heating process, we investigated how short term heating in a fluidised bed affected egg albumen powder functional properties. The principle of the fluidised bed process is to maintain the powder particles in a small flow area by forcing hot air through a bed as illustrated in Figure 1. The air velocity is high in order to suspend the powder particles above the bed in a fluidised way.

The present report is part of a larger study, which is being published in the International Journal of Food Science and Technology (Hammershoj et al., 2005a; Hammershoj et al., 2005b).
Materials and methods
Two spray-dried egg albumen powders were used as start-material for each of two experiments (A and B) conducted in a fluidised bed. The treatments in the two experiments were temperature 90°C and 130°C and low relative humidity (r.h.) of the air ~2% in experiment A, and temperature 115°C and low and high r.h. (by adding vaporised water) of the air ~2% and ~20%, respectively, in experiment B. Powder samples were collected at time t = 0, 1 and 3 h in sterile plastic bags. As reference dry-heating was used an industrial process of 21 h heating at 90°C under constant agitation of the egg albumen powder from each of the two powders in experiments A and B, respectively.

The samples were analysed for total bacteria/g after incubation for 5 d at 30°C using plate count agar CM0325 (Oxoid Ltd, Basingstoke, UK). Egg albumen powder suspensions of 0.25-1 g/L in phosphate-buffer were analysed for protein surface hydrophobicity ($S_0$) by the cis-parinaric acid method (Kato & Nakai, 1980). Egg albumen gels were prepared and gel texture analysed by uniaxial compression and water holding capacity (WHC) as described previously (Hammershoj et al., 2004). The obtained data were subjected to principal component analysis (PCA) using the Unscrambler® software (v 9.1, Camo Process AS, Oslo, Norway).

Results and discussion
In Figure 2 is given the score plots of samples in the two experiments, respectively. There is a significant effect in experiment A of the high temperature 130°C, compared with the spray dried samples and the 90°C treatment. The first principal component (PC) explains 89% of the variation structure of the analysed variables and is mainly caused by the difference in temperature, whereas the second PC explains 7% of the variation and reflects the time effect.

In experiment B the difference in air r.h. level is less significant comparing the low versus the high level. However, the effect is significant compared with the spray-dried samples, but the analysed variables of egg albumen samples dry-heated in the fluidised bed does not reach the level of the reference samples in this experiment.
Dry-heating of egg albumen powder: M. Hammershøj and H.C.D. Rasmussen

Figure 2  Score plots of egg albumen powder samples dry-heated in a fluidised bed in experiment A (temperature) to the right and experiment B (air r.h.) to the left.

The legends are: white square = spray dried (untreated), black square = references, for both experiments. Experiment A: grey circle = 90°C, grey triangle = 130°C. Experiment B: grey circle = 2% r.h., grey triangle = 20% r.h.

The loading plot in Figure 3 shows a high positive correlation between the textural parameters, which is confirmed by the correlation coefficients in Table 1. The WHC is less correlated with texture of the gels, however, it seems that the impact of dry-heating in the fluidised bed on bacterial count has a similar but opposite effect on the WHC. In other terms: when high efficiency of fluidised bed treatments results in low bacterial count a high WHC is obtained. As seen in Table 1, the WHC and bacterial count correlates with r = -0.616. In experiment A, only the high temperature treatment ensured a proper bacterial reduction according to the EU-requirements (European Commission, 1989) of < $10^5$ bacteria/g, whereas in experiment B both air humidity treatments fulfilled this after 3 hours treatment.

Figure 3  Loading plots of analysis variables for egg albumen powder samples dry-heated in a fluidised bed in experiment A (temperature) to the right and experiment B (air r.h.) to the left. The PC’s refer to those of Figure 2.
Table 1 Correlation coefficients (r-values) of analysed parameters on egg albumen powder samples subjected to dry-heating in a fluidised bed, (n=56).

<table>
<thead>
<tr>
<th></th>
<th>Gel strength</th>
<th>Fracture point</th>
<th>Work to fracture</th>
<th>Axial stress</th>
<th>Hencky strain</th>
<th>$S_0$</th>
<th>Bacterial count</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHC</td>
<td>0.486</td>
<td>0.670</td>
<td>0.513</td>
<td>0.604</td>
<td>0.602</td>
<td>0.277</td>
<td>-0.616</td>
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<tr>
<td>Gel strength</td>
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<td>0.995</td>
<td>0.981</td>
<td>0.919</td>
<td>0.912</td>
<td>0.825</td>
<td>-0.398</td>
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<tr>
<td>Fracture point</td>
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<td>0.914</td>
<td>0.989</td>
<td>0.825</td>
<td>-0.604</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work to fracture</td>
<td>0.978</td>
<td>0.928</td>
<td>0.910</td>
<td>-0.417</td>
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<tr>
<td>Axial stress</td>
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<td>0.888</td>
<td>-0.494</td>
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<tr>
<td>Hencky strain</td>
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<td>0.883</td>
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<tr>
<td>$S_0$</td>
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<td></td>
<td></td>
<td></td>
<td>-0.338</td>
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</tr>
</tbody>
</table>

Figure 4 Effects of fluidised bed dry-heating of egg albumen powder conditions: time (0, 1, 3 h), temperature (90°C, 130°C), air relative humidity (2, 20%) on heated gel WHC (left), gel textural axial stress (middle) and surface hydrophobicity $S_0$ (right).

In Figure 4, there is a clear effect of treatment time in the fluidised bed on all parameters. Especially, at 130°C and high air r.h. the WHC, gel textural strength and $S_0$ increases with treatment time. The increased $S_0$ partly explains the increase in gel textural properties (Table 1, Figure 4) as unfolding of the egg albumen proteins contribute to formation of the gel network (Hammershøj et al., 2005b). At lower temperature and air r.h. the time effect is less pronounced, however, longer treatment time at these conditions is expected to increase the effects. It is unclear whether the levels of the analysed parameters are able to reach those obtained at the higher temperature and air r.h. levels during a shorter process time.

Conclusion
All three process variables: time, temperature and air r.h., are important for obtaining effective dry-heating of egg albumen powder in a fluidised bed. Compared with the present dry-heating methods of hot room storage or vessel agitation, the process time in egg albumen powder industry can be reduced significantly by applying a fluidised bed treatment on account of an increased temperature and air moisture content.
References


