Effects of heat treatment on protein denaturation and starch gelatinisation in wheat flour

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ABSTRACT

In the EU, chlorination of soft wheat flour has been replaced in recent years, to some extent, by heat treatment for baking of high ratio cakes. The heat treated flour has enabled recipes to be developed which generate products with longer shelf life, finer texture, moist crumb and sweeter taste. It is not fully understood how heat treatment improves the flour; however, it is known that during the heat treatment process, protein denaturation and partial gelatinisation of starch granules occur. Therefore, it is important to quantify these property variations as they have a marked affect on the quality characteristics of baked products.

Heat treated flour was prepared by heating base flour in a laboratory fluidised bed dryer using a range of temperatures and times. The gluten was extracted from the flour and its quality was tested in an extensibility gluten rig attached to a texture analyser to obtain objective and comparative information on the extent of protein denaturation. Another portion of the flour was used to measure gelatinisation temperature and peak viscosity.

The results indicated that heat treatment of flour decreases gluten extensibility showing that protein denaturation occurred. Also, partial gelatinisation of the starch granules took place. The effects improve the baking quality of the cake product such as texture, height and volume.

Keywords: Flour; heat; protein; denaturation; gelatinisation.

INTRODUCTION

The first reference to heat treated flour was made in 1970 by Russo and Doe [1], who patented the process using a temperature range of 100°C to 115°C for a time of 60 minutes.

In 1976, a patent was filed by Cauvain et al. [2] who suggested a heat treatment of whole wheat and semolina, dried to a moisture content of 6%, and then heating the dried material for a specific time/temperature combination. The grain was then milled in the normal way.

Hanamoto and Bean [3] in 1979 also patented a method for producing heat treated flour, where the temperature was maintained at 71°C for 4-5 days.

Guy and Mair [4] in 1993 first heat treated base flour gently to a moisture <5.0%w/w, when the gluten was not extensively denatured. After the initial drying process, the flour needed to be heated to a temperature of 130°C to 140°C for 30 minutes to achieve the optimum performance.

By applying heat treatment to the flour and removing the moisture, it is possible to modify the physical, rheological and bacteriological properties. The effect of heat treatment is denaturation of the proteins, partial reduction or inactivation of alpha-amylase and partial gelatinisation of the starch [5]. Starch improvements to the flour may originate from the modification of the function of the starch granules which might involve the proteins and lipids in the surface layer.

The removal of moisture is an integral part of achieving the overall changes required, but it is important that the flour moisture content is equilibrated with the atmosphere for optimum baking results.

The two principal proteins in gluten are composed of gliadins and glutenins. Gliadins are present as monomers, which are responsible for gluten extensibility and cohesiveness, while glutenins form higher molecular weight polymers and contribute to the elasticity of gluten. These help to bind water and stabilise the liquid phase of the batter during the early stages of baking. If the gluten is too severely denatured by heat treatment, there will be a loss of stability in the batter resulting in defects in the cake structure.

The objectives of this work are to determine the optimum time/temperature treatment of base flour to produce heat treated flour by evaluating the protein quality and degree of starch gelatinisation.
MATERIALS & METHODS

Heat treated flour was prepared from base flour in a fluidised bed dryer (Sherwood Scientific, model MK11) using a range of temperatures (80-130°C) and times (5-30 minutes) when the moisture content reduced from 13% to <4% (wet basis). The moisture content of the heat treated flour was increased to its original value by spraying a known volume of water onto the flour during mixing in a Kenwood mixer (model KM199). Moisture content analyses were carried out using a convective oven at 130°C for 90 minutes.

A portion of the flour was hand washed according to the standard method [6], which consisted of kneading the dough sample approximately 10 minutes under cold running water to produce a cohesive, extensible mass, i.e. gluten, which was “rested” for 30 minutes before analysis began. The sample was then placed in a test tube and centrifuged for 5 minutes at 5000 rpm to remove air bubbles. After centrifugation, the sample was pressed for 40 minutes at 24°C to allow the gluten to relax, after which it was moulded into fine strips which were used for analysis.

The gluten quality was tested using a Kieffer Dough and Gluten Rig (A/KIE using a 5 kg load cell attached to a TA-XT2 texture analyser) to obtain information on the extent of denaturing of heat treated protein.

Another portion of the flour product was made into a slurry to measure gelatinisation temperatures and peak viscosity using a Brabender visco-ograph which measured viscosity in a rotational stainless steel bowl (75 rpm) as the temperature increased/decreased by 1.5°C. Results were recorded on a chart in Brabender Units (BU). Peak viscosity (BU) at peak temperature is the gelatinisation temperature.

RESULTS & DISCUSSION

Gluten Extensibilities. These show a decreasing extensibility (mm) which is possibly due to a reduction in gliadin caused by heat treatment. Figures 1, 2 and 3 represent the extensibility results for culinary flour, heat treated flour at 120°C for 30 minutes and heat treated flour at 130°C for 30 minutes.

![Figure 1. Extensograph culinary flour](image)
Figure 2. Effect culinary flour heat treated (120°C for 30 mins).

Figure 3. Effect of culinary flour heat treated. (Optimum time/temp).

The gluten samples had also lost their cohesion, indicating that there was a reduction in gliadin level.

*Braebender Viscograph Viscosities.* In Table 1, the gelatinisation temperature for the heat treated culinary flour is within the narrow range 57.2°C to 57.8°C. The culinary flour had a gelatinisation temperature of 58.9°C. It also shows that the peak viscosity progressively increases as temperature/time increases suggesting that a higher number of starch granules have swollen resulting in high peak viscosities.
### Table 1. Flour analysis for Treated, Untreated and Control flours.

<table>
<thead>
<tr>
<th>Prepared Flour</th>
<th>Moist % (oven)</th>
<th>Peak Viscosity BU</th>
<th>Gelatinisation temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 min at 120°C</td>
<td>11.0</td>
<td>321</td>
<td>57.5</td>
</tr>
<tr>
<td>30 min at 120°C</td>
<td>10.8</td>
<td>326</td>
<td>57.8</td>
</tr>
<tr>
<td>60 min at 120°C</td>
<td>10.6</td>
<td>371</td>
<td>57.4</td>
</tr>
<tr>
<td>10 min at 130°C</td>
<td>11.5</td>
<td>323</td>
<td>57.3</td>
</tr>
<tr>
<td>30 min at 130°C</td>
<td>9.2</td>
<td>366</td>
<td>57.4</td>
</tr>
<tr>
<td>60 min at 130°C</td>
<td>8.9</td>
<td>491</td>
<td>57.2</td>
</tr>
<tr>
<td>Control</td>
<td>12.2</td>
<td>320</td>
<td>57.8</td>
</tr>
<tr>
<td>Culinary</td>
<td>13.1</td>
<td>220</td>
<td>58.9</td>
</tr>
</tbody>
</table>

Table 2 shows the results of heat treatment over a range of times. Again, as time increases there is an increase in peak viscosity and a decrease in gelatinisation temperature, (Figure 4)

### Table 2. Flour analysis for Culinary flour treated at 100°C.

<table>
<thead>
<tr>
<th>% Moist (oven)</th>
<th>100°C for 10 min</th>
<th>100°C for 20 min</th>
<th>100°C for 30 min</th>
<th>100°C for 40 min</th>
<th>100°C for 60 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscograph</td>
<td>11.3</td>
<td>11.0</td>
<td>10.6</td>
<td>9.8</td>
<td>9.6</td>
</tr>
<tr>
<td>Peak Viscosity</td>
<td>230</td>
<td>238</td>
<td>242</td>
<td>250</td>
<td>255</td>
</tr>
<tr>
<td>Gelatinisation °C</td>
<td>58.6</td>
<td>58.4</td>
<td>58.1</td>
<td>57.9</td>
<td>57.7</td>
</tr>
</tbody>
</table>
Figure 4 Gelatinization temperature decreases with increase in time.

These results indicate that heat treatment increases the ability of the starch granules to absorb more water. To some degree, denatured proteins may also have contributed to the level of viscosity. The proteins on the surface of the starch are hydrophilic albumin and globulin which would be modified by heat treatment allowing the starch granules to absorb more water. The culinary flour had a peak viscosity of 220 BU suggesting that the unmodified starch granule surface had less ability to absorb water. Johnson et al [7] in 1980 suggested that the effects of heat treatment of starch improved baking quality, viscosity being the controlling factor for the final cake volume.

CONCLUSIONS
Heat treatment decreases gluten extensibility as well as cohesion showing that protein denaturation occurs during the heat treatment process.
Peak viscosity of the flour progressively increased as the time/temperature of heat treatment increased, due to the increased ability of the starch granules to absorb water.

REFERENCES