Introduction and Objective

Bread crumb firming is a complex process. It is generally accepted that amylopectin retrogradation is an important contributor to crumb firming during storage, but there is no direct cause and effect relationship between both processes. Besides formation of amylopectin crystals, water diffusion also affects crumb firmness during storage. Literature is scarce about the impact of such diffusion. It occurs on a macroscopic scale, i.e. from crumb to crust, as well as on a molecular scale, i.e. from gluten to starch. However, the relative importance of water redistribution and amylopectin retrogradation for bread firming is still under debate. Since water related phenomena are involved in crumb firming, the use of low resolution (LR) proton Nuclear Magnetic Resonance (1H NMR) to examine bread crumb holds promise. The objective of this study was to investigate changes during bread storage, thereby distinguishing between the effect of crumb to crust migration and evaporation of water and the effect of amylopectin recrystallization with water incorporation into the resulting starch network.

Results and Discussion

During storage of bread for 168 h, $\Delta H_{FP}$ increased while the relative amount of FW decreased (Table 1). Water becomes unfreezable due to inclusion into the amylopectin crystals but also due to inclusion into the continuous, rigid amylopectin network. No amylopectin retrogradation was observed during drying. Crumb firmness increased during storage and drying (Figure 1).

<table>
<thead>
<tr>
<th>Storage time after cooking (h)</th>
<th>FW (%)</th>
<th>$\Delta H_{FP}$ [J/g crumb (DM)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>47.0 (4.1)</td>
<td>5.25 (0.02)</td>
</tr>
<tr>
<td>48</td>
<td>48.0 (1.3)</td>
<td>2.03 (0.06)</td>
</tr>
<tr>
<td>120</td>
<td>39.9 (4.5)</td>
<td>3.26 (0.18)</td>
</tr>
<tr>
<td>168</td>
<td>38.5 (1.7)</td>
<td>3.34 (0.22)</td>
</tr>
</tbody>
</table>

The decreased crumb moisture content during storage did not result in an increased crumb firmness (Figure 1), showing that amylopectin retrogradation was largely responsible for crumb firming during storage. However, the increase in melting enthalpy levelled off after a couple of days of storage (Table 1), while crumb firmness increased further. This points to an additional phenomenon which contributes to crumb firmness.

With 1H NMR, changes in the distribution of protons from water and biopolymers can be observed. During storage of bread, the area of population B (hydrated protons of gluten) (Figure 2b). The moisture content (36%) was still high enough to hydrate the gluten network. Dehydration of this network in stored bread crumb contributed to the increase in crumb firmness after a couple of days of storage (Figure 1).

Conclusions

The combined results from 1H NMR, DSC and texture analyses allowed proposing a more profound interpretation of the bread crumb firming mechanism. Amylopectin retrogradation and the formation of a continuous, rigid, semi-crystalline starch network which includes water in its structure were strongly related to the increase in crumb firmness, especially during the first days of storage. This water inclusion, together with moisture diffusion from gluten to starch and from crumb to crust, reduce the moisture content of the gluten network. After a couple of days of storage, the moisture content had dropped below the critical point for gluten to be fully plasticized, resulting in increased stiffness that contributed to crumb firmness.

Experimental

Bread making process

Bread was made using a straight-dough method [100.0 g wheat flour (14.0% moisture), 5.3 g compressed yeast, 6.0 g sucrose, 1.5 g NaCl, 57.0 mL water] as described in Bosmans et al. (2012). 5. Differential scanning calorimetry (DSC) measurements

The melting enthalpy of retrograded amylopectin ($\Delta H_{FP}$) and the relative amount of freezable water (FW) were determined with DSC.

Firmness measurements

Crumb firmness was detected with an Instron 3342 (Instron, Norwood, MA, USA) on fresh, stored (for 168 h) and dried bread crumb.

1H NMR measurements

Proton relaxation measurements were performed on a Bruker Minispec mq20 spectrometer (Bruker, Rheinstetten, Germany) operating at 20 MHz and at 25 °C.

References


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