Colloidal interactions in an alternate make cheese

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Abstract

The role of emulsion structure and interactions on the material and technical functionality of an alternate make cheese (AMC) was investigated. Lab scale cheese samples (25 g comprising 23 wt.% fat and 20 wt.%) were prepared by recombining model emulsions with a separate protein phase under controlled temperature, shear speed and residence time in a rapid visco analyser (RVA). Sodium caseinate and Tween 20 were used respectively to stabilize fat globules for the model emulsions. Preliminary experiments were carried out for samples prepared using either calcium caseinate or sodium caseinate as protein phase. Structural characterisation of samples showed emulsion structure and distribution within these phases to be dependent on protein type. It was inferred that the calcium from calcium caseinate matrix modified the interfacial layer of the emulsions stabilised by sodium caseinate, as indicated by the increased fat globule size distribution after cheese making. In comparison, the size of fat globules covered with sodium caseinate appeared relatively stable in cheese produced form cheese curd. Based on these observations, caseinates were subsequently replaced by cheese curd as the protein phase for the remainder of the study.

For cheese samples prepared with low fat cheese curd, fat droplets stabilised with sodium caseinate were hypothesised as binding with the surrounding protein matrix, and thereby these fat globules could be considered as ‘active fillers’. Confocal laser scanning microscopy supported this hypothesis showing homogeneously dispersed fat droplets within the protein network. This emulsion system did not show fat-protein phase separation in baking (170 °C 10 minutes) as droplets were prevented from coalescing as a consequence of entrapment within the protein phase.

Fat globules covered with Tween 20 were hypothesised as behaving as ‘inactive fillers’, with the adsorbed layer not anticipated to form bonds with the surrounding protein network. Confocal and scanning electron microscopy instead showed localised domains of fat droplets within the protein structure that underwent partial coalescence on cooling of the cheese after manufacture. Cheeses comprising Tween stabilised droplets exhibited phase separation on baking and visible oil-off on the surface of cheese arising
from extensive coalescence taking place within the localised regions of fat due to melting of the partially coalesced structures. Additional rheological analysis of cheeses was carried out to determine the effect of droplet-protein interactions on the material properties of the cheese samples. Notably, findings were presented in relation to a non-fat control cheese. Findings showed that, at temperatures below 30 °C when fat was crystallized, both inactive and active fillers had a higher relative modulus to the non-fat sample. However, at elevated temperature without fat crystals, inactive fillers resulted in a relative reduction in storage modulus when compared to the non-fat cheese, while active fillers increased relative storage modulus.

Model cheeses prepared with either sodium caseinate or Tween 20 stabilised emulsions were then compared to cheese samples comprising non-homogenised cream as the emulsion phase. Structural analysis of samples determined that cheeses comprising fat globules stabilized with native milk fat globule membrane behaved in a manner analogous to samples prepared with the Tween stabilised emulsion, indicating the presence of inactive droplets. However, it was also observed that increasing the residence time of cheese production within the RVA caused a transition of the interaction behaviour of the emulsion from inactive to active, as evidenced by corresponding changes to structural, material and functional properties of the cheese.

Further exploration of this transition determined that the mechanical work applied during cheese preparation was sufficient to homogenise fat droplets during extended shearing, resulting in a reduction to fat droplet size. Droplet homogenisation during shearing was also found to have disrupted the native milk fat globule membrane, allowing protein adsorption to take place. It was also determined that whey proteins were the predominant interfacial fraction adsorbed as a consequence of extended shearing, and were considered responsible for the transition of droplets from inactive to active. Combined findings have shown that the material and functional properties of an alternate make cheese composition could be strongly influenced by the interactions of the emulsion phase with the surrounding protein network. These interactions could, in turn, be manipulated through formulation and/or process design, providing greater control over product properties.
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Figure 6.18: Cheeses were produced using the cream after sonication with serum collected from non-fat cheese. The cheese was produced in 15 minutes at 800 rpm 60 °C. (a) Fat globule size distribution is compared in cheese (fresh cheese, ■; 7 days 4 °C stored cheese, ■; and the cream, ■) used for cheese producing; (b) CLSM images were taken using lenses of x40 (left photo) and x25 (right photo) on cheese in 7 days storage at 4 °C.

Figure 6.19: Small strain rheological properties are compared in cheese heated up from 4 °C to 80 °C. G’ is cheese storage modulus and Gm’ is cheese matrix storage modulus, which was measured on non-fat cheese of the same ratio of water to protein. Cheeses were made by varied constant shear speed, producing temperature and preheated natural cream. Cheese made in 40 minutes 600 rpm 60 °C (▲) within 45.3 kJ/kg total shear work; cheese made in 10 minutes 1200 rpm 60 °C (◉) within 19.0 kJ/kg total shear work; cheese made in 15 minutes 1200 rpm 60 °C (●) within 35.0 kJ/kg total shear work; cheese made in 30 minutes 1000 rpm 70 °C (▲) within 42.8 kJ/kg total shear work; cheese made in 10 minutes 800 rpm 60 °C and the cream was precooked with 4 % NaCas (X); cheese made in 15 minutes 800 rpm 60 °C and the cream was after sonication with serum collected from non-fat cheese (■).

Figure 6.20: Schematic diagrams of the impact factors to transit inactive fat fillers to active fat fillers in cheese production.
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Acronyms

AMC  Alternate make cheese
AMC_{NaCas}  Alternate make cheese produced from emulsified fat fully covered with sodium caseinate
AMC_{Tween}  Alternate make cheese produced from emulsified fat fully covered with Tween 20
AMC_{NC}  Alternate make cheese produced from fat globules with native milk fat globule membrane
AMC_{AMF}  Alternate make cheese produced from anhydrous milk fat without emulsifiers
AMF  Anhydrous milk fat
β-ME  β-Mercaptoethanol
Ca  Capillary number
CaCas  Calcium caseinate
CLSM  Confocal laser scanning microscopy
cm  Centimetre
d(0.1)  Volume-weighted diameter of 10 % smallest droplets
d(0.9)  Volume-weighted diameter of 10 % largest droplets
d_{4,3}  Volume-weighted average mean diameter
EDTA  Ethylene diamine tetra acetic acid
FG  Fast Green
FO  Free oil
g  Gram
G'  Storage modulus
G''  Loss modulus
G_{m}'  Storage modulus of non-fat cheese
Hz  Hertz
LFCC  Low fat cheese curd
m  Mass (in equations); or meter (after numbers)
<table>
<thead>
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<tbody>
<tr>
<td>min</td>
<td>minutes</td>
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<tr>
<td>mm</td>
<td>Millimetre</td>
</tr>
<tr>
<td>mg</td>
<td>Microgram</td>
</tr>
<tr>
<td>nm</td>
<td>Nanometre</td>
</tr>
<tr>
<td>NaCas</td>
<td>Sodium caseinate</td>
</tr>
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<td>NaOH</td>
<td>Sodium hydroxide</td>
</tr>
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<td>NR</td>
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<td>PEG</td>
<td>Polyethylene glycol</td>
</tr>
<tr>
<td>Re</td>
<td>Reynold number</td>
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<tr>
<td>RhPe</td>
<td>1,2-dimyristoyl-sn-glycero-3-phosphoethanolamine-N-(lissamine rhodamine B sulfonyl)</td>
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<tr>
<td>RVA</td>
<td>Rapid visco analyzer</td>
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<tr>
<td>rpm</td>
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<td>SDS-PAGE</td>
<td>Sodium dodecyl sulfate-poly acrylamide electrophoresis</td>
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