# High-Pressure-Induced Starch Gelatinisation and Its Application in a Dairy System

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# Abstract

This study investigated pressure-induced starch gelatinisation in water and milk suspensions. A rheological method, termed ‘pasting curves’, provided an objective and analytical means to determine the degree of pressure-induced starch gelatinisation. In addition, a polarised light microscope was used to observe birefringence of the starch granules and the degree of starch swelling was measured. The preliminary investigation into pressure-induced gelatinisation of six different starches showed that potato starch was the most pressure resistant and was not gelatinised after a pressure treatment of 600 MPa for 30 min at 20 °C. Waxy rice, waxy corn and tapioca starches showed complete gelatinisation after the same treatment while normal rice and normal corn starches were only partially gelatinised despite the disappearance of birefringence.

Based on the preliminary study, two starches (normal and waxy rice starches) were selected for more detailed studies. The effects of treatment conditions (pressure, temperature and duration) on the gelatinisation were investigated with these selected starches. The degree of gelatinisation was dependent on the type of starch and the treatment conditions. The results also indicated that different combinations of the treatment conditions (e.g. high treatment pressure for a short time and low treatment pressure for a longer time) could result in the same degree of gelatinisation. Both starch types exhibited sigmoidal-shaped pressure-induced gelatinisation curves and there was a linear correlation between the degree of swelling and the apparent viscosity of the starch suspension. After treatments at ≥500 MPa for 30 min at 20 °C, both starches lost all birefringence although the apparent viscosity and the degree of swelling of normal rice starch did not increase to the same extent as observed in waxy rice starch.

Pressure-induced gelatinisation of starch was retarded when starch was suspended in skim milk. This was attributed to the effect of soluble milk minerals and lactose present in the milk whereas milk proteins (casein and whey) did not affect the degree of gelatinisation at the levels present in 10% total solids skim milk. The presence of soluble milk and/or lactose may lead to less effective plasticising of starch chains by the suspension medium. Interactions between milk components and starch molecules may also play a role in retarding gelatinisation by reducing the mobility of starch chains.

The functionality of starch in a dairy application was tested using acid milk gels as a model system. Skim milk with added starch (waxy rice or potato starch) was either pressure treated (500 MPa, 20°C, 30 min) or heat treated (80°C, 30 min) and subsequently acidified to form acid milk gels. The addition of waxy rice starch resulted in firmer acid milk gels, and increasing the amount of starch caused an increase in the firmness of both pressure-treated and heat-treated samples. However, pressure-treated samples with added potato starch did not show significant changes in the firmness whereas the heat-treated counterparts showed a marked increase in the firmness as the level of potato starch increased. The difference between the effects of the two different starches can be explained by the extent of starch gelatinisation in skim milk. Starch granules absorb water during gelatinisation whether induced by pressure or heat which effectively increases milk protein concentration in the aqueous phase to form a denser protein gel network on acidification. The firmness of acid milk gels can be increased by adjusting the pH at pressure or heat treatment to higher than the natural pH of milk. The effect of pH at pressure or heat treatment and addition of starch on the acid milk gel firmness was additive and independent of each other up to a starch addition level of 1%.

This study provided an insight into pressure-induced gelatinisation of starch by showing gelatinisation properties of starches of different botanical origins and the effects of the treatment conditions (treatment pressure, treatment temperature and duration) on the degree of gelatinisation. Furthermore, the results from the pressure treatments of starch in dairy-based suspensions showed that pressure-induced gelatinisation was affected by other components in the system. These results demonstrate the importance of understanding the gelatinisation properties of starch in complicated food systems in which a number of other components are present. In terms of the application of starch in dairy systems, when starch was added to milk and gelatinised by pressure treatment, the acid milk gel produced by subsequent acidification was firmer than the acid milk gel made from skim milk alone.

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In unpublished study, “Effect of static heating on the starch-in-water suspensions”:

In publication, Oh, H. E., M. Wong, D. N. Pinder, Y. Hemar and S. G. Anema (2007b). "Effect of pH adjustment at heating on the rheological properties of acid skim milk gels with added potato starch." *International Dairy Journal* **17**(12): 1384-1392:

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# List of Symbols

| | |
|---|---|
| $\eta_{initial}$ | Apparent viscosity at 20 °C before pasting begins |
| $\eta_{peak}$ | Maximum apparent viscosity attained during pasting |
| $T_{onset}$ | Onset temperature of gelatinization at which the apparent viscosity starts to increase |
| $T_{peak}$ | Temperature at $\eta_{peak}$ |
| $G'$ | Storage modulus |
| $G''$ | Loss modulus |

# List of Abbreviations

| | |
|---|---|
| **CCP** | Colloidal calcium phosphate |
| **GDL** | Glucono-$\delta$-lactone |