Carbohydrate Polymers **21** (1993) 61–62

News and Views

WHAT HAPPENS TO STARCH IN THE EXTRUDER?

A two day workshop held on 'The Extrusion of Starch Products' at Nottingham University's Sutton Bonington Campus on 29 and 30 March, continued the University's initiative on extrusion. Forty delegates from five countries attended the workshop which was split into two parts. The first day dealt with the changes taking place within the material as a result of the extrusion process, and the second day covered techniques for evaluating extruded products.

Professor John Blanshard, Dean of the University's Faculty of Agricultural and Food Sciences, started the workshop by reviewing the structure of starch and changes occurring as a result of heat treatment. His research team has made significant contributions to two areas of direct relevance to extrusion; the starch gelatinisation process at low water content, and the glass transition. Dr Andrew Smith from the UK's Agriculture and Food Research Council (AFRC) then covered the changes in starch morphology occurring within the extruder. This was largely based on the extensive work that has been carried out on twin screw extrusion of maize and potato starch systems under Dr Smith's direction at the AFRC's Norwich Laboratory. A whole range of issues were raised by this talk, many of which are not sufficiently appreciated by those operating the process in an industrial environment. These include the use of the specific mechanical energy as a unifying concept and the problems that can arise with regard to product inhomogeneity as a result of uneven water distribution.

We have a long way to go in understanding what controls product expansion and air cell size. The two relevant factors must be the viscoelastic properties of the melt (which would determine the diameter of the product in the absence of bubble growth) and the nucleation and growth of water vapour bubbles. In the workshop, the first of these factors was covered by Dr Robin Guy from the Flour Milling and Baking Research Association, based at Chorleywood in the UK. Dr Guy's group has been carrying out fundamental research on starch extrusion since 1983 and it was interesting to hear some of his recent ideas. He showed how the degree-of-processing (D.P.) of a starch extrudate could be quantified by measuring the viscosity of a 1 : 10 ground extrudate : water mixture. This was then related to the die swell observed as a result of extrusion processing at temperatures just too low for bubble growth to occur, and the viscoelastic properties of the melt. The latter could be obtained from pressure measurements using a slit or capillary die on the end of an extruder, but Dr Guy described an alternative approach which is to measure viscoelasticity in a oscillatory rotational rheometer on disc-shaped samples cut from extrudates. Measurements were made immediately after extrusion at a temperature of 95°C. Essentially, die swell initially rose with a 'degree-of-processing' plateaux at about 50% D.P. A strong correlation between die swell and 'melt' elasticity was demonstrated.

The complementary question of the effect of bubble growth on expansion was discussed by Professor John Mitchell, who presented a theoretical model for the bubble growth process developed, in particular, by Mr Jin Fan who is working with the Nottingham group. This model takes into account the loss in water and decrease in temperature during the expansion process and uses a rheological model that includes the glass transition temperature as a reference temperature. Extensive data has been obtained at Nottingham on the effect of a range of sugars on the extrusion properties of maize grits, and this data was interpreted in terms of the theoretical model. This is a direct application of the glass transition data obtained through the multi-company ACTIF (Amorphous Crystalline Transitions in Foods) research project. It is clear that additional concepts that need to be introduced for a complete description are: bubble coalescence, and water diffusion from the melt to the growing bubble surface.

Andrew Smith had already demonstrated how changes in screw configuration could be used to control some aspects of extruded product structure. This theme was taken further by M. Georges Hallery from Clextral, who talked about developments in the range of screw elements available for twin screw extruders. One of the questions raised in the subsequent discussion was whether users of extrusion technology are employing the best screw geometries now available. The reluctance to alter well established processes is understandable, but there may be substantial gains to be made. The lectures were followed by seminars where delegates could discuss problems with the speakers, and demonstrations of the Clextral BC 21 by Mr John Bargery of Regis Machinery. In addition to the studies on the

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maize sugar systems, this small twin screw extruder has been used for research on protein extrusion and trial work for companies. A further three year project aimed at understanding the effectiveness of extrusion in reducing microbial contamination of powders will start soon at Nottingham.

On the second day of the workshop, methods for investigating extruded products were discussed and demonstrated. The group moved to the Department of Pharmaceutical Sciences at University Park in Nottingham to hear lectures from Dr Roger Arnold from Rank Hovis McDougall Research and Engineering, who showed some excellent optical and electron micrographs of extruded snack food, cornflake and pet-food products, and Dr Jeremy Adler from Nottingham, who discussed the potential of confocal fluorescence microscopy. This was followed by a series of microscopy demonstrations (confocal, scanning electron microscopy and conventional optical microscopy) organised by Dr Colin Melia from the Department of Pharmaceutical Sciences.

On the return to the Sutton Bonnington Campus, the lecture programme was continued by Andrew Smith, who covered the mechanical properties of extruded products, and Dr Monica Kalichevsky, who described the use of X-ray methods, differential scanning calorimetry and dynamic mechanical thermal analysis to obtain information on the degree of starch gelatinization, amylose–lipid complex formation, the extruder, and glass transitions. Lectures were completed by Mrs Sue Tian and Miss Conny Jumel, who covered the use of enzymatic and chromatographic methods for obtaining information on the extent and type of starch degradation as a result of the extrusion process.

The above methods, which are available in the Department of Applied Biochemistry and Food Sciences on Sutton Bonington Campus, were then demonstrated on the final afternoon of the workshop.