Non-Food

Proteinous Bioplastics from Bloodmeal

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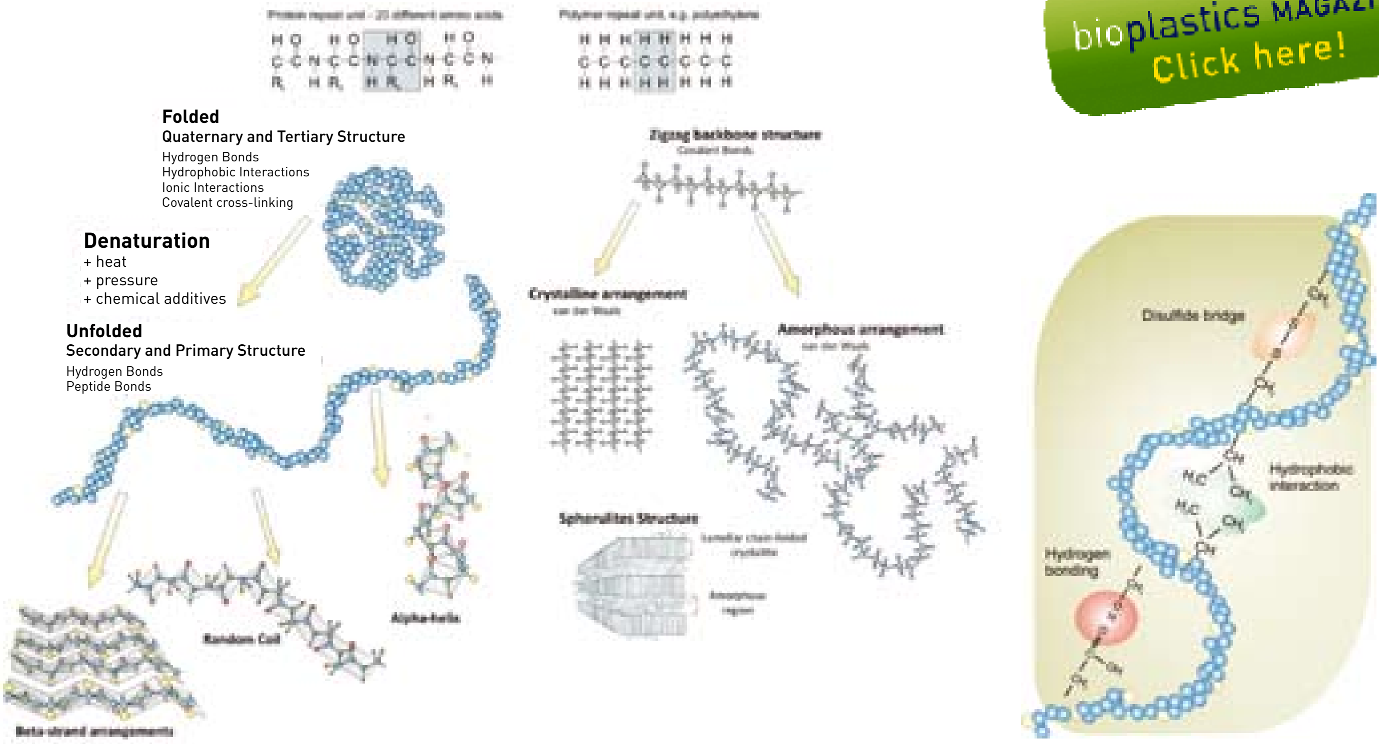
It is almost impossible to remember a world without plastics; however, environmental concerns over the origin, use and disposal of plastics have created a substantial effort into finding alternative solutions to these issues. Recycling is aimed at reducing the amount of virgin material required; biodegradable polymers are intended to solve the disposal and ultimate fate of polymers, while research into finding sustainable sources for polymer production is aimed at reducing the reliance on petrochemical sources. Although bioplastics sound like the perfect solution to these problems, bioplastics also have some drawbacks; most importantly the perceived competition with food production. As a result, attention is shifting to second generation bioplastics manufactured from non-potential food sources. However, one of the challenges for bioplastics is to be successfully integrated into common synthetic plastic processing routes, such as extrusion and injection moulding.

Chain entanglements and secondary interactions are what differentiate synthetic polymers from other low molecular weight organic substances. Inter- and intra molecular bonds, as well as chain entanglements, prevent chain slippage leading to the superior properties of polymers. Proteins are natural biopolymers and exhibit the same behaviour. Various amino acid functional groups offer a wide range of possible inter- and intra-molecular interactions, leading to the complex structure found in proteins. This implies that successful processing hinges on the ability to manipulate protein structure.

In this article thermoplastic bioplastics produced from proteins, obtained as a co-product in the meat industry, are discussed. Bloodmeal is mostly unfit for human consumption and is currently used as a low cost animal feed supplement. With more than 80% protein, it has the potential to be used as a thermoplastic biopolymer. However, during the production of bloodmeal, proteins are exposed to high temperatures, inducing aggregation and cross-linking. Cross-links are heat-stable, covalent bonds between either cysteine or lysine amino acid residues, resulting in an insoluble powder. Previous studies have claimed blood proteins not to be extrudable, failing to produce a homogenous plastic material.

This offers a great challenge to its processability since the wrong conditions may lead to further cross-linking, not only leading to a non-homogenous material, but also potentially



blocking the extruder or injection moulder. It was found that processing requires sufficient protein denaturing leading to the exposure of different amino acid functional groups, followed by rearrangement of chains by means of plasticisation and shear flow and finally allowing new interactions to be established during the solidification stage and appropriate additives. Successful processing therefore requires appropriate modification by eliminating or introducing intermolecular bonds at the correct time during processing.

Bloodmeal is a powdery product and processing is therefore required to consolidate the particles to prevent adhesive failure. It was found that denaturation of bloodmeal using water, heat and pressure was not enough to break covalent bonds, resulting in a heterogeneous material. Thermoplastic processing required a combination of aggressive denaturants, reducing reagents and plasticizers to form a homogenous and extrudable material.

By relying on Fourier Transform Infrared analysis (FTIR) the structure of a processable bloodmeal based bioplastic could be assessed. Results confirmed a shift from α-helix to a predominantly β-sheet and random coil structure. It is interesting to note the similarity between the mixed random coil/ α-helix structure of these proteins compared to that of synthetic semi-crystalline polymers. In synthetic polymers chains in the crystalline regions are typically kept in position by hydrogen or van der Waals forces in an extended zigzag conformation. Chains then fold into and out of this crystalline lamella forming amorphous regions. It is therefore an important observation that the β-sheet/ random coil structure of extrudable proteins closely resembles that of synthetic semi-crystalline thermoplastic polymers.

Initial trials showed mechanical properties of extrudable bloodmeal bioplastics to vary depending on the moisture and plasticiser content. The tensile strength of linear low density polyethylene (14 MPa) was easily surpassed, however, the material was considerably stiffer. Potential applications are in the agricultural and horticultural markets, more specifically products such as seedling trays, tree guards and possibly extruded netting. Technology in the area is still in its infancy and considerable research is still required to improve properties such as long term stability and embrittlement. This patented technology is currently owned by Novatein Ltd., a spin-off company by WaikatoLink Ltd., the commercial arm of the University of Waikato.

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