FINAL REPORT

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Plastics and polymer blends from proteins produced by animal co-product industry

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OBJECTIVES:

The chief objective of the present work is to test and evaluate possibilities to translate the methodology of making plastics and polymer blends from soy proteins to the proteins produced by the rendering industry.

Project Overview:

We proposed to test and evaluate possibilities to translate the methodology of making plastics and polymer blends from soy proteins to the proteins produced by the rendering industry. During initial part of study, we have started working on preparing and characterizing the bio-plastic materials. The initial results indicate the brittle nature of this plastic; although it has modulus comparable with polystyrene plastic. The next immediate step is to incorporate different impact modifiers such as recycled rubber powder, acrylate and polystyrene-butadiene particles to improve the toughness properties of these plastics. In the future, polymer blends, where the proteins will be mixed with industrially produced biodegradable polymer (polycaprolactone), will be also prepared and tested.

Impacts and Significance:

Recommendations derived from the proposed study will suggest efficient directions for further investigations in manufacturing/fabrication of polymeric materials with improved characteristics employing the animal proteins as a component.

BRIEF LITERATURE SURVEY:

The rising oil prices helped to stimulate early interest in biodegradables back in the 1970s and concerns over the dwindling availability of landfill sites are reviving interests in biodegradable materials today. A biodegradable material or green polymeric material can be obtained in various forms such as neat polymer, blended product, and composite from renewable resources.[1] Biodegradable plastics will be important in applications for articles that are unlikely to be recycled, such as trash/rubbish and compost bags, mulch films and disposable diapers/nappies.[2]

Both wet and dry processes are used to prepare the biodegradable plastic materials. The 'wet process' requires the biopolymer dispersion in a film-forming solution and has been extensively studied and applied to produce edible or biodegradable films and coatings. The 'dry process' is based on thermoplastic properties of some biopolymers (mainly starch and proteins) in low water content conditions and had been applied with success to produce edible and/or biodegradable materials by using common melt processing technologies (e.g. extrusion, molding or rolling mill procedure).[3]

Paetau et al.[4] studied the preparation and processing conditions for making soy-plastic through compression molding. The plastic specimens had strength comparable to polystyrene. Results indicated that molding the material at 140°C resulted in specimen with higher tensile strength compared with those molded at lower temperatures. Soy protein plastics prepared from soy protein powder with 11.7% moisture content had a tensile strength of 40MPa at a 140°C molding temperature, whereas the tensile strength was 35 MPa at a 125°C molding temperature. One study on soy protein demonstrated that the curing strength of protein was also greatly affected by curing pressure. The maximum stress of 42.9 MPa and maximum strain of 4.61% of

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[1] Mohanty, A. K. et al. *Macromolecular Materials & Engineering (2000)*, 276/277, 1-24.

[2] Villar, M. A.; Thomas, E. L. and Armstrong, R. C. *Polymer (1995)*, 36 (9), 1869-.

[3] Swain, S. N.; Biswal, S. M.; Nanda, P. K. and Nayak, P. L. *Journal of Polymers and the* Environment (2004). 12(1), 35-42.

[4] Paetau, I.; Chen, C.-Z. and Jane, J. *Industrial and Engineering ChemistryResearch (1994)*. 33(7), 1821-1827.

the specimen, were obtained when soy protein was molded at temperature 150°C and pressure 20 MPa for 5 minutes. The water absorption of the specimen decreased, as molding temperature and time increased. At high temperature (e.g., at 150°C), it took about 3 minutes to reach optimum curing quality; however, at low temperature (120°C), it took about 10 minutes to reach optimum curing quality.[5] Although, plastics made from soy protein have high strength and good biodegradable performance, but the brittleness of soy proteins has not been resolved thoroughly.

Polymer blending is also an important method in polymer manufacture and has received increasing attention. These blends may combine the advantages of both component and may have better properties than either component. Polycaprolactone (PCL) is biodegradable synthetic aliphatic polyester. Blending PCL with natural polymers, such as protein, cellulose, and starch, has attracted attention. However, most natural polymers are hydrophilic and are not miscible with synthetic hydrophobic polymers. The blends consist of two distinctive phases, whose interfaces are bounded weakly with a poor interaction, and this result in inferior physical properties. A third component (compatibilizer) usually is added to an immiscible blend to increase the compatibility and/or to modify the interfacial adhesion of the blend and, hence, to improve the mechanical properties.[6]

Experimental:

Various protein meals such as feather meal (CP 87.2%, fat 8.5%), pet food poultry meal (CP 70.2, fat 11%) and blood meal, have been provided by Fats and Proteins Research Foundation (FPRF). We have picked up feather meal in the beginning for understanding the plastic formation process through compression molding. Defatted protein meal from feather meal was recovered by dissolving fat by using hexane as solvent and then dried to evaporate residual solvent. After this, protein meal was ground and sieved with a stack of sieves with pore size of mesh 0.4 inch, 600 micron, and 300 micron, respectively to get protein powder of 300 and below 300 micron. The sieved protein powder was found to contain around 10% moisture content. The mixture was compression molded using Carver press at 150° C temperature and 15

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[5] Mo, X.; Sun, X. and Wang, Y. J. *Journal of Applied Polymer Science (1999)*, 73, 2595-2602.

[6] Zhong, Z. and Sun, X. S. *Polymer (2001)*, 42, 6961-6969.

MPa pressure for 5 minutes. Figure 1 shows thermoplastic nature of protein powder and paves way for building improved and refined plastic films and biocomposites.

Fig. 1. Bio plastic from feather meal protein

Figure 2 is a DSC thermograph, which shows the heat-induced denaturation of proteins, as unfolding protein absorbs heat when it is denatured; the peak temperature is denaturation temperature (T_d). The heat-induced denaturation disappears in the second DSC scan, which means that feathermeal protein is an irreversible thermal set polymer. This protein decomposes at 225°C, as shown in TGA scan (Figure 3). The first weight loss occurs between room temperature and approximately 100ºC, mainly from water evaporation. Protein weight remains constant from 100ºC to 200ºC and then the protein starts to lose weight, primarily from the decomposition of the components in the protein. The solids left after 400ºC are mainly ashes. The results are in good agreement with the soy protein.[7]

[7] Wool, R. P. and Sun, X. S. *Bio-based Polymers and Composites (2005)*,Chapter 9, pg. 292-326, Elsevier Academic Press.

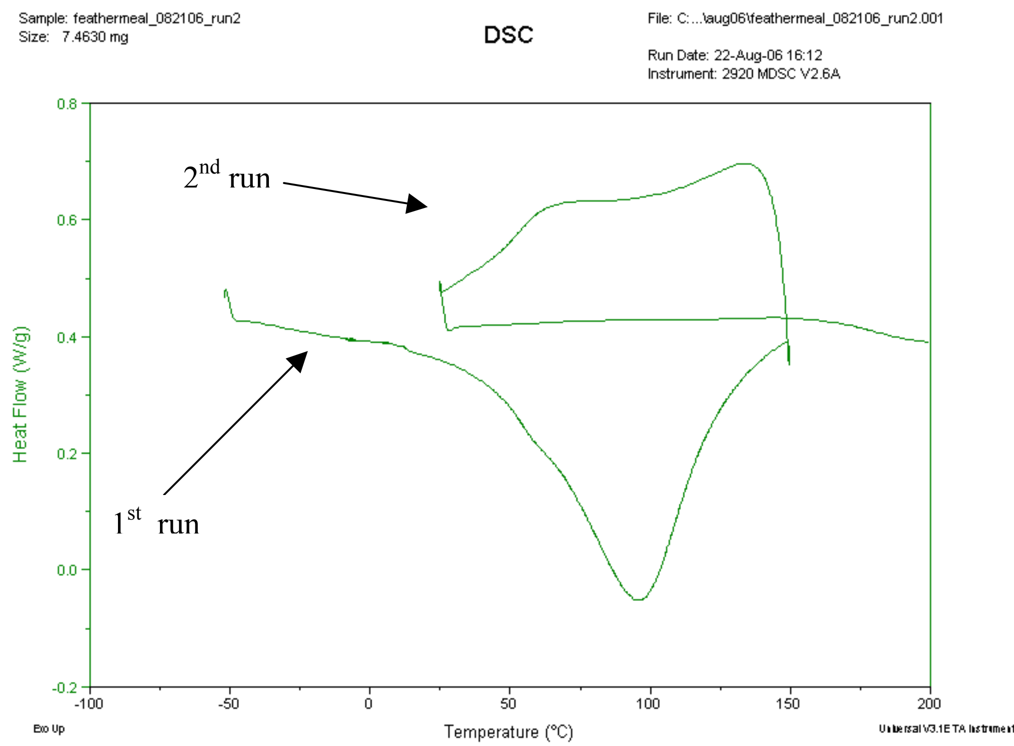

Fig. 2. DSC scan of feather meal protein

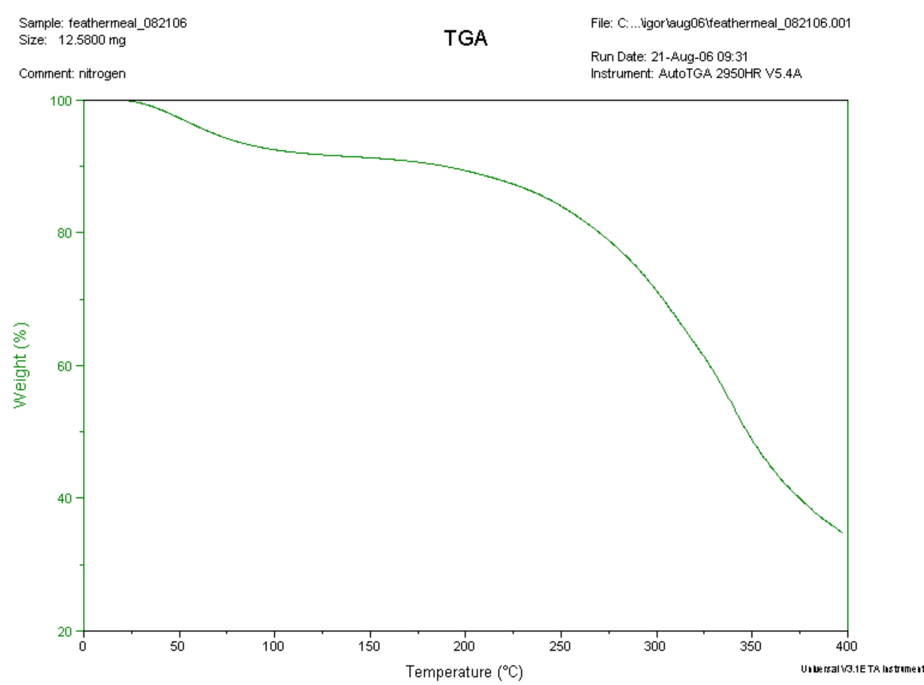

Fig. 3. TGA scan for feather meal protein

The maximum stress of 9 MPa, maximum strain of 1.4 % and modulus of 2.17 GPa were obtained during tensile testing. The elastic modulus was found to be 1.6 GPa and glass transition temperature (Tg) was 70°C using dynamic mechanical analysis (DMA).

Future work:

The processing and material parameters such as pressure, temperature, moisture, and time, would be optimized to improve the mechanical properties of the films. We also plan to mix impact modifiers such as styrene-butadiene based modifiers MBS, acrylate based modifiers AIM, and recycled rubber to improve the impact resistance of the films.

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