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Fabrication and Analysis of Soy Flour Filled Polyethylene Fibers

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INTRODUCTION

- Textile fibers from annually renewable agricultural products have attracted increasing attention due to economic and environmental sustainability concerns.
- Such fibers are attractive because they can be produced with current industrial processes in addition to reducing on the dependence over oil based resins which are non-biodegradable and from non-renewable resources.
- Defatted soy flour is an inexpensive material (50 cent/lb) used as a filler in polymeric composites, though its physical properties are not suitable for direct use as fibers or films.
- Blending soy flour with polyethylene (PE), improves spinnability of soy flour, and enables new nonfood applications of soy flour.

OBJECTIVES

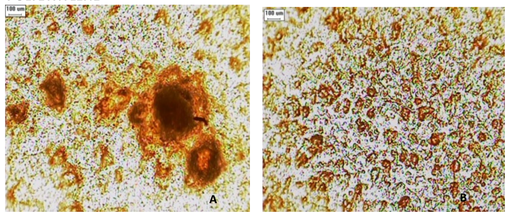
- Converting soy-flour into non-food, value-added products such as fibers and textiles
- Fabrication the PE-soy fibers by a continuous melt process
- Characterization of the properties and microstructure of PE-soy composite fibers spun

EXPERIMENTAL

- Fine defatted soy-flour was obtained from ADM Specialty Food.
- The flour was dispersed in PE with a compatibilizer by using a DSM extruder. Effective dispersion of flour in PE matrix was evaluated using Olympus BX60 optical microscope.
- Pellets of well dispersed blend were extruded and drawn into fibers with an Alex James fiber spinning unit.
- The microstructure of PE-soy fibers was studied using S4800 scanning electron microscope.
- The fibers were stained with Coomassie Brilliant Blue R-250 to detect soy particles on the PE-soy fiber lateral surface. Image PRO Plus software was used for measurement of the surface areas of particles on the fiber surface.
- Fibers were boiled for 10 min in 0.1 M NaOH aqueous solution for an accelerated washing simulation.
- Tensile properties of the fibers were measured on ATS 900 tensile testing machine according to ASTM D2256 .

DSM micro extruder was used for dispersion of soy flour in PE matrix and the production of PE-soy pellets. The micro-extruder has a recirculation channel and was operated in semi batch mode.

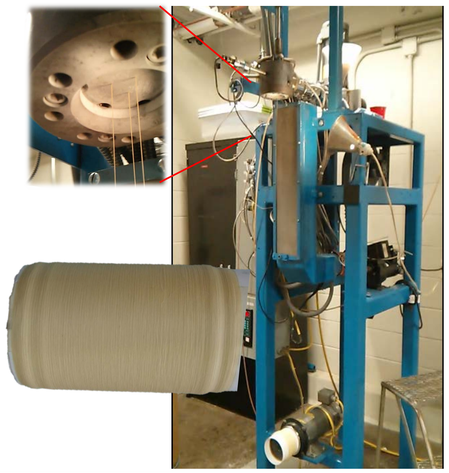
ANALYSIS OF SOY FLOUR DISPERSION IN POLYETHYLENE



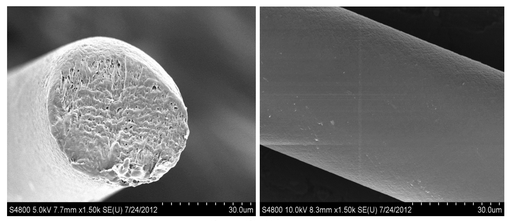
Transmission optical images of PE-soy composite films after 2 mins (A) and 6 mins (B) compounding and extrusion through a slit die attached to the DSM extruder. Nominal film thickness : 50 µm

- A 3 fold increase in mixing time resulted in significantly better dispersion with reduced agglomerates and better spinnability of the blend.
- Increase in mixing time allows the agglomerates more number of passage over the high stress regions of the micro compounder, which reduces size and enhances soy distribution in PE.

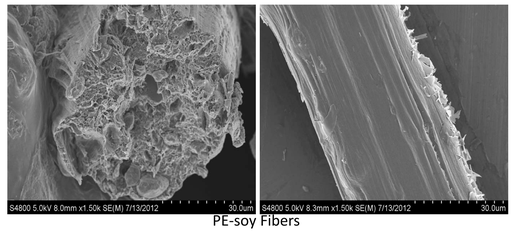
SPINNING OF SOY-PE FIBERS



Alex-James spinning unit (1.3 m) and the spool of soy-PE fibers . Average fiber diameter was 52 ± 4 µm or 22 denier with a draw down ratio (DDR) of 92



Base PE Fibers

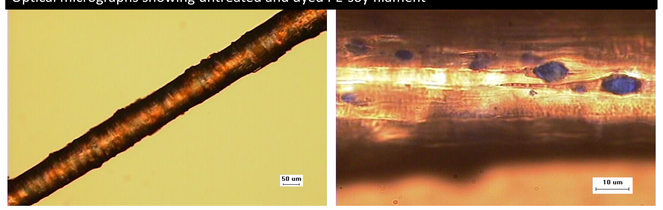


PE-soy Fibers

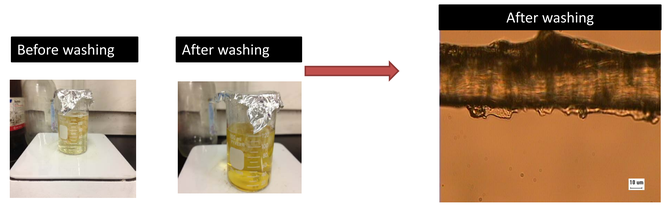
- PE-soy fibers displayed a significant extent of dispersion; the lateral surface reveals generally uniform features of the fibers though some elements of fibrils.

SEM micrographs comparing the cross section and lateral surface PE-soy fibers to that of base PE.

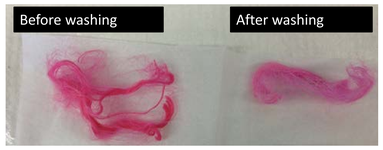
Optical micrographs showing untreated and dyed PE-soy filament



- PE-soy fibers have soy particles appearing on the surface with some particle agglomeration evident.



- Fibers were boiled for 10 min in 0.1 M NaOH aqueous solution for an accelerated washing simulation.



- Fibers were stained.
- The color of fibers became lighter because of soy flour on the fiber surface gets dissolved during washing.

MECHANICAL PROPERTIES OF PE-SOY FIBERS

Sample	Tensile Modulus (MPa)	Tensile strength (MPa)	Strain to failure (%)
Base PE	950 ± 220	43 ± 14	513 ± 192
PE-soy	615 ± 138	32 ± 8	292 ± 52
Washed PE-soy	690 ± 233	32 ± 2	262 ± 53

- Tensile properties of PE-soy fibers are marginally lower than those of base PE.
- Tensile properties were comparable to those of the base PE even after accelerated washing simulation.

CONCLUSIONS

- About 6 minutes of compounding in a DSM semi-batch micro extruder sufficiently dispersed soy flour (30 wt%) in PE matrix.
- The blend could be successfully melt-spun into fibers with diameter of 52 ± 4 µm.
- The use of soy flour, the cheapest of all the soy protein alternatives, provides for a greener alternative by reducing olefin content in fibers without sacrificing the mechanical integrity. The PE-soy fiber tensile properties are comparable to those of the pure PE in spite of the small soy agglomerates present on the fiber surface.
- Washing does not deteriorate fiber mechanical properties drastically.

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