BRIEFING NOTE

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BIOPLASTICS FROM LOCAL AGRI-INDUSTRIAL RESIDUES

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KEY FINDINGS

Conventional non-biodegradable plastics made from petroleum are causing widespread pollution of land and aquatic environments. In addition, the use of fossil fuels contributes to greenhouse gas formation. These problems may be alleviated by introducing bio-based and/or biodegradable alternatives for selected applications. For this project, two types of plastic polymers were synthesized from agri-industrial wastes. In the first study, microbial strains were screened for production of polyhydroxyalkanoates in hydrolysates from Canola fines. The most promising results were obtained with strains of *Gordonia* species, with some novel findings. For the second study, starch-based bioplastic films were chemically synthesized using glycerol as a plasticizer and Canola fines as a filler to improve the mechanical properties of the films. This study showed that films with reduced brittleness and mechanical properties consistent with 'desirable' literature values could be obtained by optimizing the amount of glycerol and Canola fines content to 30% and 10% w/w dry starch, respectively. Overall, the study results indicated that Canola fines show promise as a low-value, high volume, non-seasonal feedstock for microbial synthesis of biopolymers and as a filler for improving the mechanical properties of starch-based bioplastics, both avenues meriting further research.

INTRODUCTION

The classification of "bioplastics" is rather complex, covering an array of plasticized polymers that are either biodegradable and/or compostable or manufactured from bio-based feedstocks. Polymers used as alternatives to conventional Group I plastics include recalcitrant polymers synthesized from biological feedstocks (bio-based, Group II), bio-based and biodegradable polymers (Group III), and petroleum-based biodegradable plastics (Group IV). In this project, two forms of Group II bioplastics were selected for synthesis from wastes from the Canola and maize wet-milling industries.

Canola fines are the straw-like material and other lignocellulosic debris that is separated from the seeds prior to oilseed processing (Figure 1a). In this study, pre-treated Canola fines hydrolysates were used as a growth medium for PHA production by actinobacterial strains. Secondly, bioplastic films were chemically synthesized from corn starch waste. Although the latter is proven technology, starch-based films tend to be brittle and are sensitive to moisture. This project focused on overcoming these drawbacks by adding Canola fines as a structural filler and optimizing the plasticizer volume.

METHODOLOGY

For the first study, Canola fines were pre-treated by mechanical grinding followed by steam explosion with acid and enzyme hydrolysis to release sugars for microbial growth. A central composite design experiment was used to test a range of parameters to optimize the biomass load (2% to 8%), acid concentration (0 to 2% v/v H_2SO_4) and temperature (20°C to 55°C). A synthetic medium was formulated based on the optimal sugar concentrations obtained and used to screen actinobacterial isolates for PHA production.

For the second study, a factorial design was applied to screen the effects of the plasticizer mass fraction (15% to 30%), filler mass fraction (6% to 2%), acetate concentration, waste starch type (spillage, extract from reject corn kernels) and type of filler (cellulose, mixture of lignin and cellulose) on the mechanical properties (tensile strength, elongation at break, water absorption) of bioplastic films. Based on these results, a response-surface methodology model was applied using Canola fines as a filler. The effects of filler mass fraction (0 to 20%) and plasticizer content (19.5% to 40.5%) on the mechanical properties were determined.

MAIN RESULTS

For the first study, the model predicted optimal pre-treatment conditions for sugar release from Canola fines as 6.8% (w/w) biomass loading and 1.7% H_2SO_4. Temperature had no effect, indicating that no energy would be required for heating. The maximum total sugar yield was 28.3% (w/w) of Canola fines, higher than other studies using rapeseed or Canola fines. The sugar profile comprised 44% xylose, 26% glucose, 19% cellobiose and 11% arabinose. Of the original 12 actinobacterial strains tested, the highest amount of polyhydroxybutyrate (PHB) was measured in the fermentate from *Gordonia lacunae* strain $BS2^T$ grown in synthetic hydrolysate of Canola fines. This isolate utilized all 4 sugars for growth (76% cellobiose, 26% glucose, 18% xylose, 8% arabinose) with no nutrients added. Intracellular accumulation of PHA by *Gordonia lacunae* can be seen as the colorless areas in the transmission electron micrograph shown in Figure 1b.

Figure 1: Canola fines (a) and transmission electron micrograph of *Gordonia lacunae* BST^2 showing the intracellular accumulation of polyhydroxyalkanoates as carbon storage products (b).

This was the first time that detailed production of PHA by *Micromonospora* and *Gordonia* species has been described. *Gordonia* is a robust, fast-growing member of the actinobacterial family that is used in a variety of industrial biotechnological applications. Future work will focus on optimizing the production of PHA by *Gordonia lacunae* BST^2 by varying parameters such as the carbon to nitrogen ratio and oxygen availability, and determining the structure, mechanical properties, and possible applications of the PHA polymers.

For the second study, it was found that wastewater and spent filter aids from maize wet milling did not contain sufficient starch for synthesizing bioplastic films. Crushed reject kernels, kernel extracts and spillage contained 57%, 78% and 89% starch, respectively, with higher amylopectin (75%, 62% and 55% starch w/w) than amylose contents, which is desirable for bioplastic synthesis. Screening results indicated that the types of starch and filler and the amounts of starch, filler and plasticizer had significant effects on the mechanical properties of the bioplastic films. When added in incorrect proportions the films were brittle (Figure 2a).

In the optimization study, the tensile strength, elongation, and water absorption results obtained from the experimental runs ranged from 1.4 MPa to 7.7 MPa, 6.1% to 146%, and 40% to 144%, respectively. The tensile strength increased, but the elongation at break decreased with increased Canola fines, while the converse was found with the plasticizer. Increases in both plasticizer and filler favorably decreased the water absorption. Overall, it was shown that films with reduced brittleness and mechanical properties consistent with 'desirable' literature values could be obtained by optimizing the glycerol and Canola fines content to 30% and 10% w/w dry starch, respectively (Figure 2b).

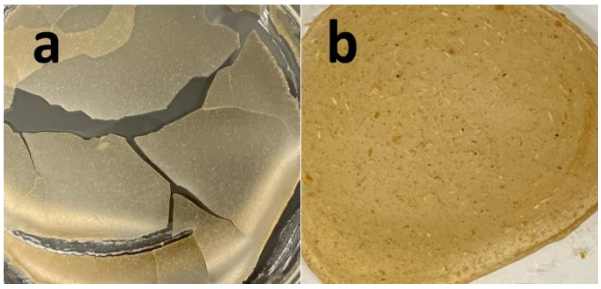

Figure 2: Examples of brittle starch bioplastic film synthesized during the screening study (a), and starch bioplastic film with desirable mechanical properties obtained with optimized glycerol and Canola fines contents.

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