Continuation of Rice Straw and Rice Waste Bacterial Conversion to Poly Lactic Acid Biodegradable Plastic and Bioethanol: RP-16

2011 rice research board-summary.doc

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Summary:

Lactic acid can be produced from rice straw and rice hull waste materials via bacterial fermentation. The overall goal of the research is to produce lactic acid from rice hull and rice straw waste to biodegradable plastics by using selective bacteria, which transforms sugars to lactic acid. The lactic acid will subsequently be polymerized into the most common biodegradable plastic, namely, polylactic acid (PLA). The research project is a continuation of a feasibility research project on converting rice hulls to lactid acid. This project improved the conversion of 40% of the rice straw and 35% of the rice hulls to glucose then lactic acid. The project optimized base solution pretreatment of rice straw and rice hulls, developed a Simultaneous Saccharification and Fermentation (SSF) process, improved the purification method of the glucose mixture, improved the polymerization methods for PLA, investigated super critical CO_2 method for pretreatment of rice hulls and rice straw. M-206 medium grain of variety 206 was used in the research. Rice hulls and straw were collected by a local farmer and provided to Chico State for the research.

The improvement in conversion of rice straw to lactic acid was due primarily to the new SSF process which combines the conversion of cellulose to glucose and conversion of the glucose to lactic acid. The optimum pretreatment process is Mild base treatment (2% NaOH), mild acid (0.5 % HCl), and formic acid (0.5 %) to remove lignin and hemicellulose. Stock enzyme amalgamate (cellulases and amylases) was used to convert the cellulose to glucose, and tested with a standard glucometer. The optimized pretreatment process converted between 30 and 40% of the rice hulls or rice straw to glucose. The maximum amount of rice hulls or rice straw that can be converted to glucose and then lactic acid is 40% which represents the amount of available cellulose.

The conversion process of glucose to lactic acid was between 95 and 100% of the glucose from rice hulls or straw. The lactic acid was then purified with ion exchange process and then polymerized to polylactic acid powder plastic in a two-step process. Lactic acid was polymerized to PLA via condensation reaction through azeotropic dehydration. [1] with Dean-Stark trap for water removal. Lactic acid and *m-Xylene* were added together in a flask at 138°C for 30 hours. After 12 ml of water was removed the Dean-Stark trap was replaced with a molecular sieve to recycle to aezeotropic mixture. The resultant mixture was polymerized at 138°C for an additional 30 hours. Approximately, 60 grams of PLA was produced in powder form. The polymerization process was limited by the malfunction of the vacuum pump needed to procure the ring opening polymerization process. A new pump is needed to continue the process.

The process of bacterial conversion of rice waste to glucose and lactic acid is technically feasible due to the 8-day conversion process from rice waste to PLA plastic. The steps in the conversion process include the following:

1. Pretreatment of rice straw or rice hulls (5 days)

2. Rinse and clean rice straw to reduce pH to 7 (0.5 day)
3. Enzyme treat rice straw to glucose (1 day)
4. Bacterial convert glucose to lactic acid (1 day)
5. Polymerize lactic acid to lactide (0.25 day)
6. Ring open lactide to PLA (0.25 day)

A prototype 5-gallon vessel was developed to convert the rice straw to glucose on a larger scale and a faster process. Taguchi Design of Experiment (DOE) methodology was used to establish key parameters and to reduce the conversion time of the rice straw to glucose. The conversion time was reduced by 50% with the introduction of sodium hydroxide and higher temperatures. The conversion time was reduced to 4 days. More research is needed to further reduce the conversion time to less than 1 day.

Bioethanol was produced from the rice straw in low concentrations. The rice straw was chopped and treated with sodium hydroxide solution for 3 days and then acidic solution from lime juice. Glucose concentrations were less than 5%. The glucose solution was fermented with yeast in a 1 gallon reactor for 6 days. The alcohol production was less than 5% in the mixture. The conversion process from rice straw is feasible but the quality and conversion rates are low. Further research will optimize the conversion and fermentation process.

Major Accomplishments:

The research was beneficial to the agricultural industry by converting an agricultural waste product into sugars and then to lactic acid. Lactic acid can be polymerized into a biodegradable plastic, namely, polylactic acid. The research project converted rice straw and rice hull waste to lactic acid by using selective bacteria, which transforms sugars to lactic acid. The research was successful in

- Converting up to 40% of rice straw to glucose and then to lactic acid.
- Converting of 35% of rice hulls to glucose and then to lactic acid.
- SSF pre-treatment produced 20% more lactic acid results than the enzyme pretreatment method and 50% reduction in conversion time.
- The optimum pretreatment process is mild base treatment (2% NaOH), mild acid (0.5 % HCl), and formic acid (0.5 %) to remove lignin and hemicellulose
- Prototype 5-gallon vessel was developed to reduce pretreatment time by 50%.

Impact Statements:

A significant accomplishment was converting to 40% of rice hulls and 40% of rice straw to glucose and then to lactic acid with faster production process. Additional accomplishments included development of Simultaneous Saccharification and Fermentation (SSF) process.

Dissemination, publications and presentations of research:

The work was presented at the following:

1. **"Organic Synthesis and Degradation of Polylactic Acid,"** Chemistry and Bio Chemistry Poster Session, CSU Chico Presentations, Chico, CA, May 2011

2. "Rice Hull and Rice Bran Waste Conversion to Biodegradable Plastics via Bacterial Transformation – Status Report," **Rice Research Council, (February 2011)**

3. "Rice Hull and Rice Bran Waste Conversion to Biodegradable Plastics via Bacterial Transformation – Status Report," **Rice Research Council, (November 2010)**

4. **Television coverage of Rice Research, News 10 Sacramento (March 2010)** http://www.news10.net/video/default.aspx?bctid=71052169001#/Chico%20State%20finds%20new%20use%20for%20rice%20waste/71052169001 March 2010

5. "Rice Hull and Rice Bran Waste Conversion to Biodegradable Plastics via Bacterial Transformation - Status Report," **Rice Research Council, (February 2010)**

Budget:

Source	Amount
ARI	$0.
Rice Research	$10,000
Other Match	$0.
Total	$10,000

Note:

- Expenses
  - Student wages
  - 1-month summer salary for Dr. Greene
  - Supplies
  - Travel, and
  - Overhead