2001 Project Abstract
For the Period Ending June 30, 2003

TITLE: Accelerated Technology Transfer for Starch-Based Plastics
PROJECT MANAGER: Professor Kim A. Stelson
ORGANIZATION: Department of Mechanical Engineering, University of Minnesota
ADDRESS: 111 Church Street SE, Minneapolis, MN 55455
WEB ADDRESS: http://www.me.umn.edu/faculty/Stelson.html
FUND: Future resources fund
APPROPRIATION AMOUNT: $90,000
LEGAL CITATION: Laws 2001, First Special Session, Chapter 2, Section 14, Subd. 8 (d) Accelerated Technology Transfer for Starch-Based Plastics

Overall Project Outcome and Results

A patented process[1,2] to make starch-based plastics has been developed University of Minnesota. U of M starch-based plastics are biodegradable and can be made from corn, wheat or soybeans. The purpose of this project is to help move this technology out of the laboratory and into everyday life. We will raise public awareness of biodegradable plastics by distributing spoons made of U of M starch-based plastic with milkshakes sold by the Gopher Dairy Club at the Minnesota State Fair. We will also distribute literature describing the benefits of this new technology.

Starch based plastic – a completely biodegradable material containing 70% Minnesota grown and renewable resource such as starch and proteins were injection molded into a milkshake spoons. The current polymer is a blend of natural and synthetic polymer and is completely biodegradable. It degrades in a compost as well as in soil and marine environments. The material can be processed into end products having acceptable physical and chemical properties pertaining to their end use. The increased environmental friendliness of the product may open an avenue for increased usage of farm commodities and other renewable resources. Melt processing (usually done in an extruder) is a continuous process with good controls and results in economic savings over batch processes. The blends proposed here are manufactured continuously in an extruder without using any solvents. There are no deleterious effects during processing or product development. Also, none of the materials (polymers and processing aids) have any negative side effects that require special handling (other than proper ventilation). Therefore, the environmental impacts of production are benign. The powders are mixed together with the necessary liquids, depending upon the specific formulation, and extruded into a resin which is then cooled and packaged in totes. The scrap produced at start-up and shut-down can be

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[1] U.S. patent 5,321,054, "Composition of Biodegradable Natural and Synthetic Polymers," June 14, 1994.

[2] U.S. patent 5,446,078, "Biodegradable Compositions Produced by Reactive Blending of Synthetic and Naturally Occurring Polymers," August 29, 1995.

reground and used as rework without causing production or quality problems. This is also true for off-grade product produced through production error.

These spoons were used by the University of Minnesota Gopher Dairy Club, at their booth in the Minnesota State Fair during both 2002 and 2003. A total of 140,000 spoons were distributed over the two years. In addition, pamphlets giving information on the product was also distributed to interested individuals. One outcome of this project is that a venture capital company (Yankee Tech Ventures) have taken the lead in conducting market research to develop price structure for disposable cutleries.

Date of Report: June 20, 2003
LCMR Final Work Program Report

LCMR Work Program 2001

I. Project Title: Accelerated Technology Transfer for Starch-Based Plastics

Project Manager: Professor Kim A. Stelson
Affiliation: Department of Mechanical Engineering, University of Minnesota
Mailing Address: 111 Church Street SE, Minneapolis, MN 55455
Telephone Number: 612-625-6528 **E-mail:** kstelson@me.umn.edu **Fax:** 612-625-9395
Web Address: http://www.me.umn.edu/faculty/Stelson.html

Total Biennial Project Budget:

$LCMR Appropriation	-$ Amount Spent	= $ Balance
$90,000	-$90,000	=$0

Legal Citation: Laws 2001, First Special Session, Chapter 2, Section 14, Subd. 8 (d) Accelerated Technology Transfer for Starch-Based Plastics

Appropriation Language:

8 (d) Accelerated Technology Transfer for Starch-Based Plastics
$90,000 is from the future resources fund to the University of Minnesota to produce and market biodegradable, starch-based plastic.

II. III. FINAL PROJECT SUMMARY

A patented process[1,2] to make starch-based plastics has been developed University of Minnesota. U of M starch-based plastics are biodegradable and can be made from corn, wheat or soybeans. The purpose of this project is to help move this technology out of the laboratory and into everyday life. We will raise public awareness of biodegradable plastics by distributing spoons made of U of M starch-based plastic with milkshakes sold by the Gopher Dairy Club at the Minnesota State Fair. We will also distribute literature describing the benefits of this new technology.

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IV. OUTLINE OF PROJECT RESULTS:

The Problem. Disposal of single-use plastic items is a major source of environmental damage from incineration and landfills. Of the 50 million pounds of plastic used annually in the United States, 16 million pounds is used once and then discarded. One million pounds of these single-use plastics are food service utensils (knives, forks, spoons, plates, cups, etc.). At the present time, most cutlery (knives, forks and spoons) is made of polystyrene. Polystyrene is made from petroleum, a non-renewable resource. It is not biodegradable, and thus remains in landfills indefinitely. The incineration process of polystyrene generates dioxin, a known carcinogen.

A Solution: U of M starch-based plastic. By using U of M starch-based plastic, we replace imported petroleum with domestically produced grain. If U of M starch-based plastic replaced synthetic plastic for food service utensils world-wide, it would increase demand for corn by about ¼ of the usual annual corn crop for Minnesota. U of M starch-based plastics have the potential of creating entirely new leading-edge businesses in Minnesota for the future "green economy." These plastics are biodegradable, thus eliminating litter, landfills and incineration. There is nothing comparable on the market today.

U of M starch-based plastic manufacture has no significant negative environmental effects. U of M starch-based plastics are easily biodegradable, not only in a compost, but in natural, marine and aquatic environments. This means that U of M starch-based plastics can be collected and composted in the same manner as ordinary yard waste. When compared to alternatives, U of M starch-based plastics are superior in cost, biodegradability and heat resistance. U of M starch-based plastics are also tasteless and odorless.

Composition. U of M starch-based plastics are made of a reacted blend of cornstarch (60-80%), polyester (15-35%) and compatibalizer (5%). The use of a compatibalizer, a modified polyester, is the key innovation of the University of Minnesota patent. It allows two materials that are ordinarily immiscible to mix and form a reacted blend. The result is a biodegradable material that possesses superior mechanical properties. The polyester, polybutylene succinate, is derived from petroleum, but is completely biodegradable. There are other biodegradable polyesters that can be derived from

agricultural sources. When these become commercially available, they could be used in the U of M starch-based plastic, creating a material that is entirely derived from renewable resources.

Other crop-based materials can also be used for biodegradable cutlery. Polylactic acid is a plastic made by Cargill using a fermentation process of corn. ReSource-Ware from Biocorp is a mixture of cornstarch, cellulose from cotton seed, and a proprietary binder. For competitive reasons, Biocorp refuses to disclose composition percentages of its product.

Cost. When produced in the same volume as other commodity plastics, U of M starch-based plastic is projected to cost $1.00 per pound. This compares with $0.85 per pound for polystyrene, $1.50 per pound for Cargill's polylactic acid and $2.50 per pound for the Biocorp material. Thus, U of M starch-based plastics have a considerable cost advantage over other crop-based, biodegradable alternatives.

Biodegradability. U of M starch-based plastics have superior compostability when compared to competing materials. Because Cargill's polylactic acid is difficult to compost, its primary advantage is that it is derived entirely from agricultural sources. The Biocorp product is usually disposed of in carefully managed commercial composting operations. For example, SKB Environmental, the commercial composter for the DNR and PCA cafeteria waste, uses forced air to maintain a constant composting temperature of 140°F. Complete composting of the waste takes nine to twelve weeks. If lower temperatures are used, the biodegradation rate would decrease considerably. Thus, the Biocorp material will degrade much slower at lower temperatures, such as those found in unmanaged composts or natural, marine and aquatic environments. For the same conditions (temperature, humidity, airflow and level of bioactivity) U of M starch-based plastics will degrade at a substantially faster rate than competing materials.

Heat Distortion and Taste. U of M starch-based plastics have superior heat distortion and taste performance. Both Cargill's polylactic acid and the Biocorp material have heat distortion problems. In a recent test for acceptance of cutlery for use by the U.S. Army, a minimum heat distortion temperature of 185°F. was required. Samples from Biocorp had heat distortion temperatures between 160° and 170°F. U of M starch-based plastic samples had a heat distortion temperature between 185° and 200°F. U of M starch-based plastics are tasteless and odorless. In contrast, the Biocorp material has a taste that about 10% of the population finds objectionable. Both the heat distortion problem and the taste problem were confirmed by a representative of Biocorp.

Conclusion. When compared to other crop-based alternatives, U of M starch-based plastic is superior in cost, biodegradability and heat distortion. It is also tasteless and odorless. This makes U of M starch-based plastic an attractive choice for cutlery and a host of other practical uses.

Result 1: Demonstration of Cutlery Production:

LCMR Budget: $90,000 **U of M match:** $27,000
LCMR Balance: $0 **U of M match balance:** $0

We will raise public awareness of biodegradable plastics by distributing spoons made of U of M starch-based plastic with milkshakes sold by the Gopher Dairy Club at the Minnesota State Fair. We will also distribute literature describing the benefits of this new technology. We require an injection mold. U of M starch-based plastic and a technician to do a pilot demonstration of cutlery manufacturing. The injection molding machine itself will be provided by the University of Minnesota.

Professor Tony Seykora of the Department of Animal Science at the University of Minnesota has been contacted. He is faculty co-advisor for the Gopher Dairy Club. He has agreed to consider using the starch-based plastic spoons. Final acceptance of this idea requires student member approval.

We have budgeted sufficient technician time and material to manufacture about 120,000 spoons. This matches the requirements of the Gopher Dairy Club well, since they sell between 50,000 and 60,000 milkshakes each year. Since the project will not be funded until July 2001, production will not be available for the 2001 State Fair. We expect to supply the complete needs of the Gopher Dairy Club for the 2002 and the 2003 State Fairs.

Personnel: LCMR ~~$50,521~~ ($51,752); match: $0; total: ~~$50,521~~ ($51,752) (technician, 50%, 24 mo.)

Equipment: LCMR: $28,000; match: $27,000; total: $55,000 (injection mold)

Other: LCMR: ~~$11,479~~ ($10,248); match: $0; total: ~~$11,479~~ ($10,248) (U of M starch-based plastic, $10,000; maintenance, ~~$1479~~ ($248).

August 28, 2003: $1231 was transferred from the maintenance budget to the personnel budget because it required slightly more time than anticipated to manufacture the spoons. Also, less money was required for machine maintenance than anticipated.

Completion Date: June 30, 2003. After initial setup and die acquisition, starch-based plastic spoon production will be continuous. About half of the spoon will be produced in time for the 2002 State Fair. The remainder will be produced by the end of the contract for use in the 2003 State Fair.

Results Status:

December 18, 2001. Initial experiments were conducted to determine the properties of various blends of natural and synthetic polyester to evaluate the suitability of various formulations for use in ice-cream spoon. The following blend composition was selected (i) 50% natural/50% synthetic, (ii) 60% natural/40% synthetic, and (iii) 70% natural/30% synthetic. The 50% natural product required the least pressure to mold but took the longest to cool. The 70% natural required the largest pressure and cooled the quickest.

For each blend moldability parameters were estimated. This involves changing machine parameters to produce acceptable parts. We decided to proceed with a polymer that has 60% natural content as higher natural content would lead to higher pressures and would severely restrict the operation of the machine. Based on initial studies involving pressure drop, cycle time, and machine size etc. a two-cavity mold has been designed.

June 28, 2002. The mold was ordered in mid December and scheduled for trial in early March at the tool makers facilities. Initially problems were encountered regards to mold filling. This was corrected and a second trial conducted in mid April. After some minor re-tooling, the mold was obtained by the end of April. It is a two cavity mold with a cold runner system. During the month of May several blend compositions were evaluated to estimate (i) pressure drop, and (ii) cycle time two of the key parameters (along with physical properties). A small problem regarding part ejection was encountered which had to be corrected by the mold maker. The material has been ordered and is expected to be delivered by the middle of July.

January 21, 2003 Update: The molding part of the project has been completed. We have made the required number of spoons (approximately 65,000). These are being packed in boxes containing 2000 each and sealed. Two pallets have been delivered to the Gopher Dairy Club. The rest will be delivered when the remaining 10,000 spoons are packaged.

August 25, 2003 Update: Starch based plastic – a completely biodegradable material containing 70% Minnesota grown and renewable resource such as starch and proteins were injection molded into a milkshake spoons. The current polymer is a blend of natural and synthetic polymer and is completely biodegradable. It degrades in a compost as well as in soil and marine environments. The material can be processed into end products having acceptable physical and chemical properties pertaining to their end use. The increased environmental friendliness of the product may open an avenue for increased usage of farm commodities and other renewable resources. Melt processing (usually done in an extruder) is a continuous process with good controls and results in economic savings over batch processes. The blends proposed here are manufactured continuously in an extruder without using any solvents. There are no deleterious effects during processing or product development. Also, none of the materials (polymers and processing aids) have any negative side effects that require special handling (other than proper ventilation). Therefore, the environmental impacts of production are benign. The powders are mixed together with the necessary liquids, depending upon the specific formulation, and extruded into a resin which is then cooled and packaged in totes. The scrap produced at start-up and shut-down can be reground and used as rework without causing production or quality problems. This is also true for off-grade product produced through production error.

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V. Total Project Budget:

All Results: Personnel: LCMR: ~~$50,521~~ ($51,752); match: $0; total: ~~$50,521~~ ($51,752).

All Results: Equipment: LCMR: $28,000; match: $27,000; total: $55,000.

All Results: Other: LCMR: ~~$11,479~~ ($10,248); match: $0; total: ~~$11,479~~ ($10,248) (supplies and maintenance)

TOTAL BUDGET: $90,000 (with an additional $27,000 U of M match)

VI. PAST, PRESENT AND FUTURE SPENDING:

A. Past Spending:	$120,000	(1992-95, U.S. Dept. of Agriculture)
	$85,000	(1992-95, Minn. Corn Promotion Research Council)
	$237,500	(1995-98, Intl. Wheat Gluten Assoc.)
	$507,510	(1996-98, U.S. Dept. of Energy)
	$76,603	(1997-99, Minn. Soybean Research and Promotion Council)
	$299,997	(1997-2000, National Science Foundation)
	$180,000	(1999-2002, U.S. Dept. of Agriculture)

B. Current and Future Spending: Matching Funds of $27,000 provided by University of Minnesota.

C. Project Partners: Professor Mrinal Bhattacharya, Department of Biosystems and Agricultural Engineering, University of Minnesota. Professor Vaughan R. Voller, Department of Civil Engineering, University of Minnesota. No cost to the project for either.

D. Time: Two years

VII. Dissemination: The goal of this project is the dissemination of information. We will raise public awareness of biodegradable plastics by distributing spoons made of U of M starch-based plastic with milkshakes sold by the Gopher Dairy Club at the Minnesota State Fair. We will also distribute literature describing the benefits of this new technology.

VIII: Location: U of M starch-based plastic spoon production will be located in the Department of Biosystems and Agricultural Engineering on the St. Paul campus of the University of Minnesota. The Gopher Dairy Club will distribute U or M starch-based plastic spoons and literature at the Minnesota State Fair.

IX: Reporting Requirements: Periodic work program progress reports will be submitted no later than January 1, 2002; July 1, 2002; and January 1, 2003. A final work program report will be submitted by June 30, 2003.

X: Research Projects: not applicable.