2017

An example of commercializing biobased coatings and binders

Darren Jarboe
Iowa State University, jarboe@iastate.edu

Tong Wang
Iowa State University, tongwang@iastate.edu

Tao Fei
Iowa State University, feitao@iastate.edu

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Abstract
Commercialization of emerging biobased technologies delivers new functionality and value to manufacturers and customers. Navigating this process can be difficult and value extraction from the technology elusive. A biobased coatings and binders example will be used to demonstrate: (1) the development of an initial research, development, and commercialization plan; (2) the influence and importance of industry partners throughout the project; and (3) the use of licensing and other methods to create value.

Keywords
biobased coating, biorenewables, soybean oil-based coating, technology commercialization

Disciplines
Agricultural Science | Food Biotechnology | Technology and Innovation

Comments
This paper was written for presentation at the 2017 ASABE Annual International Meeting, Spokane, Washington, July 16-19, 2017. doi: 10.13031/aim.201700802. Posted with permission.

2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

An ASABE Meeting Presentation
DOI: https://doi.org/10.13031/aim.201700802
Paper Number: 1700802

An example of commercializing biobased coatings and binders

Darren Jarboe, Tong Wang, and Tao Fei

1041 Food Sciences Building, 536 Farm House Lane, Ames, Iowa 50011

Written for presentation at the
2017 ASABE Annual International Meeting
Sponsored by ASABE
Spokane, Washington
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ABSTRACT. ***Commercialization of emerging biobased technologies delivers new functionality and value to manufacturers and customers. Navigating this process can be difficult and value extraction from the technology elusive. A biobased coatings and binders example will be used to demonstrate: (1) the development of an initial research, development, and commercialization plan; (2) the influence and importance of industry partners throughout the project; and (3) the use of licensing and other methods to create value.***

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Introduction

Historically, the physical properties of soybean oil-based wax, such as being too hard and flaky or too soft and greasy, have limited its use. Soybean oil-based waxes have been used and tested as candle wax (Rezaei et al., 2002a and b) and crayons. Chemical or structural modification of hydrogenated soybean oil makes it behave much more like conventional waxes (Wang and Wang, 2007; Cap, 2009). Continued development of new soybean oil-based wax technologies by university scientists has created new materials from soybean oil with the potential to deliver new functionality that adds value for manufacturers, customers, and society. This paper discusses technology commercialization planning and execution using a soybean-oil based coating developed to substitute for petroleum-based paraffin wax as an example.

Initial Planning during Proposal Development

The initial target for this research project was development of a beeswax substitute for art supplies due to the interests of university scientists and artists. This market was very small and did not get traction with funders. We conducted market research on the wax industry to discover the most fertile potential markets for biobased waxes. In 2006, Cargill estimated that the major wax applications in North America were paper and paperboard (34%), candles (25%), and coatings and inks (13%) (see figure 1) (De Guzman, 2007). Estimating that U.S. candle wholesale wax revenues were approximately $1 billion ($1/lb. or 50% of retail price) (Facts and Figures, 2011), the U.S. paper and paperboard, and coatings and inks categories wholesale market value was approximately $1.4 billion ($0.75/lb.) in U.S. sales for these markets, which were being served by beeswax, microcrystalline wax, paraffin wax, and other waxes. Using U.S. Energy Information Administration data, the U.S. paper and paperboard market was estimated to be $250 to $500 million (Petroleum Supply, 2009). Freedonia estimated the U.S. paper and paperboard wax market was 750 million pounds annually with a market valuation of $375 to $750 million (Rubber World, 2009).

American Fuel & Petrochemical Manufacturers (formerly National Petrochemical & Refiners Association) estimated that about 25% of finished wax capacity could be considered "at risk" (~0.5 billion lb/yr), greatly affecting industries using petroleum-based waxes (Wax Facts, 2013). Paraffin prices had been increasing due to three main factors: 1) better efficiency in oil refinery fluidized catalytic crackers, thus reducing paraffin output in favor of higher value products; 2) less gasoline demand (more efficient cars and less driving), so less by-product, such as paraffin, is available; and 3) shale gas drives more ethane cracking and less naphtha cracking, leading to less paraffin (Wax Facts, 2013). Prices for beeswax ($2.00–$3.00/lb), microcrystalline wax ($0.50–$2.00/lb), and paraffin wax ($0.50–$1.00/lb) (Bradbear, 2009; Velez-Conty, 2012) were expected to be within reach of new biobased materials if reduced supply of petroleum-based materials increased prices, particularly if additional functionality offered value. The United Soybean Board (USB), a targeted funding organization, expressed interest in wax applications for paper and paperboard as well as other coating applications.

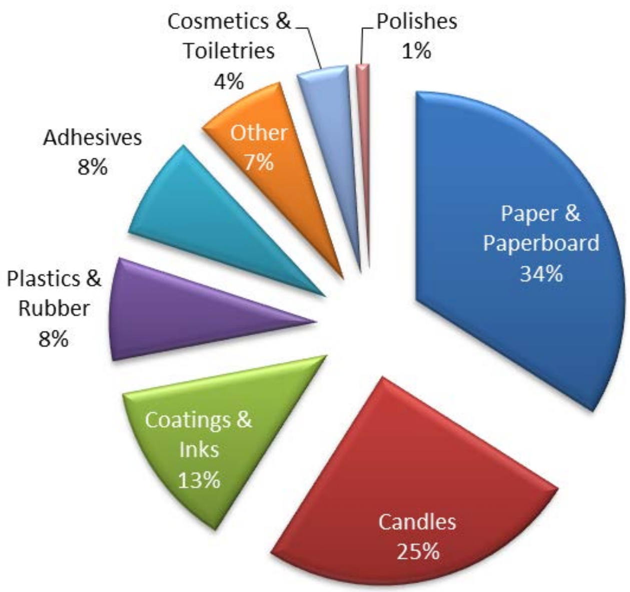

Figure 1. North American wax applications (source: Cargill, Inc., 2006)

This market information drove our decision to target the creation of a paraffin wax substitute, which was the main thrust of the work proposed to USB and it required a commercialization plan.

The reasons to target paraffin were the market size, multitude of uses, and a price point within reach of the technology. Paraffin is a group of highly evolved materials with desirable properties such as cohesiveness, plasticity, known melting and crystallization profile (phase transition temperatures and range), and low cost, but these materials also have the challenges of shrinking supply and not being recyclable or repulpable.

Evolution of the Technology

The initial two years of work focused on the oil chemists synthesizing various fatty esters from soybean oil that mimicked the molecular structures of beeswax to achieve superior plasticity and chemically modifying the triacylglyceride structure of partially and fully hydrogenated soybean oil to improve cohesiveness and plasticity. Materials were tested for terrestrial biodegradability and carbon release using a small pilot-scale anaerobic digester system at the Iowa State University (ISU) BioCentury Research Farm. The team successfully developed the latter technology, but no patent was filed by the university. Greater industry involvement was sought to gain knowledge and in the longer term, prepare for commercial scale evaluation and adoption of later iterations of a suite of wax technologies.

The knowledge gained about modification of the materials and the use of material combinations were employed to further explore potential soybean oil-based waxes for two years. The team continued work on developing materials that mimicked the molecular structures of beeswax components to achieve superior plasticity and high melting point. Industry partners were identified for commercial-scale testing and evaluation.

The past two years, the chemistries of two materials were fine-tuned, a paraffin wax substitute and a carnauba wax substitute. An Iowa company desired a binder for agricultural feed uses, working with us to develop a food grade binder. These three materials were produced at bench and small pilot scale (1 kg). Cardboard coated with the paraffin wax substitute was tested on a small scale by Western Michigan University. The coating showed excellent signs of being biodegradable and recyclable. The samples processed left little to no wax residue on the machinery and recycling and repulping appeared to be successful, but further evaluation at larger scale is needed.

These new products need to be cost competitive with petroleum products for the functionality provided. Cost is heavily dependent on the chemistry and modifications chosen. The early cost analysis indicated the new biobased material could be competitive with petroleum-based competitors. The initial work used a multiple-step chemical modification process that was higher cost; thus, more feasible methods for improving the first soybean oil-based wax's physical properties were undertaken (Yao and Wang, 2012). Our scientists worked on process improvement, specifically moving from a two-pot reaction to a one-pot reaction, which reduced the cost of the material.

Importance of Industry Partners

Industry partners have been important drivers in the research, development, and commercialization of the biobased wax and coating materials. The initial industry partner was a box manufacturing company that provided excellent industry insight, including process and cost data. The company worked closely with us, including bringing in their wax supplier on board, until our project champion left the company in 2014 and the collaboration was dropped.

A coatings manufacturer joined our industry advisory team in year 2 and over time helped us understand the potential for a carnauba wax substitute. This partner continues to collaborate on the project, providing industry perspective and applications testing expertise.

The following year the Advanced Processes and Packaging Team of the United States Army showed interest in the potential of the biobased wax materials in food packaging for troop rations. They tested materials for speed of degradation in different environments.

In 2014, a specialty chemical manufacturer and a paper and packaging company became commercial partners for the project. The former interested in wood sizing applications and both companies were attracted to corrugated box coating applications.

A feed company and the ISU Center for Industrial Research and Service (CIRAS) asked the team to explore using the knowledge gained in earlier work to develop a binder for agricultural applications. The company wanted to replace an animal-based binder with a vegetable-based binder to meet the requirements of potential new markets. The collaboration included site visits to learn about the company's manufacturing processes, allowing identification of potential challenges and opportunities for a new soybean-based material.

The USB has funded much of the work and provided technical consultations, through USB contractor OmniTech International, to improve our understanding of the binders, coatings, and waxes industries. In some cases, they also provided market information. The reason for USB's interest was the creation of new soybean oil products to compete with petroleum-based paraffin in box coatings and other market segments.

These industrial partners had great influence on our team by supplying information, industry expertise, and testing capabilities that helped us determine the direction of the research. These have proven invaluable in understanding the chemistry and modifications of the feedstocks and materials, commercial coatings and finished goods manufacturing systems, and potential end-use markets that would find these biobased materials valuable.

Creating Value

As at most, if not all research universities, ISU works to commercialize technologies developed by the research enterprise. To be commercially viable, the technology must create enough value for all value chain participants to profit. Our work with industry collaborators ensured commercial relevance was taken into account, but we did not explore the entire value chain. In addition, the technologies develop are generally not finished products when they leave the lab on the pathway to commercialization. The first candidate for commercialization was the paraffin wax substitute, which will be used as an example.

At ISU, commercialization can take various forms, with the major pathways being licensing by an existing company, option or licensing by a startup company, and applied research projects supported by company sponsorship. The paraffin wax substitute has generated significant interest from companies because the market is looking for water repellency and strength enhancing solutions that are biodegradable and in the case of cardboard and paper products, recyclable and repulpable. The water repellency and strength data showed similar performance to paraffin, while anecdotal data showed superior recycling and repulping performance, generating significant interest in this technology. The paraffin wax substitute is very similar to current waxes on the market that are used for food applications and should be able to receive the U.S. Food and Drug Administration (FDA) designation Generally Recognized as Safe (GRAS), although additional testing may be necessary to earn the designation from FDA. If government regulations for material recyclability and repulpability are enacted and enforced, it would significantly impact the potential markets for this material.

After conducting market research and exploring the market potential with industry partners, the focus was shifted to cardboard and paper coatings due to industry interest in biorenewables and the potential for recyclability and repulpability, two large factors in the cardboard box user community. The produce box company wanted to manufacture boxes that could be recycled rather than sent to the landfill. Although this market was a small fraction of the cardboard coating industry, the properties needed to serve this market were similar to those required by a significant portion of the industry.

Summary

The three materials developed by the soybean oil-based research project appear to be headed down three different pathways which were made possible by industry collaboration and support. An agricultural processing company is negotiating a license for the paraffin wax substitute. This material will need additional applied research work done to make finished products using the technology. The carnauba wax substitute is not a perfect replacement due to its high melting point, approximately 140°C compared to about 84°C for carnauba wax. This may create unique opportunities for the technology, which has made it a good candidate for a student-led startup company. A student is evaluating potential markets for the carnauba wax substitute and if the evaluation is positive, he plans to purchase an option on the technology. The food grade seed binder needs additional processing and application research conducted; thus, the research team will need to identify a new source of support for its continued development.

Acknowledgements

We appreciate the support provided by the United Soybean Board through grants #2434, #1340-612-6280, and 1440-612-6280. The project also received financial support from the ISU CIRAS and a private agricultural processing company. The ISU Center for Crops Utilization Research provided facilities and expertise for this work.

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