ISSN: 0379-5462
IPPTA: Quarterly Journal of Indian Pulp and Paper Technical Association
Vol. 31, E1, 2019, pp.12-15

Development of More Sustainable Barrier Technology for Packaging

Larry Hutchinson

ABSTRACT

When did you last purchase something that was not in a package? How did the design, graphics or functional properties of the package influence your buying decision? Did you consider the origin and cost of the packaging materials or where the packaging would end up?

Sustainability is more than a slogan; ignore it and something important will be in short supply. The paper industry hasmuch to be proud of; its wood and plant-based fiber solutions are some of the most sustainable and ecologically responsible. We have innovative ways to impart a wide variety of functional and barrier properties to an array of paperboard grades and paper-based flexible packaging; however, not without consequences.

Plastics are robust and versatile. Formed into packaging or combined with paper or board, plasticsare wonderful. Unfortunately, some of the very properties that make plastics so wonderful are creating problems in the environment. Thus, we are developing barrier technologies from sustainable raw materials that deliver the required performance while being significantly more recyclable, re-pulpable, and compostable than polyethylene (PE), polylactic acid (PLA), polyethylene terephthalate (PET), paraffin wax, and per fluoro carbon (PFC).

We are utilizing vegetable oils and unique micro-encapsulation technology to create more sustainable barrier systems. We briefly introduce our novel technology and present a case for its application in cup stock board and in paper-based flexible packaging. In each case, we discuss how we achieve functional requirements; the economic benefit; and recyclability, re-pulpability and compostability, as applicable.

Introduction

As a society, we have at our command unprecedented technology. Our ability to produce, package, transport, market, sell, and distribute a vast array of goods ranging from the essential to the supremely frivolous seems to know no bounds. Our consumption of raw materials, energy, and other resources proceeds, at times, at a rate that would lead one to believe we think we have an infinite supply. Negative consequences occur because of this, and as much as we would like to wave a magic wand to make them all disappear, we cannot. Wanting to make a difference, our company chose to work ondeveloping ecologically responsible barrier solutions for packaging.

Solenis has a long history of providing functional and process chemistries, programs, and solutions to the paper industry in general and to the fiber-based packaging segmentin particular. In March of 2018, we acquired Belgium-basedTopchim, a company withunique barrier coatings technologies. Our vision,using our expanded technology portfolio,is to supply ecologically responsible barrier solutions based on sustainable raw materialsto the fiber-based packaging segment so that they can produce fully recyclable paperboard and packaging papers. Where it is feasible and reasonable our goals are to support the circular economy—minimizing waste and maximizing resources—and where it is impractical, our goal is to minimize the negative impacts of single use packaging. We focus here on two key areas: cup stock board and paper-based flexible packaging.

Utilizing vegetable oils and unique micro-encapsulation technology, our solutions target the replacement of several less sustainable barrier solutions. We target replacement of polyethylene (PE) with water borne dispersions that deliver required barrier properties while being recyclable and repulpable. We target replacement of perfluorocarbon (PFC) for oil and grease barrier applications with both water borne dispersions and solid bio-wax,depending on the particular substrate and end use. Finally, we utilize solid bio-waxes to replace petroleum-based paraffin waxes in a variety ofpaper-based flexible packaging and corrugated applications.

MAKING THE CASE

We are still continuallydevelopingand testing additional formulations; however, using our current barrier system applications we can make a case for and discuss the benefits provided to our customers, our society, and our environment by our barrier systemwhen applied in cup stock board and paper-based flexible packaginggrades. Our discussion includes the technical successes and any failures to achieve

functional requirements, the economic benefits, and discussionof re-pulpability and compostability.

Recycle and Recover

PE is a truly remarkable material with myriad uses. Unfortunately, some of the very properties that make it a wonderful packaging material contribute to the significant, worldwide marine and terrestrial plastics problems. The origins of the lowly paper cup trace back to imperial China. Twelve years after its upgrade in 1907, it became known as the Dixie Cup. What started out as a simple paper cup held a cup of water quite nicely for as long as it took to drink it;provided improved hygiene for public water dispensers; and was completely recyclable, re-pulpable, and fully reusable. The high quality fiber from each cup was recoverable; thus, more than 100 years ago, we could go "cup to cup" if we chose to.

The estimates vary but indicate that consumers annuallyuse approximately 600 billion cups, of which 250 billion are hot and cold to-go "paper cups". Fast-forward over a century since its 1907 upgrade and the paper cup has evolved into a hi-tech composite structure of paperboard and PE that does not re-pulp very well. Today's cups include at least one layer of PE, which provides both the barrier properties and the ability to seal the seams of the cup during the cup forming process.Many of today's cups are high tech marvels—but for typical,single use, they might well be significantly overdesigned.

Technically, almost anything is recyclable; however, at what cost? PE containing cups are not commonly recycled because of the difficulties the PE film causes. PE does not degrade under industrial or home composting conditions; therefore, composting operations do not want either pre or post-consumer cups. Consequently, the cups end up in landfills, as terrestrial litter, and as plastics contamination in the marine environment.

This is a tragic situation—a waste of resources and a source of pollution. Using round numbers let us consider a PE-coated cup stock volume of one millionMTPY(metric tons per year) and a fiber cost of $1,000/MT(metric tons). Assuming a 1:1 displacement ratio (no recycling of PE-coated cups), this equates to a single use fiber raw material loss of $1 billion/year thatgoes to the landfill or worse.A PE application of roughly 10% would equate to about 100,000 MTPY of plastic going to terrestrial and marine environments. If global cup stock volumeswere at three millionMTPY that would representa lost opportunity of potentially $3 billion/ yearin fiber recovery.As an industry, we can discuss cost models, material values at "x" stage of life, recovery rates, "broke" values, how the cost/value model should be constructed, and so forth, and we should;however, the most likely conclusion is that the lost opportunity in high quality, clean, strong, virgin fiber is far greater than $1 billion per year.

The paperboard used to produce cups is predominantly virgin fiber.What if we were to recover only nice clean converting waste and then re-use it as broke for cup production? If it were not PE contaminated and we were to assume converting waste of~15%,it would represent an opportunity of more than $150 million. That would be a significant improvement. The greater economic and environmental value, however, is in re-pulping and re-use of post-consumer cup waste, which arecurrently neithereasy nor cheap to do.The UK seems to be having success with this ina handful of facilities that can handle post-consumer cup. Although their success is a step forward, it likely is not globally scalable for several reasons. However, even if it were, more likely than not, the majority of this fiber would be "downcycled" into something like recycled linerboard or corrugating medium where relatively low-quality wastepaper can be tolerated. This is yet anotherlost opportunity. Key players in the beverage industry have aspirational goals: They are working to ensure that for every PET bottle being produced, one is recovered and converted into a new bottle.Should we be satisfied with post-consumer cups going to landfills? Why cannot we strive for cup tocup?

Sustainable Barrier Technology for Cup Stock Board

The quest for a viable PE replacement is not new; across the industry much time and effort has been expended looking for better solutions. Balancing barrier properties, cup functional properties, sealability, blocking, re-pulpability, and compostability is challenging especially when the targets vary by application. Used as a PE replacement, polylactic acid (PLA) has demonstrated some advantages. However, although it composts much better than PE does, a disadvantage of PLA based on our repulping studies is that it does not seem to re-pulp well. It remains to be seenifPLA-coated cups provide any significant advantage vs. PE in industrial composting environments. Development of PE replacements that can be applied through existing extrusion equipment continues and for good reason.

We developed an alternate pathway in the form of water borne dispersions. More than six years of development work by the R&D team in Belgium resulted in barrier coating formulations for hot and cold cups(see Figure 1) that can be applied by typical on or off machine coaters and, film presses, or printed via reverse gravure or flexographic presses for specific applications. Non-contact coating operations, such as air knife or curtain coaters, have advantages for application of barrier coatings; rod coaters work well, and bent blade/soft tip configurations can also be used, and we've gained significant experience with all types.

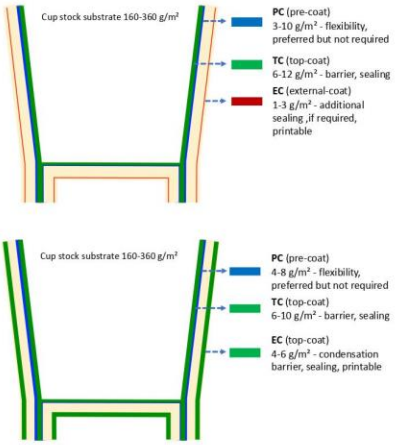

Figure 1. *Application models for hot (top) and cold (bottom) cups.*

Using our barrier coating, we are able to achieve acceptable barrier properties with acceptable Cobb values, equivalent edge wick performance to PE on the same substrate, and hot cups that will hold hot coffee for extended periods of time without leakage. The cup stock converts well on a wide range of cup converting equipment, on low and high-speed machines with both heat and ultrasonic sealing.The cups exhibit no malodors or taint and are fully re-pulpable. The application model varies to meet customer requirements for barrier properties and sealing for a particular cup format and substrate. We can make good cups for different uses in several ways. The simplest and least expensive

method usesminimum level oftop coat (TC) with which acceptable barrier and sealing can be achieved. Another method, which provides a middle ground between performance and cost, usesa combination of pre-coat (PC) followed by TC. The most involved method uses a three-component system of PC and TC on what will become the inside of the cup and EC (external coat) on the outside of the cup, which provides additional sealing while maintaining printability. Considerable work has gone into customization of formulations to optimize performance and to understand and address the different challenges for barrier coating application across a range of coater types, coater configurations, operating conditions, and substrate quality.

Do these cups meet our sustainability, recycle and reuse goals? In terms of compostability, we are confident that we can meet EN13432 requirements for industrial composting and perhaps home composting as well. Testing of different barrier system combinations and product formulations is currently underway. Compostability under the current ASTM protocols has not yet been determined. Determining compostability is not as straightforward an issue as we all would like; debate is ongoing regarding the applicability of the current standards in the case of paper cups, and brand owners, cup producers, and cup stock producers have not yet reached a consensus regarding product requirements versus "nice to have" features. We would argue that the most ecologically sound solution in the long termwouldnot include composting in any significant way becausethe real value lies in the re-pulping and reuse of pre and post-consumer cupstock and putting cups back into paperboard products with as manyas possible going "cup to cup".

We repulped cups coated with PE, PLA, and our barrier system at 2-3% consistency at 40 °C in tap water with varying shear exposure in a British Standard Disintegrator. We then formedhand sheets on a Rapid Köthenh and sheet machine (see Figure 2).

Figure 2. *Handsheets of re-pulped PE (left) and PLA extruded cup stock (center) vs. our barrier system (right).*

Clearly,several variables exist, relating to the base sheet, barrier system applied, and repulping conditions, that will influence pulp quality. However, our trial work to date shows that our barrier system is significantly lower in levels of solid contaminants that could result in process, runnability, or sheet quality issues.

Could dissolved and colloidal contaminants originating in the barrier formulations contribute to process, runnability, or sheet quality issues? We do not yet have a complete answer. The work performed to date indicates that reuse in the mid ply of multi-ply board should result in few if any issues. Weanticipate that running at 20-25% recycled barrier coated board in the mid-ply furnish shouldbe easily achievable. As a company, we believe we have the monitoring, diagnostic, and treatment tools needed to effectively deal with any issues that might arise.

Will the novel barrier system be cheaper than PE? In a comparison based solely on barrier application costs, it would be unlikely. Cost, however,is only part of the equation. When one factors in efficiency gains by going straight from the board machine to the converter, transportation impacts, fiber recovery value, and mitigation of costs and environmental impacts associated with landfill, we believe the direct economic benefits are compelling.

The novel barrier technology is viable; we can make good cups with significant advantages over PE or PLA,however, we cannot do this alone. A coordinated effort among brand owners, cup producers, cup stock producers, waste management providers, government, and barrier technology providers is required to effect meaningful change. Closed Loop Partners and the NextGen Cup Challenge are recognition of that. We are proud to have been selected as one of the challenge winners and look forward to working with the consortium partners.

Sustainable Barrier Technology for Paper-Based Flexible Packaging

Paper-based flexible packaging offers many advantages over thermoplastic films. Paperboard and corrugatedboard can be used to replace some or all of the plastics used in a wide variety of applications. Like cups, the transformation from plastics to paper-based packaging is complex and has both common and distinctly different issues. We have developed barrier technology as a replacement forPE, paraffin wax,and PFC for oil/grease, water, and moisture vapor barrier for a variety of end uses.

PE, paraffin wax, and PFC offer proven barrier performance. PE is commonly used in a wide variety of food service applications for its barrier properties and to control MVTR (moisture vapor transfer rate). However, as stated previously, its use has negative consequences. Packaging treated with paraffin waxes are not "re-use" friendly. Attempts to re-pulp and re-use paraffin wax-coated packaging and corrugated board have met with varying degrees of success prompting a shift to "bio-based" alternatives. A further issuewith some systems prompting much debate is the migration of MOSH and MOAH (mineral oil saturated hydrocarbons and mineral oil aromatic hydrocarbons) from packaging to the contents. These concerns are resulting in some shifts from coated recycled board to folding box board produced with virgin fiber by some brand owners and investigation into alternative barrier systems.Although in the US the volume of paraffin wax used in packaging has declined substantially, a significant opportunity remains for improved "waxed" corrugated recycling, increased re-use of high value fiber, and adoption of sustainable alternatives with fewer negative consequences. Finally, increasing concerns with impacts of PFCs began with a shift in formulations, and now legislation for their eliminationin some states is creating strong interest in alternative oil & grease barrier technology.

We have developed specific formulations to deliver required barrier properties for a variety of applications that fall into two categories. The first category is

from one or more plant-based oils. The raw materials can be adjusted onthe basis of regional availability and cost competitiveness or to accommodate specific customer requirements with regards to source. These products are provided in either solid or molten form, and formulations are specialized according to end use requirements. Examples of this would be high melting point formulations for hot fill conditions common to QSR (quick serve restaurant) applications such as French fry bag or burger wrap. These types of applications also require the correct level of MVTR anda grease barrier. We have high-gloss formulations, commonly used for cheeses, which also require specific MVTR characteristics because the cheese ripens in the packaging. We also developed heat sealable bio-waxes that provide a viable alternative to PE in many food-packaging applications. Twist wrap for candies and confectionary require specific properties.We have laminating wax formulations for twist wrap to foils or bi-axially-oriented polypropylene (BOPP) type films.

Reference applications for bio-waxes range from bread bags in Belgium to butcher wrap and twist wrap in France, Italy, and Germany. A customer in Belgium has used the TÜV OK Compost/OK Compost Home certification of our bio-waxes as a major selling point for bread bag applications supplied to everyone from local bakeries to global supermarket chains. This certification, combined with the other ecological features and no MOSH and MOAH issues, has given them a significant competitive advantage in strategic markets. Typical application employs a roll coater or any application method suitable for paraffin type waxes. Formulations can be adjusted to accommodate specific customer needs regarding viscosity or melting point allowing an easy transition from paraffin.

The second category is water borne dispersions applicable to a wide variety of grades requiring water, oil, and grease resistance and MVTR barrier properties.These proprietary formulations are high solids and are produced with a high level of non-petroleum-based raw materials. These formulations can potentially replace PE, paraffin wax,or PFC, depending on substrate and application, and can be applied on a size press, film press, or coater, and in some cases withreverse gravure or flexo presses.

CONCLUSION

Polyethylene, paraffin wax, andperfluorocarbon are proven barrier solutions with negative consequences. Terrestrial and marine litter from plastics has far-reaching implications for the environment. Unsustainable reliance on high levels of petroleum-based raw materials coupled with poor compostability resulting in post-consumer waste going to landfills are significant motivators for change. The barrier technologies discussed here deliver solutions that are more ecologically sustainable. These technologies can be cost competitive in a circular economy. They enable re-cycling of cup stock and cups, which recovers the fiber value instead of wasting it in a landfill andeliminates a source of plastic otherwise destined for the environment.