Development of a synthetic polymer film as a replacement for cellophane

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DEVELOPMENT OF A SYNTHETIC POLYMER FILM AS A
REPLACEMENT FOR CELLOPHANE

by

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ABSTRACT

This study evaluates the feasibility of Styrene-Butadiene, also known as SBS copolymers, as an excellent substitute for cellophane in packaging hard candy. Packaging hard candy presents an excellent potential for the plastics industry. The study will consider the problems inherently existent with cellophane, be they environmental, of a use of resources nature, or simply the physical properties. The methodology followed describes the various stages that led to the development of a product code named TA-1010, a blend of SBS copolymer and other polymers. This revolutionary product simulates the excellent packaging properties of cellophane, but without the above mentioned disadvantages. Furthermore, the polymer blend possesses an economic advantage in that it gives a 30% yield over cellophane. The paper also contains a sensitivity analysis for the different properties of TA-1010. The short term business strategy is to penetrate the hard candy packaging industry. The long term objective is to project a derivative product that would allow expansion into the soft candy and the produce packaging industries.

This report starts with a background of the hard candy industry and its growth over the last twenty years. It then describes the current practices of various hard candy manufacturers. The description includes the limitations of such practices. An analysis of the external environment surrounding the industry is given. This analysis examines the economic, social, political, and technological factors influencing both the hard candy and the plastic industry.
This report concludes by discussing the existing future potential in the packaging of soft candy and vegetables. The report also contains a bibliography of the various sources used for writing this report. Appendix I comprises TA-lOlO’s technical data sheet. Appendix II contains the most recent census bureau statistical data (published in 1995) concerning the growth of the candy market between the years 1970-1993. Appendix III contains the technical data sheet of ‘flexel’, a cellophane product, for comparison purposes.
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CANDY INDUSTRY BACKGROUND

Candy is one of the most popular foods. It is sold pretty much everywhere. According to the former president of the National Confectioners' Association, in his book "All about Candy and Chocolate", the recorded history of candy goes back at least forty centuries to hieroglyphics on temple walls and crumbling papyrus rolls of ancient Egyptians (Gott, 1958).

People ate candy first because it tasted good. Today, we know that it satisfies a basic and biological need by providing energy-giving nutrients quickly and easily. The chief ingredient in candy is sugar. Chemically, sugar is a compound of carbon, hydrogen, and oxygen in the carbohydrate group of foodstuffs. Sugar can be obtained from sugar cane, sugar beet, the maple sugar tree and the palm tree as well. However, early in the twentieth century, corn syrup was discovered and substituted for sugar in many candy production facilities.

Candy, today, is divided into two major groups: hard candy and soft candy. The former, due to its lower content of fats and oils, has been gaining ground and an increasing market share steadily.

Over the years, the market has grown significantly. For instance, Gott reports that the retail sales figures for both hard and soft candy have increased from $200
million dollars in 1913 to a little over $2.2 billion dollars in 1958 (Gott, 1958). However, the discovery of Nutra-Sweet, Saccharin, and other artificially inverted sugars have really created a revolution in the industry. Their low caloric content has helped in reaching record high sales, simply because one can eat all the candy one wants with little concern about gaining weight. According to the census bureau statistics published in 1995, the market has increased from wholesale sales figures of $2 billion dollars in 1970 to $10.7 billion dollars in 1993. Employment in just the United States’ industry has soared to 51,500 in 1992 (Census of Manufacturers Report, 1995).

Candy is a very delicate product. If left unwrapped, moisture from the atmosphere causes it to become sticky or grainy. With increasing globalization of markets and a greater concern for logistics, packaging is a vital factor.

Currently, glassine, cellophane, and polyethylene are the packaging options for candy makers. They not only protect the product by reducing contamination and spoilage, but also they add to its attractiveness. Research shows that food items sell better when properly and attractively packaged. Candy, being an impulse buy, relies on transparent wrappers to make it possible for the customer to see it in a sanitary state. Therefore, the potential for this industry is unlimited. Needless to say that packaging is part of this potential. Later, in this report, by demonstrating the environmental superiority and cost advantages of SBS copolymers over cellophane, the potential of TA-1010 in this $10 billion dollar market will be demonstrated.
II

CURRENT PRACTICES OF HARD CANDY MANUFACTURERS

For decades, cellophane was the film of choice available on the market for hard candy packaging. In comparison to the alternative packaging materials such as wax paper and laminated foil, cellophane proved to be the best alternative. It possessed the added value of superb optical clarity and high gloss properties. Besides, many unique properties that the film presents made it the perfect package for hard candy:

1 - Its high clarity tremendously increased the appeal of hard candy.

2- It possesses an excellent dead fold property, an essential element in hard candy packaging. This stands in opposition to polymer-based films which possess memory, thus eliminating their suitability for twist type packaging.

3- Cellophane has high stiffness and no elongation. These are crucial since the candy wrap process is a stop-and-go procedure; elongation can result in stretching, compromising the physical properties and causing irregularity and tears. Furthermore, stiff or “hard” films present excellent suitability for high-speed automatic packaging equipments.

4- Package integrity. Cellophane’s specially structured coating provides exceptional moisture and gas barrier characteristics. Cellophane protects much of the product’s original flavor, moisture content, texture, and aroma without the risk of affecting its taste despite the heat conditions it is used under.
5- Easy Machinability is evident in the high speed packaging equipment used in the candy industry.

6- Cellophane presents no static electrical charge. This packaging requires a static free environment. Otherwise, it could result in a high scrap rate and machine downtime due to film and packaged candy clinging and sticking to walls, components and surfaces of the machine.

7- Cellophane’s manageability is high due to the ability to print on either side by the flexographic or rotogravure systems with standard inks. It is also well suited for thermal, adhesive, or polymount laminations.

In addition to the above advantages, the processing of cellophane is not terribly complicated. Principally, cellophane is created when wood pulp and solvents are blended at high temperature. Once blended, the next stage entails processing the blend through a flat T-die onto chilled smooth rolls section to a winder. The last stage comprises slitting and rewinding the film into a finished product that conforms to customers’ specifications.

Cellophane has enjoyed immense popularity throughout the years in various applications, such as lamination for food packaging, gift wraps, and photo-album protective pages. This has resulted in a tremendous demand for wood pulp and solvents.

Over the years, the requirements for packaging hard candy have changed consistently with the rising standards of customer service and product quality.
Fortunately, cellophane was able to satisfy those changing needs until the late eighties when environmental awareness had peaked. With the rising concern for cleaner air and water, and preserving the environment, two major phenomena were bound to occur:

1- A reversal in the popularity of cellophane’s use due to its composition of two environmentally sensitive components: wood pulp and toxic solvent; and

2- The massive capital expenditure requirements due to more stringent environmental compliance laws.

Both phenomena drastically affected the desirability and the profitability of that industry causing many manufacturers to either relocate or divest into other areas of work.
III

EXTERNAL ANALYSIS

The market dominance that cellophane enjoyed throughout the years was ultimately due to come to an end. In the late eighties, the fast globalization trends demonstrated by the formation of General Agreement on Trade & Tariffs (GATT), the collapse of the Soviet Union, the opening of Eastern Europe, the formation of the European Community (EC) and lastly the North American Free Trade Agreement (NAFTA) affected cellophane packaging for hard candy in two ways:

1 - The presence of trading blocks facilitated conducting negotiation on a continental basis, and accelerated the pace of environmental awareness and its accompanying stringent environmental laws. Cellophane’s composition and the environmental sensitivity of its components -- wood pulp and chemical solvent -- intensified the effects.

2 - Globalization eliminated trade geographical barriers, therefore, inviting new competitors into the market.

Under the first condition, the increased awareness was evident in the changing mood and social behavior of political leaders. The spirit was no longer to search for responsible parties and to assign them blame. It was now more geared into exercising collective efforts to solve and most importantly eliminate the sources of environmental
problems. It was finally abundantly clear that local environmental problems are not local in their consequences. Environmental threats such as pollution and the ozone layer depletion proved to have no boundaries. In his book "The New Realities", Peter Drucker identified the destruction of tropical forests as the "greatest ecological catastrophe" of this century (Drucker, 1989).

Accordingly, since government officials are elected and should respond to their voters' concerns, the trend in the legislative branches of governments to devise transnational and local environmental laws kept up with the awareness. They became highly restrictive, and compliance nowadays requires massive capital expenditures. Furthermore, it is becoming harder to justify that entire communities bearing the costs of environmental damage rather than using penalties to punish polluting corporations. As a result, fines have become extremely punitive in nature.

Another result of this trend was larger budgets for environmental protection divisions of governments. The increase of such budgets is being financed by higher taxes. Protection is no longer looked upon as an "externality", it is a direct cost of doing business.

This drastic change in political and social perspectives affected the industry tremendously on the technological and economic fronts since cellophane uses both wood pulp, a byproduct of tree farms yet the public perception is a cause of forest depletion, and chemical solvents that emit toxic pollutants.
On the technological front, the recent developments in the field are more geared toward developing pollution control measures rather than attempting to improve the production technology. This trend slowed the innovation pace of this industry, since more capital expenditures have to be allocated to comply with regulations rather than for pure research and development purposes.

The bulk impact of this assault on the industry was felt economically. The effects were manifested in at least four different forms. At first, the massive capital expenditures have burdened manufacturing companies with a cost increase of as much as 60% in some cases. This change has forced many firms to adopt divestiture strategies and abandon the market altogether. To illustrate, let us consider the situation of firm X, a cellophane producer located in California. Firm X generates an annual output of 10 million pounds of cellophane. At a selling price of $2.30 a pound, to achieve the firm’s required 7% rate of return on capital invested, the company has to generate sales in the amount of $16 million. However, for X to comply with the Environmental Protection Agency (EPA)’s clean air act, they have to invest $12 million in pollution control measures. This expenditure not only eliminates the profits generated, it also would place the company at a net loss. Add to the above, costs incurred to comply with state environmental protection laws, such as the Air Quality Management District (AQMD) laws of California, firm X is forced to pursue one of two strategies:

1 - Relocating the manufacturing plant into another location where environmental laws are friendlier. However, this strategy would create another expense, or
2- Abandoning the market altogether, and pursuing a divestiture strategy.

Secondly, the globalization trend has practically eliminated the logistics barriers, and foreign competitors with less stringent or in some cases no environmental compliance burdens have a considerable advantage, especially when you add lower labor costs and lower taxes. This effect is primarily responsible for not passing on the environmental costs to the consumer. Cellophane end users have more interest in keeping their costs of raw materials down than in the location where cellophane is produced.

Thirdly, an annual industry growth of 7% has toppled the equilibrium price. A higher demand for wood pulp and chemical solvents and a lower supply due to overregulation and limited availability of pulp have redefined a higher equilibrium price for raw materials.

Lastly, the increase of environmental laws necessitated larger environmental protection divisions in governments simply for enforcement purposes. Larger protection divisions imply larger budgets. Most governments finance budgets with their chief source of income --taxes, be they income taxes or capital gains taxes. However, in some cases, government agencies are self funded, that is, they rely on fines and penalties to generate their budgets. In such cases, these agencies, rather than acting as a support group guiding manufacturers into compliance at the lowest possible cost, act as militants with the sole purpose of generating incomes to justify their presence. In either case compliance laws
are raising the cost of doing business extensively and consequently shrinking corporate profits.

Adding to the above, two undeniable facts that surround the cellophane film industry, lead to the unavoidable demise of cellophane:

1- As cellophane ages, it becomes brittle and its moisture barrier is significantly affected.

2- Synthetic materials present all-around better properties at a significantly lower cost

All these practices have made it practically impossible for corporations to survive in that industry, let alone increase their profits and prosper. These problems have forced the hard candy industry to explore substitute films. Major film companies initiated research to look for a synthetic film replacement, which would simulate, behave, and perform like cellophane, without the environmental disadvantages. Most competitors and major producers considered Crystalline PolyPropylene (CPP) or Biaxially-Oriented PolyPropylene (BOPP) films as a potential replacement and committed massive resources investments to develop these products.

After several years of research, development, testing, and marketing, these products failed to significantly penetrate the hard candy packaging industry and give cellophane considerable rivalry. Hard candy producers rejected PP products simply because despite all the enhancements, they still suffered from weak dead fold, cutting problems, slower converting speeds, and higher scrap rates.
Faced with the disappointing results that most major film manufacturing companies incurred due to pursuing PP or BOPP films, SBS copolymers looked very promising as an alternative avenue to pursue.
IV

SBS COPOLYMERS PROPERTIES AND USES

The selection of Styrene Butadiene Copolymer known as SBS was not without problems. During the research and development stages numerous problems were encountered and abandonment of the project altogether was contemplated.

Initially, SBS was selected due to the many promising properties the product possessed. Its dead fold property, for instance, showed promising potential for enhancement so to match cellophane’s. Its machinability, high gloss and clarity, and stiffness, given the intended application, were certainly convincing factors. Furthermore, the product was “environmentally friendlier”

A. Composition

SBS copolymers, first produced commercially in the early seventies, are manufactured in a polymerization process by the sequential addition of the monomers 1,3-butadiene and styrene.

Styrene monomer is a sweet smelling liquid at room temperature. It is a naturally occurring chemical and is ingested daily. Styrene is present in many common foods including vegetables, fresh fruit, meat, fish, fruit juices, beer and wine. The levels in these products can range from 20 to 200 ppb (parts per billion). In 1987, the overall evaluation of styrene by the International Agency for Research on Cancer classified it as a group 2B (i.e. possibly carcinogenic to humans).
Styrene monomer is polymerized into polystyrene, which is the major component of the copolymer and forms the styrene block that provides the mechanical strength and excellent clarity.

Butadiene monomer is a colorless gas at room temperature. This monomer has caused cancer in laboratory animals and is considered a suspect animal carcinogen. The polybutadiene portion of the copolymer forms a matrix of non-continuous polybutadiene domains that give the polymer its impact resistance and toughness.

The polymerization of styrene and butadiene monomers produces the styrene-butadiene (SBS) copolymer, which is physically and chemically different from the starting monomers and is known not to have any of the adverse health effects associated with the starting monomers.

Because the polymerization process used to manufacture SBS copolymer is very effective at monomer utilization, residual monomer levels in SBS copolymers are extremely low. Residual styrene levels in SBS copolymers typically average less than 10 ppm (parts per million). The levels of residual styrene in SBS copolymer is, in fact, much less than that found in the general purpose polystyrene with which SBS is often blended. In addition, migration studies on SBS copolymer bottles which were filled with water and stored under ambient and elevated temperatures (140°F, 60°C) for up to 8 weeks demonstrated no styrene migration to the water using an analytical methodology sensitive to 1 ppb. Residual butadiene levels were not detectable using analytical methodology
sensitive to 1 ppm. These levels of residual styrene and butadiene in SBS copolymers are not anticipated to present a risk to human health in the processing or use of SBS copolymers.

When the polymerization process is finished, the polymer is finished to remove residual volatiles and formed into a pellet in which form it is sold.

B. Properties

SBS is suitable for applications that call for brilliance, glass-like clarity, and high toughness. Its properties at a glance are: crystal clarity, brilliance, toughness to very high impact resistance, universally processable, possessing excellent thermoformability, with very little water absorption, printable, weldable, coatable, physiologically harmless, and sterilizable with gamma-rays. Besides, SBS can be reprocessed multiple times without significant effects on the processability of the resin itself. The most important measures of quality of SBS film are: transparency, toughness, stiffness, low shrinkage, and surface finish.

However, the SBS finished product exhibits limited thermal stability. The reason for this is the polymer’s two-phase morphology: the blocks of styrene and butadiene, which are incompatible with each other, separate out in the solid to form a lamella structure. The resultant rubber phase is sensitive to heat and is easily damaged. The formation of gel particles is the direct result of processing the material at temperatures that are too high. It is because of this that stabilizers have assumed a central role in SBS
copolymer product development. However, despite all the progress in stabilization that has been made, the melt temperature of SBS should not be allowed to exceed 200\(^0\) C. Neither should the resin be allowed extremely long residence times in the extruder displayed in dead spots or accumulations in the mixing section, if gel formation and crosslinking are to be avoided.

An additional distinctive advantage that characterizes SBS is its environmental friendliness. Considering the ambient political, social, and environmental climate, the recyclability of a product has become a crucial element in defining its use and popularity. SBS composition allows its recycling in various ways:

1- **Reuse or Recycling:** SBS can be recycled along with general-purpose and high-impact material. The production scrap can be easily reground and reused. As a result, scarcely any of the scrap needs to be disposed of. Post-consumer waste made from SBS products such as disposable packaging can be mixed with polystyrene recyclate and so improve its toughness.

2- **Incineration:** SBS can also be chemically recycled to produce petrochemical products. Being a pure hydrocarbon and not containing any added heavy metals, SBS produces only carbon dioxide and water when burned in the presence of an adequate supply of air. Hazardous emissions or residues do not occur. Its incineration contributes more energy in a waste-to-energy system.
Landfill: SBS copolymers are neutral when placed in landfill. It cannot form degradation products that could pollute the air, soil, or groundwater. SBS copolymers thus fulfill the basic requirements of ecologically sound landfill sites. Use of landfill only comes into question when direct recycling or incineration is not possible.

Since the interest in this paper concerns the packaging of foods, the specific properties that make SBS an attractive film for packaging, shrink wrap, and labeling are highly emphasized.

SBS has relatively low barrier properties which make it attractive in several food packaging applications:

1- **Permeability**: Packaged fruits and vegetables require a balance of oxygen, carbon dioxide, and water to maintain the ripening process and preserve freshness. SBS copolymers film allows for the introduction of oxygen and the release of carbon dioxide and water vapor. While this film slows the ripening process, once the package is open, normal ripening resumes. To illustrate, a simple but nonetheless impressive test on green tomatoes revealed that those packed in SBS film ripened within ten days, while those packed in polyethylene, which inhibits the ripening process, remained green.
2- **Shrinkage**: Shrink film made from SBS copolymers is suitable for packaging goods with a variety of shapes and sizes. The low shrink force properties, allow the film to shrink up to the package with no deformation or dog-ear problems.

3- **Heat Sealability**: To produce bags, or enclose a product in a package, an SBS film may be heat sealed using the same techniques such as LDPE and HDPE. SBS films typically seal at a lower temperature and require less dwell time than most PVC or polyolefin films. Under proper conditions, heat seal strength would approach film strength.

4- **Chemical Resistance**: Water and most water-based products, or powdered and granular substances do not chemically attack SBS copolymers. Most organic solvents such as alcohols, ketones, esters, and ethers will dissolve or soften SBS copolymers. Most oils also affect SBS resins, but the rate of severity of their effects are highly dependent on storage conditions and edible oils may be further restricted due to their fat content.

5- **Stress Cracking**: SBS films will crack when stressed beyond their limits, especially when the molded geometry concentrates stress or when the film contacts certain deleterious chemicals such as fats and oils.

6- **Product Alteration**: Taste and odor are the most sensitive to consumer acceptance and regulatory concern. To retain the quality of the food product, the package must not induce detectable change in taste, aroma, color or consistency.
Normally, fats are the most susceptible to acquiring odor and taste since many organic chemicals are soluble in them. To properly determine the suitability of SBS copolymers for preventing product alteration, actual storage tests need to be conducted at various temperatures and durations.

C. Processing conditions

Processing SBS films can encounter many problems if specific conditions are not met. However, preventive maintenance and proactive planning can alleviate the risk of problems:

1- For instance, if the equipment is not cleaned and purged with polystyrene prior to extruding SBS copolymers, low melt flow polymers can readily purge the SBS resin out of the film line.

2- SBS resins are not always stored under optimal conditions. Even though SBS does not absorb moisture, it can still collect surface moisture. To prevent this problem, SBS resins need to be dried for one to two hours at 140°F (69°C).

3- If the melt is left to stagnate in the extruder, crosslinking can occur. It can be observed by measuring the rise in the extrusion pressure over time at constant temperature. Increasing pressure is a clear indication of crosslinking occurrence.

4- Gel formation occurs with long residence times.

5- Despite the active wax present in the polymer, blocking of wound films, especially thin films, can occur. Addition of slip agents can remedy the situation.
6- To avoid wrinkles, SBS must be laid at 50-60°C. More importantly though, is a shorter path between take-off and the central wind-up, since wrinkles can form directly after the take-off due to air pockets in the flat-laid films. This could be achieved by slightly increasing the closing of the rolls.

7- The height of the frost line, the point where the temperature of the film falls below the softening range of the resin, should be checked to insure that it is not low, otherwise, the bubble will be unstable.

8- To prevent resin degradation, when shut down is necessary, reduce operating temperature and slow the extruder to just few RPMs to allow some movement in the extruder and prevent heat soak of the resin. Such practice will result in less maintenance, down time, and less purge time due to degraded resin.

9- When reprocessing SBS copolymers, use a chopper with sharp blades, narrow clearance and adequate ventilation to avoid heat buildup.

10- Lastly, but most importantly, the melt temperature is a very important factor if high quality film is to be produced. Under no circumstances should the melt temperature exceed 220°C.

Typical processing conditions for SBS copolymers, to avoid the risk of gel formation, crosslinking, and wrinkles, comprise a feed zone temperature range of 140-160°C, a melt zone temperature range of 160-180°C, a metering zone temperature range of 160-180°C, a die temperature range of 160-180°C, a melting temperature range
of 170-200°C, a blow-up ratio range of 1:1.1 to 1:3, a die-to-nip distance of 2-4 meters, and film thickness of 10-250 μmeters.

Several commercial grades of SBS copolymers exist on the market today. BASF and Phillips Petroleum Company are the two major producers of this product.

D. Applications

SBS copolymers, when first introduced, were intended to bridge the gap between high cost, high performance plastics like polycarbonate, and low cost but brittle plastics such as high impact polystyrene. Nowadays, besides the excellent clarity and toughness SBS copolymers possess, they are easily processed by most conventional processing methods.

Alone or in blends with general purpose polystyrene, SBS can be extruded into sheet and thermoformed on conventional equipments at high output rates. SBS copolymers process equally well in injection molding, providing good cycle times and design flexibility. An example of an injection molded application utilizing SBS copolymers’ properties is the clear living hinge box. SBS copolymers allow the part to fill through the narrow hinge, yet still have enough toughness to provide a good hinge life. In blow molding, SBS will process on most conventional equipment, allowing the molder to run a crystal clear bottle without expensive machine modifications, special molds, different screws or adding dryers.
SBS copolymers are blow molded in a broad range of sizes and shapes from small pill bottles and medical drainage units, to very tall display bottles. SBS copolymers can also be injection blow molded, without machine modification, into extremely high impact bottles with glass-like clarity. Produced as film, SBS copolymers make a clear stiff high gloss film suitable for applications such as shrink wrap and overwrap. This combination of features along with economical advantages has resulted in the growth of use of SBS copolymers.
DEVELOPMENT OF PRODUCT TA-1010

Despite the commercial availability of the resin since the early seventies, the technology for producing quality film was not developed until recently. The product was subjected to tests to ensure that the physical properties were not significantly affected. These tests revealed that side effects introduced newer problems.

The initial stage was to compare the properties of SBS copolymer various grades to cellophane’s properties and to explore the possibility of achieving a close to identical match. SBS itself was a stiffer polymer than any other potential replacement for the hard candy packaging application. However, its stiffness was nowhere comparable to cellophane’s. Naturally, SBS major producers were approached to exhaust the option of creating a grade with increased stiffness. However, it was ruled out.

The next step entailed searching for an additive that could supply the incremental stiffness. The Research & Development Department having dealt with a similar issue in the recent past felt that this problem could be easily overcome.

Besides, major SBS producers such as BASF & Phillips Petroleum claim that mixing SBS with crystal clear general purpose polystyrene (PS) result in highly transparent stiff films. They also contend that the versatility of the SBS-PS blend allows the packaging designer to maximize consumer appeal without sacrificing performance and economy. Attractive display is particularly beneficial for food products.
Furthermore, blending is usually done both because of economy, since PS costs less than SBS, and to modify specific physical properties.

Thus, the initial stage of actual development concerned creating a blend recipe to increase stiffness so as to match cellophane’s stiffness. A product marketed by Chevron Chemical Company as a high heat crystal polystyrene was targeted. This specific product is a high molecular weight homopolymer polystyrene that has < 1800 ppm total residual volatiles content, low gel count and excellent clarity. The product complied with Food Additive Regulation 21 CFR 177.1640 for polystyrene, which states that such materials may be safely used in contact with foods.

when experimenting, the perspective was to keep the blend mainly of SBS nature. A low percentage of PS was used. The results indicated that the stiffness increased but it still was not at the desired level. The content of PS was elevated in the next experiment, resulting in an increased, but not adequate stiffness. A third experiment was conducted with a higher PS content, the optimal stiffness was achieved. However, whereas stiffness, hardness, and heat distortion resistance increased when PS was added, the toughness of the film fell.

The product developed in the experimentation process a tearability problem on two fronts: process tearability and dart impact resilience. The resulting premature tearing greatly affects the acceptability of the film for hard candy packagers.
At this juncture, two courses of action were possible. On the one hand, we could discard the PS and look for another polymer, which basically meant scrapping twelve months of work on the project altogether and starting over. On the other hand, we could search for another polymer that we could add to the blend to solve the premature tearing.

The issue was studied carefully. Recommendations were sought from internal as well as external production experts. The decision was made to research the option of adding another polymer to the blend to solve the problem.

At the end of four weeks of consulting with different suppliers, a high impact styrene monomer also produced by Chevron was decided upon as a solution to the problem.

The grand blend recipe did not change since the percentage of SBS in the mix was still identical, but what changed was the composition of PS in the SBS-PS blend. The high impact styrene solved the tearing problem, did not affect the stiffness and the deadfold properties, but unfortunately, it compromised the clarity and the elongation properties of the film.

At this stage, the development of the product was getting harder to push forward. Every time a problem was encountered, the result was to add another polymer to the blend which would create a different problem only making it harder to pinpoint the source and harder to achieve blends that would not affect the desired physical properties previously achieved.
The issue was tackled on two fronts: On one hand, attempts, using an elimination process, were made to identify the polymer or polymers responsible for the problems.

On the other hand, experimentation with the three polymers were conducted to achieve a suitable blend that would eliminate the newly created clarity and elongation problems, resolve the tearability problem, and keep the stiffness and dead fold properties unharmed. This went on for several weeks without any breakthrough. Concurrently, in an effort to contain costs, management made a decision to research the market for a substitute resin that could provide high impact without the clarity and elongation problems.

Market research was back on the spotlight to determine the viability of this project. Fortunately, a high density polystyrene (HDPS) product manufactured by Denki corporation of Japan originally intended for injection molding of household products and industrial packaging applications such as high clarity boxes for mechanical tools, and picnic boxes was discovered. The HDPS was evaluated. Its physical properties looked very promising, but at that stage, skepticism reigned as to the abilities of this resin.

HDPS possessed unique properties desperately needed to match cellophane’s abilities. It was a high density, high clarity styrene monomer that possessed high impact properties. Research & Development started experimentation with the new resin hoping for a better fate then its predecessor, the high impact styrene. Initially, similar percentages to the high impact styrene were tested in the original PS-SBS blend. HDPS proved its superiority.
For the next few weeks experimentation was made in the blend percentages to achieve the optimal mix. When reached, HDPS had demonstrated impressive results. Besides eliminating the tearability problems displayed by the original crystal clear styrene-SBS polymer blend, it did not display any changes in the clarity of the blend nor in its elongation properties.

Furthermore, HDPS was responsible for other significant major properties. It improved the stiffness of the film, the dead fold property of the blend, the cutting of the film, the tearability whether dart impact or premature tearing, the elongation, and finally its clarity. Its tensile strength was also within the acceptable range.

At that stage, it was felt that the product is finally ready to replace cellophane. With a few weeks of fine tuning, the product would be ready for market especially the hard candy packaging industry. Several potential customers were contacted and presented with samples for testing.

The feedback was not positive. Apparently, packaging hard candy was a delicate procedure simply because it is done while candy is hot. At that stage, candy’s properties are very unstable and thus can absorb odor, moisture and taste from its environment. On the other hand, TA-IOIO when exposed to heat, due to its styrene content can release a sweet styrene odor. Given these conditions, the chemical reaction was bound to occur. The candy possessed a sweet styrene taste.
Another elimination process was used to identify and pinpoint the source of the new problem. BASF, Phillips Petroleum, & Denki Corporation were contacted to study whether SBS’ composition, PS’ composition or HDPS’ composition were individually or collectively responsible for the problem. Possible factors that would cause taste alteration were examined. It was determined that any polymer with an above normal volatile content could release odor to its environment in the following manner: As polymer is being subjected to a heat environment, if its volatile content is excessive (>200 ppm) there is great chance for a “Blooming effect”, which would bring the styrene odor to the top of the film, to take place. Both SBS and HDPS were ruled out as possible contributors. The solution was simple: Replace the high impact styrene with another high impact styrene that possesses a low volatile content. However, once replaced, a test needed to be conducted to ensure that no adverse effects were noticed upon the other physical properties of the blend.

Chevron was able to provide the new high impact styrene polymer. When replaced at the existing percentage, there was a noticeable decrease in stiffness and tearability. Six to eight weeks of blending experiments were conducted in order to regain the same stiffness and tearability without the odor problems.

Once again the product was ready for market. Customers were recontacted and given newer samples for testing. The product functioned properly, except there was a surface decoration problem and a static problem.
As for the former, the ink did not adhere to the wrap. Analyzing the costs that were incurred in research and development up to that point, justification was required for incremental development costs. A simple comparison of unprinted hard candy packages’ market share to the total hard candy packaging market reflects that decorative appeal is a crucial element in that market. Major SBS producers who did not encounter such problems before were contacted. They suggested to switch from water-borne printing inks since they adhere less well than those containing organic solvents. They also suggested treating the film twice with a corona discharge. They claimed that the discharge polarizes the surface of the film and considerably improves the adhesion of polar inks. Both suggestions proved unsuccessful.

Once again theoretical research and experimentation were conducted. After four weeks of intensive efforts, the source of the problem was pinpointed. Development engineers discovered that the SBS copolymer was responsible for the ink problem and particularly that the butadiene content was the factor.

The dilemma was that the butadiene polymer is responsible for giving the polymer its impact resistance and toughness. On the other hand, it caused the printability problem. Both elements were essential for the marketability of the product.

Four weeks of theories testing and experimentation passed. A theory suggesting blending two grades of SBS could result in lowering the content of butadiene without sacrificing the impact strength and toughness of the polymer. The market was searched
for a grade of SBS that possesses a low butadiene content. Fortunately, Fina Oil & Chemical Company marketed such a product. Development engineers perfected the blend and achieved the desired physical properties once again in a period of one week.

During the procedure it was discovered that if high filtration using multiple screens in the extrusion process could be achieved, the result would be a significant reduction in gel formation.

At that stage, the only unsolved issue was the static problem. This problem was serious in nature and a key to selling in the candy industry. Styrene is by nature amongst the highest static film of any of the plastic film products. Thus, due to their styrene content, all elements of the product were contributing to the static problem. To complicate matters further, it was learned that the current candy packaging machines used by candy producers are compact and contain many rollers that the film has to travel on during the packaging process. Such conditions would only intensify the static problem.

The first attempt entailed the trying to neutralize the film using mechanical devices during the extrusion process. Anti-static metal bars that would eliminate the electrical charges responsible for creating static were installed. Testing was conducted. The bars seemed to have eliminated the problem at the extrusion end. However, the static problem reappeared when the film was subjected to processing while packaging the candy. This option was ruled out.
The next attempt entailed trying to eliminate the problem at the source. Evaluating the situation with different suppliers and scanning the market for any antistat additives revealed a product that could be blended with the resins before the extrusion process. Under this approach, a resin is blended with an antistat additive that is made with a resin carrier of the same blend. The options available on the market were the following:

1- The first resort comprised compounding an antistat additive made of HIPS resin as a carrier with the TA-1010. Due to polystyrene’s popularity on the market since the additive shared the same base as one of the resins in the product, the process looked very promising. However, the results were disappointing. The film had become hazier and elongation problems were encountered due to the softness the film had acquired. Since maintaining clarity and stiffness was crucial to rival cellophane and to appeal to candy makers, the process, in essence, worked against what we were trying to accomplish, and the product had become commercially unacceptable.

2- The second attempt entailed compounding an antistat additive made of crystal styrene resin as a carrier with the TA-1010 blend. This blend did not encounter a better fate than its predecessor. The problems resulting from the blend, when extruded, were gel formation and lack of clarity. In the industry, such problems signify a low quality film. Given the marketing importance of a candy package appeal, these problems meant the death of the product.
Blend # 3, comprised compounding and antistat additive made of either SBS copolymer or the HDS polymer as a carrier. The results were terrible: haziness, lack of clarity and gloss, and gel formation problems were all encountered.

It is noteworthy to mention that all through the attempts at the problem, constant input and feedback was sought from both resin producers and additive producers and suppliers. They had no solution nor any advice on alternative courses of action that could be pursued to reach a solution. After exhausting all logical possibilities, a suggestion was made that if the composition of the additives was analyzed along with a study of the physical properties of the components, a fresh perspective could be reached. The principle was the following: achieving an optimal blend between the antistat and the resins to eliminate static without having to compromise the physical properties of the resin. Additive suppliers were contacted again. As a result, a very promising antistat fluid additive chemical was introduced.

The chemical, a clear, pale, straw-colored, oil-based fluid, was a permanent, internal cationic agent for the use in polyolefins and styrenics to eliminate static electricity in processing and end-use applications. The chemical was intended to dissipate the most intense static charges, and eliminate the self cling. Its dust repelling function allows film-wrapped products to remain on the shelf for extended periods without losing customer appeal. Further, the FDA sanctioned the use of this agent as antistat at levels that exceed 0.1% by weight of polyolefin food contact films.
The initial experimentation with the product entailed subjecting it to the previously explored theories. The compounding method was attempted. New problems developed. Apparently the compounding was causing the resin to stick to the wall and to other components of the extruder due to the oily base of the chemical. This has created a "gum" effect in the resin, despite the high filtration system installed on the extruder. Unsuccessful efforts at regulating the amount of chemical in the compound led to ruling the compounding option out.

Since the chemical was of a liquid nature, an unconventional attempt generated the optimal solution without any negative effects. The method comprised the following:

1 - Drilling a hole in the barrel toward the end of the extruder to provide an area for injecting the chemical antistat agent.

2 - Installing a calibrated valve that could control and regulate the input of the chemical antistat agent into the film.

The results were very impressive. TA-1010 has achieved the stiffness, the dead fold, and the clarity of cellophane, only without the environmental disadvantages and furthermore with a yield and price advantage.
VI

FUTURE OUTLOOK

Looking back, all efforts paid off at the end. The product is a winner. The evident superiority the product has demonstrated over other cellophane replacement alternatives has been established earlier in the paper. Concerning cellophane, TA-IOIO’s future looks promising. With the continuing trend in environmental awareness and its matching regulations, and due to the increased local and foreign competition caused by globalization, cellophane is bound to lose market share to SBS. Furthermore, from a cost standpoint, extruding film using TA-IOIO is proven less costly than using cellophane as appendices I and III of this report reveal. Despite the fact that the major physical properties such as stiffness, clarity, elongation, dead fold, and toughness are greatly comparable, the two products differ in yield and gauge properties. It is evident that at any thickness, there is a 30% more yield with TA-IOIO than with cellophane. Besides, the cost of a pound of TA-IOIO film is 25% cheaper than its respective cellophane.

Encouraged by the success that TA-IOIO has shown, and in accordance with the long term strategy of dominating the $10 billion film food packaging industry, research efforts are currently concentrating on developing a derivative product of TA-IOIO that would allow further expansion into the soft candy packaging market and the produce packaging industry. Through innovation and relentless pursuit of excellence, a successful product will be invented soon.
VII

CONCLUSION

This report has demonstrated the superiority of SBS copolymer, as an excellent substitute for cellophane in packaging hard candy. The study revealed the problems inherently existent with cellophane, discussed the external factors affecting the plastic industry and presented a revolutionary product that simulates the excellent packaging properties of cellophane, thus, without the above mentioned disadvantages. Furthermore, the report revealed using technical data, the economic advantage the polymer blend possesses over cellophane. A 30% yield advantage and a 25% cost advantage, coupled with a promising future potential makes this product the film of choice.
VIII

APPENDICES
TA-1010

APPLICATIONS

Product applications for TA-1010 include: hard candy, snacks, cookies, baked goods, and packaging of a variety of food and non-food items. TA-1010 is well suited for form-fill-and-seal and overlap applications requiring maximum release and/or slip to overcome critical machine conditions. TA-1010 can be used in various adhesive and extrusion laminations.

YIELD AND GAUGE

<table>
<thead>
<tr>
<th>Type</th>
<th>Units</th>
<th>140</th>
<th>160</th>
<th>180</th>
<th>195</th>
<th>220</th>
<th>250</th>
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<td>Yield</td>
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ADVANTAGES

Package Integrity TA-1010 provides exceptional gas and moisture barrier properties. TA-1010 is specially formulated to provide low temperature heat sealability, as well as, excellent qualities for twist wrap applications.

Machinability TA-1010 runs at high speed on form-fill-and-seal equipment instantly releasing from heat seal jaws. TA-1010 runs efficiently on overlap machines, bag makers and other film handling equipment.

Package Appearance TA-1010 has excellent roll conformity and high clarity to promote high visibility and excellent product appeal.

Printability TA-1010 has a smooth glossy finish and can be printed by the flexograph or rotogravure systems with standard or water based inks.

Laminations TA-1010 provide strong, reliable bonds for thermal, adhesive or polymount laminations.

FDA COMPLIANCE

TA-1010 complies with the United States Food and Drug Administration requirements for the packaging of food products.

*TA-1010 is recyclable.*
# APPENDIX - I

## TA-1010

### PHYSICAL PROPERTIES

<table>
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<tr>
<th>Property</th>
<th>Test Method</th>
<th>Standard</th>
<th>Metric</th>
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<td></td>
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<td></td>
<td></td>
<td>TD</td>
<td>3.2</td>
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<td><strong>Elongation @ Break</strong></td>
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<td>%</td>
<td>Value</td>
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<td><strong>Heat Seal Strength</strong></td>
<td>275°F-0.5 sec-6psi (135°C-0.5 sec-.42kg/cm²)</td>
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<td><strong>WVTR Water Vapor Trans</strong></td>
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<td><strong>Carbon Dioxide Permeability</strong></td>
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<td><strong>Nitrogen Permeability</strong></td>
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<td><strong>Haze</strong></td>
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<td><strong>Gloss</strong></td>
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### Forms Available

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<td>6&quot;</td>
<td>22½&quot;</td>
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<td>38760</td>
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### APPROXIMATE LINEAR FOOTAGE PER ROLL

- Standard

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### APPROXIMATE LINEAR METERS PER ROLL

- Metric

**TRANSMERICAN PLASTICS CORP.**
5601 East Santa Ana St., Ontario, CA 91761 • (909) 988-8555 • FAX (909) 983-6686
Table 33. Candy and other confectionery products. Sales, value, and supply and utilization, with quantity, per capita consumption, and value of sugar use, 1970-1983

<table>
<thead>
<tr>
<th>Year</th>
<th>Millions</th>
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<th>Mill. Dols.</th>
<th>Pounds</th>
<th>Mill. Dols.</th>
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<th>Unit value</th>
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<th>Unit per</th>
<th>Per with</th>
</tr>
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“K” HB-23

DISTINGUISHING FEATURES
HB-23 is a transparent cellulose film coated on both sides with a moistureproof, heat-sealable, high-barrier polymer (PVDC) coating. This film offers the same excellent moisture and oxygen protection as other HB types, but with additional surface treatment on one side for added jaw release and/or increased film to metal slip.

USES
Product applications for HB-23 include cookies, baked goods, snack crackers, candies, and a wide range of non-food items. It is well suited for form-fill-and-seal and overwrap applications requiring maximum release and/or slip to overcome critical machine conditions. HB-23 can be used in various adhesive and extrusion laminations. The release coat should be positioned to the outside of the package.

YIELD AND GAUGE

<table>
<thead>
<tr>
<th>Type</th>
<th>Units</th>
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<th>160</th>
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<td>20.3</td>
</tr>
</tbody>
</table>

BENEFITS
PACKAGE INTEGRITY: HB-23’s specially structured coating provides exceptional moisture and gas barrier characteristics, plus instantaneous heat seals under marginal condition. Products packaged in HB-23 retain much of their original flavor, moisture content, texture and aroma.

MACHINEABILITY: HB-23 runs at high speeds on form-fill-and-seal equipment because the release coated surface (so labelled on each roll) achieves instant release from heat seal jaws. The non-release coated side promotes strong seals and bonds of great integrity, HB-23 performs efficiently on overwrap machines, bag makers and other equipment.

PACKAGE APPEARANCE: HB-23’s dimensional stability means less wrinkling on the surface of a package and less tightening at the edges. Its high moisture and grease resistance minimizes distortion allowing for optimum product visibility and sparkle for the package.

PRINTABILITY: Either highly transparent surface of HB-23 can be printed by the flexographic or rotogravure systems with standard inks designed for polymer coated cellulose films.

LAMINATIONS: HB-23 is well suited for thermal, adhesive, or polymoon lamination. Strong, reliable bonds can be achieved on non-release coated surface.

FDA STATUS
Flexel cellulose films for food packaging use comply with United States Food and Drug Administration requirements under the Federal (U.S.) Food, Drug and Cosmetic Act as amended.

The statements and comparisons made herein and the conclusions drawn therefrom, are based upon results obtained in laboratory tests made using random samples of the material and under closely controlled conditions. Equivalent results may not be obtained under differing conditions or operating methods. No product guarantees or warranties, expressed or implied, including warranty of fitness for any particular purpose, are made hereby.
IX

BIBLIOGRAPHY


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