

Polymers for Innovative Food Packaging

An Interactive Qualifying Project Report

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Abstract

This paper aims to obtain a better understanding of food packaging polymers and potential hazards they currently pose on public health. Through the use of an extensive literature review, key problems are identified with current food packaging plastics including leaching of toxic chemicals into food as well as food plastic's economical and environmental impact. Research and independent studies concerning consumer purchases and availability of the different types of polymers were then conducted and showed the direct impact these issues had on the average consumer. Independent studies involved a survey of 207 participants as to what factors affect food purchasing decisions and a study on the prevalence of food packaging plastics in local supermarkets. Ultimately, a general outline for a national recycling program is proposed in order to address some issues regarding environmental and economical impact as well as increase awareness of issues with current food packaging plastics.

Executive Summary

The purposed project addressed current issues with food packaging polymers and potential solutions. Food packaging is an important part of the food industry, allowing for preservation of food as well as mechanical support and protection in transit. Polymers have long been a vital part of food packaging due to their mechanical strength, inexpensive cost, and ease of processing and manufacturing. However, through an extensive literature review of common food plastics, three main issues have been identified with current methods including food-material interactions which can lead to the leaching of toxic chemicals into food, the environmental impact of food packaging polymers, and the economical impact of the industry.

Though these key problems are indentified, independent studies were conducted to apply their relevance to the average consumer and the social impact these issues may have. These studies included recording the prevalence of various types of plastics in the supermarket and therefore investigating how often a consumer is exposed to a certain plastics as well as a survey of 207 people in order to obtain a better understand of the factors that affect the average consumer when making decisions regarding food and food packaging. Impact of each issue could then be drawn to the average consumer and possible solutions were researched regarding recycling programs and new polymer technology to replace current plastics used.

Ultimately, a need for a national recycling program was described and a potential solution was discussed based off of the recycling program currently used within Worcester Massachusetts. This solution would provide an incentive for the average consumer to recycle as well as provide some funding for the programs themselves. Governmental regulations and laws may need to be investigated in order to full develop a plan to create a national program.

1.0 Introduction

The food industry, from domestic products alone, in the United States was an approximated \$561 billion in 1997 and has grown in the past 10 years (Economic Research Service: USDA). Of this, approximately 15% was spent of food packaging (Economic Research Service: USDA). This multi-billion dollar industry affects the everyday consumer as well as multiple business industries around the world (Spitz 1996). Food packaging provides not only a method for transporting food safely, but extended self-life as well as protection from harmful bacteria, contamination, and degradation that would occur otherwise (Siracusa 2008).

Over the past several years, modifications in polymers, glass, and paper packaging materials have made it possible to store, protect, and preserve food from spoiling and damage (Apendini 2002). Though current methods for food packaging and storage are efficient, most are petroleum-based, synthetic materials that provide minimal barrier properties and mechanical support (Moosheimer 1999, Vergnaud 1998). With declining petroleum supplies and an abundance of non-biodegradable plastics in landfills across the country, the need for environmentally friendly, cheaper, and more effective methods of packaging are required to extend shelf life and preserve the quality of the food while also improving the barrier and mechanical properties (Rico 2007, Siracura 2008).

Current technologies aim to preserve the freshness and integrity of the food while providing businesses with a cheap and efficient way to package their goods (Spitz 1996). Though this method is efficient, advances in technology have allowed for far greater advantages in food packaging while maintaining a low price for businesses (Kerry 2006). With growing concern for the environment, biodegradable polymers are now being investigated for

food packaging while still maintaining mechanical strength and functionality (Avella 2005, Del Nobile 2009). New recycle programs are also working in conjunction with new technological shifts to address the growing concern of producing a more environmentally friendly method of food packaging (Santos 2005, Subramanian 2000).

This paper aims to obtain a better understanding of current food packaging technologies and the function, environmental, social and economical problems they present as well as new technologies and possible programs that may aid in addressing them. Through the use of extensive literature review, current practices and technologies were investigated as well as new technologies coming into practice, which address the papers main concerns. Finally individual investigation was completed on commonly used plastic materials in local supermarkets as well as a survey of students at Worcester Polytechnic Institute to better understand social views and knowledge on food packaging and recycling. Ultimately, research was done on possible solutions to common concerns involving food packaging and improvements that can be undertaken that are functional, economical, and helpful to society as a whole.

2.0 Objectives

The main objective of this project is to explain and understand current food packaging techniques, procedures, and materials, as well as their effect on the foods themselves. Though current methods are cheap and effective methods for transporting food, they are often inefficient and potentially hazardous to public health. Not only this, but plastics have an increasingly negative impact on the earth due to a lack of biodegradability and poor recycling practices, leading to an ever increasing need for a solution that is effective and efficient. It is the goal of this project to understand the food packaging industry, materials and processes used, and potential hazards it poses while understand societal awareness of the effect food packaging has on the product itself as well as on the environment.

Through research, interviews, and individually collected data, an understanding of the current methods, techniques and materials used in food packaging was obtained. Independent research, such as recording current materials used in common supermarket products, was conducted to obtain a better understanding of what polymers are currently used. It was then important to understand the impact on both society and the consumer by researching possible hazards in the use of such food plastics and the quality of preservation and mechanical support that such materials provide. A survey was created to obtain a better understanding of public knowledge concerning food plastics and food packaging materials and research into recycling programs and awareness of the environmental impact of food packaging was done.

Ultimately the project would accumulate in determining the need for adjustments to the food packaging materials, explaining possible solutions to potential hazards and harms, and

developing and researching new technology and solutions that may aid in solving the issues surrounding food packaging. By examining the social, economical and environmental impact of new technologies and strategies for food packaging as well as recycling, a change may be made in how the food packaging industry works and its effect on the world.

3.0 Background: Literature Review

In order to fully understand food packaging plastics and the food packaging industry, research must be conducted into current processing methods and materials. By obtaining a base of knowledge of current practices, information on problems involving functionality properties of food packaging plastics as well as their economical and environmental impact can be sought and explained. Finally, a review of recycling programs currently in place must be done to find ways in which these methods can be improved.

3.1 Current Packaging Plastics: PET, HDPE, PVC, LDPE, PP, PS

The plastics industry is the third largest manufacturing industry in the United States at 10.9 billion dollars (SPI 2010). Although this includes many industrial plastics, the food packaging industry comprises almost a fifth of the net revenue of the plastic industry with the use of polyethylene terephthalate (PET), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low-density polyethylene (LDPE), polypropylene (PP), and polystyrene (PS) as the main components of common food packaging plastics (Bell 1982). In 1988, the plastics industry began implementing the use of resin identification coding for each type of plastic in order to aid in informing consumers which types of plastics are recyclable and which are not (American Chemistry Council). The numbers 1-6 correlate with the type of plastic used and the numbers and polymer type can be seen in Table 1. There is also a resin number 7 which correlates to “Other” plastics, which is either a plastic other than the common 6 or a mixture of the 6 and have varying properties depending on the composition of the plastic (American Chemistry Council).

Each food packaging plastic is used in a certain way due to their unique properties. A plastic such as PET has very good tensile and yield strength properties as well as being transparent after processing but melts very easily, making it ideal for cold beverages which need a strong material to contain the liquid while preventing chemical interactions (Girija 2005). HDPE is used for clouded containers or bottles for foods such as milk where a strong material is also needed, but the clarity is not required. Since HDPE is cheaper to buy as raw material and process, it is used when clarity is not as great a factor (Li 2007, Bell 1982). PVC is most commonly used for clear plastic wrapping because of its cheap cost and stretching capabilities as well as being easy to extrude into sheets (Pearson 1982). LDPE is used for food storage bags because it is very low cost and has a large stretch capacity as well as having excellent barrier properties (Pedroso 2005, Bell 1982). PP is used in rigid containers like baby bottles and cups and bowls because of its high strength properties, though it is slightly more expensive than other plastics (Sahin 2005). PS is commonly used in Styrofoam food containers and cups as well as meat and egg trays that require a rigid form or heat resistance (Bernardin III 2007, Bell 1982). Due to the varying properties of the “Other” category, it can be used for a variety of things from 3-5 gallon water jugs to oven-bake bags (American Chemistry Council).

Though these materials provide protection for the food it stores, they often lack in both mechanical and barrier properties and give minimal support to prevent damage (Mark 2006). Table 1 and 2 shows the mechanical and barrier properties, respectively, of all 6 commonly used plastics. Though all the mechanical properties are pertinent to how strong the material is and what kind of support and strength it will have, the tensile strength is the most commonly looked at aspect of a material since it will indicate the materials resistance to stress and strain.

Of the barrier properties, oxygen and water transfer are the most important aspects to food packaging since an increase in oxygen or water can often speed up the decay of food (Muratore 2006). It is also important to note that none of the current packaging plastics address other packaging problems such as biodegradability, prevent or warn of contamination, or preservation of the food (Helmroth 2002, Kerry 2006).

Table1: Mechanical Properties of Common Food Plastics*

Material Characteristic	#1 PET	#2 HDPE	#3 PVC	#4 LDPE	#5 PP	#6 PS
Density (g/cm ³)	1.35	0.959	1.3-1.58	0.925	0.905	1.05
Modulus of Elasticity (GPa)	2.76-4.14	1.08	2.41-4.14	.172-.282	1.14-1.55	2.28-3.28
Yield Strength (MPa)	59.3	26.2-33.1	40.7-44.8	9.0-14.5	31.0-37.2	-
Tensile Strength (MPa)	48.3-72.4	22.1-31.0	40.7-51.7	8.3-31.4	31.0-41.4	35.9-51.7
Percent Elongation (%)	30-300	10-1200	40-80	100-650	100-600	1.2-2.5
Fracture Toughness (MPa sqrt (m))	5	-	2.0-4.0	-	3.0-4.5	0.7-1.1
Coefficient of Thermal Expansion (10 ⁻⁶ (°C) ⁻¹)	117	106-198	90-180	180-400	146-180	90-150
Thermal Conductivity (W/mK)	0.15	0.48	0.15-0.21	0.33	0.12	0.13
Specific Heat (J/kgK)	1170	1850	1050-1460	2300	1925	1170

*(Mark 2006, Birley 1982)

Table2: Current Packaging Materials: Barrier Properties**

Material	Gas Trans. (O ₂)	Gas Trans. (CO ₂)	Water vapor	Hot Fill Temp. (°F)	Drop Impact	Chemical Res.
#1 PET	13.5	71	3.45	153	G	G
#2 HDPE	185	580	0.3	250	F/G	F/G
#3 PVC	17	27	3.0	160	G	F/G
#4 LDPE	300	2700	1.3	220	F/G	F/G
#5 PP	135	390	0.3	260	F	F/G
#6 PS	330	1160	8.5	220	F	F/G

**<http://www.petpower.nl/Plastic-PET-Bottles-and-jars/barrier/petpower.aspx>

O₂ BARRIERE (oxygen) CC-MIL/100 SQ IN. - 24 HR (lower = better)
CO₂ BARRIERE (carbon dioxide) CC-MIL/100 SQ IN. - 24 HR (lower = better)
RATINGS: P = POOR / F = FAIR / G = GOOD / E = EXCELLENT

3.2 Additives to Plastics

Additives in packaging materials are typically used to strengthen the mechanical or barrier properties of plastics (Shepherd 1982). Additives can range in a variety of materials from silicon to wood flour, each having its own unique purpose and use (Birley 1982). In some cases an additive is chosen in order to lower the cost of a polymer while retaining its mechanical properties or another additive can be added in order to alter barrier properties and may slightly increase cost (Murphy 2007). The choice of which additive is needed all depends on what is demanded of the end product polymer (Markarian 2002).

Additives are usually combined with polymers in a matrix form, integrating the polymer and additive together (Callister 2006). The molecular structure of the polymer is altered so that the additive is incorporated within the very structure of the plastic, altering the properties depending on which additive is included (Murphy 2007). This allows uniform strengthening of the material as well as replacing some volume that would otherwise be filled with polymer, which can often lead to a less expensive product (Brydson 1999).

Though there are many different types of compounds and chemicals that can be added to plastic, it is important to denote the categories they fall under (Birley 1982). These groupings help to categories how they will modify the polymer (Brydson 1999, Murphy 2007). Though not all additives are used for food packaging plastics, the categories below show the types of additives that may be used.

3.2.1 Fillers

Fillers are usually added to polymers in order to lower cost. Fillers tend to maintain barrier and mechanical properties while filling the polymer with a relatively inexpensive molecule, reducing polymer volume and cost (Shepherd, 1982). Though it is not the purpose to enhance any properties of the polymer, some fillers do enhance tensile and compressive strength, toughness, abrasion resistance, and dimensional and thermal stability (Markarian, 2002). A variety of materials can be added to accomplish these criteria including silica flour and sand, carbon black, limestone, talc, and other synthetic polymers (Murphy 2007).

3.2.2 Plasticizers

This type of additive is used to strengthen flexibility, ductility, and toughness of polymers while also reducing hardness and stiffness (Callister 2006). Plasticizers work by decreasing the strength and amount of the intermolecular forces in the material (Altenhofen da Silva 2009). These additives are usually liquids that have low molecular weights and vapor pressures (Brydson 1999). Plasticizers are usually used in polymers that are brittle at room temperature and lower the glass transition temperature of the polymer so that the plastic can be used in applications requiring some pliability and ductility as well, such as plastic wrap (Markarian, 2002). Common plasticizers include Bis(2-ethylhexyl) phthalate (DEHP) and Bis(n-butyl) phthalate (DBP) both used in plastic wraps (Callister 2006).

3.2.3 Stabilizers

Stabilizers are meant to prevent deterioration of mechanical properties due to such things as UV light and oxygenation (Hourston 2010). This is accomplished by combining an additive to absorb either UV light or oxygen (Markarian 2002). An additive can also be added to

repair damage that has already been caused, though this process is often more complicated and expensive (Shepherd 1982). The most common of the stabilizers is carbon black (Callister 2006).

Even with the use of additives, there are still issues involving mechanical properties, material-food interaction and lack of environmentally sound practices that impact society greatly (Testin 2010). Though there is a pursuit for an economical, environmentally friendly, and functional solution, it is important to understand the components of each problem first.

3.3 Issues with Current Food Packaging Materials

Though current practices are effective, there are still many issues including the materials used and possible interactions they may have with food, especially when food plastics are reused (Testin 2010, Birley 1982). In addition, the common disposal methods of food plastics as well as poor recycling policies and results have caused environmental damage that will only increase if a solution is not found (Fletcher 1999, Aarnio 2008).

3.3.1 Material-Food Interactions

Current food packaging plastics have been used for several years, but there are some material-food interactions that have been discovered that can cause additives within materials to leak into the food (Figge 1973). This can be toxic in many cases, causing harm to whoever consumes the food as well as allowing the food to become contaminated with bacteria if the barrier and mechanical properties are lost because of the leaching (Hourston 2010).

As previously discussed, additives are integrated into the matrix of a polymer, allowing the molecular structure the plastic to alter and the additive to incorporate itself within the material (Kerry 2006). When the polymer is heated, or in some cases is exposed to UV

radiation, the matrix can loosen or distort (Murphy 2007). This can cause some of the additives to be released and “leak” out of the matrix bond that was holding it (Birley 1982). These additives, though usually inert and nontoxic when bound by the matrix of the polymer, can interact with food and become harmful in large doses (Kerry 2006). Most commonly, additives are able to latch on well to fats and oils because they are very easily solvable into them and can then be consumed and be toxic (Figge 1973).

Though this problem isn't commonly seen in PET or HDPE, plastics like PVC that are used in plastic wrap are often heated in the microwave and are capable of leaching chemicals as well as PP which is used in baby bottles and is sometimes put in the microwave or heated in hot water (Figge 1973). One study found leaching of PVC chemicals and additives with change in temperature. Though the study did not test food specifically, it found that when PVC polymers reached temperatures greater than 100 °C, chemicals would leach from the plastic (Wong 1988). Another study found additives leaching into water from PS cups along with styrene particles which are toxic (Ahmad 2006). The group found that when hot water was poured into PS cups, styrene chemicals and additives would leach from the cup into the water in unsafe amounts (Ahmad 2006).

Studies have also been conducted on the reuse of plastic containers. Schmid's group found that when PET bottles are reused and sanitized using solar water disinfection, exposure to UV for 6-9 hours while filled with water, the plastic leaches additives (Schmid 2008). They also found an increase in leaching when the bottles were exposed to UV light and heated to 60 °C (Schmid 2008). Though additives may help obtain some mechanical and barrier properties that are necessary for food packaging, they can also be dangerous if they interact with food and

leach harmful chemicals. Through microwaving and heating common food packaging polymers, dangerous toxins can leach from the plastics into food and be hazardous (Hourston 2010).

It is important then to have a method for measuring additive leaching. This, however, is difficult due to measurement of leaching and the various values for diffusivity that are calculated (Rosca 2006). Studies have found variations in diffusivity on the order of two times the magnitude in LDPE (Brandsch 1999, Begley 2005) and ten times in PET (Pennarun 2004). Though varying results occur, each study still found additive leaching which can be harmful to anyone who consumes the toxins.

3.3.2 Environmental Impact: Disposal of Food Packaging Materials

Many current food packaging plastics are not biodegradable, leading to an increasingly large problem for the environment (Alter 2005). Though there are many recycling programs across the nation, billions of tons of plastic end up in landfills causing a strain on our resources as well as our environment due to leaching and a lack of volume control (Aarnio 2008). Though there is currently no economically sound way to solve this problem, a reduction in plastic use or alteration in material may help to lessen the overwhelming issue (Fletcher 1998).

In 2008, 13 million tons of plastic waste was generated from containers and packaging alone, making up as much as 12 percent of solid waste produced in the United States (EPA 2010). Of the plastic waste generated, approximately 23% of containers are recycled (CRI 2010), while the rest are put in landfills to biodegrade slowly over time or not at all (Aarnio 2008). Due to relatively low recycling rates and the toxic leaking and environmental damage such landfills can have, it is important to address other possible solutions (Singh 2009).

Most recycling programs aim to reuse plastics for industrial purposes, reducing the amount of plastic that is created each year (Aarnio 2008). This however does not minimize plastic consumption from food packaging since recycled plastics cannot be used unless it meets specific government standards costing more money to produce such containers (FDA 2006). Due to the lack of a nationwide recycling program and resources to start one, various states have their own recycling programs and therefore only accept certain plastics (regardless of resin numbers), which make it inconvenient and confusing to the everyday consumer as to which plastics are recyclable (Sidique 2010). Not only this, but recycling is often inconvenient away from home and few public facilities have separate containers for recycling plastics, making it harder to recycle plastics outside of the common household (Evison 2001).

Despite the nearly 6,000 various recycling programs throughout the nation, there is no cohesive recycling program nationwide that provides less confusion for the everyday consumer nor is there any requirement for separate recycling receptacles in public areas (Bohm 2010, Wang 1997). Furthermore, varying results are due to a number of issues such as confusion as to which plastics are recyclable, willingness to comply with town programs, convenience, and reward for complying with such programs (Evison 2001, Shaw 2006, Sidique 2010). Therefore a change is needed in order to reduce or subsidize recycling program costs as well as provide a generalized policy for recycling plastics that is nationwide and that will effectively decrease the amount of plastics in landfills.

3.3.3 Economic Impact: Cost of Food Plastic Polymers

The food industry spends approximately \$84 billion a year on food packaging and processing (SPI 2010). Of the total food cost, approximately 8% of the price to the consumer is

spent on food packaging and processing (USDA 2010). Therefore, it is beneficial to both the consumer and the food industry to use food packaging methods that are both functionally and cost effective. Table 3 below shows the cost of raw materials of each of the common food plastics. After being purchased, the materials still need to be processed into the various containers or plastic wraps that the consumer commonly sees. Due to the relatively inexpensive prices and availability of these plastics, they have come to be the dominant forms of food plastics (SPI 2010).

Table3: Current Packaging Materials: Cost***

Material	Cost (\$US/kg)
#1 PET	-
- Raw	2.10-3.40
#2 HDPE	-
-Raw	2.00-3.70
#3 PVC	-
-Raw	2.40-3.80
#4 LDPE	-
-Raw	2.20-3.15
#5 PP	-
-Raw	1.55-2.85
#6 PS	-
-Raw	2.10-3.15

***(Spitz, 1996)

Besides the cost of production and processing of plastics, it is also important to consider the cost of recycling programs for plastics. The cost to run and maintain recycling programs, including the cost of collection, processing and treatment, and transportation of recycled plastics, averages about \$75-\$209 per ton of plastic waste recycled (Bohm 2010, Dijkgraaf 2008). This means that the total cost to recycle plastics in a year could amount to as much as \$624 billion (Bohm 2010, CRI 2010). In addition, maintaining landfills costs approximately

\$40,000-\$100,000 each year in 1992 depending on the size in the United States and has increased over the past decade (Hershfeld 1992, EPA 2010).

Without the development cheap and effective packaging materials with a smaller environmental impact or more efficient recycling programs, the use of polymers for food packaging may have a tremendous ecological and economical effect. It was therefore the goal of this study to examine the role the consumer has on both recycling and food packaging choices as well as possible technological solutions that could aid in developing a method to reduce the economic and environmental impact of food packaging plastics.

4.0 Methodology

Along with extensive research on developing technologies available for food packaging and new recycling programs that show improved promise, several independent investigations were carried out to see the impact of food packaging on the daily consumer and social awareness of the negative effects food packaging can have.

Research was done through an extensive literature review on new technologies that are being developed to address the environmental issues of food plastics as well as advances in functionality and reduction of cost. This research was mostly focused on the impact biodegradable food plastics would have on the food plastics industry as well as the use of sensor technology to improve functionality. Research involving new recycling programs was carried out through an investigation of the current recycling programs in the Worcester Massachusetts area and developing plans the towns and cities have to enhance their recycling as well as results of running the program for the past few years.

The independent investigations were used to identify the impact that food packaging had on the average consumer. The first investigation was to see what types of plastics were most common within a supermarket for food packaging and how prevalent each type of plastic was. This would allow for analysis of the types of plastics used and give a better idea of how many products use polymers which are recyclable or biodegradable and which do not. This would also allow for an analysis as to which polymers are available to society and the quantities in which they affect the food packaging commonly purchased. The investigation involved visiting 3 local supermarkets and recording various items for the plastic resin number. This would indicate the type of plastic used and allow for some analysis as to how common each type of plastic was in a

typical market place and to better understand food packaging plastics. This investigation was conducted on three separate days and items were chosen based of a compiled list of common products purchased at a supermarket. Each investigation selected 20-30 items in the store and recorded the plastic numbers found on each container. Appendix A shows the items and resin numbers recorded during all three of the investigation. The outcome of the investigation is discussed in the Analysis section of this paper.

The second investigation involved a survey taken of Worcester Polytechnic Institute students as well as being available to the public. This survey was conducted in order to obtain a better understanding of if the average consumer is aware of food packaging hazards, if they recycle, and if the packaging factors into decision making during food shopping. This would allow a better understanding of how food packaging affects each person and if they are aware of potential harms that food packaging can have.

It was important to the investigators that the survey be short and easy to take as well as extract valuable information about the consumer. It was decided that the survey be 5-10 questions and be multiple choice in order to limit answers and provide usable data as well as simplify the process. The first task was to compile a list of questions in which the investigator wanted to be answered. It was determined that the 4 questions below were the most important factors to this paper and that would provide the most information valid to this project. These questions were deemed as important because they would provide insight into how the average consumer thinks and what factors effect a purchase. It also takes into consideration any impact the packaging of the food has, if any.

1. Do people consider material of a product when buying?
2. Do they recycle?
3. Do they reuse containers?
4. What type of containers/plastics do they microwave in?

Based on these four questions, survey questions were developed in order to extract this information without producing a bias for one answer. This was done through extensive revision of the questions and conference with Professor Satya Shivkumar as to how the questions should be worded.

Question one on the survey answered the first of the five questions, asking about what factor impacts purchasing an item the most. The choices were given as cost, brand name or container type. This would allow an insight as to if the type of container is considered during purchasing or if the consumer has other priorities. Question two also aims to answer the first question, asking that if a product of the same price came in different containers, which the consumer would purchase. The choices were glass, plastic, cardboard or metal. This would allow some insight as to the type of material preferred for food packaging. Question three also correlates with this question, asking what, of the three choices, was a major deciding factor in answering question two. The choices were the recyclability of the item, its reusability or the effectiveness of the material as a container. This would allow analysis of what factors influence a consumer's choice when focusing on the packaging material of an item.

Question four would address the question regarding reusing take out containers and what they are used for. This would also aid in answering what type of containers a consumer uses in the microwave. Question five of the survey also refers to using plastic wrap in the microwave. As explained in the literature review, plastic wraps can sometimes use harmful additives which can leach out of the plastic into food when the plastic is heated in the

microwave. It would therefore be important to know if the consumer is aware of this hazard as well as what types of plastics they are willing to use in the microwave, if any. This issue is also answered through question six of the survey, asking if the participant uses plastic containers in the microwave.

Question seven asks about the normal recycling routine at home and if the participant recycles. It also looks to see if there is a recycling program available where the participant is, as well as if they take advantage of it. This question would help identify if recycling was available nationwide as opposed to just in regional areas.

Once completed, the survey was distributed online via SurveyMonkey.com and also made available to WPI students through an e-mail sent to each student at the university. After a 21 day period, the results were compiled and analyzed. Though a longer period of data collection would have been preferred for a larger sampling group, time constraints did not permit the survey to be conducted longer. A sample of the survey questions can be found in Appendix B.

Results from the survey questions are shown the Results section of this paper. From this survey, a generalized analysis was done and speculation about what factors effect consumers the most during shopping and how food packaging can be changed to benefit the consumer, food industry, and the environment were made in the Analysis section of this paper.

5.0 Results

The results of the research on new technologies as well as innovative recycling programs are shown below as well as table and graphical representations of the results of the independent investigations carried out. The results of all the steps in total allowed for an analysis of public awareness of food plastic hazards and what might be the most effective solution to the problems they pose.

5.1 Research

Results of the research conducted showed several new technologies that could be used for food packaging. With the use of new technology, it could lead to possible economical and ecological solutions. New recycling policies were also investigated and the change of programs in Worcester and Shrewsbury Massachusetts and information was gathered as to the cost, effectiveness and sustainability of the programs.

5.1.1 Biodegradable polymers

With the growing need for an environmentally friendly alternative to current food plastic packaging, development in the area of biodegradable polymers has shown some potential. These polymers are made of natural composites of materials such as starch-based polymers, Poly(lactic acid) (PLA), or other naturally occurring substances and are partly or completely biodegradable which may prove useful for food packaging (Arvanitoyannis 1999). However, there are still issues with biodegradable polymers such as a decrease mechanical function and more complex and difficult processing techniques that make these polymers less functionally useful and more expensive in terms of processing (Bae 2008, Chandra 1996). If

these difficulties can be addressed, biodegradable polymers may be the solution to the environmental problem that current food packaging plastics pose.

5.1.1.1 Starch-Based Polymers

Starch-based polymers are usually comprised of a mixture of starch additives and the petroleum-based polymers (Siracusa 2008). Due to the relatively cheap cost of starch additives and its availability, this technique is cost effective and enhances currently used food packaging polymers (Arvanitoyannis 1999). Using this additive can provide some biodegradation at a faster rate as well as provides strengthening properties from the starch additive itself (Fang 2005). Fang's group showed that increased percentages of starch-based additive, when combined with polymers such as PE and PS, showed improved strain curves when force was applied. Though the study focused mostly on film based processing and mechanical function, it did show positive results toward the stability of such polymers.

These starch-based polymers can also be thermally processed and can undergo extrusion, injection molding, compression, and film casting (Lui 2009). Lui's group showed extensive work on processing techniques that can be used on starch-based materials as well as phase transitions during processing. They also tested processing properties of the starch-based polymers by observing effects of water, glycerol, citric acid and other plasticizers and additives. His group showed that after processing, there was some loss in mechanical function due to temperature changes during processing. The group also showed that processing needed to be controlled and mechanical function of the polymers was based largely on the processing technique and control of moisture within each stage, as an increase in moisture greatly affected the mechanical function in the end stage of processing. Several other studies also found

difficulties in working with starch-based polymers and attribute it to difficulties with phase control and control of heat and moisture during processing (Dintcheva 2007, Nitayaphat 2009).

The besides difficulties with processing, another issue is that, when combined with petroleum-based polymers, they are not completely biodegradable (Siracusa 2008). Though starch-based polymers may offer a solution, its limitations in processing and loss of mechanical functions due to heat make it a less than ideal candidate for food packaging applications.

5.1.1.2 Poly(lactic acid): PLA

PLA is a common natural polymer used in various applications ranging from biomaterials to food packaging (Conn 1995). PLA is comprised of lactic acid molecules, which is a natural occurring molecule found in the human body. It is easily broken down and biodegradable into lactic acid which can be metabolized by micro-organisms to water and carbon monoxide (Oksman 2003). PLA can be made from a variety of renewable resources such as sugar, potato starch or cornstarch and processing produces a highly transparent material with a high molecular weight and resistance to water solubility (Moore and Saunders 1997).

PLA can also be crosslinked in order to provide more mechanical stability and strength (Yang 2008). Yang's group tested both the thermal and mechanical properties with varying degrees of crosslinking in order to determine its effect. Figures 1 and 2 below are taken directly from this study in order to show the thermal and mechanical properties of PLA. PLA denotes a sample without any crosslinking while PLA-1,-2,-3, and -4 denote increases in crosslinking percentage as the numbers increase. Tests were done for thermal properties using computer analysis and 6 mg samples while mechanical testing was completed using a dynamic mechanical analyzer (Yang 2008).

Figure 1: Thermal Properties of PLA crosslinking

Samples	T_g (°C)	ΔH_c (J/g)	T_m (°C)	ΔH_m (J/g)	χ (%)
PLA	61.2	28.17	170.5	43.23	32.02
PLA-1	61.2	25.01	167.5	35.39	26.62
PLA-2	61.9	26.56	166.1	31.78	23.54
PLA-3	60.2	23.35	156.7	28.47	21.09
PLA-4	59.9	12.18	153.8	14.03	10.39

Abbreviations: T_g —glass-transition temperature determined from the inflection point of the heat flow curve; ΔH_c —enthalpy of the cold crystallization; T_m —temperature of the melting peak; ΔH_m —the melting enthalpy; χ —crystallinity; $\chi = \Delta H_m / \Delta H_m^* \times 100\%$; $\Delta H_m^* = 135$ J/g, the melting enthalpy of 100% crystalline PLA (Yang 2008)

Figure 2: Mechanical Properties of PLA crosslinking

Samples	Tensile strength (MPa)	Tensile modulus (GPa)	Elongation at break (%)
PLA	65.78 ± 0.39	1.68 ± 0.07	8.91 ± 0.44
PLA-1	73.56 ± 0.51	1.74 ± 0.07	7.48 ± 0.39
PLA-2	75.24 ± 0.63	1.87 ± 0.08	7.40 ± 0.32
PLA-3	67.86 ± 0.48	1.95 ± 0.04	3.87 ± 0.21
PLA-4	65.17 ± 1.14	1.99 ± 0.15	3.21 ± 0.19

Table of mechanical properties of PLA and PLA crosslinked samples (Yang 2008)

The figures show that as the number of crosslinks are increased, the glass transition temperature and peak melting temperature decrease, but the tensile strength was improved. It is important to note that these mechanical properties are similar to those of polymers used currently in food packaging plastics (as seen in Table 1) and thus would provide similar mechanical strength to products already available. One major problem this study saw was the increase in brittleness as crosslinks increased which could have an effect on the functionality of the polymer as a food packaging plastic.

Another major disadvantage of PLA is that when exposed to high humidity conditions, it begins to break down and loss its mechanical integrity and thus must be process and kept in a controlled environment (Fang 2005). Despite these issues, PLA could be a promising polymer that may prove to be economically beneficial as well as environmentally safe.

5.1.1.3 Gelatins Films

Gelatin is a biodegradable polymer that can be obtained from porcine, bovine, or fish skins though due to religious, health, and social reasons, most studies are now being conducted on fish as well as fish skins be a common waste product and readily available (Bae 2008, Darby 2009).

Studies have found that the molecular weight and amino acid composition of fish gelatins directly correlates to their mechanical and barrier properties (Gómez-Guillén 2009). Muyonga published a series of two papers that set up a study investigating the effect of molecular weight and amino acid composition on the mechanical properties of fish gelatin and found that with a higher proportion of low molecular weight amino acids lowered the tensile strength of the gelatin and made it more difficult to process (Muyonga 2004). By using amino acids that were similar in composition, Muyonga was able to determine that the variation in molecular weight had direct effect on the mechanical properties of the gelatin. By choosing gelatins with higher molecular weight amino acids, the group found that mechanical properties could be manipulated.

The other major issue with gelatins is their lack of barrier properties necessary for food packaging materials. In order to address this issue, a study was conducted by Bae to add clay composites as a filler additive to gelatin in order to make them less permeable (Bae 2008). The

study found that with increased amounts of clay additive (9% was the most additive added in the study), both tensile strength properties and barrier properties increased. The study found a 75% decrease in oxygen and water permeability through the gelatin with the addition of the largest amount of clay additive (Bae 2008).

Other types of additives could include chitosan, which is obtained from the chitin in the exoskeleton of several invertebrates (Rivero 2009). It is biodegradable, known to have antimicrobial characteristics, and also has film-forming capabilities (Dutta 2009). Chitosan is most commonly used as an additive in combination with other material to enhance mechanical and barrier properties. In a study by Portes, chitosan was added to fish gelatin in varying amounts using glycerol as a solution to mix in the chitosan and found that mechanical strength decreased. The group then attempted to add chitosan without glycerol and found mechanical and barrier properties increase. Stress strain curves showed a 20% increase in strength while barrier properties increased by 50% (Portes 2009).

Though various kinds of additives may be added into gelatins, there are still issues that have arisen. Besides insufficient mechanical and barrier properties without additives, few studies have been done as to the leaching properties of fish gelatin and possible negative effects of food-polymer interactions (Karim 2009). Other issues involve insufficient raw materials, as the type of fish skin used affects the amino acids within the gelatin and in return affects both the mechanical and barrier properties (Shadihi 1994). It may also be difficult to find skins from the same type of fish in large quantities on a consistent basis (Shadihi 1994). Variable quality of fish skin and other factors such as odor, color, and viscosity of fish gelatin may all negatively affect the gelatin strength and are difficult to control (Gómez-Guillén 2002). These varying factors

make fish gelatin a difficult product to mass produce on a scale necessary for food packaging materials and therefore may not be suitable as a biodegradable material for this industry.

Though there are a variety of biodegradable polymers available, the aforementioned fields are leaders in developing safe and useful biodegradable food packaging plastics. Though there are still issues with each, research is still being done to use these polymers in a variety of fields and may largely impact the food packaging industry in the future.

5.1.2. Current Recycling Programs

Recycling programs vary around the nation, with almost 6,000 different programs, all producing varying results due to lack of incentive, confusion among community members as to which plastics are recyclable, and awareness or willingness to comply (Bohm 2010, Evison 2001, Wang 1997, Sidique 2010). Of the various programs, a new system taking place in various towns around Massachusetts seems to have positive results (Worcester Country Recycling 2003).

The new program, which was implemented in 2006, requires all trash be thrown away in specially purchased bags put out by the town and available at various super markets. These bags, ranging in cost from \$5.00-\$7.50, require the consumer to pay for trash pick up, while recycling pick up is still free of cost if contained within a bin that is easy for workers to empty into the recycling truck (Worcester Trash and Recycling).

The main idea behind this program is that the average consumer must pay the town directly to throw away trash. This in turn would bring incentive to the consumer to not waste space in a trash bag by putting in items that are recyclable. By making recycling pick up free and trash pick up a cost to the consumer, they are more likely to recycle in a household than use the trash.

This particular program has increased recycling in Worcester tremendously over the past 4 years. Last year alone, 10,700 tons of materials were recycled (Worcester.gov) as opposed to 8,200 tons collected in 2000 (Worcester.gov). Though more statistics were not available, it is clear that the program has made an impact on the amount of material recycled, which in turn reduces the environmental impact that food plastics make.

5.2. Independent Investigations

As mentioned in the Methodology section of this paper, independent research was completed in order to understand the effect of food packaging on the everyday consumer as well as under its impact on the mindset of the average person. Through an investigation as to the prevalence of the resin identification numbers and a survey, an understand food packaging plastics impact was developed. Below are the results of each independent investigation.

5.2.1 Investigation #1: Prevalence of Resin Identification Numbers in the Supermarket

A summary of results of the first investigation are shown below in Table 4. The table shows a summary of how many items were found with the correlating resin number as well as lists the items found within that category. From a total of 49 objects recorded, the most prevalent plastic was PP (#5) followed by PET (#1), the least common being PVC (#3), LDPE (#4) and PS (#6). Though some items are named twice under various resin numbers sections, the variation was due to supermarkets and their individual packaging methods where as commercially available items that did not vary from store to store had the same resin numbers and packaging.

Table 4: Prevalence of Resin Numbers in Common Food Plastic Containers

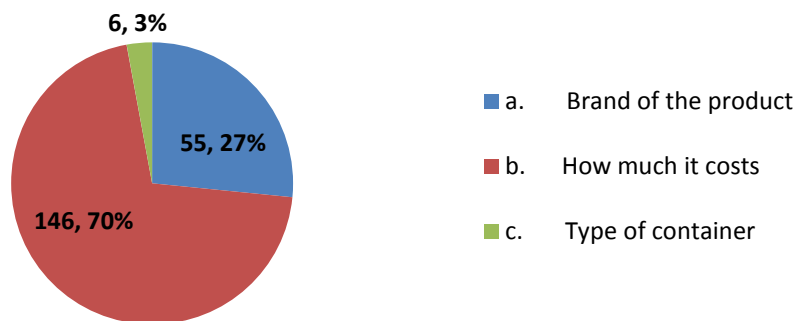
	#1 PET	#2 HDPE	#3 PVC	#4 LDPE	#5 PP	#6 PS	#7 Other
Total Items	13	10	1	2	17	3	6
Types of Items	Strawberries (plastic)	Cooking Oil (large)	Instant Coffee	Grapes (bag)	Cranberry sauce	Eggs (Styrofoam)	Deli fresh meat
	Soda(20 oz bottles)	Milk		Tub of Ice Cream	Spice container	“Lunchable” container	Jello (pudding Snacks)
	Water (20 oz bottles)	Maple syrup			Maple syrup	Mushrooms	Microwave pasta
	Horseradish	Tofu			Yogurt		Ice cream sandwiches
	Eggs (plastic)	Apple Cider			Microwaveable mashed potatoes		Ice tea
	Cooking oil (small)	Naked Juice			Sarah Lee Ham		Ground beef
	Spice container	Gallon of water			Cut pineapple		
	Ready-made salad	Soup at hand			Meal on the Go		
	Fruit cup	Powdered Half and Half			Thai noodles (microwaveable)		
	Maple syrup	Coffee (container)			Ravioli		
	Peanut butter				Steam in bag vegetables		
	Blueberry container				Ice tea container		
	Lettuce packaging				Cool whip		
					Ricotta cheese		
					Jello (Snack Size)		
					Instant soup (microwave)		
					Instant microwavable dinner		

5.2.2 Investigation #2: Survey

The second investigation involved the use of the survey which was taken by a total of 207 people over a 21 day period. The results to each question were graphically represented separately using a pie chart in order to get a visual understanding of the proportions at which each answer was given. Figures 3-9 show the results of questions on the survey respectively.

Figure 3: Results of Survey Question #1

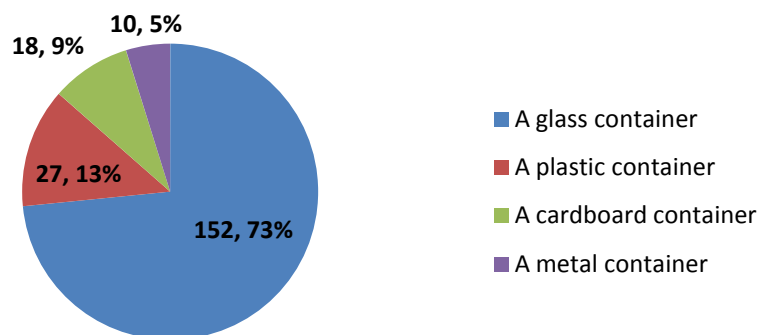
1. When shopping for a product, I look at:



The chart shows that 70% of participants valued cost, while 27% of participants were concerned with the brand of the item and only 3% considered at the container it came in.

Figure 4: Results of Survey Question #2

2. If a product came in the following types of containers, for the same price, which would you buy?



The chart for question two represents the number of participants who buy each type of container. This allowed for an analysis of preference for container type regardless of price. The chart shows that 73% of participants chose a glass container as their preference over all other choices.

Figure 5: Results of Survey Question #3

3. What was the major deciding factor in your choice for Question 2?

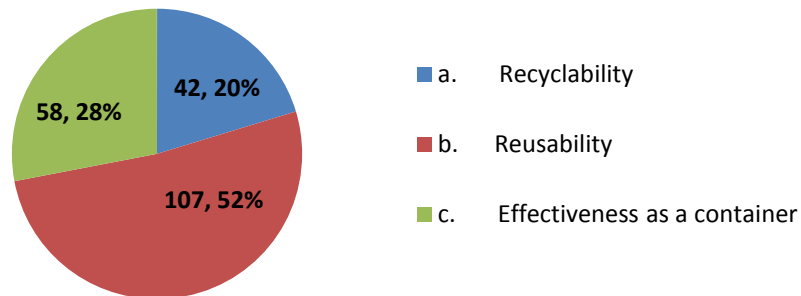


Figure 5 shows what major factors affected the answer to survey question #2. 52% chose reusability as the main reason for picking their choice while effectiveness of the container and recyclability each received about a quarter of the responses (28% and 20% respectively).

Figure 6: Results of Survey Question #4

4. Do you reuse plastic take-out or food containers?

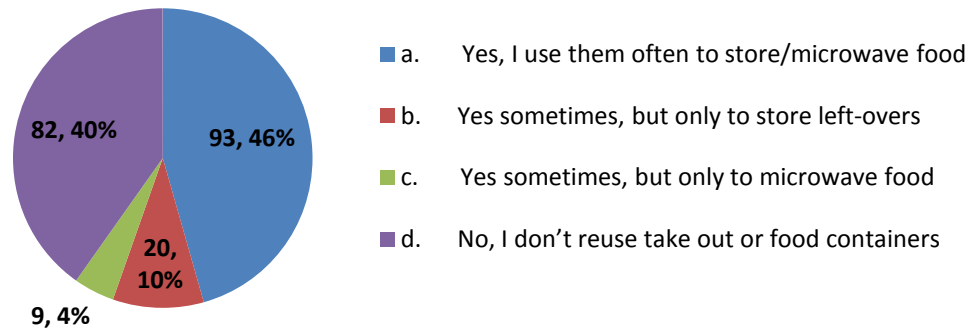
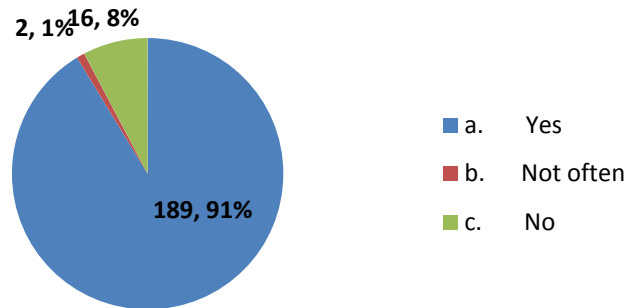


Figure 6 shows most participants either reuse containers to store or microwave food (46%) or do not reuse food containers (40%), with few participants saying they only store (10%) or microwave (4%) in reused containers.

Figure 7: Results of Survey Question #5

5. Do you use plastic wrap to microwave with?



The results of question 5 show that 91% of participants use plastic wrap when they microwave. Only 8% do not use plastic wrap at all and 1% does not use it often.

Figure 8: Results of Survey Question #6

6. Do you use plastic containers to microwave in?

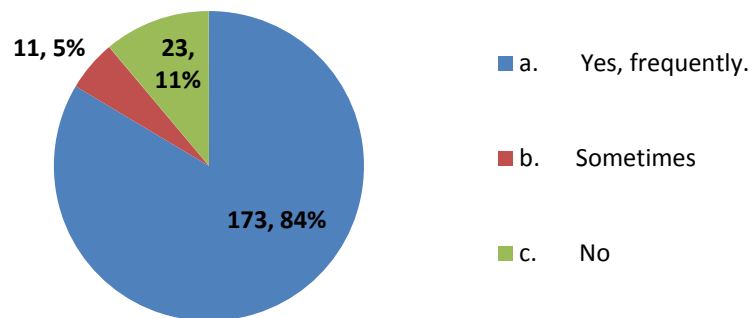


Figure 8 shows that a majority of people (84%) frequently use plastic containers in the microwave while 5% said they sometimes did and 11% do not use plastic in the microwave.

Figure 9: Results of Survey Question #7

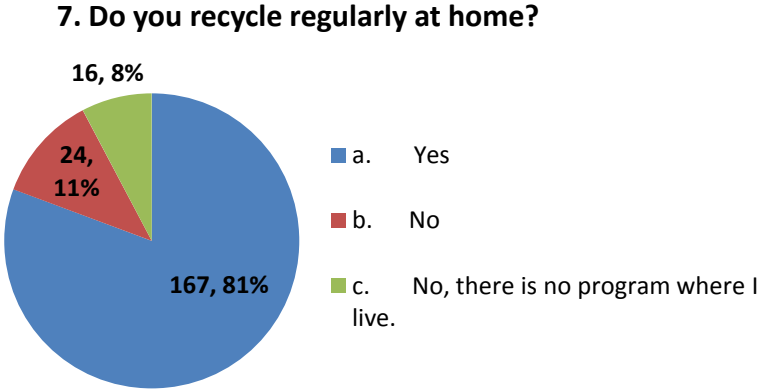


Figure 9 shows that 81% of people do recycle regularly at home while there is no program available to 8% of participants and 11% do not recycle regardless of the recycling program available to them.

6.0 Analysis

Analysis of each component is important in order to identify and extract key information as well as putting all data into perspective. It is important to note that though the data included is not inclusive of all communities and may not apply everywhere, it is a good basis for understanding local recycling programs and food packaging awareness.

6.1 Research Analysis

Through all the research gathered, there were both good and bad points for the use of biodegradable polymers for food packaging and the various types of new plastics that are being developed. Starch-based polymers, PLA, and gelatins are among the most researched biodegradable polymers and may be the most helpful for food packaging. These polymers are relatively inexpensive, provide good mechanical and barrier properties (or can be modified to have strong properties) and most importantly are biodegradable in order to address the environmental issue that current food packaging plastics pose.

However, the major issues within each of the three categories suggest that more research must be done in order to make them usable materials for food packaging. Starch-based polymers lack the ability to be processed well since they degrade with high heat and moisture. Due to the necessity to monitor processing precisely, it may drive the cost of production up and ultimately make using it as a food packaging plastic more expensive than current methods. Though PLA may not have as many issues with processing, its susceptibility to humidity and the decrease in mechanical properties may affect its functionality as a suitable food packaging material. Gelatins, though able to combine with multiple additives to achieve tailored properties, have problems with availability as well as with difficulties generating a

product that is consistent in its protein make up, which directly affects its mechanical and barrier properties.

Though these major issues prevent the use of these materials right now for food plastics, developing research may make it economically and functionally feasible to use, and thus address the environmental problem involving current methods. Though this information is important to looking at a technical solution to the environmental issue, the use of both independent investigations may help lead to a social solution as well.

6.2 Analysis of Investigation #1

Investigation #1, involving the prevalence of each resin number in commonly purchased supermarket items, was important in understanding the consumer's exposure to each type of plastic as well as what type of plastics are used for what types of containers. As seen in the Results section of this paper, PP and PET were seen the most in the items cataloged. While this information may not be important by itself, when taking a closer look at what types of items were packaged in which plastic, there seemed to be a potential hazard.

As discussed in the Literature Review section of the paper, PP has the potential to leach additives from plastic when heated (Figge 1973). From the data collected, shown in Table 4, most food packaging that is made from PP is used for "microwave ready" containers. These items are placed directly into the microwave to heat food, causing a potential leaching of additives into food. This can cause a serious health problem and the toxic chemicals that leach out may interact with food.

This investigation showed the possible hazards that food packaging plastics currently has on the average consumer and shows the need to expand awareness of the possible dangers as well as change the way food polymers are used for packaging.

6.3 Analysis of Investigation #2

The results of the survey investigation answered the four specific questions mentioned in the Methodology section of the paper. These questions were determined to be important in understanding the concerns of the average consumer as well as seeing how food packaging impacted their decision and if they recycled at home.

1. Do people consider material of a product when buying?
2. Do they recycle?
3. Do they reuse containers?
4. What type of containers/plastics do they microwave in?

“Do people consider material of a product when buying?” is an important question to ask in order to understand what impact the packaging has on the consumer. Question one of the survey, regarding what factor most influences the purchase of an item, showed that 70% of participants valued cost over brand name (27%) or type of packaging container (7%). This shows that the majority of consumers look at price rather than packaging material and supports the idea that food packaging is a relatively low factor when purchasing an item. Question two of the survey then asks the participant to consider container packaging when the item and price are the same in each case. The results showed 73% preferred a glass container and results of question three showed that a majority (52%) of participants answered question two based on

the reusability of the packaging, while effectiveness of the container and recyclability each only received 28% and 20% respectively.

“Do they reuse containers?” is posed due to the potential hazards of continued use, degradation, and repeated heating and leaching if the container is used in the microwave (Figge 1973). From question four of the survey, 46% of participants reused containers for microwave use while 40% did not reuse food containers at all. Only 14% of participants used containers for only storage or only microwaving. This shows that though some people do reuse plastic containers for microwaving, a majority do not save their containers for repeated use, either throwing them away or using other containers they already own.

“What type of containers/plastics do they microwave in?” allows the investigator to understand which plastics are being used in the microwave and if current behaviors are hazardous to public health. Though question four does indirectly help answer this question, question five shows that 91% of participants use plastic wrap when microwaving, while only 8% do not use plastic wrap and 1% does not use it often. This information shows that plastic wrap, (PVC) is often used in the microwave, yet has also been shown to have additive leaching which can be toxic with food-material interactions. Question six also shows that 84% of people frequently use plastic in the microwave, and though some plastics are safe to use, not all are and a potential health hazard could be occurring due to leaching of additives or degradation of the plastic which could lead to contamination of the food inside.

“Do they recycle?” is a necessary question to ask to understand if recycling programs are available and if the average consumer recycles at all at home where they have the most control over waste management. 81% of participants said they did recycle regularly at home

while 11% reported not having a recycling program in their town. 8% of people reported not recycling at all at home, despite having a town program in place. This data gives some idea as to how prevalent recycling is at home and can give some insight as to how to improve recycling outside of the home as well.

In all, the survey provided helpful information that would allow for a generalization of the public. Due to the small sample size, it is hard to tell whether these results are accurate throughout the nation, and so a more extensive survey may need to be completed in order to understand the factors that affect the consumer. The relatively low number of participants makes it difficult to make any definite statements about the behavior of the average consumer, but it is possible to take this information and being to apply it to possible solutions regarding food packaging changes and implementation of new recycling programs.

Through the use of the independent investigations, correlations between the issues within current food packaging plastics and its impact on the average consumer can be drawn. Through investigation #1, it can be seen that the hazards with PP and additive leaching has a direct impact on food the consumer buys and choices in purchasing as well as increasing awareness of potential dangers may decrease the average use of “microwave ready” foods. Investigation #2 shows the factors that affect consumer purchasing as well as identifies some recycling habits and draws correlation between everyday behavior and potential hazards such as the use of PVC plastic wraps on food in the microwave. Finally, the research conducted allows for an understanding of possible future solutions to come and technological advances that may aid in addressing the issues that current polymers have, though development and testing is still needed before these new materials can be ready for commercial use.

7.0 Discussion

From all the data and research conducted, there are some major changes that may need further investigation, research, and problem solving. This paper has pointed out the environmental and functional problems that the use of plastics has in food packaging. In order to address these problems, research and independent studies were done to see what methods may be the most effective in solving these issues.

The potential problems concerning the function issues with PP and PVC leaking additives into food under heating conditions is a hazard to public health and should be addressed through a change in material usage or restrictions on the types of additives used in food packaging. These restrictions should follow FDA regulations and prevent leaching of harmful toxins into food during contact in the microwave (Lampi 1977). Possible changes to material may be possible with thermally resistant plastics, though they generally cost more than polymers used currently (Brighton 1982).

The environmental impact, as discussed in the Literature Review section, is of great concern and will only grow in coming years. Without changes now, environmental damage may be too great to repair and cause permanent damage. Steps to move toward biodegradable food packaging is one option, but limitations to these solutions cannot be fixed without continuing research and development over the new few years. It is therefore important to make changes now, so that as technology develops, there is still a decline in the amount of polymer waste in landfills and a decrease in ecological damage.

Enhancing recycling programs seem to be the most effective way to make a large environmental impact now. Though the use of both independent investigations and the in

depth research completed on current recycling programs, a government program should be purposed in order to organize a nationwide plan. This program would have to be cost efficient, convenient to the consumer and encourage recycling, and be organized.

Based on investigation #1, it would be important to recycle PET and PP plastics at the very minimum since they are the most prevalent. Though current programs do not accept all types of plastics, these plastics are the most prevalent in food containers and should be considered the highest priority for recycle processing. The survey in investigation #2 suggests that though most people recycle at home, some do not even when programs are available. It would then be important to give an incentive to recycle rather than use municipal waste. One way of doing this would be to use a program much like the one used in Worcester and surrounding towns where specific trash bags must be bought in order to be collected. This would give incentive to recycle rather than throw it into the trash and would also help pay for such a program. A nationwide program would have to unite all the states and work out a contingency that was efficient and effective. Though there may be limitations to this method such as subsidizing costs for the lower class as well as organization, this program may help dramatically increase recycling throughout the nation by giving incentive and having a clear and defined program.

8.0 Conclusion

The ultimate goal of this paper was to increase awareness of potential hazards in current food packaging practices as well as address issues involving environmental and economical impact of the food packaging industry. Through a literature review, issues with food-material interactions, environmental damage, and economical effect were identified. With the use of two independent investigations as well as in depth research, possible solutions were explored and effectiveness of the solutions was identified based on consumer feedback, research, and data trends of current solutions in place. In all, a generalize solution was purposed as well as initial objectives and possible constraints. Though there are various aspects of a nationwide program that need to be worked out, the purposed solution may be the initial step in lessening the environmental impact that food packaging plastics and the average consumer have on the world.

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Appendix A

Food Packaging Plastics; Prevalence of Resin Identification Numbers

Strawberries- 1
Grapes- 4
Cranberry Sauce- 5
Yogurt-5
Soda, Water (20 on bottles)- 1
Horseradish- 1
Milk- 2
Eggs (plastic)- 1
Eggs (Styrofoam)- 6
Cooking Oil (small, big)- 1, 2
Spices- 1,5
Microwaveable mashed potatoes- 5
Dole Salad- 1
Tofu- 2
Burtoli Pasta- 7
Sarah Lee Ham- 5
Apple Cider- 2
Price Chopper Fruit Cup- 1
Naked Juice- 2
Cut Pineapple- 5
Gallon of water- 2
Meal on the Go- 5
Thai Noodles (microwaveable)- 5
Ravioli- 5
Instant microwavable dinner- 5
Soup at hand- 2
Arizona Ice Tea- 5 and 7
Ground Beef- 7
Blueberry container- 1
Lettuce packaging- 1
Mushrooms-6
Coffee (container)- 2
Instant Coffee- 3
Maple Syrup- 1,2,5
Powdered Half and Half- 2
Peanut Butter- 1
Ice Cream Sandwiches- 7
Tub of Ice Cream- 4
Cool Whip- 5

“Lunchable” container- 6
Deli Fresh Meat- 7
Ricotta Cheese- 5
Jello (Pudding Snacks)- 7
Jello (Snack Size)- 5

Organized list:

Strawberries (plastic container)- 1
Soda(20 oz bottles)- 1
Water (20 oz bottles)- 1
Horseradish- 1
Eggs (plastic)- 1
Cooking oil (small container)- 1
Spice container- 1
Ready-made salad- 1
Fruit cup- 1
Maple syrup- 1
Peanut butter- 1
Blueberry container- 1
Lettuce packaging- 1
TOTAL PET ITEMS- 13

Cooking Oil (large container)- 2
Milk- 2
Maple syrup- 2
Tofu- 2
Apple Cider- 2
Naked Juice- 2
Gallon of water- 2
Soup at hand- 2
Powdered Half and Half- 2
Coffee (container)- 2
TOTAL HDPE ITEMS- 10

Instant Coffee- 3
TOTAL PVC ITEMS- 1

Grapes (bag)- 4
Tub of Ice Cream- 4
TOTAL LDPE ITEMS- 2

Cranberry sauce- 5
Spice container- 5

Maple syrup- 5
Yogurt-5
Microwaveable mashed potatoes- 5
Sarah Lee Ham- 5
Cut pineapple- 5
Meal on the Go- 5
Thai noodles (microwaveable)- 5
Ravioli- 5
Steam in bag vegetables- 5
Ice tea container- 5
Cool whip- 5
Ricotta cheese- 5
Jello (Snack Size)- 5
Instant soup (microwave)- 5
Instant microwavable dinner- 5
TOTAL PP ITEMS- 17

Eggs (Styrofoam)- 6
“Lunchable” container- 6
Mushrooms-6
TOTAL PS ITEMS- 3

Deli fresh meat- 7
Jello (Pudding Snacks)- 7
Microwave pasta- 7
Ice cream sandwiches- 7
Ice tea- 7
Ground beef- 7
TOTAL OTHER ITEMS- 6

Appendix B

Survey: Posted on

1. When shopping for a product, I look at:
 - a. Brand of the product
 - b. How much it costs
 - c. Type of container

2. If the same product came in the following types of containers, for the same price, which would you buy?
 - a. A glass container
 - b. A plastic container
 - c. A cardboard container
 - d. A metal container

3. What was the major deciding factor in your choice for Question 2?
 - a. Recyclability
 - b. Reusability
 - c. Effectiveness as a container

4. Do you reuse plastic take-out or food containers?
 - a. Yes, I use them often to store/microwave food
 - b. Yes sometimes, but only to store left-overs
 - c. Yes sometimes, but only to microwave food
 - d. No, I don't reuse take out or food containers

5. Do you use plastic wrap to microwave with?
 - a. Yes
 - b. Not often
 - c. No

6. Do you use plastic containers to microwave in?
 - a. Yes, frequently.
 - b. Sometimes
 - c. No

7. Do you recycle regularly at home?
 - a. Yes
 - b. No
 - c. No, there is no program where I live.