Benefits and Obstacles to Smart Packaging in Food Labeling

Emmalyn H. Goulden

Graphic Communication Department

College of Liberal Arts

California Polytechnic State University

2014

Abstract

This project explores the reasons why food spoilage indicators are not yet sold in grocery stores for consumer use. Food spoilage indicators, or time-temperature indicators as they are more widely known, are used to determine whether or not products are safe for consumption. There are several potential barriers to the wide market usage of packaging containing indicators including lack of consumer interest, additional cost, and manufacturing difficulties. However, the benefits that the product offers in the way of consumer safety cannot be overlooked.

Extensive research was augmented by a survey of 119 shoppers at local grocery stores in the central California Area to gauge consumer interest in the product. Additional research was conducted by way of a case study in which a professor at Cal Poly was interviewed on his knowledge of the smart packaging industry and the feasibility of wide market release of food spoilage indicators.

Table of Contents

Chapter 1: Purpose of Study

The Problem

Smart packaging is oft touted as the future of packaging and printing for packaging. A smart package is anything that offers the consumer something extra in addition to the containment of the product. Many of these products are already in wide release – for example the pour spout in a milk carton or a straw in a juice box can be considered simple forms of smart packaging. Moving into the future, scientists are considering color changing labels for food products that tell consumers when a product is ready to eat. These indicators can be used on foods ranging from more obvious products such as meats and vegetables, which have a short shelf life, to seemingly shelf-stable products like pasta sauces and condiments that do not begin to go bad until opened and deteriorate much slower. While most foods already come with a "best by" or "sell by" date, these can be deceiving and are often not required for sale. Moreover the USDA and FDA have not developed a standard for dating on perishable food items.

Despite the benefits of spoilage indicators on foods, they have yet to reach the mainstream market. The technology is available and being explored by scientists and yet we are still years away from seeing such products at local markets. This is due in large part to hesitance at the hand of consumers and suppliers. Concerns about the safety and added costs of indicators prevent them from gaining full support necessary to push them into mainstream use. The purpose of this research was to study how products can be adjusted appropriately and then marketed more effectively to overcome these barriers.

Significance of the Problem

In the short run: Assuming companies were able to produce smart labels adding little or no cost to the final sale price, it is certain that the addition of color-changing labels to perishable items would provide a huge draw for consumers. By this measure the first producer to discover a way to produce labels effectively and cheaply would have a huge advantage over the competition. Despite the initial excitement, it would be only a matter of time before all companies were able to harness the technology and it became a product standard.

In the long run: With the industry-wide push to move online, it has long been a widely accepted that the demand for print is declining. This is not entirely true – print is unlikely to disappear altogether, rather it will take new forms and provide for different applications. People will come to expect more from their package than a container that simply protects the product. In an increasingly technology-obsessed society the best way to keep consumers interested is to offer them an additional function from what they are buying. The smart food label does just that. It would be hard to argue that it is necessary when we have lived without it for so long, but a color-changing label sure is a lot more convenient and offers consumers a benefit they did not know they were missing.

Interest in the Problem:

I am a graphics for packaging for concentration and as such have been required to take quite a few food science classes. The main thing I have gathered from these courses is that it is hard to know a whole lot about the food that we are eating (where it came from, when it got there, etcetera). For example, most home refrigerators are not cold enough to keep meats fresh for longer than two days after purchase even though the sell by date may be a week away. Besides being new and exciting, the color changing labels can prevent food-borne illness, help

people purchase fresher foods, and increase overall customer satisfaction. My one complaint is that I still have yet to actually see any of this at my local grocery store.

Chapter 2: Literature Review

Issues in Food Labeling Practices

It is nearly impossible to know everything about the foods we are putting into our bodies. While government agencies like the USDA (United States Department of Agriculture) and the FDA (Food and Drug Administration) are charged with the task of ensuring our safety, tainted products sometimes fall through the cracks. This can result in food product recalls, outbreaks of foodborne illness, and on rare occasion, deaths. A major issue in food safety is the accurate reporting of spoilage dates. Expiration dates, sell by dates, best if used by dates, and any other variation of the above can be misleading to consumers and are often not even required for sale. For example meats are often marked with a sell buy date meaning that they are still good for a period of time after being purchased. What is not communicated on the label is that most home refrigerators do not get cold enough to keep the meat good for more than two days after the listed date, so people may be eating spoiled meat without knowing it (Gogoi, 2006). Additionally, food dating is not required by the United States government for any foods besides baby formula.

Although producers who do decide to date their products must adhere to some guidelines, according to the USDA website, “there is no uniform or universally accepted system used for food dating in the United States” (USDA, 2013). Critics speculate that the USDA and FDA purposely place loose regulations on food dating in order to protect themselves in case of a breach in food safety. According to Mark Harrison, a professor of food science at the University of Georgia, “Once the consumer takes it home, not even the government can find out exactly what happened” (as cited in Gogoi, 2006). It is safer for most producers to offer a “best by” date rather than a definitive “use by” which offers consumers a greater guarantee of safety at the risk of the agency in charge of dating the products. If the regulatory agencies directly in charge of the

safety of our food cannot or will not provide an accurate way of protecting against food spoilage, consumers must look to alternative methods for measuring spoilage.

Smart Packaging: Definition and Applications

A smart package is a package that provides the consumer with an additional offering beyond the protection, containment, and communication of the enclosed product. Smart packaging falls into one of four categories – mechanical, chemical, electrical, or electronic (Perkowski, 2010, p.10). Mechanical applications are the simplest of the four and can be defined as anything that adds a functional mechanism to the package. Most consumers are already familiar with this type of smart packaging, which includes a pour spout in a milk carton or a straw in a juice box. Packages that include a chemical component are most often used in food packaging to produce a visible result when a chemical change in the product contained in the package reacts with chemicals built into the package itself. This may manifest as a color change that signals when the package has been breached or when the product has gone bad. Electrical packages contain a small paper battery that can produce a small electrical charge. These are used mainly to show that a package has been opened or tampered with or can be used in the production of re-closable packages. Electronic packages, the most advanced type of smart packaging, rely on paper-thin circuitry to produce an effect beyond the simple functionality of the package. They can be used to "power electronic displays, send sound, light, or electronic signals, or provide product/supply chain information" (Perkowski, 2010, p.10). According to S. Rangarajan, smart packaging has seen rapid growth in recent years and looks to be on the rise, due in large part to the proliferation of printed electronics as a viable method for mass-producing cheap, functional electronic products. This will purportedly cut production costs by 99% and as a

result the smart packaging industry is expected to grow to "$1.45 billion from $7.5 million in 10 years" as of 2010.

Smart Packaging for Food Products

One of the largest sectors of smart packaging is packaging for perishable food products. This is in large part due to the growing "consumer interest in convenience, safety, health, and product security" (Perkowski, 2010, p.8). Smart packaging for food helps inform consumers about the exact age and wellness of the food they are purchasing and can therefore help reduce foodborne illness. This sector can be broken down into three subcategories each offering a different advantage that caters to a specific type of food item.

Time-temperature indicators (TTIs) provide information on the time that has passed since the food was manufactured or collected, in combination with temperature to which the food has been exposed, to determine how ready the food is for consumption. There are many different types of TTIs that react in response to either physical, chemical, or biological changes in the package contents. The most basic indicators reflect a constant change in color or appearance that may be exacerbated by an inappropriate environment and respond to package surroundings much like the food product would. The same principle is used to create labels that detect temperature abuse. These TTIs change color only after a certain temperature has been reached that could be potentially harmful to the food product. A third type of indicator is used for foods commonly perceived as shelf-stable that do not begin to deteriorate until opened. These sensors are pressure sensitive and begin changing at a steady rate concurrent with the rate of food spoilage once activated. TTIs can be extremely useful in detecting abuse in the distribution process which may not be evident once the product has reached point of purchase and for general food safety measures (Abdullah et al., 2011).

For certain types of foods more specific types of smart packaging may be desirable. Fish and meat require their own unique types of labels that can accurately communicate the freshness of the package contents beyond what can be known about the physical conditions the package has been exposed to. Dyes in colorimetric labels for fish change in response to pH fluctuations that effect meat spoilage to show exactly how fresh the product is. Scientists hope to use this technology to produce "dynamic "best-before" dates that may lead to important and exciting improvements in the quality assurance sector" (Abdullah et al., 2011).

Fruits are another type of product prone to spoilage that can be monitored with smart packaging technology. Unlike any of the other indicators, fruit labeling responds to the aroma given off by the contained product to indicate level of ripeness by gradually changing from red to yellow. This packaging is unique also in the fact that it caters more to consumer desires rather than the danger posed by a spoiled product. Each of the three indicator types presents a unique advantage to consumers (Abdullah et al., 2011).

Time Temperature Indicators

Although few packages containing time-temperature indicators are ready to come to market, research suggests that the use of TTIs is a feasible and desirable innovation for consumers and retailers alike. A 2014 study conducted by Herbon, Levner, and Cheng about potential mainstream production of TTI packaging considers the profitability of the technology with respect to "attitude of a customer toward freshness in comparison with price and cost of using TTIs". One instance where TTIs could prove particularly useful is in price differentiation based on expiration date. Retailers often price items based on how close they are to their sell by dates when they arrive at the store. This offers incentive for consumers to buy and helps stores clear inventories of unwanted merchandise. However, this method is not foolproof "since

unexpected events may cause inventory items to be damaged before expiration, some damaged goods may inadvertently be sold to customers […] unless a TTI-based AD [automatic device] is incorporated in the product" (Herbon, Levner, & Cheng, 2014, p.2). It is clear the benefit that TTIs offer, but this must be weighed against the costs of producing such technology. The study used algorithms to determine how much the addition of a TTI benefits the retailer with respect to profit, as well as the exact point at which the product no longer becomes desirable to consumers based on cost. It was found that the addition of TTIs in packaging for price differentiated products increased profits 7-30% over packages that did not contain TTIs. The study also found that consumers would be willing to pay more for a TTI package until the additional cost exceeded 20% of the total product cost. The addition of TTIs also helps to mitigate profit variability because consumers are more likely to buy when they are certain about the expiration date of the product.

Colorimetric Sensors for Meats and Fish

Smart packaging for fish has long been a desirable concept, but problems in the technologies required to test for spoilage have prevented the sensors from coming to fruition. In 2007 a group of scientists developed a colorimetric pH sensor to be placed on the outside of fish packages, but it was quickly discovered that leaching of the dyes used to measure spoilage provided false results and could potentially pose a threat to the product. Moreover the pH tester was temperature sensitive which caused results to be skewed even more drastically. Scientists Kuswandi et al. (2011) are currently studying an alternative technology that relies on polyanaline (PANI), "a polymer that changes conductivity and color with change in pH as a result of changes in the degree of protonation of the polymer backbone". PANI has many benefits as a smart packaging indicator. Because the polymer and pH tester are combined in the PANI film, there is

no need for a separate indicator and matrix support as is required with other technologies. Perhaps the greatest advantage to using PANI film is that it can be mass-produced cheaply and effectively using inkjet printing. This is done by printing the polymer directly onto the substrate. Inkjet printing is a desirable method for the production of PANI film because it is precise enough to achieve the intricate "two-dimensional pattern, thickness, and conductivity" required for a functioning product (Crowley, Killard, Morrin, & Smyth, 2013). There are still some flaws in the chemical mechanisms behind the PANI technology and results cannot be considered accurate enough for mainstream use. However, this method remains the most viable solution to date for accurately reporting spoilage in fish and meat products.

Aromatic Sensors for Fruits

Fruit packaging is one area of the smart packaging for the food sector that has already advanced to a point where it is viable for wide market release. *Ripesense* is an aromatic fruit label produced and distributed in New Zealand for packaging of pears. The package is a clamshell design that contains four pears with a color-changing label to indicate level of ripeness. The label was first manufactured in 2004 and received immediate acclaim, being awarded a spot in Time Magazine's 36 Greatest Inventions of 2004. In 2009 the company partnered with packaging supplier Fresh Technologies to open a division in the United Kingdom and expand their brand. At that time they revealed that they were working on expanding their technology to be used in distribution of avocados and had begun "producing free-flow packaging, which enables the packing process to be fully automated and reduces the volume of packaging used" (Knowles, 2009). Despite the apparent success of the product, reviews and additional information about the company are scarce. Since 2009 there has been little evidence of company growth and the product has yet to appear in major grocery stores. The company

declines to provide financial statements for public use, so it is difficult to know if they are busy developing new technologies or if there just has not been sufficient demand for the product. If the latter is true, this could be due to additional cost of packaging or a lack of interest in this type of product by either retailers or consumers. While *Ripesense* is not exactly analogous to spoilage sensors it could be used as a predictor for the demand and ultimate success of like-minded products when they are ready for wide release.

Barriers to wide release of Smart Packaging for Foods

Although many of the technologies needed to produce food spoilage indicators have been available for a while, they are still rarely found on store shelves of major retailers. This has less to do with the barriers to manufacture, but rather can be credited to hesitance from consumers and retailers alike. The benefits of such technologies are clear, but they also present a new set of obstacles not associated with "dumb" packaging. From a consumer standpoint the addition of sensors will inevitably present an added cost and may potentially create an added risk. Indicators contain chemicals that could, under rare circumstances, leach into the contents of the package rendering the food dangerous to the consumer. Smart packages often require the foods to be packaged in new ways to provide head space in which chemicals released from the food can collect. Fruit, which is generally displayed unwrapped in open air containers must come packaged in a plastic clamshell container. In addition to radically increasing costs for consumers this is also presents a new issue of sustainability. Producers must also consider the environmental impacts of the chemical-containing sensors which may not be recyclable. Finally, retailers themselves are likely to be hesitant to the idea of smart packaging. Some unscrupulous sellers falsify expiration dates; an episode of NBC dateline revealed "the questionable practice by several national grocery chains of extending sell-by dates on meat products" (Lewis, 2002).

Many of these obstacles stem from misconceptions. As shown in the TTI study the addition of a sensor actually served to increase profit and consumers were willing to pay a premium for it up to a certain extent. Colorimetric labels for fish can be produced efficiently and cheaply with inkjet printing. It would seem that the biggest barrier to wide release of spoilage indicators is lack of marketing and consequently knowledge about the innovations.

Conclusion

In a society reliant on the constant growth of technology, the current system for ensuring food safety is outdated and insufficient. Adding spoilage indicators will help producers and distributors more efficiently provide food to consumers by minimizing waste. Indicators will also regulate the spread of foodborne illness and allow consumers to become informed about the foods they are buying. For several reasons this technology is not yet readily available for mainstream use. However, many of these reasons are founded on misconceptions about the safety and cost of food spoilage indicators. Through further research and marketing it may be possible to pinpoint the sources of these misconceptions and properly educate people on the benefits of indicators, so that they may reach the market.

Chapter 3: Methodology

The purpose of this study was to determine the positive effects of food spoilage indicators for food packaging versus the risks associated with such technology. The study examined perceptions of consumers and retailers regarding the effect of smart packaging for food labeling. Research objectives were to:

- Gauge consumer interest in spoilage labels while taking price increase of the product into consideration
- Determine if and how the indicator could be cost-effectively produced based on expert opinions

Data Collection Plan

A group of 119 randomly selected grocery store customers were asked to indicate their interest in a food product including a spoilage label. Questions included a sliding scale for the maximum amount consumers would be willing to pay for different types of food products. Separate questions about interest and price were asked to accommodate for different indicator types and product types. The group was split between males and females over the age of 18 who stated that they were the primary shopper for their household. In addition, experts in the packaging, printed electronics, and smart packaging sectors were interviewed to determine if production would be possible at a profitable rate. They were asked about safety concerns of indicators containing chemicals, cost of production, and feasibility of production. They were also asked if their company had considered manufacturing such a product and why they believed that food spoilage indicators are not yet readily available.

Data Analysis Plan

Once the data was collected, a statistical analysis was conducted to predict the projected cost of a spoilage indicator label and the anticipated success of the product at market. The case study was examined to determine the likelihood of the product to come to market in the near future.

Chapter 4: Results

The purpose of this study was to determine through use of public survey and case studies the demand for, and barriers to, production of time/temperature indicator labels for food products. A survey was developed and distributed over the period of several weeks in April and May of 2014 (Refer to Appendix A for complete survey). Results were collected and analyzed to gauge interest in the project. The other component of the project entailed contacting and interviewing industry professionals to determine the feasibility of the project. Two Cal Poly faculty members were interviewed with the intention of gaining contacts that may have been able to provide more insight into the development and distribution of time/temperature labels. This goal of this study was to consider the future of food packaging and to determine how packaging manufacturers can better respond to consumer needs and preferences.

Survey Results

A survey was developed that included eleven questions asking participants to indicate their interest in a time-temperature indicator label for a variety of different food products. The survey also included questions to gather information on participant demographic in order to draw correlations between a consumer's characteristics and their shopping habits. 119 responses were collected. It was calculated that in relation to the total population in the sampled area of San Luis Obispo, which comprises 45878 citizens, this sample size provided about a 9% confidence interval. Surveys were distributed at random to visitors to local businesses throughout the San Luis Obispo area.

The demographics of survey respondents was highly skewed older and female. 78.71% of respondents were female and 80.21% indicated that they were 46 or older (refer to charts 1 and

2). Respondents were also asked to write in what grocery store they frequented most often. This question generated a wide variety of responses; those most oft repeated were Trader Joes and Albertsons, although there was not a significant percentage of any one answer.

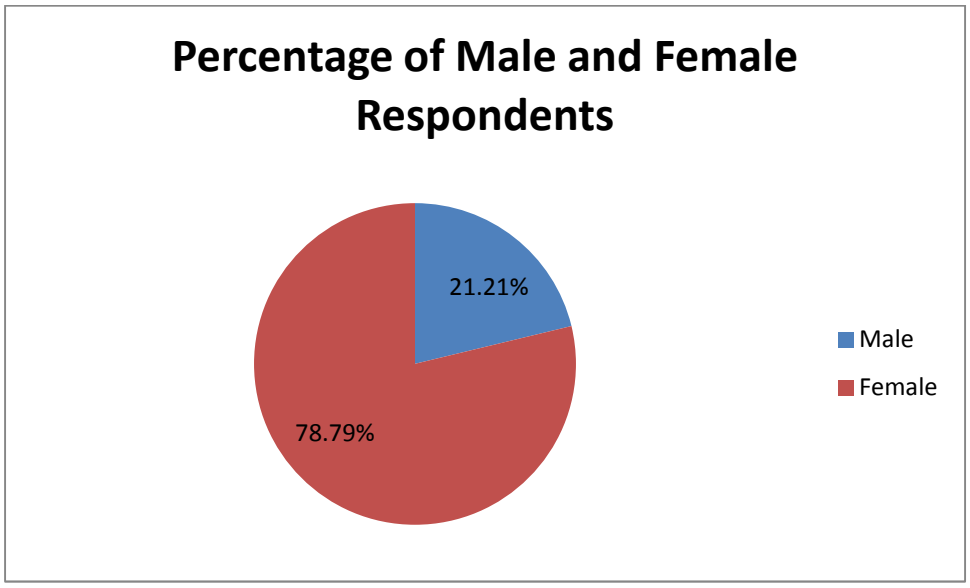

Chart 1: Percentage of Male and Female Respondents

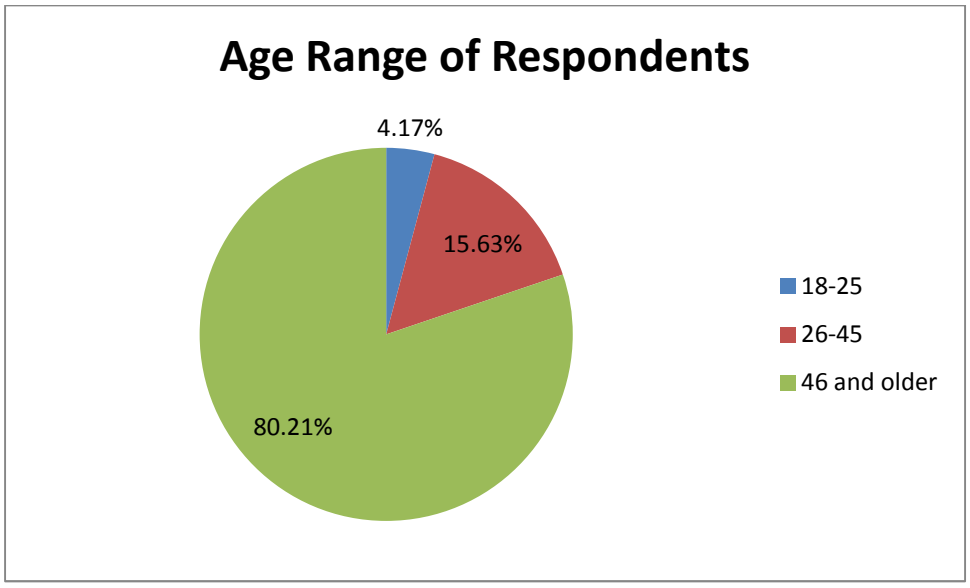

Chart 2: Age Range of Respondents

Participants were first asked to indicate general interest in a food spoilage indicator that would let them know if their food is expired. A majority of 55% answered that they would be very interested in this kind of product. 36% said they would be somewhat interested, 8 percent said they would not be very interested, and 1% answered that they would be not at all interested (refer to chart 3).

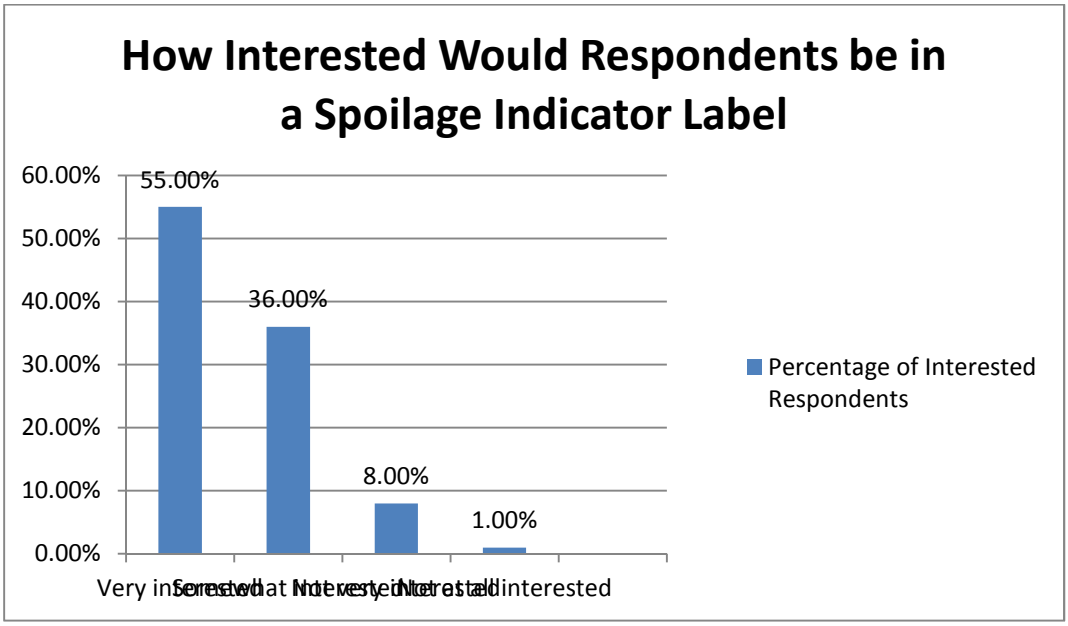

Chart 3: Interest of Respondents in TT labels

The next two questions were included to determine how much consumers would be willing to pay in addition to base product price for a product containing a food spoilage indicator. Because different products are priced differently and consumers place different values on different products, separate questions were asked regarding fruit and vegetable packaging and meat and fish packaging. A majority of 82% of participants answered that they would be willing to pay the lowest price bracket of 0-10 cents for a food spoilage indicator on fruit and vegetable products. 13% were willing to pay 10 to 25 cents, 4% were willing to pay 25-50 cents, 0% was

willing to pay 50-75 cents, and 1% was willing to pay 75 cents – 1 dollar (refer to chart 4). For meat and fish products a majority of 42.42% of participants were willing to pay between 0 and 10 cents for the addition of a food spoilage indicator. 32.32% were willing to pay 10 to 25 cents, 17.17% were willing to pay 25-50 cents, 3.03% were willing to pay 50-75 cents, and 5.05% were willing to pay 75 cents – 1 dollar (refer to chart 4).

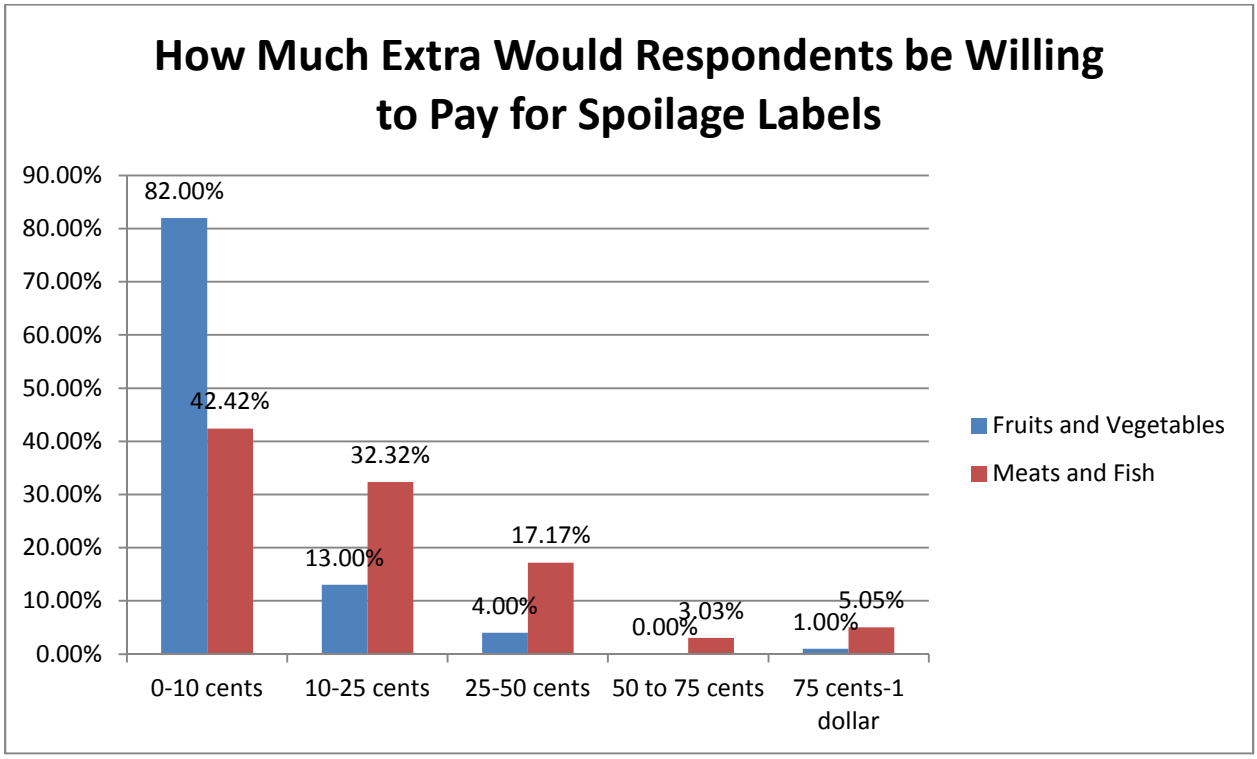

Chart 4: Additional Cost of a Spoilage Indicator

Participants were asked to check any products from a given list that they would be interested in buying with the addition of a spoilage label. This question was intended to determine which products would be most successful if they were to reach market. The most popular selection was refrigerated or temperature sensitive foods, with 77% of respondents

checking this answer. 75% chose meats, 72% chose fish, 30% chose fruits, 28% chose vegetables, and 6% chose none of the above (refer to chart 5).

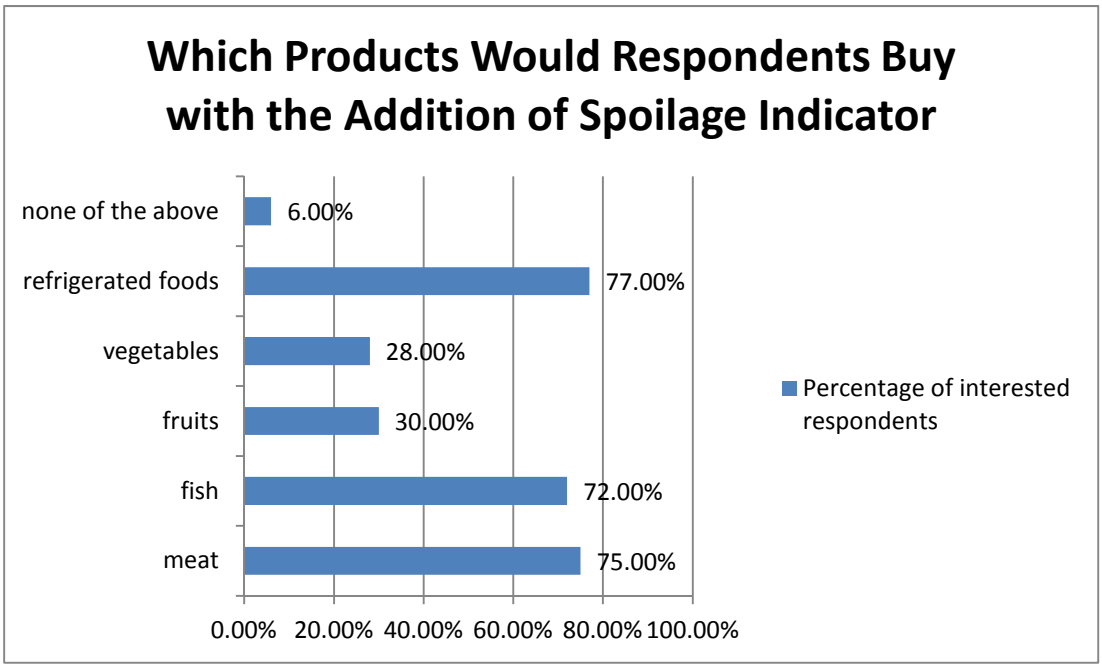

Chart 5: Percentage of Respondents Interested in Different Products

The last two questions focused on specific types of food spoilage labels that offer the consumer other information. First consumers were asked to indicate how interested they would be in a label for fruits and vegetables that indicates the ripeness of the product. These labels are used primarily to help consumers make selections based on their personal preferences rather than safety of the product. A majority of 42.86% of respondents said they would be somewhat interested in a ripeness indicator. 10.2% said they would be very interested, 27.55% said they would be not very interested, and 19.39% said they would be not at all interested (refer to chart 6). The last question addressed safety of the food product with regards to handling. Participants were asked how interested they would be in a label that indicates whether a seal has been broken

to indicate possible tampering or mishandling. A majority of 38% indicated they would be very interested, 35% said they would be somewhat interested, 17% said they would be not very interested, and 10% said they would be not interested at all (refer to chart 7).

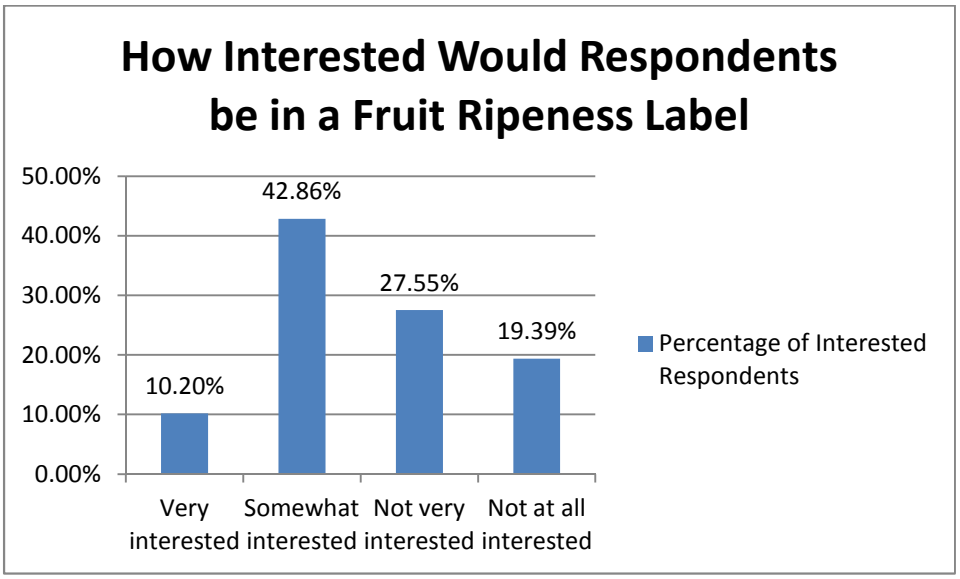

Chart 6: Consumer Interest in Fruit Ripeness Labels

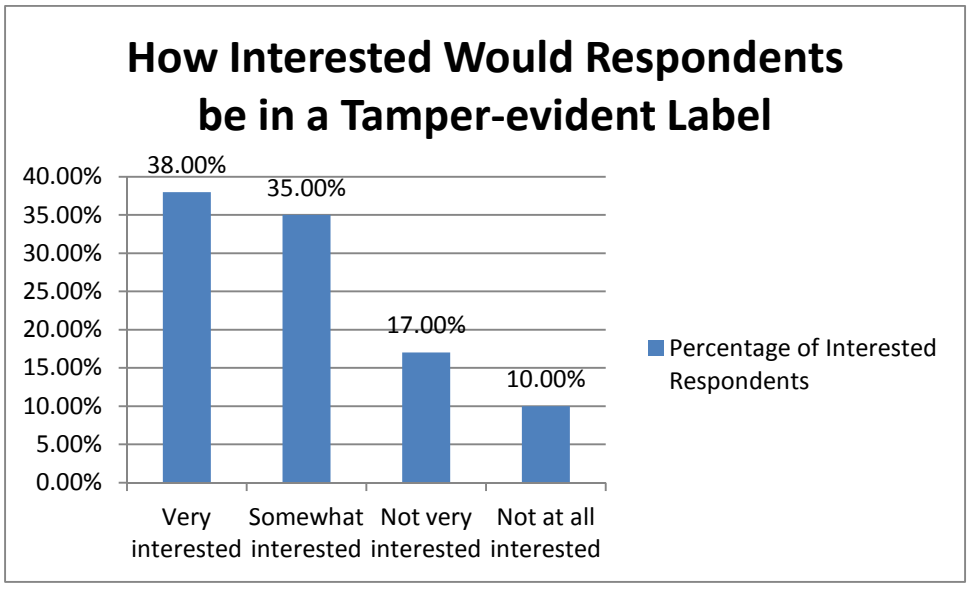

Chart 7: Consumer Interest in Broken Seal Indicators

The way the survey was conducted created an inappropriate skew in the demographics of the respondents. The process was intended to create a random collection of respondents by surveying grocery store patrons over the course of several hours. Because it was the middle of the day, most of the shoppers tended to be older; also a disproportionate majority of women was surveyed that did not reflect the general makeup of grocery store shoppers. Additionally, this process did not yield enough responses and other means were required for gathering additional responses. Patrons at two local coffee shops and at a local optometrist were also surveyed. These factors all created a less than random sample. However, skewed results were considered acceptable for this study because of the limited time and resources allotted for the survey.

Case Study Results

Cal Poly Professors Malcolm Keif and Colleen Twomey were both interviewed and asked to provide potential contacts to share insight into the manufacture of time-temperature labels. Professor Keif did not have knowledge of any producers of these types of products, but was able to provide some information on the production process. Professor Twomey suggested two contacts at sealed-air container. Although both were contacted, no response was received from either.

The intent of the case study was to gather information on costs of producing the time-temperature labels, safety concerns associated with having chemicals in close contact with food products, and interest of suppliers in providing specially packaged food products. Professor Keif was able to share some insight into most of these issues. In his personal experience Keif was given the opportunity to tour the New Zealand plant responsible for producing RipeSense, a consumer preference indicator for determining the ripeness of pears. According to Keif, the plant was a largely traditional print plant of moderate size that had happened upon the technology for

producing the aroma sensitive labels. Keif commented that he was surprised by how relatively ordinary the plant was – he had expected something big and impressive. Additionally the company had not cut its traditional offerings after discovering the new technology; in fact the RipeSense labels were only a small part of what they offered. He had an example of their clamshell package for four pears that he had purchased at Albertsons a few months prior. When asked if he would purchase the product if he did not have special interest in packaging he said probably not.

Professor Keif hypothesized that the cost of the label would be fairly low assuming it comprised a temperature or time sensitive ink that changed color and some sort of substrate. At most the additional packaging cost would be not more than a few cents. He did not think this would be a major barrier to wide release of the product. With regards to safety it was agreed upon that as long as the spoilage indicator is placed on the outside of the package, as is usually the case, it was unlikely to pose a significant threat to the safety of the food product. Keif made the point that in addition to consumer demand and producer profitability, suppliers would have to be equally interested in carrying the product. In accordance with research findings, Keif believed that grocery stores may be hesitant to carrying a product that offered such abundant transparency to consumers. The fact that they case study did not completely reach fruition and that no contacts could be found or contacted demonstrates the lack of companies that have explored a time-temperature food label.

The goal of the case study was to determine the reasons that time-temperature labels have yet to reach the relevant consumer market. Without the ability to talk to companies that are currently using or considering using this technology, it was difficult to do anything beyond

hypothesize the reasons for this disparity. With the limited time given to complete the case study it was hard to develop an ongoing conversation with the contacts provided.

Chapter 5: Conclusion

The ultimate goal of this project was two-fold - to determine the reasons why food spoilage indicators are not yet in wide release for consumer use despite the fact that the technology to develop the packaging is available and to suggest solutions. The two possible contributing factors were lack of consumer interest and manufacturing barriers. The results indicate that consumer interest is likely not the problem. There is not sufficient information to determine why packaging manufacturers are not yet utilizing food spoilage indicator technology.

Consumer responses to the survey were fairly positive with a majority of respondents stating that they would be very interested in food spoilage indicators in general and especially with respect to meats, fish, and refrigerated food products. A majority also said they would be very interested in a label that would indicate tampering with a package. The one label type that did not garner as much consumer interest was the consumer preference label for fruit ripeness, and that category still received a majority response of “somewhat interested.” It is then safe to assume that a lack of consumer interest in food spoilage indicators is not a major barrier to wide proliferation of the product.

Additional package cost of the indicator could potentially be a problem according to survey results. For both meats and fruits consumers were willing to pay only the lowest price bracket for the addition of a food spoilage indicator. A high percentage of respondents answered that they would pay within the second lowest price bracket for meats, which are generally considered a higher risk food if consumed after spoiled. Even so, it was hypothesized that the additional cost of the label would unlikely be much outside of the lowest price bracket, so this is also unlikely to be a barrier for market release.

Because there is not a lack of consumer interest in a food spoilage indicator, and because the cost not a major issue, there must be other factors preventing the wide market release of food spoilage indicators. These factors are likely either related to disinterest in the project by manufacturers or suppliers or an inability to mass produce the indicators. Without significant information from an expert on the topic of time temperature indicators, it is difficult to pinpoint the real reasons why food spoilage indicators are not yet appearing in stores and what the future holds for the project. Likewise without knowing the root of the problem it is difficult to present possible solutions for product production and release.

If a definitive answer is to be reached additional research will be required. Future case studies should be conducted that question packaging manufacturers and experts in the printing industry on the feasibility and desirability of the project. An additional survey should be conducted to gauge supplier interest in carrying food products containing food spoilage indicators. Once more information has been collected solutions can be developed and implemented.

Appendix A

Gauging Consumer Interest in Food Spoilage Indicators Survey

The goal of this project is to study how interested grocery store consumers would be in special labels for food packaging that tells them additional information about what they are buying. The labels contain special technologies that will let you know if your food is ready to eat or spoiled, if your food has been improperly handled at inappropriate temperatures that might have caused it to go bad, and if the seal has at any time been tampered with. Thanks for your help!!

What is your gender?

Male

Female

What is your age range?

18-25

26-45

46 or older

Which grocery store do you frequent most often?

_____

How interested would you be in a label that contains a food spoilage indicator to let you know if your food is expired?

Very interested

Somewhat interested

Not very interested

Not at all interested

How much extra would you be willing to pay for a food spoilage indicator on fruit products?

0-10 cents

10-25 cents

25-50 cents

50 cents-75 cents

75 cents-1 dollar

How much extra would you be willing to pay for a food spoilage indicator on meat and fish products?

0-10 cents

10-25 cents

25-50 cents

50 cents-75 cents

75 cents-1 dollar

Which food products would you be interested in buying with the addition of a spoilage label? (choose all that apply)

Meat

Fish

Fruits

Vegetables

Refrigerated or temperature sensitive foods

None of the above

Would you be interested in a label for fruits that shows how ripe they are based on consumer preference?

Very interested

Somewhat interested

Not very interested

Not at all interested

Would you be interested in a label that indicates whether or not the seal has been broken to show whether or not the food should be eaten?

Very interested

Somewhat interested

Not very interested

Not at all interested

References

Crowley, K., Killard, A., Morrin, A., Smyth, M. (2013). Printing polyaniline for sensor applications. *Chemical Papers*.

Gogoi, P. (2006). The Truth About Food Expiration Dates. *Businessweek Online*, 14.

Herbon, A., Levner, E., & Cheng, T. E. (2014). Perishable inventory management with dynamic pricing using time–temperature indicators linked to automatic detecting devices. *International Journal Of Production Economics*, *147*(Part C), 605-613.

Knowles, M. (2009). Ripesense signs major UK deal. *Eurofruit*. Retrieved February 5, 2014, from http://www.fruitnet.com.

Kuswandi, B., Heng, L., Ahmad, M., Abdullah, A., Wicaksono, Y., & Jayus. (2011). Smart packaging: sensors for monitoring of food quality and safety [electronic resource]. *Sensing And Instrumentation For Food Quality And Safety*, *5*(3-4), 137-146.

Kuswandi, B., Heng, L., Ahmad, M., Abdullah, A., Jayus, & Restyana, A. (2012). A novel colorimetric food package label for fish spoilage based on polyaniline film [electronic resource]. *Food Control*, *25*(1), 184-189.

Lewis, C. (2002). Food freshness and 'smart' packaging. *FDA Consumer*, *36*(5), 25-29.

Perkowski, F. (2010). Smart Packaging. *Paperboard Packaging*, *95*(2), 8-11.

Rangarajan, S. S. (2013). Smart packaging expected to grow to $1.45 billion from 7.5 million in 10 years. *Popular Plastics & Packaging*, *58*(11), 14.

U.S. Department of Agriculture, Food Safety Inspection Service. (2013). *Food product dating*