Temperature Sensitive Food Stickers

Avani Thillainathan, Christopher Jimenez, Ismael Gomez, Jamaal Thompson, Keval Singh,

Morgan Yeung, Sophia Auyung

ENGL 21007: Writing for Engineers

Professor Crystal Rodwell

May 8, 2023

A significant amount of food is wasted globally every year, contributing to environmental issues such as greenhouse gas emissions, the unnecessary consumption of water and energy, and the inefficient use of agricultural land. A solution to lessen the amount of food being wasted is smart packaging, extending the shelf life of perishable dairy products and providing consumers with accurate information about food freshness. Our innovative smart packaging solution for dairy products is the use of temperature-sensitive food stickers. These stickers incorporate temperature-responsive materials that change color when the product has been exposed to temperatures outside its optimal storage range. By alerting consumers and retailers when a dairy product has been exposed to unfavorable temperatures, these stickers can help prevent the consumption of spoiled or unsafe products and minimize food waste.

Table of Contents

Introduction

Food waste is a complex issue that affects not only the environment but also the economy and society. In addition to contributing to environmental problems such as greenhouse gas emissions and inefficient use of natural resources, it also has significant economic implications. The economic cost of food waste is enormous, in the United States, 40% of the food it produced is wasted equating to an estimated $218 billion. Moreover, food waste exacerbates food insecurity, which is a major concern in many parts of the world, particularly in developing countries. When food is wasted, it means that fewer resources are available to produce food for those who need it. This is particularly problematic given the projected population growth over the coming decades, which will increase demand for food and put additional pressure on already strained food production and management systems. Addressing the problem of food waste is therefore critical for achieving sustainability and promoting social equity. This requires a multi-faceted approach that involves improving food storage and handling practices, reducing overproduction, and investing in infrastructure for food distribution. It also requires raising awareness among consumers about the importance of reducing food waste and encouraging changes in behavior.

Our temperature-sensitive food stickers offer an innovative solution to the problem of food waste by improving the safety and freshness of products while reducing waste. These stickers provide a visual indication of the temperature history of a product, allowing consumers and retailers to monitor the product's safety and quality. By incorporating these stickers into food packaging, manufacturers and retailers can ensure that products are stored and transported at optimal temperatures, reducing the risk of spoilage and waste. In addition to enhancing food safety and quality, temperature-sensitive stickers can also provide significant economic benefits.

By reducing the amount of food wasted due to temperature fluctuations, manufacturers and retailers can save on production costs and increase their profitability. They can also avoid the considerable costs associated with disposing of spoiled products. Temperature-sensitive stickers also have the potential to improve consumer trust in food products, particularly in the case of perishable items such as dairy products, meat, and seafood. These stickers provide consumers with a reliable indicator of product freshness, which can help to build brand loyalty and increase customer satisfaction. Overall, the adoption of temperature-sensitive stickers for food products has the potential to create a more sustainable and efficient food system. By reducing waste, enhancing food safety, and improving consumer trust, these stickers can contribute to a more sustainable and equitable food system.

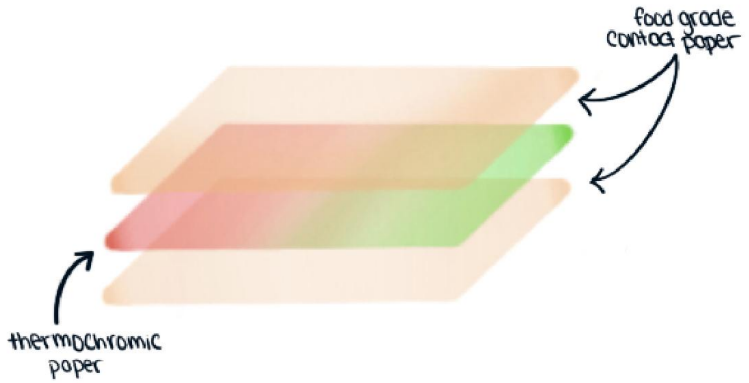
Temperature sensitive stickers can benefit both manufacturers, retailers, and consumers. As for consumers, it allows them to be aware of the quality of the dairy products they are going to purchase using a visual indication, and helps reduce food waste by limiting the amount of dairy products groceries leave unattended. Temperature sensitive stickers can help consumers make more informed decisions when purchasing by providing clear information about the freshness of the products they're considering. They improve food safety. By allowing consumers to identify potentially spoiled food, temperature-sensitive stickers can help prevent foodborne illnesses. Additionally, it can lead to reduced waste at home. By selecting fresher products, consumers can reduce the amount of food wasted at home, saving money and resources. As for manufacturers, these stickers can enhance food safety. For retailers, it can improve inventory management. Retailers can use temperature-sensitive stickers to quickly identify items nearing their expiration date, allowing them to prioritize selling those products or take appropriate action to prevent spoilage. It can also enhance customer trust. By providing a visual indicator of

freshness, retailers can boost consumer confidence in the quality of their perishable products. These stickers can also reduce the amount of food waste from the retail sector. By better managing perishable inventory and providing information to customers about food freshness, retailers can ultimately reduce the amount of food waste in their stores.

Temperature sensitive stickers not only help manufacturers, retailers, and consumers, but also the environment by limiting food waste. Reducing food waste has significant environmental benefits, as it conserves resources like water, energy, and land that would otherwise be used to produce, transport, and dispose of wasted food. And by preventing the production of greenhouse gasses associated with food waste decomposition, temperature-sensitive stickers can contribute to the fight against climate change.

Proposed Program

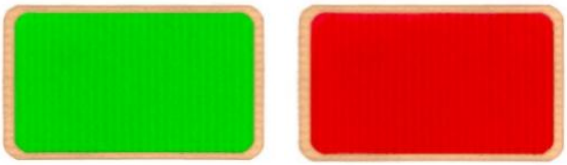
Our temperature sensitive food stickers will be two inches by one inch, and is made up of three parts. Going from bottom to top, our stickers will have the sticker base, the temperature sensitive layer, and the sticker cover, as shown in the figure below.



The sticker base is what sticks onto dairy products. The base is made of food grade contact paper, is clear, and is 2 inches by 1 inch.

The temperature sensitive layer detects whether the dairy product has been exposed to temperatures outside its optimal storage range. This layer is made of thermochromic paper, and is 0.75 inches by 1.75 inches. The thermochromic paper will be able to display only two colors. The initial color, green, indicates that the dairy product has not been exposed to unfavorable temperatures, and is therefore safe to consume. The exposure color, red, indicates that the dairy product has been exposed to unfavorable temperatures and is no longer safe to consume. The figure below presents this information in a table and shows what the sticker would look like under both conditions.

	Display Color	**Status**
Initial Color		Safe to Consume
Exposure Color		Not Safe to Consume



The sticker cover is what holds all the parts together. The cover, just like the base, is made of food grade contact paper, is clear, and is 2 inches by 1 inch.

The figure below displays what our stickers would look like when assembled. Note that the thermochromic paper is white in the figure only for visual purposes.

Innovation Process

The first step for the manufacturing process for thermochromic paper is the material selection. The paper base must be able to withstand the temperature range for which the paper is designed. Typically, high-quality paper grades such as bond, offset, or coated papers are used. The thermochromic coating must be chosen based on its sensitivity to temperature changes, compatibility with the paper base material, and desired color change properties. Next is the preparation. The paper base is prepared by coating it with a layer of thermochromic ink. The thermochromic ink is typically made up of microcapsules containing temperature-sensitive dyes, which rupture when exposed to the desired temperature. The ink can be applied to the paper base using various printing techniques such as flexography, gravure printing, or lithography. After that is the coating application. The thermochromic coating is applied to the paper using a printing process. The ink is typically applied in a pattern or design to create the desired effect. The ink can be applied as a continuous coating, a series of dots or stripes, or in other configurations depending on the application. Then the drying and finishing. The paper is allowed to dry; time will depend on the ink formulation and printing technique used. Once the paper is dry, it may be finished with additional coatings or laminates to improve durability, water resistance, or other properties. Finally comes the testing and verification. The paper is tested to ensure that it responds appropriately to the desired temperature range and that it is durable enough to withstand handling and storage. Additionally, the paper must be tested for regulatory compliance, such as compliance with FDA regulations for food packaging.

Thermochromic stickers have a similar process of creation. In terms of material, synthetic materials such as polyester or polypropylene are used for the sticker. The sticker base is then prepared by printing any required text or graphics onto it using conventional printing techniques,

such as flexography or lithography. The sticker is then coated with a layer of thermochromic ink. This layer can be applied using screen printing, gravure printing, or other printing methods. The sticker must be tested for regulatory compliance, such as compliance with FDA regulations for food packaging.

The process of creating thermochromic stickers can differ depending on whether the pigment is irreversible or reversible. Irreversible thermochromic pigments change color permanently, while reversible thermochromic pigments can change back and forth between colors multiple times as the temperature changes. The process for irreversible and reversible pigments differs in terms of the testing process. For irreversible thermochromic stickers, the stickers are tested to ensure that they respond appropriately to the desired temperature range and that the color change is permanent. The reversible thermochromic stickers are tested to ensure that they respond appropriately to the desired temperature range and that the color change is reversible. Both types of stickers must be tested for regulatory compliance, such as compliance with FDA regulations for food packaging.

The use of thermochromic ink in temperature-sensitive stickers is a key feature that enables the stickers to provide a reliable and accurate indication of temperature exposure. The thermochromic ink used in these stickers contains microencapsulated pigments that are designed to react to temperature changes in a precise and consistent manner. When the temperature threshold is exceeded, the microencapsulated pigments undergo a reversible or irreversible phase change, resulting in a change in color or appearance of the ink. The use of thermochromic ink in temperature-sensitive stickers is a highly effective and reliable solution for monitoring temperature exposure in food products. One of the advantages of using microencapsulated pigments in thermochromic ink is that they are highly stable and resistant to degradation over

time. This means that the stickers can maintain their accuracy and reliability over extended periods of time, even under challenging storage conditions. Additionally, the use of microencapsulation technology allows for precise control over the properties of the pigments, such as their melting point and color change characteristics, enabling custom formulations to be developed for specific temperature ranges and applications.

The use of irreversible or permanent thermochromic ink in temperature-sensitive stickers is an important aspect of their design, as it provides a clear and unambiguous indication of whether a product has been exposed to unfavorable temperatures. Once the ink is exposed to temperatures outside the optimal range, it undergoes a chemical reaction that causes a permanent color change, which cannot be reversed by subsequent changes in temperature. This can help to prevent cases of foodborne illness and reduce the risk of liability for manufacturers and retailers. The stickers' two color display provides a clear and unambiguous message that can be easily understood by consumers and retailers alike. This simplicity also makes it easier for manufacturers to implement the stickers across their entire product range, as they do not need to develop custom formulations for different temperature ranges.

The figure below displays a table of the costs to make our temperature sensitive food stickers.

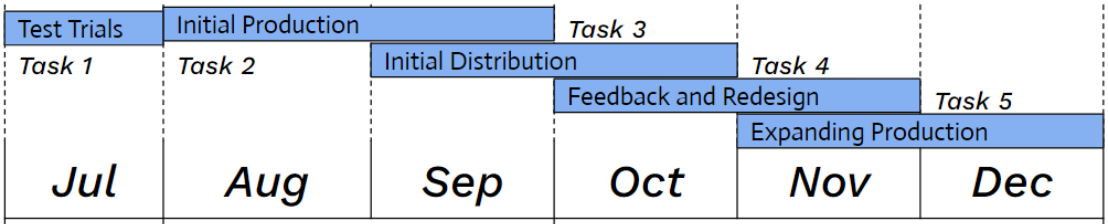
Cost of Materials	
Materials	**Cost**
Food Grade Contact Paper	$100 per roll
Thermochromic Paper	$200 per roll

Cost of Materials for One Sticker	
Materials	**Cost**
Food Grade Contact Paper	$0.002
Thermochromic Paper	$0.004

Other Expenses		
Expense	**Purpose**	**Cost ($)**
Warehouse	Rent	$5,000/month
Equipment	Printing	$500/month

Appendices

Our initial process to produce temperature sensitive food stickers will span about half a year, taking place from July to December of 2023. Our first task, taking place in the month of July, is the test trial of the food stickers. This process is to ensure that our stickers function as intended and abide by FDA regulations. The second task is the initial production of the stickers. This will span from the beginning of August to the end of September. After the production comes the initial distribution of our stickers, in which our stickers are shipped to some manufacturers and retailers. The distribution period will take place from the beginning of September to the end of October. After some time, we will receive feedback from the manufacturers and retailers that we shipped our stickers to, and redesign the stickers based on their feedback. This process will take place from the start of October to the end of November. Our final task, spanning from the beginning of November to the end of the year, is to expand our production, distributing our stickers to more manufacturers and retailers.



Tasks	Description	Time Period (2023)
Task 1	Test Trials of the Food Stickers - Standard Design is developed	July 1st-July 31st
Task 2	Initial Production	August 1st-September 30th
Task 3	Initial Distribution - Stickers are sent to some retailers and manufacturers	September 30th-October 31st
Task 4	Feedback and Redesign - Receive feedback and redesign	October 1st-November 30th
Task 5	Expanding Production - Distribute to all retail and manu.	November 1st-December 31st

Sources

Kalinke, I., & Kulozik, U. (2022). *Irreversible thermochromic ink in the identification of over- and under-processed product segments in microwave-assisted freeze drying. ScienceDirect*. https://doi.org/10.1016/j.jfoodeng.2023.111470

Kooroshnia, M. (2013). *Leuco dye-based thermochromic inks: recipes as a guide for designing textile surfaces*. ResearchGate. https://www.diva-portal.org/smash/get/diva2:887704/FULLTEXT01.pdf

MarketsandMarkets,. (2019). *Thermochromic Materials Market by Material (Leuco Dyes, Liquid Crystals, Pigments), End-use industry (Packaging, Printing & Costing, Medical, Textile), Region (Europe, North America, APAC, South America, Middle East & Africa) - Global Forecast to 2024*. MarketsandMarkets. https://www.marketsandmarkets.com/Market-Reports/thermochromic-material-market-2699772.html

Rožić, M., Šegota, N., Vukoje, M., Kulčar, R., & Šegota, S. (2020) *Description of Thermochromic Offset Prints Morphologies Depending on Printing Substrate*. https://doi.org/10.3390/app10228095

Vukoje, M., Miljanić, S., Hrenović J., & Rožić M. (2018). *Thermochromic ink–paper interactions and their role in biodegradation of UV curable prints*. SpringerLink. https://link.springer.com/article/10.1007/s10570-018-1970-5