

A Technological Methodology of Responsive Cellophane Films for Real Time Spoilage Detection

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Purpose:

A Technological Methodology of Responsive Cellophane Films for Real Time Spoilage Detection. Cellophane films have been used globally to protect and cover foods to ensure slower bacteria spread and spoilage rate. Responsive Cellophane films allow the ability to detect spoilage rates through colors qualitatively rather than quantitatively. Throughout this project I had looked at the degradation timing, quality, durability, and overall stability of the innovative spoilage detecting cellophane. Using this experimental as well as innovative project, it can be used in the real-world in markets, households, transportation, and shelf life.

Variables:

Independent/Manipulated variables

The variable purposely changed by the scientist.

- Temperatures (Room temperature and fridge temperature 40 degrees fahrenheit)
- Type of food
- Time of day when observations are taken

Dependent/Responding variables

The outcome or what is being measured in the scientific test.

- Change of ammonia strip
- Change of pH strip
- Physical change of food (Smell, Texture, Temperature, etc)
- Cellophane color change
- Physical observation of cellophane (Texture, Smell, Look, Tears/Rips)

Controlled variables

The variables that are kept the same throughout the whole entire experiment

- Amount of milk poured
- Size of turkey slice
- Size of cucumber slice
- Trays used to spread cellophane
- Scissors
- Masks
- Gloves
- Paper towels
- Containers
- Ammonia strip type
- pH strip type
- Blender
- Strainer

- Red Plastic cups
- Sharpies
- Light source
- Amount of glycerin for each cellophane trial
- Amount of cornstarch for each cellophane trial
- Amount of gelatin for each cellophane trial
- Amount of water for each cellophane trial
- Temperature of heat from stove to melt cellophane materials
- Thickness of cellophane
- Ziploc Bags

Hypotheses:

Color Change of Cellophane Over Time When Placed on Food?

If the indicator films made of biopolymer material and infused with natural indicators, are exposed directly to the food in the container, then over time, the more acidic the solution, the more color will shift from purple to pink and then red because an increase in acid production lowers the average pH and alters the original molecular structure of indicator molecules in the film. It turns specifically from a range of purple to pink because the way of the light reflection and absorption shift based on the change in the molecular structure. Because pH indicators are weak acids or bases in their different forms, they gain protons in acidic solutions to become the acidic form and lose protons in basic solution in order to become a basic form.

If the indicator films are exposed directly onto the food in the container, then over time, the more alkaline the solution is, the more the color will shift from blue to yellow because of the alteration in the structure and the hypothesized prediction of the color change.

Although the color change is unpredictable until the project is held, the aforementioned is the hypothesized color change from previous research and experiments held by different universities over time.

Color Change of Cellophane Over Time when on the Inside of the Lid?

If the indicator is placed on the inside of the lid the results may appear more slowly because it is further from the food and may not detect the ammonia as quickly, therefore it may not meet the purpose of detection before spoilage.

Although the indicator results may appear more slowly, it is expected that less fade and degradation will be found because less moisture will be in direct contact with the food items.

The aforementioned color changes are expected to be the same, however, much slower, with less color fade and degradation that food placed directly on food.

Time it takes for Cellophane degradation

If the cellophane is left out of the fridge, then it will take 7-10 days to degrade. If the cellophane is placed in the fridge, then the cellophane should stay in detectable condition for about a month. When the cellophane is left out of the fridge, degradation will be promoted because of light and heat. These may contort the cellophane itself or change results by weakening it or allowing stickiness, allowing fade to overall results.

If the cellophane is left in the fridge, then it may last longer because the cellophane is in an enclosed area away from lots of bacteria, light, and warm temperatures. The fridge provides a cool and dark area that ensures the avoidance of major bacterias and shape of the cellophane as well as strengthening characteristics.

Trial 1 vs. Trial 2

If the trial 1 cellophane is placed inside a container, then it will be slower in detection than trial 2 because of the minimal amount of indicator placed in the mixture. If the trial 2 cellophane is placed in a container, then the result will be stronger and faster because the dose of natural indicator is much more concentrated. Another change that will be made is more glycerin, to ensure flexibility and durability. If both trial 1 cellophane and trial 2 were compared, then trial 2 would be better and more successful because of the larger concentration of natural indicator and glycerin.

In Fridge vs. Out Fridge

If the indicator is placed in the food inside the fridge, then the indicator will react better, and degrade much slower because it avoids light and is stored in a cool place, staying away from foodborne bacterias from humid and warm temperatures.

If the indicator is placed in the food outside the fridge, then the film will degrade faster because it comes in contact with more bacterias and is exposed to much more light as well as humid temperatures.

It is believed that the infringe stored indicator will survive longer and maintain faster results and obtain detection faster than those who are outside.

Research:

What is pH?

pH refers to the power of hydrogen and plays a significant role in identifying the chemistry of spoiled foods over time. The pH scale can be identified as a scale in which 14 points are found, ranging from 0-14 measuring the acidity or base of a substance. Constantly, a pH lower than the value of 7 occurs in an acidic based substance and a pH higher than 7 occurs within a base, hereafter referred to as an alkaline substance. The letter “p” within “pH” is used to indicate the definition “power” and the letter “H” refers to “hydrogen ions”. Data suggests that the scale of pH is derived from a logarithmic form. According to Chemistry Libretexts it states that, “Logarithmic means that each whole number change on the scale represents a tenfold change in the concentration of Hydrogen ions (*The pH Scale*, 2023).” For instance a pH of 6 would be 10 times more acidic than a solution of pH 7. Each unit within the pH scale represents 10 times the acidity (tenfold). There are more hydrogen ions present within an acidic solution, however, the more hydroxyl ions are present within an alkaline solution.

What is Ammonia?

Ammonia can be identified as a colorless gas made of a conglomerate of nitrogen as well as hydrogen. In defined terms, one nitrogen atom and three hydrogen atoms. Ammonia (NH_3) produces a sharp, unpleasant smell, which often negatively affects the human lungs. At room temperature, ammonia is not visible to the human eye because of its colorless characteristics. Nevertheless, once the gas is contained and compressed, it can be formed into a somewhat visible clear liquid. Like ammonia, hydrogen sulfide maintains the elements of colorless observation, pungent smell, and flammability. Once ammonia is detectable within an area of food, it is unsafe and dangerous to the human body. The higher the ammonia quantity, the more lethal to the human body. Ammonia can be observed with two different analytical methods. Firstly, qualitatively, which is the test done to identify whether ammonia is present within the observable solution. Oftentimes this test may simply be done using litmus paper, and sodium hydroxide solution. The following steps provide a clear procedure on how to safely gather data on the presence of ammonia. Firstly, a few drops of the sodium hydroxide solution is poured into the testing tube or container. Next, the tube must be gently warmed using a blue flame off of a gas stove. The tube must be held on top of the flame for 5-10 seconds before results may show. A piece of somewhat damp red litmus paper must be held on top of the tube, not touching the tube itself. If the red litmus paper visibly turns blue, then ammonia gas is present within the solution, confirming the overall presence of ammonia ions in the contained area. An alternative method to this detection can be done using hydrogen chloride and observing whether a white smoke is produced from the area, however, this method is often used in labs, while safety precautions are taken. The subsequent analytical method, quantitative, can be measured using various different techniques. The simplest and precise way is to use an approved gas detector. A gas detector incorporates electrochemical sensors to measure ammonia concentration in the air. A gas detector may be reliable within the setting of gas leaks, in contrast, not within a contained area. Besides the area, a gas detector often ranges from \$400-\$1000, expensive for a test innovative experiment. More practically, ammonia probes, used in labs and experiments, measure the quantity of ammonia through different types and methods. Electrochemical sensors convert the gas (ammonia) into an electrical current which reads the gas concentration in a contaminated area. Unlike electrochemical sensors, semiconductor sensors use metal oxide, a metal that reacts to oxygen, which changes the electrical conduction allowing for the probes to measure ammonia when contact is found. Metal oxides are composed of a minimum of one metal atom and one oxygen atom (magnesium oxide, aluminum oxide, etc). As a final method, USED, often termed Ion-Selective Electrodes, measures specific ions in a solution. Although unlikely to be used throughout the procedure of this project, a slight overview and method has been researched. This type of probe holds the application within clinical studies and scientific experiments. The device is built to quickly measure ions like potassium, chloride, and calcium in blood. The three methods elaborated above are how ammonia can be detected using modern day devices and experiments. Since it is often used throughout a lab environment, considerations must be taken while dealing with ammonia probes. The probes change measurement depending on temperature, interfering gasses, and even high maintenance. Temperatures which hold high humidity, may change the results. Modern probes may have this issue solved by incorporating a solution into its procedure. Some probes may include a filter which filters out unnecessary gasses. This method effectively measures the gasses desired. This process is often done using the method of selective membranes, which act as a barrier towards the gasses. As a final point, further steps of maintenance must be taken to provide precise quantitative results. It is required for probe maintenance such as, changing the electrolyte of a solution or the membrane to be taken to ensure the highest rank of measurement of the ammonia gas.

Which Foods Produce Detectable Spoilage Gasses Fastest?

Foods that obtain lots of moisture and are porous often spoil much faster. Foods that are much wetter or exposed to food collect bacteria and attract bacterial organisms. It is necessary to find fast spoiling foods to observe, test, and create an analysis much faster. Faster spoiled foods create speed in order to reach a conclusion much faster. Primarily, cucumbers, which have a high moisture content and porous skin and nature. Secondly, deli meats, which are exposed to a large variety of bacteria molecules and air when handling. This allows moisture and bacteria to find its way through meat especially when sliced or cut. Dairy wise, raw milk contains naturally occurring bacteria and the warmer the milk is the faster the spoilage. The natural product of fermentation in milk is lactic acid which is a chemical compound and organic acid. In conclusion, milk, cucumbers, and deli meat are all safe options for speedy spoilage and positive color change results.

Bacterial Action and Unhealthy Gasses Due to Food Spoilage?

An integral part of the procedure every food cycles through in order to reach the level of spoilage, takes part with bacterial action and the spread of unhealthy gasses. Although no specific level of gas identifies whether food is spoiled or not, the general presence of hydrogen sulfide and ammonia are automatically key indicators of spoilage to the contaminated food. The overall presence of these components often mean the process of unsafe bacterial action and conditions have been present to the food. A high concentration of one or more gasses can identify bacterial spread, however, not quite that pathogens are present. As stated by Science Direct, "Pathogenic bacteria can be defined as bacteria that cause infections and diseases. (*Pathogenic Bacteria - an Overview | ScienceDirect Topics*, n.d.)" The attendance of these gasses concluded that bacteria had been breaking down in the food. Spoilage and pathogenicity are both different aspects of the bacterial process in which both are related, however not the same. Spoilage bacteria forces food to become unappealing to the eye and mouth, yet not making one sick. Pathogenicity makes food unappealing at most times as well as unhealthy and sickening to the human body. Breakdown or spoilage of food often leave sensory observations which include the appearance, smell, taste, and texture. After bacteria has contaminated the food, it may appear as slimy, squishy and a variety of different colors and mold depending on the moisture value of the product. Spoiled foods often emit a pungent, unpleasant, fish-like odor. Food that goes through the cycle of spoilage, frequently tastes sour and mushy to the touch of the mouth. The texture of degraded foods may soften to feel and even dissolve when spoiled and not composed for a long period of time. The bacterial spoilage procedure has three broad steps in order to reach complete breakdown. Initially, the bacteria releases enzymes which break down complex compounds like proteins and carbohydrates. Enzymes are essential chemical reactions to living organisms. Enzymatic breakdown is the process where bacteria discharge and breakdown often leads to the release of enzymes which disintegrate larger sized foods. Proteases are a class of enzymes that tear down proteins into small peptides and amino acids. In foods, acids are produced, resulting in a sour taste of the spoiled food (*Yi & Xie, 2021*). When these foods reach the spoilage rate, gasses are produced, which often cause expansion in packed goods or canned items. As a result of the initial breakdown, the bacteria generates acids and gasses as waste from this process. The collection of these wastes emerge into chemical and physical changes towards food, which often leave spoilage signs including discoloration, sliminess, and bad odor.

When food reaches the spoilage stage, it often releases gasses that can affect the human lungs and the food's known tastes. There are three head gasses which are released once food starts to spoil. Primarily, ammonia, which is released during decay of proteins and provokes bad smell. Secondly, hydrogen sulfide, which creates a bad smell and is an obvious indication of protein breakdown. Ultimately, carbon dioxide, which is fabricated during the process of fermentation and mainly happens to food products that contain yeast.

What Level of pH Eventually Becomes Unhealthy Due to Food Spoilage?

Every food product has their own scale boundaries based on health, safety, and physical observation of the food category. There is no defined point or aspect where pH of food specifically becomes unhealthy. However, for each category there is a defined range of points where, if surpassed or dropped, it tends to attract more microbial activity and bacterial action. The first category that will be tested within this project is dairy, more specifically fresh, raw milk. Milk usually ranges between the pH value 6.7-6.9 pH. When it degrades near pH 5, it often reaches the point of curdling, often a sign of spoilage. Harmful yeasts and unhealthy bacterias start to grow onto the base of the milk when it reaches 5 or lower, or 7 or higher. Most often, the pH drops in value as the spoilage process begins, however, a higher pH indicates varying issues including, the blood let out from the cow who produced such milk. Physical observations such as, bitter tastes, and sour like smells indicate spoilage through a much more obvious observation.

Produce is a more challenging category to work with, as there is a large fluctuation in water supplement, dryness, and chemical bonds of the produce. Within this project atmosphere, cucumbers will be the main target throughout testing. The healthiest range of cucumbers may reach from 5.5 - 7.2 pH. The main spoilage levels of cucumbers can average between 6.8-7.2 pH. A spoilage point higher than 6.5 may begin to produce unhealthy acids and multiply bacteria wise.

Lastly, over roast turkey, deli meats. Deli meats like turkey are often a cheaper option in this category, however, are one of the many household commons globally. The spoilage point often ranges between 6-6.4 pH. Once this point is increased, it attracts microbial growth, leading to unhealthiness and an increase in spoilage rate. The higher the pH, the more prone the meat is to spoilage and infection of unhealthy bacterias.

How Long does the Indicator Remain Stable when Embedded in Biopolymer Film?

Oftentimes when indicators are embedded into biopolymer films, the temperature it is exposed to implies the stability of the cellophane and the positive time span. As already known, the timespan is not permanent and maintains a temporary functional system. Many indicator films last about 3-4 weeks depending on the circumstances it is under. When placed in a stable cold and dark environment, it lasts longer and maintains a functional color change. During this time, the indicator should remain embedded into the biopolymer films and respond stability to the changes without extreme fade. The higher the temperature, the faster the degradation process of the cellophane. Another element that produces significance within these tests is moisture level. The more moisture content the less responsive the film may be. Ultimately, the lower the temperatures and darker the lighting is necessary for long lasting use. While higher temperatures lead to speedy degradation.

What are Natural PH indicators?

A large span of this project is in relation to natural pH indicators. Natural pH indicators are derived from plants and sometimes microscopic organisms. These indicators change colors in response to the acidity and alkalinity of a solution of the product. This change often happens because of the chemical structure change, which alters how they absorb light. These indicators include anthocyanins, betalains, or curcuminoids. Examples of natural

pH indicators include; red cabbage, beet juice, turmeric, and cherry juice. When pH changes the structure of the pigment reshapes and a visible color can be observed. Red cabbage extract is considered one of the best natural indicators because it contains anthocyanins molecules which create a water soluble color changing pigment. The molecular structure of anthocyanins includes: flavylium cation core, which is the basic structure flavylium ion and positively charged chromophore, C6-C3-C6 skeleton which is two phenyl rings connected by a three-carbon bridge, anthocyanidin, the core structure without sugar, glycosylation, which are sugar molecules attach through glycosidic bonds. Although beet root juice may last longer, it does not provide the strongest pigments. Beet root juice and red cabbage juice are both fairly strong pigments.

Beet root juice includes the following advantages and disadvantages:

1. Betalains pigments
2. Limited pH scale, and must be in very strong conditions
3. Hard to test when conditions are slight
4. Non toxic and easy handling
5. Narrow pH scale
6. Betalains degrade easily
7. Less suitable for testing as degradation when happening rapidly

Red cabbage juice includes following advantages and disadvantages:

1. Wider range of pigments specifying whether acidic or basic
2. Transition of colors much more obvious, easier for experiment testing
3. Easier to prepare, through boiling process
4. Less precise than experimental lab tester
5. Stability is based on temperatures and storage conditions.

In conclusion, there are many disadvantages and advantages in natural indicators. However, red cabbage extract is the strongest, most reliable, and safest option.

Which Biopolymers Create the Strongest Film?

The base of this cellophane will be fabricated using a collaboration of biopolymers. In order to assemble the strongest, most durable cellophane, it is necessary to know the proper biopolymer plastics that will ensure strength. Primarily, starches from foods like potatoes or corn (cornstarch) create a very sturdy base for the film itself. Starch films are biodegradable, inexpensive, and transparent when boiled with a mixture, however, if incorporated alone, it may result brittle. Plasticizers like glycerin may help the elasticity. Consequently, starch is great for the environment but alone, will brittle and become much weaker than chitosan and cellulose. Secondly, protein based films, which are made of gelatin and other blends. Gelatins have strong film properties and create flexibility. The strength can be improved significantly if other elements like plasticizers, linking agents, or other polymers. While gelatin does promote moderate strength, by itself, however it does not provide a good bond alone. If concocted with other polymers it can be considered a strong option. Cellulose based films are extremely stronger, however, much more complicated to fabricate in a house setting. Cellulose is initially found in plant cell walls. Chitosan has a strong chemical forming ability and a very high mechanical strength. It often helps to avoid major speed up spoilage and adds overall durability. Glycerin, as mentioned before, occurs to add flexibility and less brittle damage over time to the cellophane. When biopolymers are added to antioxidants or essential oils, it allows for a strong, sturdy, lasting film.

There are three main purposes of these elements:

1. Barrier Enhancing properties
 - a. Biopolymer nanocomposites create stronger oxygen barriers

- b. These nanocomposites prevent degradation of indicators in the film
 2. Antioxidant properties
 - a. Essential oils, protect the spoilage rate and are richer to the film color wise
 3. Improved barriers and mechanical properties
 - a. Natural extracts help improve the mechanical properties and protect the indicator inside.

Ultimately, cellulose, starches, glycerin, gelatin, and natural oils, all allow for strengthened films, however, must be concocted with various elements, rather than alone to ensure the highest of results. The results of this research is a large step towards creating the packaging while keeping it safe for the environment but at the same time detecting the spoilage. Not only saving the lives of humans, but keeping the community clean and all organisms surrounding the affected areas of harmful products and chemicals away from reaching the surface of the environment.

What is the Shelf Life of the Indicator Film Before it Expires?

The shelf life of an indicator often depends on the type of indicator and the storage temperatures. The light exposure is often a key factor in determining the stability and time span of the natural indicator. Short term tests that have been previously done with indicators are quite reliable. Long term tests however, may be more challenging due to the temperatures and exposure to specific rays which degrade the effect and quality of the indicator. The best case of storage would last 2-4 weeks, when stored in a dark, dry, cold environment, and is contained in a sealed container. When stored at room temperature, it lasts about 7-14 days with gradual color fading and slower spoilage gases. Oftentimes anthocyanins degrade due to light exposure, oxygen, heat, and moisture. Consequently, natural indicators are great monitors, however, it must be preserved and taken care of to ensure stability and accurate results.

How Accurate are Natural Indicators?

Many natural indicators are good for qualitative values rather than quantitative values. The indicators very clearly show when a chemical change has happened and accurately indicate the pH value. Although not as stable as synthetic ones they still provide an effective pH value for a solution. The main concern about these natural indicators are the effectiveness when in contact with fluctuating temperature, which can be subjective to observations and judgments. These indicators often have a limit to the different colors the chemical structure may appear as. Therefore, this project will allow one to create their own scale to ensure preciseness.

The following scale gives a brief on the color and pH value during the change in structure of the indicator:

- pH 2-4: Red/Pink
- pH 5-6: Purple
- pH 7: Blue/Violet
- pH 8-9: Green
- pH >10: Yellow

As represented by the scale, these values are not as precise and reliable as tested with verified lab material. Since food spoilage often lets out major chemical changes, indicators are reliable when detecting ammonia and organic acids, oftentimes the color changes before a strong odor is noticeable from the food. In conclusion, although not as precise as lab work, these indicators provide an accurate enough result that is ready for real world applications and detection.

What Happens when Indicators are Exposed to Food Moisture?

Biopolymer films contain an element named hydrophilic groups. These groups naturally are attracted to water. When films made of biopolymers come in close contact with moisture or high humidity, water molecules that are spread are often absorbed into the polymer. As a result of this water absorbent, it may increase water content and disrupt the bonds which affect the anthocyanins that release color and provide the change. If the biopolymer film is obtained in a high water concentration, it may allow the film to slowly dissolve or plasticize, resulting in the blurring of pigment, and less stability within color production. When water starts to pass easily through the film it becomes less productive in detecting gasses as well as pH. Not only affecting overall results, however, may weaken the mechanical integrity of the indicator. Since anthocyanins include a sensitive chemical structure, when in contact with moisture, it may alter the pH response causing a color shift or color fade. Although moisture may slightly damage the film, it can also cause a positive response to the film. When light moisture is passed through the film, it may help the gasses (ammonia) reach the indicator itself much faster. Since the moisture can work as a solvent for the indicator, it may act with the gasses and chemical compounds within a sealed container. Through this process microorganisms produce gasses which create the pH change and trigger the indicator, allowing visibility for the consumer. However, too much moisture may alter the clarity, color, and preciseness of the film. In conclusion, moisture for the film can have both advantages and disadvantages, both building a unique chemical structure and result for the overall indicator.

Causes of Food Spoilage?

According to FoodPrep, and paraphrased by myself, they state that there are 4 main causes of food spoilage: microbial growth, enzymatic activity, chemical reactions, and physical damage. Fundamentally, microbial growth which includes main factors such as:

1. Bacteria, specifically pathogenic bacteria (bacteria which causes disease) causes foodborne illness
2. Molds: fungi grows on many foods especially those with warmer temperature or humidity
3. Yeasts: may ferment sugars leading to spoilage in particularly sugary or acidic foods

Subsequently, enzymatic activity produces two main enzymes. Natural enzymes in produce which cause molding such as browning and loss of nutrition. Proteolytic enzymes which is the breakdown of meats causing observable change. Thirdly, chemical reactions which mainly circle around oxidation, which is the oxygen exposure that induces bad smells and looks from rotting fats and oils, often impacting nuts and seeds. Light induced reactions are also possible, the light affects the food by degrading vitamins mostly within dairy products and nuts. Lastly, physical damage, cutting and bruising of foods allow susceptibility to bacteria and open gases. Various reasons cause physical damage, however, another primary reason includes improper storage, incorrect temperature levels, and humidity that speed up storage (foodprep, 2024).

What is Biodegradable Packaging?

Biodegradable can be defined as any form of packaging that naturally decomposes or disintegrates (Tipa-corp). Oftentimes, most packaging that is labelled and sold as “biodegradable” is still harmful to our current environment. Biodegradable material is typically supposed to naturally break down with nature and bacteria around the environment. Usually that material is plant based, but not the only option available for biodegradable. The material of the packaging depends on the molecular structure and strength of the materials polymer chain. A polymer chain can be defined as a long molecule made of repeating smaller units called monomers. In order for a plastic or material to be considered biodegradable it must be able to break down into small pieces that can later be

eaten by microorganisms. For example, conventional plastic packaging must be made of carbon chains that are very strong, therefore it takes over centuries to actually disintegrate, although it disintegrates eventually, it is not considered biodegradable. Biodegradable packaging is made of a very weak molecular structure, therefore they disintegrate very quickly. Application wise, harmful packaging that consists of polyethylene, polystyrene, petroleum, etc. have raised to 90% increase of the total volume of plastics used industrially. Using traditional plastic material provides various advantages like; flexibility, stability in extreme conditions, and low cost. Although biodegradable packaging is effective to the environment, there are still current disadvantages that include, long time decomposition, and breakdown from the materials used to produce these packagings and bags. In summary, biodegradability can be questioned with various materials depending on its rate of decomposition. This research allows one to observe and find materials along the basis that most are actually biodegradable and break down fast to align with the side goal of this project.

How much Food is Wasted Every Year Due to Food Spoilage?

Unknowingly most of the population is unaware of the immense amount of food spoiled yearly. Around planet Earth one third of all food produced is lost, wasted, or thrown away. This number is an average of 1.3 billion tonnes of food. According to Canada food waste, each household in North America and Europe waste an approximate of 95kg-115kg of food annually. While in South and Southeastern Asia it is a minimal amount to about 6kg-11kg. It is found that statistically only one quarter of the food wasted per year was saved, it could feed about 850 million people. In America an increase of 63 million tons of food is wasted. These numbers include the surplus food, food excess which is edible, yet thrown out(ReFED, 2022). A large portion of this waste is caused by food spoilage and the overall bacterial growth and degradation of food. Much of this expired food is the reason of expiry, bad smell or overall looks of the food. Earlier in the food chain, 14% of the food is already through the loss process because of transportation, harvest, and processing. More often perishable foods, like milk, deli, and produce spoil faster and are harder to store, which allow them to degrade faster than other food items. Not only is food waste major throughout society, however, it largely affects the economy as many losses are made. The idea of wasted foods leads to unnecessary use of water, energy and land and even increased greenhouse gas emissions. Consequently, the reduction of spoilage through smart packaging, fresh indicators, and increased storage properties, could significantly change global food waste.

Health Risks by Food Spoilage?

The spoilage of food has captured over 200 diseases just by the breakdown of proteins and unclean market products. This slight necessity every human being consumes everyday is a main reason for serious lethal infections. These infections are built by foodborne pathogens which may cause a wide spread of negative bacteria, leading to kidney failure, paralysis, meningitis, and various other categories of unsafe spreads of bacteria. A shared symptom for this food poisoning breakdown can be influenced through nausea and vomiting.

The following five diseases are the main types of illnesses caused by the bacterial spread of spoiled foods:

1. Sallomonellosis
2. Camplybacteriosis
3. E-Coli Infections
4. Shigella
5. Listeriosis

Salmonellosis is caused by salmonella bacteria which is due to foodborne bacteria. This bacteria is linked to animal products such as eggs. It often affects the intestinal tract, this includes the small and large intestines where food breaks down and nutrients are absorbed. This bacteria that causes the disease lives in human and animal bacteria and is usually absorbed by feces (*Mayo Clinic, 2022*). The main symptoms for this specific disease may include; diarrhea, stomach cramps, fevers, vomiting, blood in stool, and massive consistent headaches.

A frequent disease also caused by foodborne bacteria is Campylobacteriosis. This is an intestinal illness which is caused by Campylobacter bacteria. The results procured by the illness can include; diarrhea, cramps, high temperatures, and abdominal pains.

The genesis of this infection often happens for three main contaminations:

1. Animal Contact - the direct contact with infected animals or species with such disease is often spread by its feces.
2. Foodborne Illness - raw food products such as, undercooked meats, cross contaminated, unsafe foods, and even adulterated waters or milk are main causes of the food borne category.
3. Contaminated Surfaces- surfaces which come in contact with infected animal feces or general animal waste, are another basis of campylobacter spread.

This infection has been researched that it is much more common during summertimes and 1.5 million people in America have been ill to campylobacteriosis annually. This disease can often lead to signs of dehydration for adults and teens. These signs may include being very thirsty, warm to the touch, and the lack of bowel movement. Remarkably, campylobacteriosis is highly contagious.

E coli Infections, more commonly known globally, are when common strains of gut bacteria overtake the human body.

The various causes of E coli infections may include;

1. Foodborne bacteria - like campylobacteriosis, uncooked meats and contaminated dairies (specifically dairy).
2. Waterborne bacteria - contaminated waters, or unclear and cloudy waters that are not verified by the clarity of water test are often a common cause of E coli contamination.
3. Person to person contact - although not as common, unclear handwashing or even dirt spread from one being to another may cause this familiar infection. Symptoms of E coli may be evident by stomach cramps, vomiting, fever, and the feeling of tiredness or unwellness.

Shigella is another foodborne infection which is caused by the bacteria from the genus shigella. There are four main species or groups of shigella including: Shigella dysenteriae, Shigella flexneri, Shigella boydii, and Shigella sonnei. The bacteria is gram-negative, meaning it contains unique cell wall structure. Non-spore forming, which are microbes that create strong spores to survive harsh conditions. Non-motile rods, bacille formed as rods that cannot produce themselves and cannot move independently within specific environments. Shigella includes a very small number of bacteria, usually ranging as few as 10-200 cells that cause infection.

This illness is transmitted through a contamination called fecal-oral route, defining the contamination using food, water, contaminated surfaces, or any direct human contact (*Department of Public Health, n.d.*). It may also spread through corrupted recreational waters such as pools, lakes, or ponds, if such water is swallowed (*Shigellosis (Shigella Infection), 2025*). Those who are infected, may shed bacteria by stool or may remain captive with shigella for some time even after symptoms stop (*How Shigella Spreads, 2024*).

Symptoms often begin 1-2 days after the exposure. However, some may not show symptoms yet still spread the bacteria. Common signals or symptoms may include diarrhea, which may appear watery or bloody and may contain mucus. Once again, abdominal pains or cramps and the need to pass stool, although bowels are empty. A simple fever may occur due to contamination from shigella. Less common, nausea or vomiting may occur. In many

cases, the illness may last about 5 to 7 days. Others may have rather prolonged symptoms and even after recovery, it may take time (weeks) to return to normal bowel habits.

Less common outcomes, however serious, may include:

- Immense dehydration, especially in youth, may occur because of fluid loss from diarrhea
- Post-Infectious Arthritis - pain in the joints and eye irritation
- Bloodstream infection in very rare cases, may occur to those with a weakened immune system
- Neurological issues (seizures, this often happens especially among those who are very young with high fever or a source of electrolyte disturbances
- Hemolytic-uremic syndrome (HUS) FIND EXPLANATION. Mainly with toxins which produce strains, leading to serious kidney issues.

The diagnosis is often identified through the structure of stool, often molecular tests and PCR, to identify shigella. Most cases found are typically free mild and may resolve on their own usually ranging from 5-7 days with immediate supportive care and medical attention. Supportive care often includes lots of rest, absorption of fluids, and oral rehydration to prevent any dehydration. Antibiotic medications such as anti-diarrheal medications that may slow the guts process, are often not recommended and may even worsen the identified illness.

Prevention and control can be considered when dealing with shigella incidents, however so far no immediate vaccine has been found. The key prevention method is to ensure frequent handwashing with soap especially after bathroom use or preparing food.

Lastly, Listeriosis, an infectious disease caused by bacterium *Listeria monocytogenes*. *L. monocytogenes* is widespread in nature, often living in soil, water, decaying vegetables, and the intestinal tract of many animals. The bacteria alone frequently contaminates a wide variety of foods during the harvesting season, processing, packaging, transport, or storage. Different from many bacterias, *Listeria* can survive at cold temperatures, which is particularly problematic in chilled or pre-made meals. Certain groups of people are significantly at higher risk of a serious infection, those who are: pregnant women, unborn babies, senior ages (65+), and those with weakened immune systems due to illnesses or any other causes. Those who are perfectly healthy may sometimes get a mild form of symptoms or no symptoms at all, however can be exposed to *Listeria*.

There are two primary modalities of listeriosis. Primarily, non-invasive (gastrointestinal) listeriosis, which mainly affects the gut. Specific symptoms of this type may include fever, muscle aches, nausea, vomiting diarrhea, or an upset stomach. This form tends to spread quickly, however, usually resolves on its own in those who are healthy. Secondly, invasive listeriosis, which occurs when bacteria spreads beyond the intestines into the main bloodstream or nervous system. This is the more dangerous type and occurs to those who are in the high-risk groups. Common symptoms of invasive listeriosis can include:

1. Fever, chills, muscle aches, fatigue (flu-like symptoms)
2. Confusion, loss of balance, convulsions, or other signs of neurological symptoms if the infection spreads near the brain or nervous symptoms
3. Pregnant women: symptoms may occur as mild or not even present, however, if present, it can seriously affect the fetus. This may lead to miscarriage, premature delivery, or infection to the newborn
4. Newborns who are affected at birth may have very fluctuated temperature, feeding difficulties, vomiting, and breathing problems

There are various foods specified that are commonly associated with listeriosis.

1. Ready to eat meats similar to hot dogs, meat spreads, and processed meats.
2. Dairy products such as soft cheese, unpasteurized dairy, and other poorly processed dairy products.
3. Smoked seafood products that are refrigerated at average temperatures.
4. Raw produce that has been contaminated by soil or other specimens
5. Pre-made foods and salads, especially if held in the fridge for a long period of time. Listeria can grow even at low temperatures, for this reason, pre-made foods are highly risky for listeria contamination.

Although these symptoms are major, there are various actions that can be taken against listeriosis in order to oppose the effect or the whole idea of catching listeriosis. Avoiding the foods mentioned above, especially when contaminated from soils or other species, pushes away the introduction to the bacteria itself. Relating to food, maintaining hygienic food processing and practicing clean handling including clean surfaces and avoiding any cross-contamination, ensures the odds of contaminating yourself with the bacteria.

Though listeriosis is relatively rare compared to other foodborne illnesses, it is gradually becoming a much more severe recording from high hospitalization and mortality rates. Because of its prosperity in cold storage, it remains very high for ready-to-eat foods, and deli meats.

In conclusion, eating lots of fruits and vegetables may lower one's risk of manipulating and catching heart diseases because these products do not contain microorganisms naturally. Fresh produce may also be contaminated because of the surrounding agricultural elements. It is found that every 1 in 8 people in Canada gets sick every year because of these foodborne diseases(Canada, 2011). Not only do these foodborne illnesses allow the body to catch diseases, however, it also remains a threat to nutritional losses in the human body. The initial spoilage of food degrades the amount of nutrients and presence of nutrients present in the food. This includes vitamins such as C, and B complex-vitamins.

Why Does Vinegar and Baking Soda Trigger Cellophane?

Vinegar and baking soda affect the cellophanes structure because of carbon dioxide gas and moisture. Vinegar is acetic acid, while baking soda is sodium bicarbonate (a base). Because of the reason that baking soda and vinegar react fast, the pH of the cellophane shift colors quite swiftly. Since the cellophane is hydrophilic (water based) it absorbs the solution very fast releasing all the natural dye at once. The CO₂ forces the liquid upon the surface of the cellophane, allowing for a fast result to ensure a result of the cellophane. Conclusively, because of the fast chemical reaction of the carbon dioxide in both vinegar and baking soda, the cellophane results happen rapidly, allowing for a speedy result.

Procedure:

Fabricating the Indicator

In order to fabricate the main ingredient, the natural indicator, the following materials were needed:

1. Boiled Water
2. Red Cabbage
3. Whisk
4. Pot
5. Heat

6. Strainer

Firstly, a red cabbage was washed thoroughly and peeled leaf by leaf. After each leaf was cut from the cabbage, all the stems and harder areas were cut off. Later, the leaves were measured into two cups along with one cup of boiled water, both were poured into a pot and boiled for 15-20 minutes at medium temperatures until a deep, rich shade of blueish purple tint was visible. As a result, the purple liquid was strained with a strained from the pot into separate jars and left in the fridge to cool until needed. This procedure was repeated as many times as needed to make all trials of cellophane (540 pieces).

Preparing Cellophane Film Trial 1 and 2

To prepare the film needed to complete the project, the following materials were needed:

1. Boiled Water
2. Powdered Gelatin
3. Vegetable Glycerin
4. Corn Starch
5. Red Cabbage Indicator

The following items were used to help prepare the film:

1. Pot
2. Whisk
3. 3 Large Stainless Steel Trays
4. Stove- Medium and High Heat
5. mL labelled syringe

Firstly, 400mL of 300° boiled water was added into a pot along with 40g (5-6 tbsp) of gelatin. Both were stirred for 7 minutes until the gelatin had visibly dissolved into the water. Subsequently, 12mL of glycerin was added and stirred continuously for 2 minutes. Thereafter, 4-7g (1 -1 ½ tbsp) of cornstarch was added into a separate glass beaker along with 1 tbsp of cold water. Both items were mixed together until a white liquidy paste was formed. Then the cornstarch liquid was added into the boiled pot mix. The cornstarch was added into cold water first in order to activate the starch, in order to avoid previous chunky boiling. The starch allowed durability and increase in strength for the cellophane. Lastly 40-60 mL of red cabbage indicator was slowly added after the heat was turned off. After all the variables were added, the mix was stirred for 5 for minutes to ensure the avoidance of any air bubbles and unwanted gasses.

In order to ensure maximum pieces of cellophane and quality the mixture was poured evenly into the 3 separate trays covered in parchment paper with a width similar to paper size. The thinness of the spread allowed for speedier gas measurement and response as well as visibility. The film was left to cool at room temperature for 48 hours. While some of the batter remained very thick because of uneven spread, it was placed in the fridge, and then removed. After all the batter had dried, it fabricated a thin and thick cellophane. Later, it was gently peeled off and cut into similar sized square shape pieces to fit the container testing size. This process was repeated 5 times until 270 about equal sized pieces of cellophane were fabricated for observation testing. The only initial change during this trial was after the first initial making, the parchment paper was removed because it stuck very tightly to the film and was unable to be removed when added.

The following orders were used for trial 2:

1. 120mL of water
2. 120mL of indicator
3. 12 g of cornstarch (1.5 tbsp)
4. 2.5 tbsp of gelatin
5. 7 ml of glycerin

Project Setup

The project setup following this statement is implied for both trials, with a few exceptions noted at the end. Firstly, the basement area was cleared and ½ of the ping pong table was used for each trial. The tables were sanitized and disinfected then a white cloth was placed on top of the 2 sets of tables. Next, a side table was also sanitized and a cloth was placed on top. After the initial table placement, 270 containers were laid out, with each trial having 15 cups numbered with a sharpie for the assigned day. At the beginning, before the changes of the placement of the cellophane was made, each cup was taped on the inside of the lid. After, the changes of the placement was made to being inside and on the food rather than on the inside of the lid. This change was made 2 days throughout trial 1 cellophane and completely for trial 2 cellophane. Later, each cup was placed with the corresponding food out of the 3 (Milk, Turkey, Cucumbers). Each trial and product was labelled on the table cloth with sharpie for the out of fridge trials, and written labels were made for in the fridge. All containers were covered with lids to ensure the caption of all gasses and to ensure the most accurate results were applicable. A container was needed for each day because in order to find the pH and ammonia of solid food products, they must be liquified (explained deeper in next paragraphs). Lastly, a sanitary area was set as a base for gloves, paper towels, ammonia strips, pH strips, masks, food crusher, blender, utensils, and any other necessary materials.

Differences for trial 2 cellophane included that for all the out of fridge containers, there were only 5 containers per category. This was because during the first trial, only 5 day observations were made because the massive change was observed and stored, therefore, no point in continuing observations for future days. The turkey and cucumber in fridge trials were done at the normal time stamped until 15 days, and the in fridge milk was done for 10 days.

To ensure the most positive and accurate results, the exact amounts of each food was attempted. Each milk labelled container was filled with 2 cm (width) of milk. All the turkey slices were cut into 6 pieces each, each piece placed in a container. Each cucumber labelled container was placed with one slice of a cucumber. One large whole cucumber was cut into 30 pieces after washing. The pH of the milk started at 6.4 pH value and 0 ammonia levels. The cucumber pH value was 6 and 0 ammonia levels. Lastly, the turkey had pH value 6.

Daily Observation Collection

Everyday a photo of the available trials were taken for the corresponding container. 3 photos were taken, one with the lid on, one without the lid on, and one in comparison of the original cellophane to the resulting cellophane.

Milk Daily Collection

Since milk is already a liquid, even when spoiled, it can be shaken into a liquid, there is no reason to blend the food. The pH value was measured everyday by dipping the strip into the solution and compared to the chart right away. To measure ammonia, another strip was dipped, let out to dry for 5 seconds then compared to the given chart. The following links provided in the observation section show the graphs made to record data. The data charts included the observation of the food product (milk, turkey, cucumber), a deeper cellophane observation, and the overall time the trial was started.

Cucumbers Daily Collection

Unlike the milk, cucumbers are not liquids, therefore, after the pictures were taken and physical observations were written, the product was liquified.

The liquifying process is explained below:

1. Cucumber in the container placed into blender with a little bit of slightly warm water
2. Blended until applicable texture was reached
3. Ziploc placed into disposable plastic cup and mixture was poured into ziploc
4. Any remaining solid pieces in the ziploc were crushed by hand from the outside

5. The mixture in the ziploc bag was poured through a strainer into a plastic cup
6. The remaining liquid was used to test pH and ammonia with the corresponding strips
7. After each container was tested, all materials used were washed with warm water and dish soap, this applied for both turkey and cucumber observations

Turkey Daily Collection

The observation process of turkey was the exact same as cucumber, however, no ziploc was used for the reason that turkey is not completely water based, therefore, cannot be crushed.

End of Daily Collection

After the completion of the observations everyday, all the materials were washed very well to avoid any safety issues. The surface the experiment proceeded on, was washed and wiped everyday to avoid any ammonia spread, bacteria spread, or unhealthy food spread. Another requirement for safety was ensuring to wear a mask when the days started to increase, as well as gloves for the whole procedure.

Observations:

Cellophane Trial 1 vs. Cellophane Trial 2

Both experimented cellophane films were made using similar materials, however both presented different physical observations, time of results, durability, and clearness of color. Primarily, cellophane trial 1, which incorporated less glycerin as well as less concentration of indicator than trial 2. It was clear how film one was less durable and once stored into the fridge for too long, would become very flimsy as well as sensitive to touch, resulting in rips and the tendency to shrivel. When placed out, to a more room temperature surrounded environment, the cellophane resulted in attaching directly onto the foods, specifically to the bottom of the milk containers and directly onto the cucumbers. The trial one presented more struggle into keeping the color and ensuring as minimal fade as possible. Trial two, while set inside the fridge, showed signs of thriving, as the color was strong and visible, less sticky, and easy to remove. Unlike trial 1, trial 2 remained stable for much of the in-fridge duration, although absorbent of liquid and an increase in thickness. Overall, using physical, human eye observations, it can be identified that durability, sensitivity, and condition wise, trial two cellophane worked the most productively and efficiently.

In-Fridge vs. Out of Fridge

During the trials, it was observed that the out-fridge cellophane had a speedy degradation time compared to the in-fridge film. The film placed outside the fridge often stuck to the food items and identified faster signs of fading and color misidentification. The in-fridge film was often more durable and smooth, allowing for flexibility and stronger quality in color shades. The in fridge polymer film released less smell and stronger color when placed beside the out fridge trials. Conclusively, the in-fridge cellophane presented stronger results and better durability and elasticity compared to the out-fridge trials.

Cellophane Trial 1 Observations

Below is the link to the raw data collection over the days:

https://docs.google.com/spreadsheets/d/1Sn9Q5gPXZ65qITONKdDrcPHPfDj_pONxyDaa0Fdq1CA/edit?usp=sharing

The paragraphs below are defined and elaborated based on each trial and food product.

Trial 1 In-Fridge Milk

Firstly, as seen through the link, this trial had only been held for five days for the reason that even in the fridge, the milk had an unusually sped up spoilage rate, allowing for fast ammonia and pH change.

On the first day of observations, the pH value of the milk remained at 6 and the ammonia was 0. It was obvious that the color of the cellophane had turned a clear white shade. The cellophane itself was super moist and thicker than the original, it felt very smooth, and was slightly slippery. Finally, the milk remained at its normal drinking conditions.

On the second day of observations, the pH and ammonia value remained the same 6 and 0 respectively. The cellophane was super smooth, slippery, and let out a milk like smell. According to the physical observations taken, the milk had a normal texture and remained in an untouched condition.

The third day of observations presented results of a pH value of 6 and an ammonia of 200ppm. The color of the cellophane exchanged into a more opaque shade of white and remained very smooth and absorbent. A few damages, like tears, were present in the film. The milk let out a slight rotting smell, chunks of small amounts of curdling, and a somewhat rougher texture.

Following, the fourth day remained of a pH value of 6 and an ammonia rate of 300ppm. The cellophane color had darkened into a more solid white color. At this point into observations, the milk presented a very strong rotting smell, with light chunks of curdles, however, still maintaining a somewhat smooth texture.

Lastly, the fifth day had an pH value and ammonia of 5 to 300 respectively. The color of the cellophane appeared a faded white shade. The cellophane remained smooth, very sticky, slippery, yet durable. The film itself let out a pungent milk like smell. At this point of the project the milk had a rough and clumpy texture, along with a strong, fish like smell.

Trial 2 In-Fridge Milk

Firstly, as shown in the following source once again, the trial was only held for five days due to similar factors listed before.

At the beginning of the observation period, the milk came to a pH value of 6.5 and an ammonia level of 0ppm. The cellophane was clearly white, with slight opaque shading. The film displayed characteristics of smoothness, slipperiness, and light to no contortion. The film also presented a slightly thicker texture than the original comparison. The physical properties of the milk remained cold, normal smell, and an overall general condition.

Among the early stages, the second day presented a pH value of 7 and an ammonia rate of 150ppm. The cellophane had turned into a more solid, opaque, white color. The film indicated signs of smoothness as well as a flimsy build, with a very moist texture and stronger smell.

During day three of the experiment, the pH value had dropped to 6 and the ammonia rate had increased to 200ppm, with the cellophane presenting a similar, more faded white like shade. It was very obvious that the cellophane left traces of milk chunks and stickiness. The milk produced an obvious pungent smell along with layers of stickiness attaching to the film.

Nearing the end of the experiment, on day four, the pH value had decreasingly dropped to 5 with an ammonia value intensifying to 500ppm. The indicator film showed a white tinted color with the characteristics of remaining cold, attaching slightly to the milk, however smooth when chunks were removed. The smell released from the cellophane was observably strong. The observations taken from the

milk, were obvious of a skimmed like film on the top, while still liquidy, conserving a bad smell, and a normal fridge temperature.

Ultimately, on the last day of the five, the pH value had dropped to slightly below 5 and the ammonia had dramatically increased to +500, showing the color of a dark blue shade on the ammonia strip. The cellophane however, had still remained as an opaque white. The monitored film concluded a cold, soft, and not much flexible film while retaining its capture of the bad smell.

Trial 3 In-Fridge Milk

In the initial phase during day one, the present pH value was 6.4 and the ammonia rate remained constant to 0ppm. The color of the cellophane remained a clear, white-ish shade. The film presented observable changes including the folded film, smoothness, wetness, and slight delicateness. Otherwise, the film still remained in a normal and observable condition. The liquid item remained cold, normal textured, and smelling good.

During the second day, the pH had slightly decreased towards a 6 pH value and an ammonia level of 150ppm. The cellophane presented a color change to a more opaque white shade. The film identified characteristics of a soft, delicate structure, while still presenting slightly thicker and flexible. Lastly, the milk presented signs of light chunks while producing a heavier smell.

At the third stage of the trial, the pH remained at 6 while the ammonia slowly crept to 200ppm. The cellophane was a clear white shade and very sticky with lots of milk attachments, stringyness and few rips. The milk remained with no smell, no chunks, and a cold temperature.

During the fourth stage, the pH value once again remained at 6 and the ammonia rate had skyrocketed to 500ppm. The film matrix had lightly contorted into a folded form, while still remaining a durable and absorbent texture.

Conclusively, the pH value had remained at the value of 6 while the ammonia rate had accelerated to +500, using these numbers, the cellophane was present as a white shade. The indicator had slightly folded, even so, it remained in a good condition, avoiding any major changes.

Trial 1 In-Fridge Turkey

This trial was held for 14 days.

On the first day of observations the pH value and ammonia level was 6.5 and 0ppm respectively. The color of the cellophane was a normal blue and pink with only slight changes. The polymer film had a normal thickness, was slightly more delicate, as well as flimsy. The turkey was in perfect condition, showing no major change, however, slightly tinted by the indicator.

During the second day of observations the pH raised to 7 and the ammonia rate was 0ppm. The color of the indicator was a normal blue and pink. The film itself was soft, smooth, a little more delicate than the original, and very durable. The turkey was in perfect condition, had normal moisture, normal smell, and conclusively had no major changes.

The third phase of this trial presented pH value and ammonia rate 7 and 0ppm respectively. The color of the cellophane was purple with a slight tint of blue. The polymer film was smooth, the color had slightly faded, was stretchy, durable, and a strong elasticity rate. The turkey was normal, but did produce a stronger smell without an acidic flavor to it, it was moist, and had a normal and smooth texture.

On the fourth day of observation the pH value and ammonia rate was 6.5 and 0ppm respectively. The color of the cellophane was purple with a small color fade. The polymer film had appeared to be moisture absorbent, very thin and not as durable, but still color persistent. The turkey produced a normal smell, was moist, soft, and had an overall satisfactory health rate.

Throughout the fifth day of observations, the pH level and ammonia rate was 6.5 and 0ppm respectively. The color of the cellophane was purple with a slight fade. The polymer film was moisture absorbent, in normal condition, had slightly consumed the smell of the turkey, and provided good flexibility. The turkey was in its normal state, had produced a stronger smell, but not acidic, and was smooth and moist.

During the sixth day of observations the pH value and ammonia rate was once again 6.5 and 0ppm respectively. The color of the cellophane was purple and blue and the following observations were taken; a smooth surface, a tougher and stiffer structure, lighter color identification, and flexibility. The turkey had not produced any signs of spoilage.

The seventh day of observations were skipped, because of the limited observation change.

Throughout the eighth day of observations the pH value and ammonia level was 7 and 0ppm respectively. The color of the cellophane was dark blue and purple. The cellophane was very stretchy, wet, smooth, and more flimsy.

The ninth day of observations were skipped for similar reasons as the previous trials.

During the tenth day of observations the pH value and ammonia rate was 6.9 and 0ppm with the colors purple and yellow observed. The cellophane was still smooth, not as flexible, and had no rips. The turkey provided minimal changes, with only a slightly stronger smell and tinted orange shade.

Throughout the eleventh day of observations the pH value and ammonia rate was 6.9 and 100 respectively. The color of the cellophane was purple and orange. A small black dot was present on the cellophane, contradictory, the cellophane was still smooth, stretchy and durable. The turkey had a strong smell, was more dry than normal, moisture was observed on the container, and was more orange and slightly brown from the corners.

The twelfth day of observations were skipped, the following will happen for the other trials.

The thirteenth day of observations had a pH value and ammonia rate of 7.2 and 150ppm respectively. The color of the cellophane had transformed into a green and blue shade. The cellophane was intact, softened, flexible, and had a few uneven color patches. The turkey also had a slightly acidic smell, was dull and tacky, orange and pink shade, and liquid was present in the container.

Ultimately, on the last day of observations, fourteenth day, the pH value and ammonia rate was 8 and 200ppm. The color of the cellophane was green and yellow. The polymer film was soft, flexible, flimsy, and presented slight fading. The turkey had a spoiled sulfur-like smell, and was a much more dull color of grey and orange.

Trial 2 In-Fridge Turkey

This trial was held for 14 days.

On the first day of observations the pH value and ammonia level was 7 and 0ppm respectively. The color of the cellophane was a normal blue shade. There was not much of an obvious change in the

cellophane other than some moisture that was present on the corners. The turkey presented no major changes, remaining with the same smell, and presented minimal changes.

On the second day of observations the pH value and ammonia level was 6.9 and 0ppm. The color of the cellophane was once again a normal shade of blue. The cellophane presented the slightest change with only minimal color fade, absorption, and flexibility. The turkey was also in normal condition.

During the third day of observations the pH value and ammonia level remained 6.9 and 0ppm. The color of the cellophane was a normal blue and had slight shades of purple. Similar to the previous day, not much change was observed, the cellophane was soft, smooth, a little stiffer, and slightly thicker than the normal smell. The turkey had a more redundant smell, however remained with a normal texture, and some indicator had been released onto the turkey.

Throughout the fourth day of observations the pH value and ammonia level was 7 and 0ppm respectively. The color of the cellophane was normal blue and purple. The polymer film was smooth, durable, soft, released a turkey like smell, and was not as flexible as before. The turkey produced a normal smell that was a little stronger than normal, however it remained in good health.

Following, on the fifth day of observations the pH value and ammonia level was 7 and 0ppm respectively. The cellophane was a normal blue with a purple fade. The polymer film condition was smooth, had good flexibility, was a little thicker than normal, and slight absorbance of moisture was observed. The turkey had a slightly stronger smell in the container, was smooth, and moisture was present on the inside of the containers, overall no major changes were observed.

Furthermore, on the sixth day of observations the pH value and ammonia level was 7 and 0ppm respectively. The color of the cellophane was also a normal blue with a purple fade. The polymer film was slightly more tacky, thicker than normal, smooth, and durable. The turkey was a little stickier, however it remained smooth with only a lighter smell.

The seventh day of observations was skipped, like the trial before.

During the eighth day of observations, the pH value and ammonia level was 7.5 and 0ppm respectively. The cellophane color was purple and blue. The polymer film was also slightly tacky, thicker than normal, smooth, and durable. The turkey was minimally stickier than the normal, however remained smooth, and no major signs of spoilage was found.

The ninth day of observations were passed.

On the tenth day of observations the pH value and ammonia rate was 8 and 0ppm respectively. The color of the cellophane was blue, purple, and yellow in a fade. The polymer film itself was stretchy, smooth, and thinned out. The turkey had a stronger pungent smell, was less moist, it was much more dry, and had some purple dye on it.

During the eleventh day the pH value and ammonia rate was 8.5 and 20ppm respectively. The color of the cellophane was purple and orange. The polymer film was smooth, had no rips, durable, and overall was in good condition. The turkey had a rotting smell, had shrunken, and no moisture was observed in the slice.

The twelfth day of observation was skipped, similar to the previous trial.

Throughout the thirteenth day of observations the pH value and ammonia rate was 9 and 150ppm respectively. The color of the cellophane was teal and dark green. The polymer film was soft, flexible, smooth, flimsy, and had no smell releasing from it. The turkey had a strong smell, a darker orange tint, and was stuck to the bottom of the container.

Conclusively, on the fourteenth day of observations the pH value and ammonia rate was 9.5 and 200ppm respectively. The color of the cellophane was green and yellow. The polymer film released a turkey-like smell, was rougher, flexible, thinned out, and had a slight fade in color.

Trial 3 In-Fridge Turkey

This trial was held for 14 days.

On the first day of observations the pH value and ammonia level was 6.5 and 0ppm respectively. The color of the cellophane was a darker blue shade. The cellophane was smooth, soft, and a little stiffer. The turkey was in normal conditions.

During the second phase of observations, the pH value and ammonia levels were 7 and 0ppm respectively. The color of the cellophane was a slightly darker blue. The cellophane was thicker, sturdy and smooth. The turkey was in perfect condition, had a slight indicator stain, and had a normal smell.

Throughout the third phase of observations the pH and ammonia levels were 7 and 0ppm respectively. The polymer film was smooth, flexible, durable, and slightly thinner. The turkey had a normal smell, was moist, in good condition, and a fade of the indicator color.

In the course of the fourth day the pH and ammonia levels were 7 and 0ppm respectively. The color of the cellophane was the normal blue, light purple, and had a slight fade. The polymer film was slightly wet, one side was thicker, flexible, durable, and no signs of rips were present. The turkey was wet, moisturized, a few rips were visible, overall, not much change was visible.

On the fifth day of observations the pH and ammonia levels were 7 and 0ppm respectively. The color of the cellophane was a darker purple and blue. The polymer film was slightly tacky, the color was quite visible, and no contortion was observed. The turkey had a darker shade of orange, was more dry, and a stronger smell was observed.

During the sixth day of observations the pH and ammonia levels were 6 and 0ppm respectively. The color of the cellophane was dark purple and blue. The polymer film was in good condition, except the tackiness and decrease in flexibility. The turkey had no major signs of spoilage, other than a minor amount of moisture.

The seventh day of observations were skipped, similar to the other trials.

On the eighth day of observations, the pH value and ammonia rate was 7 and 0ppm respectively. The color of the cellophane was a clearer purple. The polymer film was sticky, wet, smooth, absorbent, and had shrunken. The turkey was stiffer, had a longer lasting smell, still wet, and the edges were more brown.

The ninth day of observations were also skipped.

During the tenth day of observation. The pH value and ammonia rate was 8 and 100ppm respectively. The color of the cellophane was a yellowish orange and purple. The polymer film was a bit thinner, had no smell, no rips, was flexible, and in good condition. The turkey had a stronger smell, was still moisturized, and had a darker shade of orange and brown.

On the eleventh day of observations, the pH value and ammonia rate was 8 and 100ppm respectively. The color of the cellophane was orange and purple. The polymer film was smooth, stretchy, sturdy, and durable. The turkey had an acidic smell, had changed into an orange and brown color, and moisture was apparent on the container.

The twelfth day of observations were skipped, similar to previous trials.

On the thirteenth day of observation the pH value and ammonia rate was 8.5 and 150ppm respectively. The color of the cellophane was yellow and blue. The polymer film was smooth, presenting light condensation, had no rips, and no smell. The turkey was slightly wet and slimy, had a noticeable sulfur like smell, and no visible mold was present.

Ultimately, on the last day of this trial, the fourteenth day, the pH value and ammonia rate was 9 and 150 ppm respectively. The color of the cellophane was green and yellow. The polymer film was slightly sticky, was a little less stretchy, and presented minor thinning. The turkey was more slimy and sticky, had an unpleasant, strong smell, and was prone to easy tear.

Trial 1 In-Fridge Cucumber

This trial was held for 14 days.

During the first day of observations the pH level and ammonia rate was 6.4 and 0ppm. The color of the cellophane was a faded blue. The polymer film was stretchy and flexible. The cucumber slice was wet and moisturized, had a normal smell, and did not show much change.

On the second day of observations the pH level and ammonia rate was 7 and 0ppm respectively. The color of the film was the normal blue. The polymer film was cold, stretchy, flexible, and smooth. The cucumber slice was a little drier, however, not much change was observed.

Throughout the third day of observations the pH level and ammonia rate was 7 and 0ppm. The color of the cellophane was a faded blue. The polymer film was soft, smooth, durable, and stretchy. The cucumber was moist, had a normal texture, and was still in healthy condition.

In the course of the fourth day of observations the pH level and ammonia rate was 6.7 and 0ppm respectively. The color of the cellophane was the normal faded blue. The polymer film was soft, smooth, durable, but not stretchy. The cucumber released moisture which settled on the container, was a little drier, and in a normal, healthy condition.

On the fifth day of observations the pH level and ammonia rate was 7 and 0ppm respectively. The color of the cellophane was blue and orange in an ombre pattern. The cellophane was ripped, flexible, and minimally less durable. The cucumber slice was in good condition, and was a little rougher and drier.

During the sixth day of observations the pH level and ammonia rate was 6 and 0ppm respectively. The color of the cellophane was turquoise and dark blue. The polymer film was slightly sticky, flexible, stretchy, soft, and smooth. The cucumber slice had a stronger rotting like smell, and had a rougher texture.

The seventh day of observations were skipped due to the lack of change in all data

On the eighth day of observations the pH level and ammonia rate was 5 and 5ppm respectively. The color of the cellophane was clear orange and blue. The polymer film was stuck to the food, soft,

fragile, and moisture absorbent. The cucumber food product had a stronger than normal smell, the container was wet, and the slice was more dry than the normal product.

The ninth day of observations was skipped.

On the tenth day of observations the pH value and ammonia rate was 8 and 400ppm respectively. The color of the cellophane was a yellowish orange and blue. The polymer film was sticky on the side against the cucumber directly, was durable, and had no rips. The cucumber had a strong, not as acidic smell, looked in normal condition, however, was slightly sticky.

The observations taken on the eleventh day was that the pH value and ammonia rate was 9 and a high rate of 500+ppm respectively. The color of the cellophane was mainly blue but had hints of orange. The polymer film was smooth, not sticky, stiffer, and in an overall good condition. The cucumber slice had a pungent, strong smell, and was drier than normal, however still retained some moisture.

The twelfth day of observations were skipped.

The thirteenth day of observation had a pH value and ammonia rate was 9.5 and 500+ppm respectively. The color of the cellophane was light yellow and green with undertones of blue. The polymer film was soft, moist, sticky, because of its attachment to the cucumber, had a few rips, and was flexible. The cucumber slice was dehydrated, had a dry surface, a slimy layer, and a sour smell .

Consequently, the pH value and ammonia rate was 9 and 500+ppm respectively. The color of the cellophane was yellow and green with blue. The polymer film was soft, fragile, slimy, had rips and thinning, and a vegetable odor. The cucumber slice was wrinkled and had shrunken, was slimy and mushy, and produced a stronger smell.

Trial 2 In-Fridge Cucumber

This trial was held for 14 days.

During the first day of observations the pH level and ammonia rate was 6 and 0ppm respectively. The color of the cellophane was a light and clear blue. The polymer film was smooth, had a slight change in shape, and smelt like the cucumber slice. The cucumber slice was wet, smooth, and in normal condition.

On the second day of observations the pH level and ammonia rate was 6.7 and 0ppm respectively. The color of the cellophane was blue and had no fade. The polymer film was thick, cold, delicate, soft, and overall had good durability. The cucumber slice was in normal condition.

Throughout the third day of observations the pH level and ammonia rate was 7 and 0ppm respectively. The color of the cellophane was blue and slightly purple. The polymer film was smooth, moist, absorbent, and flexible. The cucumber slice is moist, hydrophilic, and in perfect condition.

In the course of the fourth day of observations the pH level and ammonia rate was 7 and 0ppm respectively. The color of the cellophane was blue and had slightly faded. The polymer film was thin, stretchy, flexible, smooth, and did not produce any smell. The cucumber slice was moist, as well as the container, had a good smell, and was in good condition.

On the fifth day of observations the pH level and ammonia rate was 7 and 0ppm respectively. The color of the cellophane was a light turquoise fade. The polymer film was thin, stretchy, flexible, smooth, and had a good smell. The cucumber was normal, however, more moisture was present on the container.

During the sixth day of observations the pH level and ammonia rate was 6 and 0ppm respectively. The color of the cellophane was a teal ombre of pink and blue. The polymer film was very thick, absorbent, sturdy, and had signs of stretchiness. The cucumber was normal, wet, and in thriving conditions.

The seventh day of observations were skipped due to the lack of change in all data.

On the eighth day of observations the pH level and ammonia rate was 5 and 0ppm respectively. The color of the cellophane was teal blue and turquoise with a slight fade. The polymer film was sticky, not as durable, and had melted onto the cucumber.

The ninth day of observations was skipped.

On the tenth day of observations the pH value and ammonia rate was 7 and 400ppm respectively. The polymer film was sticky on the side pressed against the cucumber, was smooth, flexible, and the color had spread evenly. The cucumber was slimy, soggy, sticky, and had a super acidic smell.

The observations taken on the eleventh day was that the pH value and ammonia rate was 9 and 500+ppm. The color of the cellophane was mainly orange. The polymer film is a little thinner, smooth, sticky, and not as stretchy or flexible. The cucumber was slimy, sticky, had an acidic and pungent smell, and moisture was present around the cucumber.

The twelfth day of observations were skipped.

The thirteenth day of observation had a pH value and ammonia rate was 9 and 500ppm respectively. The color of the cellophane was yellow and blue. The polymer film was soft, had rips, was fragile, cloudy, and not as durable. The cucumber slice was dry, had a rough texture, was slimy in the centre, and had a stronger smell.

Consequently, the pH value and ammonia rate was 9 and 500ppm respectively. The color of the cellophane was green. The polymer film was super sticky, slimy, and released a strong, sour smell. The cucumber slice had a strong, acidic, vegetable like smell, was mushy from the center, and was wrinkled and dry.

Trial 3 In-Fridge Cucumber

This trial was held for 14 days.

During the first day of observations the pH level and ammonia rate was 6.4 and 0ppm respectively. The color of the cellophane was the normal blue color. The polymer film had normal flexibility, normal smell, and not much change was present. The cucumber was slightly more dry, had a rougher texture, and the smell was normal.

On the second day of observations the pH level and ammonia rate was 7 and 0ppm respectively. The color of the cellophane was a lightly faded blue. The polymer film thinned out, smooth, thicker from one end, stretchy, and flexible. The cucumber was in normal condition.

Throughout the third day of observations the pH level and ammonia rate was 7 and 0ppm respectively. The color of the cellophane was the normal blue color with slight fade. The polymer film was smooth, sticky, normal texture, and flexible. The cucumber slice was more dry, stiff, and moisture was present on the container.

In the course of the fourth day of observations the pH level and ammonia rate was 7 and 0ppm respectively. The color of the cellophane was blue with a slight shade of yellow. The polymer film was soft, thin, not as flexible, and had a stronger smell. The cucumber slice was stiffer, and was still in good condition, however the moisture had surrounded the inside of the container.

On the fifth day of observations the pH level and ammonia rate was 6.8 and 0ppm respectively. The color of the cellophane was the normal blue with hints of orange. The polymer film was strong and durable. The cucumber slice had a normal smell, normal moisture, and was a little more dry than normal.

During the sixth day of observations the pH level and ammonia rate was 6 and 0ppm respectively. The color of the cellophane was normal blue with purple. The polymer film was absorbent, had light rips, was thin, and a little less durable. The cucumber slice was moisturized, a little yellow, however it remained in good condition.

The seventh day of observations were skipped due to the lack of change in all data.

On the eighth day of observations the pH level and ammonia rate was 5 and 5ppm respectively. The color of the cellophane was blue and orange. The polymer film was sticky, wet, absorbent, and a little thicker. The cucumber slice had produced a rotting smell, had a dry layer on the inside, but did not show visible signs of major spoilage.

The ninth day of observations was skipped.

On the tenth day of observations the pH value and ammonia rate was 8 and 500ppm respectively. The color of the cellophane was blue, yellow and orange. The polymer film was stiffer, was stuck to the cucumber, had a hole in the middle, and was in average condition. The cucumber slice was moisturized, had a rougher texture, and produced a stronger smell.

The observations taken on the eleventh day was that the pH value and ammonia rate was 9 and 500+ppm. The color of the cellophane was a faded blue shade with orange. The polymer film was stuck to the cucumber, unable to be removed, was clear, and had melted into the cucumber. The cucumber slice produced a bad and pungent smell, and had dissolved into the container.

The twelfth day of observations were skipped.

The thirteenth day of observation had a pH value and ammonia rate was 8 and 500ppm respectively. The color of the cellophane was yellow. The polymer film was soft, fragile, sticky on both sides, and the color was not as obvious. The cucumber slice was orange, melted in the centre, had a rough texture, no moisture was observed, other than the condensation on the inside of the container.

Consequently, on the fourteenth day, the pH value and ammonia rate was 9 and 500ppm respectively. The color of the cellophane was yellow and blue. The polymer film had shown signs of thinning, rips, some flexibility, and produced a strong smell. Ultimately, the cucumber slice was very dry and strong, had a pungent smell, and had shrunken.

Trial 1 Out-Fridge Milk

Similar to the in-fridge milk, the observations were held for a shorter period of time than the other food items, instead of five days, a slight switch to four days. In repetition to the other milk observations, the spoilage had a very sped up rate, therefore allowing for a shorter observation period.

At the initial day of the experiment, the pH value started at 7 and a surprising ammonia rate of 400ppm. The color of the cellophane has shown a very opaque, vibrant color of white. The film substrate

was very fragile, delicate, and slightly thicker than the original. The physical observation of the milk had increasingly raised to a very strong and pungent smell, however, the texture remained normal with a very warm temperature.

In the second phase of the trial, the pH had dropped to a value of 5.9 and a steady ammonia rate of 500ppm. The cellophane remained the same color as before, a strong white shade. The film characteristics were fragile, slightly ripped, thicker than normal, and retained a bad smell. At this point in time, the milk had presented a very unpleasant smell, in the case where a mask was used. The milk texture was very stiff, however it remained a light smooth texture under the skimmed layer.

The third day of observations resulted in the pH value of 5 and an ammonia rate of +500ppm. The cellophane continued appearing as a white shade. The cellophane had stuck onto the bottom of the milk filled container, was super fragile and slightly ripped. The milk was irrationally bad smelling, very chunky, heavy weighted, and warm.

On the concluded day of the observations, the pH value dropped to 4 and the ammonia had raised to a level above 500ppm. The cellophane revealed observations of slight milk stuck, a smooth and soft texture, along with a few rips, and an irritating spoiled smell.

Trial 2 Out-Fridge Milk

Exactly similar to the trial before, this phase was held for four days.

On day one, the starting pH value was 5 and the ammonia level was a high 400ppm. The color of the cellophane started at a faded white color. The film represented characteristics of softness to the touch, chunky bits attached to it, a larger thickness, and a strong milk like smell. The milk itself was chunky, bad smelling, and warm.

The second day of observations increased to a pH value of 5.6 and an ammonia presence of 500ppm. The color as usual remained a faded white color. Light humidity was present on the cellophane by the light water drops as well as chunks and a gas smell of rotten milk. The cellophane was fragile and soft. The milk released bad smells, and was quite chunky but slightly maintaining a liquidy texture. Cellophane bits and pieces also remained inside the solidified milk.

During the third day of observations, the pH value had dropped back to a 5 and the ammonia had stabilized at a rate of 500ppm. The color of the cellophane was once again a white shade, however a little more tinted. The film identified a big grey fuzzy dot, a really bad smell, however it still had a smooth and soft texture. The milk displayed an incredibly solid texture with two different white shades from the placement of the cellophane. Once again, presenting a very strong rotting milk smell.

At the last day of observations, the pH remained at a value of 5 and the ammonia had increased past 500ppm. Lastly, the color of the was a strong opaque white. The polymer film showed characteristics of grey and blue like fuzz, light chunks and textures as well as stickiness. The milk was observed to release a pungent smell, two different off shades, and a lot of textured surfaces.

Trial 3 Out-Fridge Milk

The trial, as from before, was also held for 4 days.

During the first phase of this trial, the pH of the milk was 7 and the ammonia range had already increased to 400ppm. The cellophane color was white, and showed the characteristics of delicacy, stringiness, and slight rips along the edges. The milk was incredibly sticky, chunky, warm, and released pungent, rotten like smells.

On day two of the experiment, the pH had dropped to a 5 and the ammonia levels had increased to above 500, as the strip identified a very dark blue, off scale color. The cellophane was very soft, ripped apart, stuck to chunks of curdled milk, and not very smooth. The milk identified a bad smell, as well as two different shades once the cellophane was removed.

During the third day of observations, the pH remained at 5 and the ammonia remained at an increased value of 500ppm. The milk had exhibited an off white clear shade, a very bad smell, extremely chunky and solid, however no obvious detection of mold.

Finally, on the last day of observations the pH had once again remained at a pH value of 5 and had majorly increased passed and ammonia rate of 500ppm. The color of the cellophane was a solid white color, a few rips and stringiness were observed as well as a purple tint, bad smell, rough texture, and slight stickiness. The milk displayed chunkiness, rough and solid texture, and an extreme pungent smell.

Trial 1 Out-Fridge Turkey

The next three trials were each held for four days due to sped up spoilage rates and the safety of others in the environment the experiment was held in.

During the first phase of observations, the pH value started at 7.3 and maintained an ammonia rate of 0ppm. The color of the cellophane was a light shade of pink and blue. The cellophane was very soft, moist, stretchy and smelt like turkey. The turkey itself had a stronger smell, showed signs of light orange color change, and slight dryness.

Next, the second day of observations, had a higher pH of 7.5 and the same ammonia rate of 0ppm. The cellophane color had changed to a more purple shade and hints of yellow. The characteristics of the cellophane released a strong smell, was smooth, and slightly dry. The milk had a strong, unpleasant smell and the indicator dye had slightly faded into the milk, showing a slight purple color.

On the third day the pH increased to 9 and the ammonia raised to 150ppm, while the color of the cellophane switched to a more yellow shade. The cellophane itself was ripped, really hard to remove from the turkey, and had an ombre of two colors. An irritating smell was released, moisture settled on turkey, and had a very dry texture, however, still soft to the touch.

On the last day of observations the pH had remained at a value of 9 and an ammonia rate remained at 150ppm. The color of the cellophane had finalized at a blue and yellow shade. There were slight rips, rough textures, stickiness, and strong smells present from the cellophane. The turkey had a very nose irritating smell, a very sticky texture, was ripped apart and super rotten.

Trial 2 Out-Fridge Turkey

The following trial was held for 4 days.

On the first day of observations, the base pH had a value of 7.5 and an ammonia rate of 0, the cellophane color blue, pink, and slightly orange. Observed by the cellophane, was an ombre of different colors, thicker than normal, and a stretchy material. The turkey itself was dry, orange, and produced a stronger but still fresh smell.

During the second phase of the experiment, the pH had increased to 9 and the ammonia had raised to a continuous rate of 150. The color of the cellophane was a normal tint of blue and purple. Characteristics of the film were softness, flexibility, slight rips, and some absorbance of the turkey smell.

The third day of the trial had a stable pH of 9 and a continuous rate at 150ppm for ammonia. The color of the cellophane was blue, purple, and yellow. The film identified a sticky but smooth texture, no contortion, and an ombre of the three main colors. The turkey itself was slowly rotting, very sticky, released a bad smell, and had a rough texture.

On the last day of observations, the pH ended at a value of 9 and an ammonia rate of 150ppm, with the cellophane color resulting in a yellow shade. The cellophane had also had a rough, sticky texture, bad smell, lower elasticity, and a slight fade. The turkey produced a nose irritating and acidic scent, was sticky, ripped, and had a rough texture.

Trial 3 Out-Fridge Turkey

This trial was held for 4 days.

The starting pH and ammonia values were 7 and 0ppm respectively. The cellophane had the normal tint of blue as well as an orange tint. The polymer film was slightly thinned out and captured the smell of the turkey. The turkey was slightly dried, orange, and had a stronger smell but not as pungent.

The second phase of the trial had a pH value of 7 and an ammonia presence of 0ppm. The cellophane shade was yellow and blue, with a grey fuzzy dot (fungal), a smooth but sticky texture, and a stronger acidic smell. The turkey was dry, had no rips, a bad smell was present and a rough texture.

Nearing the end of the experiment, on the third day, the pH had increased to 9 and the ammonia had remained at 0ppm. Blue and yellow shades were present on the cellophane while acquiring a smooth and sticky texture, a slight smell, and a few rips. The turkey produced a pungent smell, lots of rips, stickiness, and loss of moisture.

Subsequently, on the last day of observations, the pH had remained at 9 and the ammonia had increased to 150 ppm. The cellophane color had majorly changed to a more teal green with slight purple and was sticky, slightly ripped, had a rough texture with slightly less flexibility and a light grey fluff layer surrounding it. The turkey had a super strong acidic like smell, was sticky, a dark orange color, and a rough texture was observed.

Trial 1 Out-Fridge Cucumber

This trial was once again held for only 4 days.

In the first phase of the trial the pH started at 7 and had an ammonia rate of 0ppm. The cellophane was blue, clear, and light orange. The cellophane observation itself was sticky, delicate, and not as bendable. The cucumber had a normal smell, however, was slightly drier and stiff.

During the second phase the pH had remained at 7 and the ammonia had remained at 0ppm. The cellophane was clear, light orange, blue and was liquid absorbent, very sticky, had a bad smell, and a slimy texture. The cucumber was orange in the middle, had a very rough, dry texture, and a bad smell.

On the third day, the pH value had risen to 8 and the ammonia had remained at 0ppm. The color of the cellophane was an orange fade, with observations taken that it attached to the cucumber, was very sticky and moisture absorbent. The cucumber itself was minimally moist, and had a big yellow dent in the middle.

Finally, on the last day of observations, the pH had a value of 8, and a final ammonia rate of 0ppm, the color of the cellophane was a pink and blue ombre. The polymer film was ripped into two pieces, was soft, absorbent, still flexible, however the black had a layer of grey fuzz.

Trial 2 Out-Fridge Cucumber

This trial was held for 4 days.

During the first phase of this trial, the pH started at 7.4 and the ammonia rate was 0ppm. The cellophane was stretchy, sticky, had no smell, and was light blue, purple, and orange. The cucumber itself was stiff, sticky, and had light moisture remaining.

On the second day of observations, the pH had very slightly increased to 7.5 and the ammonia had remained at 0ppm. The cellophane color was orange and represented characteristics of rips, grey dots with blue middles, and was sticky and slimy. The cucumber was dry and had orange dips in the centre.

During the third day of observations, the pH had increased to 7.8 and the ammonia had remained at a steady rate of 0ppm. The cellophane was orange and slightly clear, with some grey and blue fuzz, slightly sticky and soft, which was not removable from the cucumber itself. The cucumber was dry, though the container remained moist, and a bad smell was observed.

Subsequently, on the last day of the trial, the pH raised to 8 and the ammonia levels were consistent at a rate of 0ppm. The cellophane was split in the middle as it was attached to the cucumber, it was very sticky and smooth but fragile, lastly an ombre of orange and light blue was visible. An orange-y liquid and dryness were visible in the cucumber physical observations.

Trial 3 Out-Fridge Cucumber

This trial was also held for 4 days.

On the first day of observations the pH started at a rate of 7 and an ammonia value of 0ppm. The cellophane started off with a normal texture and was thicker than the original, with an ombre of light orange and blue. The cucumber slice was slightly dry but still maintained some moisture, had a normal smell, and a slightly rougher texture.

During the second phase of this trial, the pH had remained at 7 as well as the ammonia rate of 0ppm. The cellophane color was a clear orange, with observations taken that the texture was sticky, attached to the cucumber, and was hard to peel off the food item. The cucumber was dry and had crust peeling from the sides, produced a bad smell, and had a rough texture.

On the third day of observations taken, the pH had risen to 7.4 and the ammonia had remained at 0ppm. The cellophane color was a deeper orange shade and the cellophane itself had a grey and blue fuzzy dot, was hard to remove from the cucumber, and was very delicate.

Finally, on the last day of observations the pH value and ammonia rate was 7.5 and 0ppm respectively. The polymer film was completely stuck to the cucumber, had a bad smell, had a black unknown dot and a gooey and slimy texture with a clear orange color. The cucumber had slightly melted in the middle with a layer of grey and yellow fuzz, and a very pungent smell.

Cellophane Trial 2 Observations

The following link provides the raw data taken overtime during process of observation:

<https://docs.google.com/spreadsheets/d/1XCdQmy6BxwkVcPv60rNDkS4AooxQOS8YQMtGEDPzMOs/edit?gid=0#gid=0>

Trial 1 In-Fridge Milk

The following trial was held for 10 days.

During the first phase of this trial, the pH level and ammonia rate was 6.4 and 0ppm respectively. The cellophane color was white and had the characteristics of a soft, flexible, strong color identification, and was overall in good condition. The milk was in normal condition, and had a normal smell.

Following, on the second day of this trial the pH value and ammonia rate was 6.4 and 0ppm respectively. The cellophane color was clear white and was smooth, presented no smell, and was in normal condition. The milk was also in normal condition, had a normal smell, and a liquidy texture.

On the third day of observations the pH value and ammonia rate was 7 and 0ppm respectively. The cellophane color was clear white, soft, absorbent, and had folded when removed from the container. The milk was in a normal smell and condition, had a normal texture, and had a slight dye of purple.

The fourth day of observations were skipped due to lack of overall change in observations present.

The fifth day of observations presented pH value and ammonia level 6 and 0ppm respectively. The cellophane color was white, had many rips, was stuck to the bottom of the container, and had contorted into a slightly bigger size, allowing for flexibility. The milk was in normal condition, no smell was present, and purple dye was visible.

The sixth day of observations were skipped to produce stronger results on graphs because of the lack of change in different observations.

During the seventh day of observations the pH value and ammonia rate was 7 and 200ppm respectively. The cellophane color was white, ball shaped, had a few rips, and was not stretchy or strong. The milk had a slightly different smell, however remained in the normal liquidy texture and conditions.

The eighth day of observations presented pH value and ammonia rate 7 and 200ppm respectively. The cellophane color was white, smooth, delicate, and presented no rips. The milk had a stronger smell, normal texture, and no chunks were visible.

On the ninth day of observations the pH value and ammonia rate was 5 and 350ppm respectively. The color of the cellophane was a cloudy pinkish purple. The polymer film was soft, fragile, stuck to the bottom of the milk, and had retained a milk odor. The milk had a sour smell, chunky texture, and was partially separated.

Conclusively, during the last day of observations, the pH value and ammonia rate was 4.5 and 500+ppm. The color of the cellophane was pale pink, however mostly white. The polymer film was fragile, sticky, slimy, and had a few rips. The milk itself had an extremely pungent smell, a rough and chunky texture, and uneven coloring.

Trial 2 In-Fridge Milk

This trial was held for 10 days.

During the first phase of this trial, the pH level and ammonia rate was 6.6 and 0ppm. The color of the cellophane was white. The polymer film was very durable and stronger than the original film. The milk had a wet, normal condition, with no major change presence.

Following, on the second day of this trial the pH value and ammonia rate was 6.7 and 0ppm. The color of the cellophane was clear white and the polymer film was durable, slightly ripped, produced a

slight smell, however, no massive changes were present. The milk was in normal condition for all physical observations.

On the third day of observations the pH value and ammonia rate was 7 and 0ppm. The cellophane was clear white and purple. The polymer film presented a soft texture, and durable film surface. The milk was slightly covered with dark purple dye, however, a normal texture was present.

The fourth day of observations were skipped due to lack of overall change in observations present.

The fifth day of observations presented pH value and ammonia level 6.5 and 0ppm. The cellophane was a clearer white shade. The polymer film was folded, smooth, moist and wet, and had a few rips present. The milk had a smooth texture, was still cold, had a slightly dull shade of white, and presented no major overall changes.

The sixth day of observations were skipped to produce stronger results on graphs because of the lack of change in different observations.

During the seventh day of observations the pH value and ammonia rate was 7 and 0ppm respectively. The color of the cellophane was white and was folded, smooth, wet, and produced a limited smell. The milk had a little stronger of a smell, the texture was normal, and no major conditions were present.

The eighth day of observations presented pH value and ammonia rate 7 and 0ppm respectively. The color of the cellophane was white and the film was observed to be folded, smooth, wet, and had a few rips, however, no smell was present. The milk had a smooth texture, a smell was observed, no texture change, and not a massive overall change.

On the ninth day of observations the pH value and ammonia rate was 6 and 300ppm respectively. The color of the cellophane was white. The polymer film was soft, not as stretchy, thicker, and slightly more fragile.

Conclusively, during the last day of observations, the pH value and ammonia rate was 5 and 500+ppm was soft, not as stretchy, thicker, and slightly more fragile. The color of the cellophane was pink and white. The polymer film had a few rips, was smooth, sticky, stuck to the bottom, and produced a strong smell. The milk had presented signs of curdling, chunkiness, and had a strong smell.

Trial 3 In-Fridge Milk

The last trial was held for 10 days.

During the first phase of this trial, the pH level and ammonia rate was 6.4 and 0ppm respectively. The color of the cellophane was white. The polymer film presented observations of slight wetness, absorbency, very durable, and strong. The milk was in good condition, produced no bad smell, and a normal texture.

Following, on the second day of this trial the pH value and ammonia rate was 6.4 and 0ppm respectively. The color of the cellophane was clear white and presented observations of absorbency, good overall conditions, and no rips. The milk was moist and in great condition.

On the third day of observations the pH value and ammonia rate was 7 and 0ppm respectively. The color of the cellophane was a clear white and grey. The polymer film was soft, absorbent, had no rips, and had a smooth texture. The milk was liquidy, produced a normal smell and presented slight purple dye.

The fourth day of observations were skipped due to lack of overall change in observations present.

The fifth day of observations presented pH value and ammonia level 6.5 and 0ppm respectively. The color of the cellophane was an opaque white. The polymer film was wet, not as flexible, absorbent, and a stronger shade of color was observed. The milk had a minimally stronger smell, normal texture, and light purple dye was present.

The sixth day of observations were skipped to produce stronger results on graphs because of the lack of change in different observations.

During the seventh day of observations the pH value and ammonia rate was 7 and 200ppm respectively. The color of the cellophane was white and presented the following observation: rips, attachment to the sides of the containers, were hard to remove, and delicate. The milk was in a normal condition, with only a slight purple fade inside the liquid.

The eighth day of observations presented pH value and ammonia rate 7 and 200ppm respectively, with the color of the cellophane color being white. The polymer film was very smooth, had no rips, perfect texture, and slightly delicate.

On the ninth day of observations the pH value and ammonia rate was 6 and 500+ppm was soft, not as stretchy, thicker, and slightly more fragile. The color of the cellophane was white. The polymer film was ripped, smooth, hard to remove, and the color had faded. The milk had a strong smell, smooth texture, however, thicker than normal.

Conclusively, during the last day of observations, the pH value and ammonia rate was 4 and 500+ppm respectively. The color of the cellophane was white and slightly pink. The polymer film was smooth, fragile, but still afloat. The milk had a pungent smell, a rougher texture, was more chunky, and had signs of obvious spoilage.

Trial 1 In-Fridge Turkey

This trial was held for 15 days.

During the first phase of this trial, the pH level and ammonia rate was 5.8 and 0ppm respectively. The color of the film was a dark shade of purple and blue. The polymer film was flexible, presented a strong color, and was thicker. The turkey slice was in its normal condition.

Following, on the second day of this trial the pH value and ammonia rate was 5.9 and 0ppm respectively. The color of the cellophane was dark purple. The polymer film was sturdy, and presented not much change. The turkey slice was moist and healthy.

On the third day of observations the pH value and ammonia rate was 5.6 and 0ppm respectively. The polymer film was flexible, absorbent, and had a few rips. The turkey slice was smooth, produced a stronger smell, and remained in a healthy condition.

The fourth day of observations were skipped, due to lack of observation change.

The fifth day of observations presented pH value and ammonia level was 6.8 and 0ppm respectively. The color of the cellophane was blue and purple. The polymer film was smooth, flexible, had a normal smell with no rips and had an overall good texture. The turkey slice was in normal condition.

On the sixth day, the observations were passed, due to graph consistency and lack of observation change.

During the seventh day of observations the pH value and ammonia rate was 6.6 and 20ppm respectively. The color of the cellophane was pink and blue. The polymer film had some holes one side was stronger color than the other had thinned out and was a little more delicate. The turkey slice was still moist, had a strong smell, its texture was normal and had normal moisture presents.

The eighth day of observations presented pH value and ammonia rate was 6.4 and 20ppm respectively. The color of the cell phone was pink and purple. The polymer film was very strong, flexible, had good condition, no smell was present, was stretchy and had no change.

The ninth day of observations were skipped.

During the tenth day of observations the pH value and ammonia rate was 6.9 and 100ppm respectively. The color of the cell phone was blue and green with slight purple undertones. The polymer filled was tacky, thicker than normal and produced signs of elasticity. The turkey had a stronger smell was sticky less firm and still moist

The eleventh day of observations were passed.

In the course of the twelfth day of observations, the pH value and ammonia rate was 7.4 and 150ppm respectively. The color of the cellophane was green and blue. The polymer film had a sticky surface, a strong order was still moist and had a stronger color. The turkey was a darker orange shade soft and moisture was present on the container.

The thirteenth day of observations were skipped.

On the fourteenth day of observations the pH value and ammonia rate was 8.2 and 300ppm respectively. The color of the cellophane was yellow and green. The polymer film had small rips and was more fragile and slightly slimy. The turkey had a strong nose irritating smell, uneven moisture and was sticky.

Conclusively, on the last day of observations, day fifteen, the pH value and ammonia rate was 8.8 and 450 ppm. The color of the cellophane was yellow and green with faded blue undertones. The polymer film was smooth, had a few rips, and remained a little less flexible than the original.

Trial 2 In-Fridge Turkey

This trial was also held for 15 days.

During the first phase of this trial, the pH level and ammonia rate was 6 and 0ppm respectively. The color of the cellophane was a dark purple shade. The polymer film had a very strong tint, and not much change was present. The turkey had no changes and was in great condition.

Following, on the second day of this trial the pH value and ammonia rate was 6 and 0ppm respectively. The color of the cellophane was dark purple. The polymer film had a strong pigment, was smooth, and presented no smell. The turkey was normal, moist, smooth, and had no smell.

On the third day of observations the pH value and ammonia rate was 5.9 and 0ppm respectively. The color of the cellophane was a slightly faded purple. The polymer film was tacky, smooth, flexible, and had a normal dye. The turkey slice was normal and slightly purple from the dye.

The fourth day of observations were skipped.

The fifth day of observations presented pH value and ammonia level was 6 and 0 PPM respectively. The color of the cell phone was a normal blue. The polymer film was thicker because of the absorbent, smooth and flexible. The turkey was in a normal condition.

The sixth day of observations were skipped.

During the seventh day of observations the pH value and ammonia rate was 6 and 0 ppm. The color of the cellophane was purple pink and an overall faded clear shade. The polymer film was ripped with fade, and not as stretchy or flexible as before. The turkey had a super strong acidic like smell, still had moisture, was in normal texture, and only smell change was present.

The eighth day of observations presented pH value and ammonia rate was 6.5 and 0ppm respectively. The color of the cell phone was a faded purple. The polymer film was smooth, flexible, had a more strong shade, was tacky, and had a few rips. The turkey had a strong, unusual smell, and was slightly more mushy and moist.

The ninth day of observations were all so skipped like the previous trial.

During the tenth day of observations, the pH level and ammonia rate was 7 and 100ppm respectively. The color of the cellophane was blue and slightly green. The polymer film was soft, slightly thinned and fragile. The turkey had a slight orange discoloration, an unpleasant smell, and a slimy texture.

The eleventh day of observations were skipped.

In the course of the twelfth day of observations, the pH level and ammonia rate was 7.5 and 200ppm respectively. The color of the cellophane was green and blue. The polymer film had stuck onto the turkey, was hard to remove, and had a few rips present. The turkey was mushy, had a dark orange color, was acidic and had a strong odor.

The thirteenth day of observations were skipped.

During the fourteenth day of observations, the pH value and ammonia rate was 8 and 250ppm respectively. the color of the cell phone was yellow green and had slight purple Under shades. The polymer film was fragile however, had no rips, was still slightly flexible, and had thinned out. The turkey had a gray and pink color, had a thick layer of slime, and produced a strong smell.

Ultimately, on the 15th day, the pH value and ammonia rate was 8 and 300 PPM respectively. The color of the cellophane was green. The polymer film was not stretchy, super delicate, and ripped easily. The turkey had clear signs of spoilage such as a mushy texture and very dark orange color, and a strong odor.

Trial 3 In-Fridge Turkey

This trial was held for 15 days.

During the first phase of this trial, the pH level and ammonia rate was 6.2 and 0ppm respectively. The color of the cellophane was a super dark purple with strong dye. The polymer film was strong, sturdy, more absorbent, and thicker.

Following, on the second day of this trial the pH value and ammonia rate was 6 and 0ppm. The color of the cellophane was dark purple and not much change was visible. The polymer film was sturdy and presented no rips, was very strong, durable and hard. The physical observation of the turkey was in good quality and condition.

On the third day of observations the pH value and ammonia rate was 6 and 0 ppm. The color of the cell phone was dark purple with a slight fade. The polymer film was a little more fragile and absorbent of moisture, and had slightly more color loss. The turkey was smooth, moist and in good condition.

The fourth day of observations were skipped similar to the previous trials.

The fifth day of observations presented pH value and ammonia level was 6.8 and 0 ppm. The color of the cellophane was purple and blue. The polymer film was slightly moisture absorbent, was still intact, flexible and was softer than the original. The turkey was a normal condition and no major changes were observed.

The sixth day of observations were skipped similar to the previous trials.

During the seventh day of observations the pH value and ammonia rate was 6.8 and 0ppm respectively. The color of the cellophane was purple and pink. The polymer film was smooth, flexible and soft. The turkey had slight purple dye on the surface, a harsher smell, normal texture, and was a little more dry.

The eighth day of observations presented pH value and ammonia rate was 7 and 100ppm respectively. The color of the cellophane was purple. The polymer film was thicker than normal and had slightly folded, no rips were present and the color was slightly faded. The turkey had a bad acidic smell which was unpleasant and pungent, was very moisturized, the container also had signs of moisture condensation.

The ninth day of observations were passed, due to the lack of observation changes.

During the 10th day of observations, the pH value and ammonia rate was 7 and 100ppm respectively. The color of the cell phone was blue and yellow. The polymer film was less flexible, thinner, stuck to the turkey, and was hard to remove from the food product. The turkey slice was strong, had an unpleasant smell, a slimy and sticky texture, and remained in normal color shades.

The eleventh day of observations were skipped.

In the course of the twelfth day of observations, the pH value and ammonia rate was 7.5 and 100ppm respectively. The color of the cellophane was yellow, green and blue. The polymer film was weaker and not as flexible, had stuck to the food product, and was more textured. The turkey slice was strong, had an acidic smell and the color had a darker orange and pink shade.

The thirteenth day of observations were skipped similar to the previous trials.

On the fourteenth day of observations, the pH level and ammonia rate was 8 and 300ppm respectively. The color of the cellophane was green and purple. The polymer film was not stretchy or flexible, and had slightly folded. The turkey slice has a sticky surface and a strong unpleasant odor. It also had uneven moisture and the moisture was present on the container.

Conclusively, on the fifteenth day, the pH level and ammonia rate was 8.5 and 350 ppm. The color of the cellophane was yellow and purple along with a fade. The polymer film had a faded pigment, was

more gelatin like and had less structure because of its hard removal from the food product. The turkey had a dark brown and orange shade and was obvious of strong spoilage along with pungent smells.

Trial 1 In-Fridge Cucumber

This trial was held for 15 days.

During the first phase of this trial, the pH level and ammonia rate was 6.4 and 0ppm respectively. The color of the cellophane was a lighter blue color. The polymer film was stretchy and flexible. The cucumber slice was wet, moisturized, and had an overall normal condition.

Following, on the second day of this trial the pH value and ammonia rate was 5 and 0ppm respectively. The color of the cellophane was a darker blue shade. The polymer film was stretchy, lightly absorbent, and in good condition. The cucumber slice was also in normal and healthy conditions.

On the third day of observations the pH value and ammonia rate was 6 and 0ppm respectively. The color of the cellophane was a dark blue and slightly orange color. The polymer film was slightly sticky, tacky, flexible, but not as sturdy as before. The cucumber slice produced a slightly stronger, but not rotting smell, and presented an overall minimal change.

The fourth day of observations were skipped.

The fifth day of observations presented pH value and ammonia level 6.6 and 0ppm respectively. The color of the cellophane was teal green and blue. The polymer film was smooth, had a few rips, no smell was present, and was slightly tacky. The cucumber slice had a stronger cucumber smell, was drier than normal, and had a rougher texture.

The sixth day of observations were passed, due to lack of change in observation.

During the seventh day of observations the pH value and ammonia rate was 6.4 and 0ppm respectively. The color of the cellophane was teal green and blue. The polymer film was soft, had a few holes, was attached to the cucumber, and very hard to remove from the food product itself. The cucumber slice had a stronger acidic pungent smell and was dryer but still had moisture contained.

The eighth day of observations presented pH value and ammonia rate Was 6.2 and 0ppm. The color of the cellophane was blue and green. The polymer film was a little dryer however still smooth with a rougher texture was durable and did not have much degradation. The cucumber slice had a super strong smell, was dry and slightly wet.

The ninth day of observations were skipped due to lack of observations.

During the tenth day of observations, the pH and ammonia rate was 5.8 and 0ppm respectively. The color of the cellophane was green, purple and blue. The polymer film was sticky on the side directly on the cucumber and was less stretchy. The cucumber slice had a thin slimy layer, its texture was less fresh, provided a sour smell and the edges were dry.

The eleventh day of observations were skipped.

On the twelfth day of observations, the pH and ammonia rate was 5.4 and 50ppm respectively. The color of the cellophane was teal purple and green. The polymer film was more fragile, had slight rips and a faint color fade. The cucumber had a mushy center, an acidic vegetable order and dehydration in the interior.

The thirteenth day of observations were also skipped.

On the fourteenth day of observations the pH level and ammonia rate was 5 and 100ppm respectively. The color of the cell phone was pale pink and green. The polymer film was slimy, had loss of elasticity, curling edges and a strong smell. The cucumber was slimy, wrinkled, dehydrated and had a super dry texture.

On the fifteenth day of observations, The pH level and ammonia rate was 4.9 and 150ppm respectively. The color of the cellophane was a pale pink and teal. The polymer film was fragile, had small tears and uneven thickness. The cucumber was mushy and watery presenting signs of spoilage and had an acidic smell.

Trial 2 In-Fridge Cucumber

This trial was held for 14 days.

During the first phase of this trial, the pH level and ammonia rate was 7 and 0ppm respectively. The color of the cellophane was a normal blue color with a slight fade. The polymer film was cold, stretchy, smooth, and flexible. The cucumber slice was in an overall normal and edible condition.

Following, on the second day of this trial the pH value and ammonia rate was 6 and 0ppm respectively. The color of the cellophane was a normal blue shade. The polymer film was slightly tacky and sticky. The cucumber slice was moist, and in normal condition.

On the third day of observations the pH value and ammonia rate was 6 and 0ppm respectively. The color of the cellophane was dark purple and blue. The polymer film was wet, stretchy, slightly tacky, and was moisture absorbent. The cucumber was in its normal condition.

The fourth day of observations were skipped similar to the previous trial.

The fifth day of observations presented pH value and ammonia level was 6.6 and 0 PPM respectively. The color of the cellophane was blue and clear orange. The polymer film was smooth, had slight stickiness and was wet and cold. The cucumber had a normal smell, rougher texture on the inside and no signs of major spoilage.

The sixth day of observations were skipped similar to the last trial.

During the seventh day of observations the pH value and ammonia rate was 6.4 and 0ppm respectively. The color of the cellophane was blue and orange. The polymer film had an ombre of blue and clear orange and orange was present on the piece of cucumber. It was very delicate and slightly stretchy. The cucumber was dry and had a harsher smell. The moisture present on the container on the spoilage was not too strong.

The eighth day of observations presented pH value and ammonia rate 6.2 and 0ppm respectively. The color of the cell phone was clear orange and slightly blue. The polymer film had an ombre of both colors, was attached to the cucumber, very hard to remove from the cucumber, and was super delicate. The cucumber slice had a bad smell, was very dry and moisture was present on the container.

The ninth day of observations were skipped.

On the tenth day of observations the pH level and ammonia rate was 5.8 and 0ppm respectively. The color of the cellophane was pink, blue and orange. The cellophane was sticky and not as flexible as normal. The cucumber slice had a slimy surface, a top rough texture and a sour smell.

The eleventh day of observations were skipped, similar to the last trial.

On the twelfth day of observations the pH level and ammonia rate was 5.4 and 50ppm respectively. The color of the cellophane was pink and orange. The polymer film was fragile, thicker, had a few rips and uneven color patches. The cucumber had a mushy center and less water was observed.

The thirteenth day of observations were skipped.

During the fourteenth day of observations, the pH level and ammonia rate was 5 and 100ppm respectively. The color of the cell phone was light pink with slight fading. The polymer film had loss of elasticity, was thinned out, and not as flexible. The cucumber had wrinkled edges, heavy mush texture, and a strong smell.

Ultimately, during the fifteenth day of observations, the pH level and ammonia rate was 4.9 and 150ppm respectively. The color of the cell phone was pale pink with purple streaks. The polymer film was fragile, still slightly stretchy and had an uneven texture. The cucumber had a mushy and watery texture as well as a very strong acidic smell.

Trial 3 In-Fridge Cucumber

This trial was held for 15 days.

During the first phase of this trial, the pH level and ammonia rate was 6 and 0ppm respectively. The color of the cellophane was a dark purple and blue. The polymer film was soft, smooth, durable, but had limited elasticity. The cucumber was in normal, healthy condition.

Following, on the second day of this trial the pH value and ammonia rate was 5 and 0ppm respectively. The color of the cellophane was a clear, dark purple. The polymer film was smooth, tacky, and slightly sticky. The cucumber slice was slightly less moist, however, remained in normal condition.

On the third day of observations the pH value and ammonia rate was 5 and 0ppm respectively. The color of the cellophane was dark purple and clear orange. The polymer film was hard, durable, absorbent, and not as stretchy. The cucumber slice was in normal and healthy condition.

The fourth day of observations were skipped.

The fifth day of observations presented pH value and ammonia level 6.8 and 0ppm respectively. The color of the cellophane was orange and lighter blue. The polymer film was sticky, dry, slightly tacky, and presented various rips. The cucumber was dry, had a stronger smell, the container was foggy, and there was light moisture on the container.

The sixth day of observations were skipped, similar to the previous trials.

During the seventh day of observations the pH value and ammonia rate was 7 and 100ppm. The color of the cellophane was light orange and blue. The polymer film was stuck directly onto the cucumber, was flimsy, not as durable, and could not come off the cucumber itself. The cucumber slice had a bad smell, was dry, moisture was visible, and had a rough texture.

The eighth day of observations presented pH value and ammonia rate 7 and 150ppm. The color of the cellophane was clear orange and blue. The polymer film was smooth, thicker, sticky, and durable. The cucumber slice had a stronger, more acidic smell, was stuck to the cellophane, and had contorted onto the cellophane.

The ninth day of observations were skipped.

During the tenth day of observations, the pH and ammonia levels were 7 and 250ppm respectively. The color of the cellophane was purple and orange. The polymer film was soft, slightly fragile and stretchy. The cucumber slice had a clear spoilage odor and moisture was present in the container.

The eleventh day of observations were skipped similar to the previous trials.

During the twelfth day of observations, the pH and ammonia value was 6.7 and 400ppm respectively. The color of the cellophane was pink and purple. The polymer film was sticky, flexible, thinned out and had a few rips. The cucumber slice had a gray color and was soft and mushy.

The thirteenth day of observations were skipped.

On the fourteenth day of observation the pH value and ammonia level was 6 and 450ppm respectively. The color of the cellophane was pink with purple patches. The polymer film was slimy, had faded patches and tears. The cucumber slice had a slimy surface and a very strong odor.

During the fifteenth day of observations the pH value and ammonia presence was 5.8 and 500+ppm respectively. The color of the cellophane was a pale pink. The polymer film had lost structural integrity and duller areas were fragile and not as flexible. The cucumber slice was fully spoiled, had a strong acidic smell, a mushy texture and visible spoilage signs.

Trial 1 Out-Fridge Milk

This trial was held for a total of 5 days.

On the first day of observations, the pH had a value of 6.4 and an ammonia rate of 0ppm. The cellophane was smooth, soft, still durable, and was in good condition. The cellophane was a normal blue color with a slight white shade. The milk had a normal smell, was slightly purple, and the texture was smooth.

During the second phase of the trial the pH had decreased to 5 and the ammonia rate had increased to 100ppm with the cellophane color being pink and clear white. The cellophane was soft, but slightly textured, while still remaining durable. The milk had only minor changes as the texture had become slightly more chunky.

On the third day of observations the pH had remained at 5 as well as the ammonia rate of 100ppm. The color of the cellophane was clear white and had been contorted in a slight ball shape, and was very soft and flimsy, not as durable as before. Finally, the milk was chunky, had a bumpy texture, and produced a bad smell.

The fourth day of observations were skipped as there was no change at all.

Conclusively, the pH value and ammonia levels were 5 and 500ppm respectively. The cellophane color was solid white, and was directly attached to the bottom of the container, had a very clear white tint, and was hard to remove.

Trial 2 Out-Fridge Milk

This trial was also held for a total of 5 days.

During the start, the pH value was 6.5 and the ammonia was 0ppm. The color of the cellophane was blue and light white, was smooth, had a few dots of darker blue, was more absorbent and slightly more fragile. The milk was in normal condition, had a reasonable smell, and a liquidy texture.

On the second day of observation the pH value and ammonia was 6 and 0ppm respectively. The cellophane color was light pink. The observations taken were smooth, absorbent, and durable. The milk was in normal condition and was evident to not change much.

During the third day of observations the pH and ammonia values were 5 and 100ppm. The color of the cellophane was white, and the observations taken were that the color was not very visible, slight rips and degradation was visible in the milk chunkiness. The milk had a chunky texture, a pungent milk smell, and chunks were present to curdling.

The fourth day of observations were skipped due to unnoticeable changes in physical observations and data

Conclusively, on the fifth day of observations the pH value of 6 and the ammonia rate was 500ppm. The cellophane was white and slightly pink. Observations taken were that the polymer film was sticky, hard to remove, soft, and slight chunks were attached. The milk had resulted to be very spoiled, had a chunky texture and curdling was visible.

Trial 3 Out-Fridge Milk

This trial was observed for 5 days.

During the first day of observations the pH value was 6.6 and the ammonia presence was 0ppm. The color of the cellophane was blue and slightly white. The cellophane was very ripped, stuck to the container, however, was still smooth and thicker than the original. The milk had a slight purple dye, and was in normal condition with a liquidy texture.

On the second day of observation the pH value and ammonia rate was 6 and 0ppm respectively. The cellophane color was blue and slightly pink. According to the observations, the cellophane was slightly ripped but did not show major changes. The milk had slight purple dye, was still liquidy and did not show much change.

During the third day of observations the pH value was 5 and the ammonia was 100ppm. The color of the cellophane was pink and white and the following observations were made: the film was stuck in the milk, absorbent of the milk, and slightly fragile. The milk presented a bad smell, was still liquidy, and had visuals of rotting.

The fourth day of observations were skipped due to unnoticeable changes in physical observations and data.

Conclusively, on the fifth day of observations the pH value was 5 and the ammonia levels were 500ppm. The color of the cellophane was white. The polymer film was shaped as a ball after it was removed from the container, it produced the smell of the milk, and was very fragile. The milk had a yogurt like texture, a pungent smell was present, and the milk was curdled and chunky.

Trial 1 Out-Fridge Turkey

This trial was held for 5 days, with day 4 being skipped due to unnoticeable changes in observations.

On the first day of observations the pH value started at 7.3 and the ammonia rate 0ppm. The cellophane was purple and blue and the following observations were taken: the film was very flexible, stretchy, durable, and had better quality. The turkey was in normal condition, presented a normal smell, and had the usual amount of moisture content.

On the second day of observation the pH had a value of 6.5 and an ammonia level of 0ppm. The cellophane was blue and darker pink, the film was stretchy, slightly flimsy, and smooth. The turkey was very orange, had a strong smell, and had a slightly rougher texture.

During the third day of observations the pH value and ammonia levels were 6 and 0ppm respectively. The cellophane was a dark purple and had a very tough but strong texture, was smooth, slightly folded, durable, and sturdy. The turkey was a dark orange, produced a bad smell, and was completely spoiled.

The fourth day of observations were skipped due to unnoticeable changes in physical observations and data.

Conclusively, on the fifth day of observations the pH value was 6 and the ammonia was 100ppm. The cellophane was purple and pink, light fuzz was present around the film, the polymer cellophane was tacky, smooth, and not as flexible.

Trial 2 Out-Fridge Turkey

This trial was held for 5 days, with day 4 being skipped due to unnoticeable changes in observations.

During the first phase of observations the pH value started at 7 and the ammonia presence was at 0ppm. The cellophane was a clear blue shade, was soft, a little stiffer, had overall good durability, and elasticity. The turkey was in normal condition, had a good smell and good texture, not much change was present.

On the second day of observation the pH value was 6.5 and the ammonia level was 0ppm. The cellophane was blue and pink, had absorbance, was watery, and a little bumpy. The turkey was drier, less strong, and more orange.

During the third day of observations the pH was 5 and the ammonia was 0ppm. The cellophane was dark blue and purple, was smooth, absorbant, had no rips, was pretty stable, with only a few folds, and remained in good condition.

The fourth day of observations were skipped due to unnoticeable changes in physical observations and data.

Conclusively, on the fifth day of observations the pH and ammonia was 5.8 and 100ppm respectively. The cellophane was purple and orange. The polymer film itself was very thinned out, was somewhat flexible, and had a smooth texture. The turkey itself had a detergent-like smell, a very dry texture, and remained moist.

Trial 3 Out-Fridge Turkey

This trial was held for 5 days, with day 4 being skipped due to unnoticeable changes in observations.

During the first phase of observations the pH value was 7.4 and the ammonia was at 0ppm. The color of the cellophane was blue and had a slight pink fade. The polymer film was stretchy, absorbent, little stickier, however durable. The turkey was in normal conditions and released a normal smell.

On the second day of observation the pH and ammonia levels were 7 and 0ppm. The color of the cellophane was light blue and pink, was stretchy, flexible, and overall was in a stable condition. The turkey was smooth, presented a good smell, and not much change was visible.

During the third day of observations the pH was 6 and the ammonia was at 0ppm. The cellophane was dark purple. It identified characteristics of slight ball shaped contortion, was hard to remove from the turkey, little more flimsy, and absorbent. The turkey had some purple dye on it, was orange, the pieces had shrunk, and an acidic smell was detectable.

The fourth day of observations were skipped due to unnoticeable changes in physical observations and data.

Conclusively, on the fifth day of observations the pH and ammonia levels were 6.8 and 0ppm respectively. The polymer film was light orange and purple. The cellophane had a few rips, was slightly stretchy, in normal condition, and was not too degraded. The turkey had grey fuzz surrounding it and a light blue dot on the turkey, it was very dry, and released a strongly acidic smell.

Trial 1 Out-Fridge Cucumber

This trial was held for 5 days, with day 4 being skipped due to unnoticeable changes in observations.

During the first phase of observations the pH value was 6 and the ammonia level was 0ppm. The color of the cellophane blue with a slight fade. The observations taken from the cellophane were soft, smooth, durable, and had an overall strong condition. The cucumber was in normal condition, however, was slightly more dry.

On the second day of observation pH value and the ammonia level was 5.6 and 0ppm respectively. The color of the cellophane was blue and purple with slight fade. The following observations were that the film was durable, a little more moist, was sturdy, and had slightly taken the smell of the cucumber slice. The food product was dry, and produced a stronger smell, yet, not rotten.

During the third day of observations the pH value and the ammonia level was 5.4 and 0ppm respectively. The polymer film was dark purple. It was soft, squishy, not as stretchy but still durable and strong. The cucumber had orange color shades, a strong acidic smell, and a more dry texture.

The fourth day of observations were skipped due to unnoticeable changes in physical observations and data.

Conclusively, on the fifth day of observations the pH value and the ammonia level was 5 and 20ppm respectively. The cellophane color was orange and purple. Slight rips, lack of moisture, thinning and lack of flexibility were observed from the cellophane. The cucumber was very dry, and had a normal to acidic smell.

Trial 2 Out-Fridge Cucumber

This trial was held for 5 days, with day 4 being skipped due to unnoticeable changes in observations.

During the first phase of observations the pH value and ammonia level was 6.4 and 0ppm respectively. The color of the cellophane was blue with a light fade. The polymer film had the following observations: soft, cold, absorbent, and sticky. The cucumber was a little more dry, and was in an overall normal condition, with moisture only filling the container.

On the second day of observation the pH value and ammonia level was 6 and 0ppm respectively. The color of the cellophane was blue and purple. The polymer film had the following observations: very flimsy, soft, smooth, and had a strong smell. The cucumber had a normal smell, presented less moisture value, and was in an overall good condition.

During the third day of observations the pH value and ammonia level was once again 6 and 0ppm respectively. The color of the cellophane was half clear and half purple. The polymer film had the following observations: attachment to the cucumber slice, and a tinted part of the cucumber was covered by the cellophane. The cucumber was tinted orange, dry, presented less moisture, and had a slightly strong smell.

The fourth day of observations were skipped due to unnoticeable changes in physical observations and data.

Conclusively, on the fifth day of observations the pH value and ammonia level was 5 and 0ppm respectively. The color of the cellophane was orange and purple. The polymer film had the following observations: light fuzz surrounding the film was durable, not as flexible, and was attached to the cucumber slice. The cucumber had a much more acidic smell, and presented a dry texture with less moisture present.

Trial 3 Out-Fridge Cucumber

This trial was held for 5 days, with day 4 being skipped due to unnoticeable changes in observations.

During the first phase of observations the pH value and ammonia rate was 6 and 0ppm respectively. The shade of the polymer film was blue and had a slight fade of color. The cellophane was ripped into two pieces, still durable, and flexible. The cucumber was a little dry, in good condition, and the middle had some orange dips.

On the second day of observation the pH value and ammonia rate was 5.5 and 0ppm respectively. The shade of the polymer film was blue, purple, and had a slight color fade. The cellophane had a few rips, was flimsier, and had looked more absorbent. The cucumber slice was coerced in an orange tone, drier than normal, and maintained a stable usual smell.

During the third day of observations the pH value and ammonia rate was 5.4 and 0ppm. The cellophane was completely attached to the cucumber, however still soft and flexible from the corners. The cucumber released a stronger rotting smell, had an orange tint, and was very rough and dry.

The fourth day of observations were skipped due to unnoticeable changes in physical observations and data.

Conclusively, on the fifth day of observations the pH value and ammonia rate was 5 and 20ppm respectively. The shade of the polymer film was completely orange, with fade present. The cellophane was sticky, the color was obvious, and had lightly contorted into the cucumber. The cucumber presented a very strong acidic rotting smell, was still moist on the inside, and dry on the outside.

Analysis:

Cellophane Trial 1 vs. Cellophane Trial 2

Both films had different effects and results for the reason that they both had different concentrates of glycerin and red cabbage indicator. Glycerin functions as a plasticizer, which increases the overall flexibility of the film and reduces crumbling, allowing for the polymer chains to openly move without restriction. Using this inference, trial 1 contained less glycerin, thus, reducing flexibility, and allowing for brittleness especially under the circumstances of a dry environment. With the brittleness and lack of glycerin, this creates more struggling when handling because of the tearing of the polymer film. The

decreased amount of indicator concentration weakened the initial color intensity, resulting in the fast fading due to moisture exposure, and diffusion of pigment. The trial one cellophane presented more struggle to maintain color and ensure as minimal fade as possible. Trial two, while set in the fridge, the cellophane was striving, as the color was strong, visible, less sticky, and easy to remove. Unlike trial one, trial two remained stable much of the in fridge duration, although absorbent of liquid and an increase in thickness.

In-Fridge vs. Out of Fridge

Both out-fridge and in-fridge cellophane observations had different results, affecting the way the cellophane changed color and the overall quality. The out of fridge cellophane degraded faster due to higher temperature within the polymer chain, faster weakening of bonds of molecules, and increased moisture absorbance. Oftentimes when the film stuck to the food, it was for the reason that the heat would soften the biopolymer matrix of the film composition and the absorbance of the water made it much tackier. Following, the fading and discoloration present was caused by excessive amounts of moisture absorbency, therefore diluting the anthocyanins that cause the color change. This issue of absorption and moisture gathering resulted in uneven color pigmentation throughout the surface of the cellophane. In contradiction, the in-fridge cellophane had slower degradation due to lower temperatures, this also reduced moisture uptake, preventing contortion of the biopolymer structure. The improved smoothness and flexibility of the cellophane that was observed happened because stronger hydrogen bonding within the polymer chain network. The minimal amount of heat avoided thermal stress on the film composition itself. Because of the controlled exposure to spoilage gasses when in the fridge, stronger color identification and intensity was observed, resulting in slower pigmentation breakdown. As observed before, the reduced odor present while observations were taken in the fridge was because there was less microbial activity and a slower release of evaporated compounds.

Cellophane Trial 1 Observations

Analysis In-Fridge Milk

Throughout trials 1-3 of cellophane trial 1, each had a specific average in color, pH, ammonia, and overall quality of the milk product.

On the day one and two of all trials, the milk was still at an early stage with an average of pH 6-6.3. The pH had remained close to the normal pH of milk because milk is originally slightly acidic. When placed in the fridge, limited bacterial activity is present because of low temperature. The ammonia ranges from 0-100ppm, which is particularly low because no protein has significantly broken down because the cold temperatures had slowed down the bacterial enzyme action. The cellophane color itself had turned white because the high moisture content had completely diluted the anthocyanin content in the film. The absorption of the milk had dominated over the pH driven indicator. According to observations, the film was thicker and slippery, this happened because the biopolymer film (gelatin/starch) was absorbed into the liquid. The hydrogen bonding in the film had increased the swelling, resulting in the film to be thicker than the original.

On day three of observations, the middle stage, the pH had changed very little, remaining at an average of 6, this happened because the milk had still been resisting the rapid pH shifts. The ammonia had increased to an average ammonia level of 200ppm. This occurred because the protein decomposition started to produce ammonia and amines, which is the organic compound derived from ammonia itself.

The film became sticky and had tears because the excess moisture weakened the polymer chain, supporting the film composition. The mechanical stress put on the biopolymer film had produced from the swelling which caused the rips in the structure of the film. Eventually, the odor became stronger because of the nitrogen compounds which were absorbed by the film.

Finally on day four and five, the ammonia rose rapidly with an average of 430-500ppm because the protein breakdown had accelerated and increased bacterial metabolism, although maintained in a cold temperature. The pH average had slightly dropped to 5-5.6 because the lactic acid production had increased. The cellophane color had remained white instead of turning to green because the moisture interference overpowered the pH response derived by the anthocyanins. Therefore, the anthocyanins had leached or degraded in wet conditions. The film composition itself had stayed durable, however not as flexible. This took place because the plasticizer distribution and structural integrity remained, however the elasticity decreased. In the cellophane itself, strong smells were trapped in the film because of the porous matrix of the cellophane which absorbed the gas compounds.

Analysis In-Fridge Turkey

During the early stage of the observations (days one to six) the ammonia level had remained at 0ppm because the turkey was still microbiologically stable, the cold temperatures had slowed protein breakdown, and the spoilage bacteria had not yet produced any unsafe nitrogenous gases. The average pH was 6.5-7, this was because the turkey still had buffering capacity, avoiding major change in bacterial action. The indicator had remained blue and purple because it was in a normal pH environment, and that no ammonia gas was present to shift the indicator color. The cellophane composition had become moist and stretchy because the meat released water vapour inside the container, therefore, the film had absorbed moisture, increasing flexibility and thickness. Ultimately, the turkey had shown a stronger smell without spoilage because normal protein and fat odors had intensified because of the closed space where the food item had been placed. No ammonia or sulfur compounds had been found, for this reason, no spoilage had been detected.

From day eight to ten, also known as the middle or transition change, the pH began to increase from 7 to 8 as average, this happened because as a sign of early protein degradation which is released by basic compounds. Another reason for the increase in pH may happen due to the enzymatic activity increased, although placed in cold temperatures. Although the ammonia is similar and low or delayed, it often is lagged in production behind the early spoilage process. The volatile amines accumulate slowly in cold conditions, therefore limiting the range of ammonia per day. From the color average collected by data, purple, yellow, and orange, the range of colors was presented because of the uneven exposure to basic gases and the moisture interference which causes the partial color blending. The film had thinned out and became flimsy because of the capture of prolonged moisture exposure, which weakened the polymer cross link. The glycerin reduction reduced the structural strength of the polymer composition. The turkey itself became drier and tackier because of protein denaturation which is the loss of proteins and moisture redistribution. The surface had signs of dehydration although condensation was observed in the container.

During the late stages, day eleven to fourteen, the ammonia was sharp and had increased from 100-200ppm, once again this is because of protein breakdown intensification, spoilage bacteria which released amines and ammonia, and the cold temperatures slowed down, however did not stop microbial

metabolism. During this last phase, the pH had significantly risen to 9 and 9.5 values as an average. This resulted in an increase in pH because of the accumulation of nitrogen compounds.

Analysis In-Fridge Cucumber

The initial starting points of all the trials had averaged a pH across 6.2 to 6.5 this is the normal rate for fresh cucumbers which are slightly acidic. From days 1 to 6 the pH had stayed between 6 to 7 which indicates minimum microbial activity and the refrigeration that had slowed down the enzymatic breakdown of the cucumber. From days 8 to 10 the pH had begun to rise sharply from seven to eight and nine this was caused by the cellular breakdown of tissue and the release of basic nitrogen compounds. Lastly, during days 11 to 14 the pH had stabilized from 9 to 9.5 which indicates advanced spoilage. Finally, these stable patterns had gradually increased showing alkaline dominance.

From days 1 to 7 the ammonia trend had had a stable value of 0ppm this confirms that there was low protein degradation. From days eight to nine there was a small detection of approximately 5ppm which is a sign of early microbial metabolism that begins. From days 10 to 14 there was a rapid rise to 400 to 500+ppm this is caused by the breakdown of plant proteins and amino acids as well as the activity of spoilage and bacteria. The overall average trend of the ammonia started at a delayed onset and then later on became a rapid rise.

During the early phases approximately day 1 to 4 the color of the cellophane was a faded blue and clear blue shade. This indicates that the solution was neutral to a mildly acidic environment. On the mid face from Days 5 to 7:00 it had an approximate color of orange turquoise or purple undertones. This suggests that moisture absorption had mixed with the pH microzones. Next, during the transition phase, days 8 to 10, the color of the cell phone was blue and yellow along with orange combinations. This indicates that there was rising alkalinity and that there was ammonia vapor interaction. Ultimately, during the final phase, days 11:14, the color of the cellophane was green and yellow along with blue undertones, this indicated that there was high pH and a high ammonia concentration. Conclusively, the color change was gradual and consistent and less abrupt than the meat or milk.

The cellophane conditions had an average trend starting from very flexible and smooth to more sticky and fragile. During the early stages of the cellophane observations it started as flexible, smooth and durable because of the minimum moisture stress. Once it became the mid-stage of the observations it became more wet absorbent and sticky this is because the plant moisture had weakened the polymer structure. conclusively during the last stage it became fragile, slimy, ripped and thin. This was caused by the continuous moisture exposure, the acid base cycling and the ammonia polymer interactions. The reasoning for the attachment to the Cucumber had increased over time because of the surface sugars and the cell wall breakdown.

The overall changes of the Cucumber was at the beginning during days 1 to 5 it was fresh, moist and firm with minor dehydration at the edges. During day 6 to 9 the texture became rougher and drier externally because of the moisture that was accumulated and the container. From days 10 to 12 there was a slimy interior that produced a sour and vegetable odor which indicates that the cell wall had ruptured. During days 13 to 14 it had wrinkled, shrunken, and became mushy. It had a strong pungent smell that is evident to the advanced microbial spoilage. The spoilage of the Cucumber was slower than the turkey because the more moisture is protein derived.

Analysis Out-Fridge Milk

On the first day of observations it was found that there was immediate spoilage where the milk had already increased to an ammonia rate of 400ppm this was because the milk contained High proteins which rapidly break down at room temperature. The warm conditions around the milk had accelerated bacterial enzyme activity and the ammonia and amines were released almost immediately. The pH reading average was inconsistent ranging from 5 to 7. This was because the lactic acid production lowered the pH of the ammonia production and raised a pH therefore creating unstable and fluctuating pH values. Instead of the indicator turning green or yellow it had turned white, this is because of the excessive liquid contact that overwhelmed the gas based pH response. The anthocyanin pigment was diluted and leached by the milk, the high ammonia and high moisture caused color bleaching which created an unclear shift in the pH. The film had become thick and fragile and stringy because of the rapid water absorption that swelled by a polymer. Proteins and fats from the milk bound to the gelatin and starch matrix therefore the structural bond weakened almost immediately.

During the acceleration phase, days two and three, the ammonia had stabilized near or above 500ppm, this is because the peak protein decomposition was reached and the continuous release of ammonia had saturated the container. The pH had dropped towards 5 despite the high ammonia this is because the lactic acid bacteria had dominated the liquid chemistry where the acid production had outweighed the basic gas influence in direct contact to the film. The indicator had remained white throughout because the anthocyanins degraded under warm temperature, acid, liquid exposure, and oxidation. The indicator had to respond more to physical degradation than the chemistry. The film itself had been ripped, stuck and embedded into the milk because of the swelling caused by the mechanical stress and the milk curds had trapped the film. Strong odors were absorbed and retained because of the poorest polymer matrix that trapped the sulfur and nitrogen compounds, the film acted as an older sponge rather than a sensor alone.

Conclusively during the late stage, day 4, the ammonia had exceeded 500ppm consistently, this is where a complete breakdown of the milk proteins happen and advanced spoilage bacteria had dominated the cellophane system. The pH had approximately stabilized at an average of 4 to 5 because of the acidic fermentation which reached equilibrium. The gray and blue fuzz that had appeared on the film was because of the warm nutrient-rich moist environment the biopolymer film served as a microbial substrate which had sucked in the nutrients. At this point in time, the indicator accuracy had failed because of the light liquid exposure and validated gas-based sensing and the pigmentation degradation which prevented reliable color signaling, the structural damage had eliminated the overall consistency of the cellophane. Ultimately, from the result of spoilage breakdown the milk had become a solid layered and discolored form where fat and proteins had separated and the contact with indicator had altered its overall appearance.

Analysis Out-Fridge Turkey

At the start of the early stages of observations, days one and two there was a delayed spoilage. The ammonia had remained at 0ppm during early days, this is because the fresh turkey spoilage had begun with aerobic bacteria which initially produces amines and acids not ammonia. The protein breakdown had not yet progressed to advanced deamination, which is the removal of amino groups from a molecule, compared to the milk the turkey proteins degraded more slowly at first. The pH had remained near neutral from 7 to 7.5, the fresh meat had a buffering capacity therefore early bacterial activity was

minimal on the impact of the pH. The lack of ammonia production prevented the pH from increasing. The indicator showed mixed colors including pink, blue and purple because the anthocyanin indicators responded gradually to the evaporated gases. Below gas concentration causes partial color expression therefore making the film uneven. The film was soft stretchy and moist because of the water vapor from the turkey that had hydrated the polymer, the glycerin plasticizer had increased flexibility and limited the chemical stress as this stage preserved structure.

During the mid stage of observations, days two and three with the protein decomposition beginning. The pH had suddenly increased to an average of 9 this is where protein degradation had released the basic nitrogen compounds. the ammonia our mind accumulated before the full ammonia detection therefore alkaline by-products had overrun the meat buffering system. The ammonia had appeared at an average of 150ppm, which was released more slowly than the liquid dairy. At this point in time, the spoilage bacteria had reached its exponential growth phase. Vindicator itself had shifted towards yellow and blue because the anthocyanins had turned yellow in its basic environment. The increasing ammonia concentrate had altered the gas phase pH therefore uneven exposure had caused dual or layered coloration. The film had slight contortion of rips attachment to the food product and became harder to remove because of the moisture absorption which caused swelling and the meat protein to adhere to the polymer surfaces the overall mechanical stress from the swelling had caused tearing.

Conclusively, on the last stage, the fourth day, was the advanced spoilage, the ammonia had to stabilize around 150ppm instead of rising further. This system had reached equilibrium between production and release. The measurement strip detection limit may have capped readings. The pH had remained consistently high at an average of 9 the ammonia had dominated the chemical environment therefore the alkaline by-products had accumulated faster than the acidic ones. Gray and blue fuzz had appeared on the film because of the warm, moist, protein rich environment. The cellophane acted as a nutrient surface which extended the exposure allowing for fungal colonization. The film had become sticky, rough and had less elasticity because the glycerin leaching had reduced the flexibility and the microbial growth had altered the surface texture. The overall pigmentation degradation had weakened the polymer matrix.

Analysis Out-Fridge Cucumber

In the early stage of these trials, day one, the pH had an average of 7 to 7.4. At this point in time the cucumber was fresh and had a close to neutral pH value, therefore not significant microbial spoilage had happened yet. The ammonia had remained at 0ppm, firstly because there was no spoilage, secondly, because cucumbers are a low protein foods, and thirdly, the spoilage does not produce ammonia unlike meats and dairy. The indicator colors were blue, purple, and light orange because of the slight variability on the cucumber's surface, the moisture interaction which dilutes the anthocyanin colors, and the color change was driven by the water contact more than the gas exposure. The cellophane had become sticky early on because of the high water content of the cucumber which was spread into the biopolymer. The gelatin and starch biopolymer ingredients had absorbed moisture rapidly at room temperatures. Conclusively, the cucumber felt stiff and dry because of the moisture that had migrated front the film and cucumber into the air in the container.

During the middle stage, days two and three the pH had slightly increased from 7 to 7.8 on average. This happened because of the breakdown of plant cell walls that released basic compounds. This resulted in the loss of organic acids due to evaporation. The ammonia average had remained at 0ppm

because the plant spoilage does not involve proteins from amino molecules. This confirms that ammonia is not a reliable spoilage marker for this produce. Orange tones, although an indicator for spoilage, often diluted the anthocyanin color because of dilution, oxidation or weathering, and the exposure to moisture. Grey and blue fuzzy dots appeared on the film itself because mold growth was encouraged onto it because of the warm temperatures, high humidity, and the nutrients which were trapped in the biopolymer film. The film was slightly stuck to the cucumber and tore for the reason that the polymer swelling had weakened the structure, the adhesion started to increase as water had softened both surfaces, therefore, this mechanical stress caused ripping during handling and taking observations.

During the late stage, day 4, the pH had approximately stabilized at 8. The equilibrium or balance had reached between moisture loss and microbial activity. No ammonia production was present to drive further increase in spoilage. Although the main color change was supposed to be green and yellow, it had instead changed to pink and blue because of the moisture that had dominated the pH response. Black and grey fuzz had appeared because of the active mold colonization on the food and the film. The bipolymer acted as a nutrient source to the mold. Conclusively, the cucumber had appeared to have melted in the centre because of the enzymatic breakdown of the plant cell wall and loss of internal structure and water distribution.

Cellophane Trial 2 Observations

Analysis In-Fridge Milk

From days six to seven of these trials, the pH had averaged from 6.4-6.7. These pH values are normal rates for fresh milk. There were only minor fluctuations between days six and seven because the bacterial metabolism had been slowed, producing only small amounts of acids and bases. From days 9 to 10, the pH had a sharp drop going from 4 to 5 due to the lactic acid bacteria fermenting into lactic acid. This indicates advanced spoilage and curdling. The overall trend between the days was during the early stages it had a stable trend and during the late stage it had a sudden acidic shift.

Following, from days one to six the ammonia had remained at 0ppm, this indicates that there was minimal protein breakdown because milk proteins had remained mostly intact. Suddenly, around day 7 to 8, the ammonia had suddenly increased to 200ppm on average because of the protein degradation from bacterial enzymes. Finally, from Days 9 to 10 there was a rapid spike of an average of 300 to 500 plus PPM of ammonia, this is strong evidence of advanced spoilage. The amino acids had been breaking down into ammonia-containing compounds.

During the early days of observations the self and color had remained white or a clear light because it indicates the neutral pH and that there were no strong volatile gases. Once the mid-stage hit between day seven to eight it also remained mostly white despite the ammonia presence, this is because the refrigeration had limited the amount of gas diffusion. Finally, during the final days it had shifted to a pale pink and pink white because of the acidic environment and the presence of ammonia vapors that were interacting with the indicator. Conclusively the color change was a little bit delayed and subtle because of the absorption of milk into the cellophane biopolymer itself.

Over time, the cellophane had degraded, become more fragile and had contorted. In the early phases of the observations the cellophane had remained durable, flexible and smooth because of the minimum moisture absorption. During the middle phase it became more wet, folded and slightly absorbent because of the exposure to the milk moisture which weakened the polymer bonds. Lastly,

during the late phase it was fragile, sticky, and slimy. This resulted in rips and adhesion to the Container bottom which created loss of elasticity and flexibility due to acid exposure, high moisture, and ammonia interaction.

Analysis In-Fridge Turkey

As Time increased, microbiome activity increased. The bacteria on the turkey had broken down into proteins and amino acids. This process released basic byproducts, especially ammonia. by-products are unwanted substances that are produced when microorganisms digest food because of chemical reactions. The ammonia change has called the pH rise from acidic around 5.8 to 6.2 to basic 8 to 8.8. The overall polymer cellophane integration was driven by the moisture and the ammonia presence. The moisture absorption had to soften the film and the ammonia had chemically weakened the polymer bonds. This caused the physical observation of rips, stickiness, loss of elasticity, and thinning over time.

During the early stages, also known as the fresh or stable phases, from Days 1 to 5, it started at a low pH of 5.8 to 6.2. In this case, the turkey proteins were still intact, evident to the minimal bacterial decomposition. During this stage, the cellophane color was dark purple and blue which indicates a more acidic environment. The strong dye concentration caused the deep uniform color. Within a short amount of time, the polymer quality was thick, flexible, durable, and smooth. This is because there was no chemical stress from any ammonia yet. The turkey condition was in normal texture, color, smell, and moisture presence. The refrigeration has slowed down bacterial growth and the lack of ammonia meant there was no alkaline shift therefore the polymer structure remained chemically stable.

During the midstages also known as the active decomposition phase, from days 7 to 10 the pH began rising from 6.4 to 7 approximately. This identified that protein breakdown had released nitrogen compounds along the ammonia to appear at a rate from 20 to 100ppm. The cell phone color had shifted from pink, blue and green, or just green. These mixed colors show the fluctuating pH zones depending on the trial. The uneven dye intensity was due to the moisture absorption and the container themselves. The polymer film became tacky and thicker because of the liquid absorption. The rips and holes formed as the ammonia weaken the bond because some areas showed stronger color due to uneven exposure. At this rate, the turkey had been identified to have stronger and unpleasant odor as well as light slime formation and the texture had softened and became more sticky. This happened because the bacterial enzymes had actively broken down proteins and the ammonia gas had accumulated and the container. The moisture had condensed which allowed the acceleration of the polymer breakdown.

Finally, during the late stages, Days 12 to 15 also known as the advanced Voyage phase, the pH had a high average of 7.5 to 8.8 and a high ammonia of 150 to 450 ppm. This happened because of the dominance of spoilage bacteria and the strong alkaline environment. The cellophane color had ranged from green to yellow and green because of the clear indication of basic conditions. The fading blue and purple undertones showed the amount of dye degradation of the red cabbage indicator. The polymer decoloration over this phase of time was that there was loss of elasticity and stretch. The slimy gelatin-like texture and the fragile characteristics that caused easy rips were all due to chemical stresses from ammonia which disrupted polymer chains.

All of these changes happened due to high ammonia which chemically attacked the polymer. The moisture and heat inside the container had also accelerated the reactions, these were all evident of the advanced microbiome metabolism which caused the severe protein decay.

Analysis In-Fridge Cucumber

Cucumbers spoil quite differently than turkey because cucumbers include a high water content, low protein and are more acidic vegetables. Ammonia forms only once microbes become breaking down minor nitrogen compounds therefore cucumbers tend to break down slower. The levels of ammonia in a cucumber rise later when turkey and coexist with acid byproducts this causes the indicator color to change from pink green and blue sometimes incorporating all three. Cellophane degradation is driven by Moisture cycling and cucumbers repeatedly release and reabsorb water this causes the cell phone to become sticky to curl to spread uneven thickness and for the film to stick on the food product.

During the early stages days one to three, this was the fresh and stable phase observed across all trials. The pH was an approximate value of 5 to 6.5 and the ammonia rate remained at 0ppm. The cellophane colors were blue, purple and teal and the cucumber condition was fresh wet and was in an overall normal condition. The change of the pH and ammonia happen because the cucumbers naturally release slightly acidic juices. However, there was no protein decomposition therefore no ammonia had been released yet. Using this statement as evidence, the red cabbage indicator had stayed in acidic to a neutral range with colors blue and purple. The polymer remained stretchy, flexible and structurally intact.

Throughout the mid early stage from Days 5 to 7:00 this was where moisture stress and text or breakdown took place. the chemical changes and pH fluctuated between 6.4 to 6.8 as an approximate value. The ammonia was still at 0ppm except trial 3, but indicator colors were teal, green, blue and had hints of orange. The pH had fluctuated because of the cell respiration and microbial fermentation which released organic acid. Cell respiration is the essential metabolic process where cells break down nutrients and glucose and the presence of oxygen. Because of the moisture absorption this causes stickiness, small rips and loss of elasticity to the polymer film. The film stuck to the cucumber due to the surface sugars and the condensed moisture acting like glue. Finally, the cucumbers' physical changes were dry edges and a wet interior and a rough texture. It also produced a stronger vegetable or acidic smell.

Following, during the transition stage from Days 8 to 10 this is where the early spoilage had begun. The chemical indicator is where the pH started to trend downwards from an average of 6.2 to 5.8 the first appearance of this was the slime on top of the food. Although these observations were taken, the ammonia was still low or even absent. The cellophane color itself had mixed blue, purple , green and pink. This happened because of the acidic fermentation which dominates and the small ammonia pockets which slowly raise the pH. This indicator shows the overlapping colors because of moisture absorption and the blend of the dye. During the stage, the polymer was sticky on the cucumber side and dryer on the exposed side. The polymer film itself was less stretchy due to the chemical stress and uneven moisture loss, it was hard to remove because the film had softened and molded into the cucumber surface.

Nearing the end, the late stage from days 12 to 15 was a stage where Advanced spoilage and structural failure came in hand. The chemical breakdown had the pH dropping further from an approximate value of 5.4 to 4.9. The ammonia had risen from 50 to 500+ ppm. This showed the coexistence of the acidic fermentation products and the late stage nitrogen breakdown. This combo happened because the Cucumbers fermented first which is an acidic process and only later did the microbes produce the ammonia, unlike the turkey the acids dominate preventing the pH from majorly rising. The indicator color analysis ranged from pink to pale pink to teal. This provided us with the information that there was a strong acidity because of the pink color and still remained in the neutral zones because of the teal and blue color. The lack of yellow color confirms that there was not enough of a strong alkaline environment and the spoilage is driven by fermentation and not protein-driven. Although

the polymer film had lasted a long time, during the last few days it had degraded and lost elasticity because the polymer chains were weakened by the acid and moisture. The slimy texture had developed because of the cucumber and the ammonia had softened the structure. The curling edges of the cellophane provided us with the evidence that there was uneven drying within the container. Finally, the tears and uneven thickness was because of the mechanical stress and chemical degradation.

Analysis Out-Fridge Milk

On day 1 of the observations the average pH throughout the 3 trials was an average of 6.5 this is the normal pH range for fresh milk therefore showing no major changes in spoilage. During days 2 and 3 the pH had rapidly dropped to an approximate value of 5, this was caused by the rapid bacterial fermentation and the conversion of lactose to lactic acid. On day 5 the pH had stabilized around the same amount of five, this indicates that the acid production has peaked and that the environment has become restrictive to further acid producing bacteria. The overall trend was that there was a very fast acidification due to the lack of refrigeration.

At the start of observations from days one to two the three trials represented the same ammonia value of 0ppm, this was the early spoilage dominated by the acid producing bacteria. On day 3 the Amami had increased to an approximate value of 100ppm this indicates the beginning of protein breakdown. Finally, on day 5 it had risen to an average value of 500ppm, this was caused by the proteolysis of milk proteins which are the release of ammonia from amino acids and the chemical breakdown of the milk.

Throughout the first day of observations to self in color was blue with the white tint this indicates that there were neutral conditions. During days 2 and 3 the color was pink and clear right this is the response to decreasing pH and early ammonia presence. On day 5 it was solid white or white and pink, this is because of the high ammonia concentration and the saturation of the indicator dyes because of the moisture absorption of the milk. Overall, the color shifts were fast and abrupt which strongly matched the chemical changes in the milk, however because of the milk absorption the color had faded very speedily making the color presence more faded.

The cellophane condition itself during the early stages was smooth, soft and durable. During the mid-stage it became more observant and fragile which also caused contortion this happened because of the high moisture and the acid exposure. During the final stage, it was sticky, fragile and had attached to the container, this was caused by protein binding and the ammonia-induced weakening. The ball shaped deformation that was present within two of the trials indicates the loss of the polymer structure.

Conclusively, on day one the milk had a normal smell and was smooth and liquidy. On days two to three the chunking had begun and bad orders were developed this is caused by the low pH. On day 5 the milk was curdled and had a yogurt like texture and an extremely pungent smell which was evident to advance spoilage. The milk had changed much faster than the in fridge milk due to the uncontrolled microbial growth by the high temperatures.

Analysis Out-Fridge Turkey

Starting at the common pH scale which from day one had started at an average pH from 7.2 to 7.4, this indicated that the fresh deli turkey was natural and near neutral. From days 2 and 3 there was a gradual decrease of pH to an approximate value of 6 which was caused by the growth of the spoilage bacteria and the production of organic acids from the protein and sugar breakdown. On day 5 the approximate pH value ranged from 5.8 to 6.8, it had a different variability which was caused by the

differences in microbial activity and the early mold growth in some trials. The overall trend was that there was slow acidification compared to the milk because the turkey spoilage is protein dominated.

Following, from days one to three the ammonia levels were directly at 0 PPM this is because the early switch had been dominated by the acid production and not protein deamination. On day 5 it had abruptly increased to 100ppm, this was caused by protein breakdown on the release from amino acid. Trial three, however, had remained at 0ppm because of the faster mold dominant over ammonia producing bacterias.

On day 1 of the observed cellophane the color was blue and purple which indicates the neutral the slightly basic environment. On days 2 and 3 it was a dark purple and blue pink because of their response to the pH decrease and the moist protein contact. On day 5 the tones were purple, pink, and orange. This was caused by the mixed pH conditions, the low level ammonia exposure, and the moisture saturation of the indicator. Overall the turkey had produced a less dramatic color shift than the milk.

During the early stages of the cellophane condition it was stretchy, flexible and durable. During the mid-stage it became more absorbent, folded and tacky due to the moisture absorption from the meat and the acid exposure. Lastly during the final stages it thinned out, became sticky and had some rips as well as a light fuzz which was present in some trials that was caused by mold growth and protein adherence. The structural damage was much less to the milk due to lower acidity.

Analysis Out-Fridge Cucumber

On day 1 of all three trials the pH had averaged at 6.1, this identified that the Cucumber was still fresh and naturally and slightly acidic. During days two and three there was a gradual decrease of pH from 5.4 to 5.6 approximately, this was caused by the microbiome respiration and the production of organic acid. Microbial respiration is when oxygen is consumed, producing energy, heat, and metabolic byproducts such as CO₂. On day 5 the final average pH was 5, which indicates that there was advanced acidic spoilage. The overall trend was that it was a steady acidification which is slower than the milk but faster than the turkey.

Starting from days 1 to 3 the average ammonia trend was 0ppm, this shows that the cucumber contained low protein and minimal ammonia formation. On day 5 there was a small increase of ammonia from approximately 13 to 20ppm this was caused by the limited microbial breakdown of plant protein. Overall, there was a very low ammonia production confirming non-protein-based spoilage.

The cellophane color of the outfridge Cucumber had an overall color change that was gradual and consistent. On day 1 it started with a blue with slightly fading color that indicates the mild acidity to neutral ph. from days two to three the colors were from blue purple and dark purple showing the increasing acidity. On day 5 the cellophane was purple and orange, which indicates the strong acidic conditions and minor ammonia interaction in later stages.

During the early stages the self and physical condition started as soft and flexible. During the mid stages it became more absorbent, sticky and attached because of the moisture migration and the acid exposure which weakened the polymer structure. Finally during the final stage there were lots of thinning rips and reduced flexibility and even light fuzz in trial two. This is because of the overall integration which was moderate and less severe than the milk.

The indicator had a strong response to the pH decrease however a weak response to the ammonia due to the low amounts of protein the best detection was in the late splits changes because the color change was reliable on high for acidity and low for ammonia.

Conclusion:

In conclusion, this project has covered the final development of responsive cellophane films for real time spoilage detection. Data has been collected to ensure the correction of observation and research, based on refrigeration, food type, reliability, limitations, differences between trials, patterns, trial 1 cellophane vs, trial 2 cellophane, real world applications, indicator analysis, and the final takeaway.

Refrigeration effect

Overall, refrigeration has slowed down the physical degradation of the cellophane and the food allowing for the indicator film to give more accurate results and to remain intact for a longer period of time. The cold temperature and darkness in the fridge environment ensure the reduction of exposure to heat and light which help preserve the molecular structure of the bio polymer film and the natural indicator stored within it. The in the fridge cellophane showed much stronger results and color stability with less fading which improved the visibility and reliability of the cellophane polymer film itself. Because of the lower temperature stored inside the fridge this slowed down the bacterial activity inside the food which delayed the ammonia and the acid gases that were being released, still allowing for gradual detection and strength and color reliability. Those of the cellophane that were sitting in the refrigerator had degraded evenly and were less sticky, flimsy and torn compared to those out of the fridge. The moisture absorption was contained in the fridge although it still faded some of the natural indicator it helped maintain the film strength and prevent excessive pigment bleeding. Ultimately, the refrigeration of the cellophane extended the functional lifespan of the self and indicator and produced much more consistent results during data and observation.

Food Type Comparison

As explained before, three different food types were used during the process of observations. The different food types used produce different spoilage gases at different rates depending on its moisture content, protein levels, and natural bacteria presence. Firstly, the milk showed the fastest spoilage response with rapid ammonia increase that was visible on the cellophane changes although the fade had happened earlier. Following, the deli turkey produced slower initial changes but then eventually increased to a higher ammonia rate which gathered protein breakdown that intensified over time. It was found that the Cucumber spoiled slower because of the slower pH responses and the ammonia changes because this was driven mainly by the moisture loss and the surface bacteria instead of protein decay. Protein rich foods such as milk and turkey produce much stronger ammonia signals leading the cellophane to have a stronger color identification. Overall, since the milk had created instant color fade for the cellophane, it can be found that more solid foods ensure the stability of the cellophane without causing too much color fade to the cellophane itself.

Limitations

Conclusively, natural pH indicators are specifically meant for qualitative valuing not quantitative valuing meaning that the exact pH and ammonia levels cannot be found using the cellophane. The cellophane is based on color interpretation and relies on visual observations which may introduce human error I'm due to lighting differences and perspectives. Because of the moisture absorption by biopolymer films this sometimes causes stickiness, thickness changes and pigment bleeding which could affect the indicator quality and the overall pigment produced by the cellophane film. As mentioned in the paragraph before, temperature fluctuations are a big part of the cellophane indicator because of handling and observation, which may change the indication of the cellophane film depending on the environment around it. Another variation may include the thickness and indicator concentration between the different types of films for that reason two different Trials of cellophane were made to ensure the difference between them and collected data depending on the indicator concentration between them. In conclusion, since this experiment was conducted in a home environment there was limited access to advanced detection and equipment, creating a limitation for the most perfect data.

Cellophane Trial 1 vs. Cellophane Trial 2

Trial 1 and trial 2 both had different concentrations of cellophane as well as concentrations of glycerin, even with the slight changes the data observed from both trials were significantly different. During trial 2 data collection to self and showed greater durability and flexibility due to the higher glycerin than trial 1. Secondly, the higher concentration of pH indicator in trial 2 to produce stronger and clearer color differences than trial 1. Because of the initial decrease in glycerin and natural pH indicator and trial 1 this caused faster degradation, flimsiness, stickiness and prone to tearing especially when exposed to high amounts of moisture. However, trial 2 was able to maintain its structural integrity longer than trial 1, particularly under refrigerated conditions. Color fading often happens more often and try to reduce its reliability of sports detection over a span of time. Trial 2 on the other hand, responded more consistently to the pH and ammonia changes allowing for a clear identification based on perspective. Overall, trial 2 was more effective and reliable for spoilage detection due to the improvement of formulation and the ability to detect the natural pH indicator without ultimate fade.

Frequent Patterns

Throughout mainly trial 2 of cellophane data collection, it was found that the color change consistently following the pH and ammonia increased and decreased food spoilage over time. The refrigerated samples that were tested displayed slower but more consistent and predictable indicator responses due to heat and moisture differences. Protein rich foods such as turkey, delayed the initial changes followed by the sharper color shifts by the indicator. The higher the indicator concentration the stronger and more reliable the results were across the pattern of all food types. As spoilage started to intensify, the cellophane started to absorb and become thicker because of the physical change that was going on inside the container.

Hypothesis and Purpose

As identified in the beginning of this project, the purpose of this experiment was to test whether biodegradable cellophane film embedded with the natural pH indicator could detect the overall food

spoilage through color. The hypothesis predicted was that as the foods were to spoil changes in the pH and ammonia levels would start altering the molecular structure which would trigger the natural pH indicators therefore creating an obvious color change. It was hypothesized that refrigeration would slow down the degradation of the cellophane while maintaining effective spoilage detection. Using the results gathered by data and observations, the hypothesis was supported by showing that consistent color changes and specific trials were ultimately gathered due to increasing spoilage gases and pH shift. As hypothesized before, it was found that trial 2 had better fulfilled the Project's purpose due to the improved recipe and future changes made after trial 1, creating stronger stability and reliability towards the biopolymer film. Overall the experiment demonstrated that smart and biodegradable cellophane packaging could exist while creating visible color shifts.

Indicator Analysis and Chart

The natural pH indicators that were embedded into the cellophane film as noted before change color based on the pH and ammonia development around the cellophane environment. The red cabbage extract proved that it is most effective with clear transitions from purple and blue to pink to red to green and to yellow. Red defines the acidity of a solution while green and yellow define the basic or alkalinity of a solution. Colors around the shades of red and pink often define a pH range of 2-4, which is highly acidic. Shades of purple, identify mild acidity, with the pH range of 5-6. Blue and violet tones are often neutral pH values of 7. A pH range of 8-9 often identified in a green shade, which is mildly alkaline. Lastly, a pH range higher than 10, often shown in the color yellow or a clear teal.

Real World Applications

Using data and observations collected from this project, we can identify that there are various real world applications that can be found within this Innovative and experimental project. pH indicators can be used in smart food packaging to visually show the spoilage to the consumer which reduces the risk of consuming unsafe and risky foods the human body. Cellophane films which are in refrigerated storages when combined extend the shelf life and improve the detection accuracy of all foods and safety of others. These systems can be used for practicality around grocery stores, restaurants and even households. High moisture and protein-rich foods often benefit from these indicators because it provides real-time feedback and spoilage detection with which identify the freshness and health of the food. These indicators, since made of biodegradable materials and biopolymers, are often cost-effective instead of using lab testing which allows the consumers to identify the food without a mass of lab elements. Using these food spoilage detectors help prevent the waste of food which contribute to economic savings and environmental conservation because of the biodegradable materials used. Overall these experiments helped demonstrate the natural pH indicators and biopolymer films are viable for real world use and an overall application.

Final Takeaway

Ultimately, the effect of refrigeration and food type both strongly affect and influence the use of cellophane biopolymer indicators and films. Cold Storage allows the preservation of these films allowing for a longer time span of use and stronger color identification allowing for reliability. High moisture and

protein rich foods like milk and turkey tend to trigger faster and stronger changes, although not recommended to put in liquids because of the indicator fade. The trial to cellophane, which included a higher indication concentration and glycerin concentration, performed better across all solid food types showing stronger durability and clear results. Overall, natural pH indicators can be incorporated into films embedded in biopolymers which can effectively detect spoilage gases under refrigeration and cold and dark environments which highlight their potential for smart uses and packaging.

Application:

The results of this experiment can be applied to various real world applications, initially sections of food safety, household uses, grocery uses, transportation and storage, economic and environmental development, and future technology packaging. These findings suggest that natural pH indicators can be implemented effectively to create films which change colors based on the spoilage level of certain foods. This project takes another step forward to the food packaging industry. Allowing for an economically beneficial and environment friendly product which assists in the daily lives of others, increases the awareness of food waste and spoilage rates of foods held in household environments. These indicators may replace expiry dates, as the color shown will allow for the visual that the food is expired

Primarily, the idea of this cellophane ensures that the consumer is aware of the spoilage rate and ammonia increase in the food they are consuming. The cellophane change of color warns the primary consumer that the food is unhealthy and will harm the human body. This detection avoids food poisoning, preventing any spread of bacteria and foodborne diseases to the fragile human body. The early spoilage detection was fabricated to provide the result in color change in the case that the food does not present any physically observable spoilage signs. Since the films are non toxic, they are much safer than chemical tests and preservatives to detect spoilage. This often ensures the safety of children, elders, and those with weaker immune systems that may be more susceptible to foodborne causes of diseases.

Secondarily, the use of the cellophane in households and grocery stores. The use of this natural indicator film during times of storage for leftovers, allows one to identify the freshness levels in products, specifically, meat and dairy freshness. This indicator does not only warn others during times of spoilage for safety, however, reduces the amount of unnecessary disposing of good condition foods. This cellophane can be placed in containers, ziplocs, and lunchboxes to ensure the quality of the food. The indicator is meant for easy use without any other resources needed, allowing all age groups to use this tool. Once again, the film is non-toxic and biodegradable, ensuring safety in the kitchen, avoiding any contamination of any harmful substances or chemical materials. Grocery stores may use this film to maintain quality and reduce production loss because of the amount of the mass amount of thrown out foods.

Thirdly, the effect of the cellophane films when used during the process of transportation and importation of food products from long distances. The cellophane may be used when foods are being transported, which allows the detection of spoilage while foods are being transported. Therefore, it prevents the resale of food products which have reached their spoilage date already.

Fourthly, as mentioned various times before, the film is fabricated from non toxic and biodegradable materials allowing less pollution. For the reason of food products, the detection of correct spoilage, reduces the food waste sent into landfills and drains. Thus, less food waste means less methane

emissions and reduced climate impact. This sustainable packaging solution ensures the conservation of water, energy, and equipment and materials used for food packaging.

Overall, these films can change colors and use QR codes to help link consumers to the correct color coding and legend. For the future, companies could make more intelligent food packaging that could incorporate a digital tracking system. This project can help advance the overall sustainability and awareness of food waste and lack of sense towards food waste and the failure of unaware consumers, whether consuming unsafe foods, or the disposing of untouched products.

Sources of Error:

Cellophane trial 1

During trial 1 of the cellophane process, after the batter was made, when ready for pouring, half of the batter did not result as paper thin as the other half. It was very thick, and the glycerin did not work as well because of the thickness, therefore resulting very dry, not durable, and very curved, rather than flat.

After the warm batter was poured into the tray, the parchment paper that was added before stuck to the cellophane, rather than opposing that result. The cellophane was very hard to remove, therefore more batters were needed to be made, the batters poured after were spread avoiding any parchment spread.

Lastly, during the first trial, when the starch was added, it was added directly into the warm, boiling batter. However, after pouring, the cornstarch had boiled in separate chunks, not blending with the other materials. Instead, the cornstarch was removed and added to cold water first, mixed, and then poured into the batter once cooled.

Inconsistent film spread thickness

After the first cellophane trial, all trials were spread to a paper thin width. Although this is what was perceived to the human eye, it is not 100% accurate, therefore results may be slightly different because of the thickness. This error may result in a slower response to the pH and ammonia let out.

Subjective Color Readings

Since the color readings are done by the human eye and observations of cellophane and food are done by the human eye, there may be various human vision biases or a difference in lighting, allowing the shade to look different each time.

Contamination and Timing

Another source of error may include the contamination and tightness of the container. Although the container maintains good isolation, since it is plastic, there are still holes which allow gasses to seep out of. Since the foods were sliced and split, when foods are cut more moisture is present, allowing bacteria to spread faster because of the porousness. Lastly, the time each observation is taken, was tried to be taken at the same time, however, it was difficult to maintain a perfect timing schedule. These fluctuations in timings may have affected the daily data that was taken.

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