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Abstract

Beeswax food wraps have gained popularity as a sustainable, natural alternative to single use options such as plastic bags, plastic wrap, and wax paper. Despite limited evidence, sellers advertise beeswax wraps as having antimicrobial benefits that help food stay fresh longer. The purpose of this investigation was to determine the ability of beeswax impregnated cotton cloth to inhibit food spoilage relative to traditional methods. We designed a prospective trial in which strawberry, bread, and cheese specimens were wrapped in one of the 3 materials: 1) beeswax impregnated cotton cloth, 2) wax paper, or 3) plastic bags alone and followed for 15 days at 65°F for progression of mold growth and other signs of deterioration. For most specimen/timepoint combinations (87%), we found no differences between storage methods. For the 13% of specimen/timepoint combinations where we did note a significant difference, beeswax wraps fared the worst. While beeswax wraps may be preferred as a natural food storage material, their ability to preserve food is no better than conventional options.

Introduction

Beeswax food wraps have gained popularity as a sustainable, natural alternative to single use options such as plastic bags, plastic wrap, and wax paper. Sellers advertise beeswax wraps as having antimicrobial benefits that help food stay fresh longer. (1, 2, 3) However, the evidence supporting these claims is limited.

Beeswax has been reported to have antimicrobial properties. Beeswax may inhibit growth of gram negative bacteria, gram positive bacteria, and fungi. (4, 5, 6) In addition, beeswax impregnated cloth has been reported to exhibit biostatic and biocidal activity under laboratory conditions. (7) Prospective trials that test the ability of beeswax wraps to inhibit food spoilage are lacking.

The purpose of this investigation was to determine the ability of beeswax impregnated cotton cloth to inhibit food spoilage relative to traditional methods of food storage.

Materials and Methods

We designed a prospective trial to compare the ability of beeswax impregnated cotton cloth to inhibit food spoilage relative to wax paper and plastic bags alone. Beeswax impregnated cotton clothes were made using the following method. Prewashed 100% cotton sheeting was cut into 30 cm squares. Beeswax was melted. Each author used beeswax from their own hives. Fabric was laid flat on a baking sheet, brushed with melted beeswax, then heated in an oven at 200°F for

6 minutes. Wraps were removed from the oven and hung on wooden racks to dry and cool to room temperature.

Three foods representing a spectrum of food types were chosen for study: sliced part-skim mozzarella cheese (Trader Joe's, Monrovia, CA), organic white bread (Trader Joe's, Monrovia, CA), and strawberries sourced from grocery stores near each author's home. These items were selected since they are available nation-wide, are commonly wrapped and stored in households, and are prone to spoilage. Cheese and bread slices were wrapped individually. To make the samples uniform, strawberries were destemmed, sliced so as to lie flat, then grouped to approximate the surface area of a slice of bread and wrapped. Bread was briefly dipped in water prior to wrapping to promote spoilage within the research project allotted time.

Cheese slices, bread slices and strawberries were placed in each of three types of storage options: 1) wrapped in beeswax impregnated cotton wraps and placed in resealable plastic sandwich bags, 2) wrapped in wax paper then placed in resealable plastic sandwich bags, 3) placed in resealable plastic sandwich bags without additional wrapping. The wrapped items were placed flat on metal sheets and stored in dark areas in each author's house at approximately 65^{o}F (range 63-68^{o}F). Three specimens of each food item were placed in each of the three storage options by each of the four authors for a total of 108 specimens.

At three day intervals, food items were removed from storage and examined. Items were unwrapped and photographed, then rewrapped, replaced in plastic bags, and returned to storage. Only one side of each cheese or bread slice, or in the case of the strawberries, one side of the assembled slices, was examined with the same side being examined throughout the study period. Authors wore nitinol gloves and N95 masks for this process and surfaces were cleaned between specimens to avoid cross contamination.

Spoilage of food items was qualified digitally by placing a 10 by 10 square grid over each specimen photograph and counting the squares with mold growth or discoloration suggesting spoilage. A square was considered to contain mold growth or spoilage if 50% or more of the square was involved. The percentage of the surface area covered in mold or other spoilage was then calculated.

Data was stored and analyzed using Microsoft Excel (Microsoft Corporation, Redmond, WA). Graphs were created to show trends of spoilage. ANOVA and Student's t-tests were used to compare storage methods at each time point.

Results

The strawberries exhibited the quickest deterioration. (figure 1) By day 6, specimens from all groups showed significant spoilage (range 44.1% to 79.5%) with the beeswax wrapped specimens trending as the worst ($p=0.06$). (table) By day 9 the beeswax wraps performed significantly worse ($p=0.03$) and by day 12 all specimens were nearly 100% deteriorated.

Bread spoiled slower than the strawberries. (figure 2) By day 3 the beeswax wrapped bread exhibited more deterioration than the wax paper and plastic bag wrapped specimens, 10.9% vs. 3.7% vs. 5.6% (p=0.02). (table) From day 6 onward, there was no significant difference in the amount of spoilage across the groups.

The rate of spoilage of the cheese specimens was similar to that of the bread. (figure 3) There was no significant difference in the amount of spoilage between the storage methods at any time point. (table)

We noticed visible growth of a variety of fungi on the food specimens. Botrytis cinerea was seen on the strawberries starting on day 3. (figure 4) Aspergillus and Penicillium grew on both the cheese and bread. (figures 5, 6) Rhizopus stolonifer was also observed on the bread. (figure 6)

Discussion

We sought to determine the ability of beeswax impregnated cotton cloths to preserve food compared to other common options: wax paper and plastic bags. For most specimen/timepoint combinations (87%), we found no differences between storage methods. For the 13% of specimen/timepoint combinations where we did note a significant difference, beeswax wraps fared the worst. While beeswax wraps may be preferred as a natural food storage material, their ability to preserve food is no better than conventional options.

Food is wrapped to protect it from the surrounding environment and minimize deterioration. Microorganisms can be introduced to food either before or after it is wrapped for protection. Common wrapping materials used for food preservation such as plastic bags or wrap, wax paper, and aluminum foil are mechanical barriers that do not have any specific antimicrobial properties. Food packaging that contains antimicrobial agents is used primarily by commercial entities rather than consumers. (8, 9)

Manufacturers of beeswax wraps promote their products as being superior to traditional wrapping materials by providing both a physical barrier and a potential antimicrobial effect. Abeego claims beeswax wraps are “water resistant, air resistant, antibacterial, and antimicrobial,” and “keep food alive for longer than ever imagined.” (1) SuperBee asserts beeswax “has antifungal and antibacterial properties helping keep things clean and reducing risks of contamination,” and adds that their product is “ fine and proven for cheese”. (2) Goldilocks-USA claims “beeswax has naturally antimicrobial properties” and “food will stay fresher longer in a beeswax wrap compared to any other form of storage.” (3)

The ability of beeswax to back up wrap manufacturers claims made is minimal. Beeswax has been shown to inhibit growth of fungi, gram negative bacteria, and gram positive bacteria on agar plates under laboratory conditions. (5, 6) However, the antimicrobial ability of beeswax impregnated cloth has been mixed. Beeswax coated polyester/cotton/viscose blend cloth has shown low biostatic activity. Similarly treated polyester fabric may be biostatically active against select molds and bacteria and may biocidal activity against Aspergillus niger. Of note, this trial took place under laboratory conditions where specific microbial inoculums were prepared and transferred to the test cloths in specific amounts. (7). The ability of a cotton/hemp cloth infused with a beeswax, tree resin, jojoba blend to inhibit bacterial growth was mixed when directly inoculated in a laboratory setting. The same cloth had no effect on fungi or viruses. (10) None of these investigations were conducted with food. The antimicrobial ability of beeswax coated 100% cotton cloth had not been tested nor had beeswax coated cloth been tested in "real world" conditions prior to the present study.

The molds we observed are typical for the foods tested. Botrytis cinerea, a gray mold, infects strawberry blossoms then remains dormant until the fruit ripens. (11) Beginning as soft light brown lesions, it rapidly enlarges until the fruit turns grayish white. Botrytis cinerea thrives in moist, humid, conditions between 65-75°F, such as we provided in our study. (12) Aspergillus niger, one of the most common contaminants of food, presented as dark spots on the surface of the cheese. (13) Other Aspergillus species have round shapes and an array of colors from black, blue-green, yellow to gray, green with yellow, black, cinnamon to brown and pink. (14) Penicillium species also appear as round growths blue-green, gray green, olive gray, yellow or pink in color. (15) Rhizopus stolonifer, commonly known as black bread mold, presents with a blue, green or white fuzzy appearance then becomes black when spores are produced on the ends of its hyphae. (16) Had we performed microscopic analysis, we may have identified additional microbes.

The failure of beeswax wraps to show superior ability to protect food samples from deterioration may have been due to mechanical properties such as permeability or inability to adhere tightly to the food surfaces rather than a lack of antimicrobial activity. It may have been that the concentration of beeswax on the tested wraps was not enough to be antimicrobial or that the mold and other microbes grow within the food where they are not inhibited by the beeswax on the outside of the food. Lastly, beeswax may have a level of antimicrobial activity that is high enough to be detected in tests conducted under laboratory conditions, but is not enough to protect in a real world situation. Of note,the wax paper deteriorated during the study period suggesting that it may be best suited for very short term storage or storage of dry items.

Growth of mold and/or bacteria is not the only measure of food deterioration. Maintenance of flavor, structure, and nutritional value are also important. Beeswax has been shown to prolong shelf life and maintain taste of the tropical fruit Manilkara zapota compared to plastic wrap under refrigerated (28°C) conditions. (17) Given our resources and timeline we limited the scope of our investigation and did not include these factors.

Our investigation had several limitations. First, we made two decisions that were not consistent with real world food storage in order to assure that the food specimens would spoil in the limited time frame allotted for the study: 1) storing specimens at 65°F rather than in a refrigerator (37°F) and, 2) dipping the bread in water. Another alteration from typical food storage was to place the beeswax wrap and wax paper specimens in plastic bags rather than store them without. This was done to minimize environmental contamination during storage. While we did attempt to identify microbial growth on the specimens, we did not undertake rigorous speciation. Our study took place in four locations as the authors reside in Washington, Illinois, Tennessee, and North Carolina. It is possible that the microbial environment of these locations differed. While the lack of standardization may be considered a limitation, testing the wrapping techniques across a variety of real world situations broadens the applicability of our findings.

Further investigations in this area should include storage of specimens in a 37ºF environment, storage without plastic bags, and attention to the ability of the wraps to conform to the specimens. Analysis of the specific microbes on the specimens should also be undertaken to determine if wraps of one type or another inhibit certain microbes. Additional qualities such as food texture, weight loss, and taste should also be dependent variables in future investigations.

Under laboratory conditions, beeswax has been shown to have antimicrobial properties. Companies selling cotton impregnated beeswax wraps extrapolate from this to suggest that beeswax wraps are superior to conventional materials for food preservation. Our investigation is the first to examine the ability of cotton beeswax wraps to preserve food and our data do not support these claims. Further investigation is needed to test the utility of beeswax wraps for storage of additional foods and under different storage conditions.

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Table: Percentage of specimen deterioration by food type and storage material

	Day 3		Day 6		Day 9		Day 12		Day 15	
	Mean (%)	**SD**	**Mean (%)**	**SD**	**Mean (%)**	**SD**	**Mean (%)**	**SD**	**Mean (%)**	**SD**
Strawberries										
Beeswax	18.3	15.7	79.5	27.4	97.3	4.9	100	0	100	0
Wax paper	11.3	4.6	60.4	36.8	82.0	24.0	93.5	11.8	96	7.3
Plastic bag	17.9	32.5	44.1	35.9	73.9	27.3	94.3	10.5	96.5	6.4
	p=0.65		p=0.06		p=0.03		p=0.18		p=0.18	
Bread										
Beeswax	0	0	10.9	6.7	39.5	24.0	64.7	33.5	73.6	34.5
Wax paper	0	0	3.7	4.0	47.8	28.1	47.8	28.1	62.5	35.7
Plastic bag	0	0	5.6	7.4	39.3	27.0	39.3	27.0	50.3	32.8
	p=N/A		p=0.02		p=0.67		p=0.11		p=0.26	
Cheese										
Beeswax	0	0	6.2	10.0	36.4	30.6	69.9	24.1	78.7	22.0
Wax paper	0	0	4.2	5.0	29.5	33.0	63.4	41.3	79.7	31.1
Plastic bag	0	0	5.2	6.7	34.2	38.4	47.0	35.0	62.1	28.3
	p=N/A		p=0.81		p=0.88		p=0.25		p=0.23	

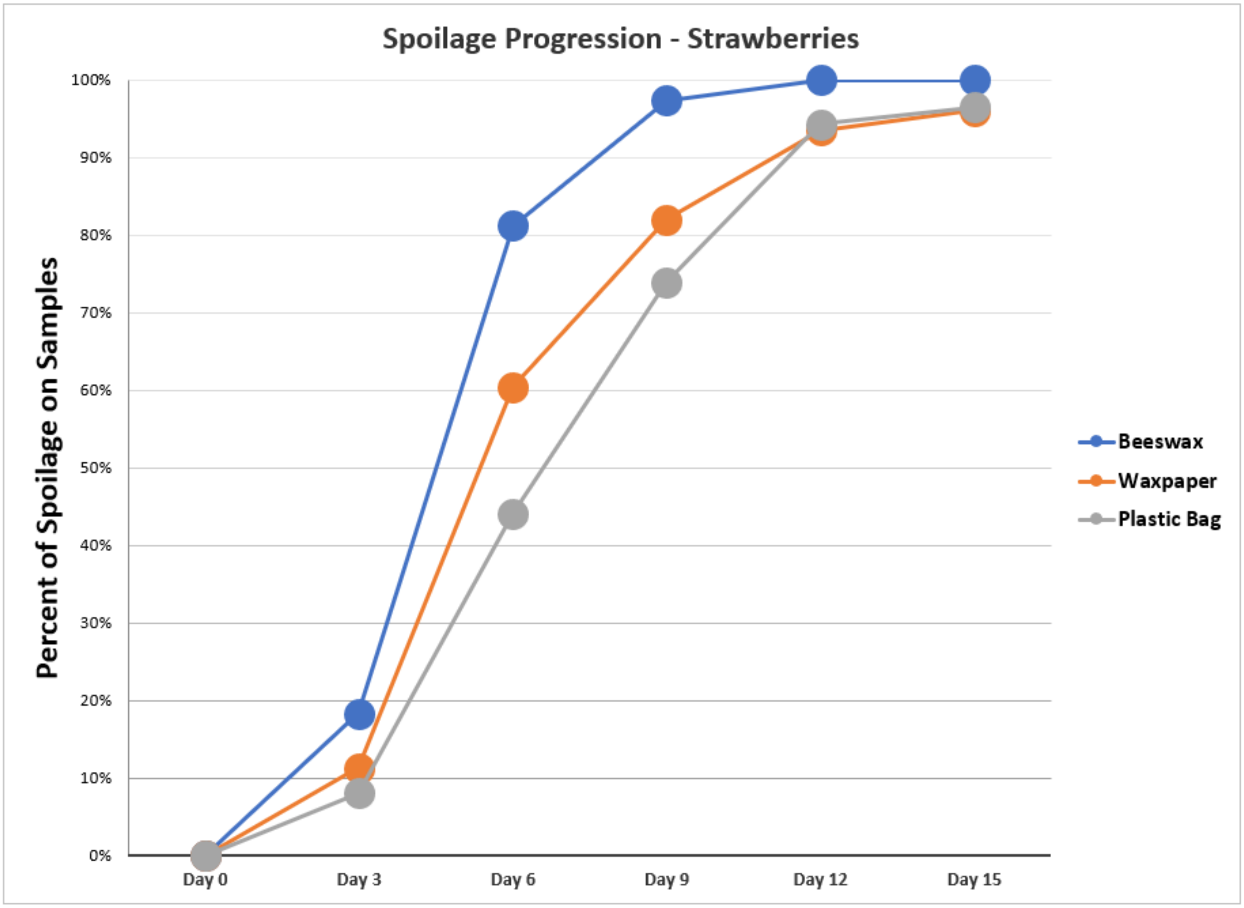


Figure 1: Average progression of spoilage in 27 strawberry samples.

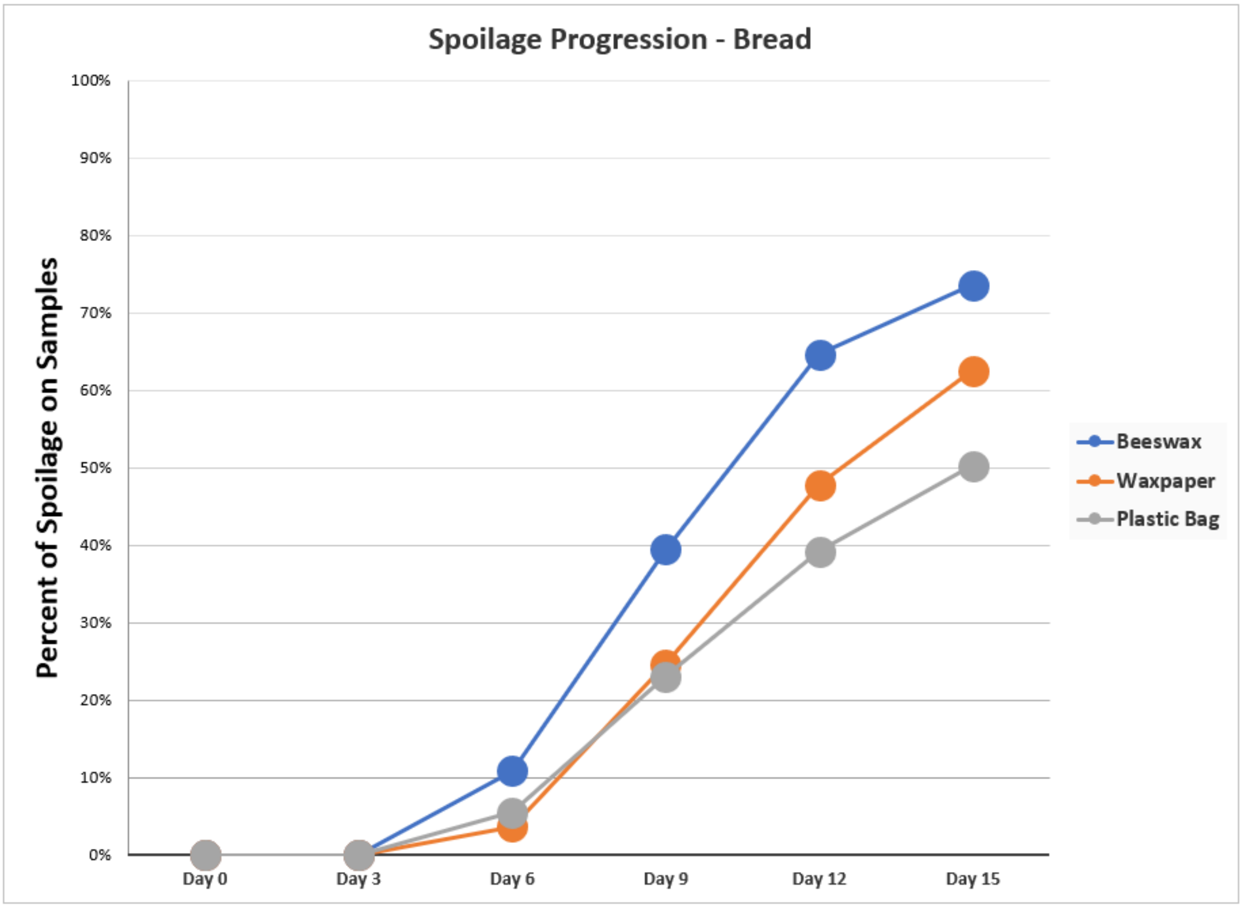


Figure 2: Average progression of spoilage in 27 bread samples.

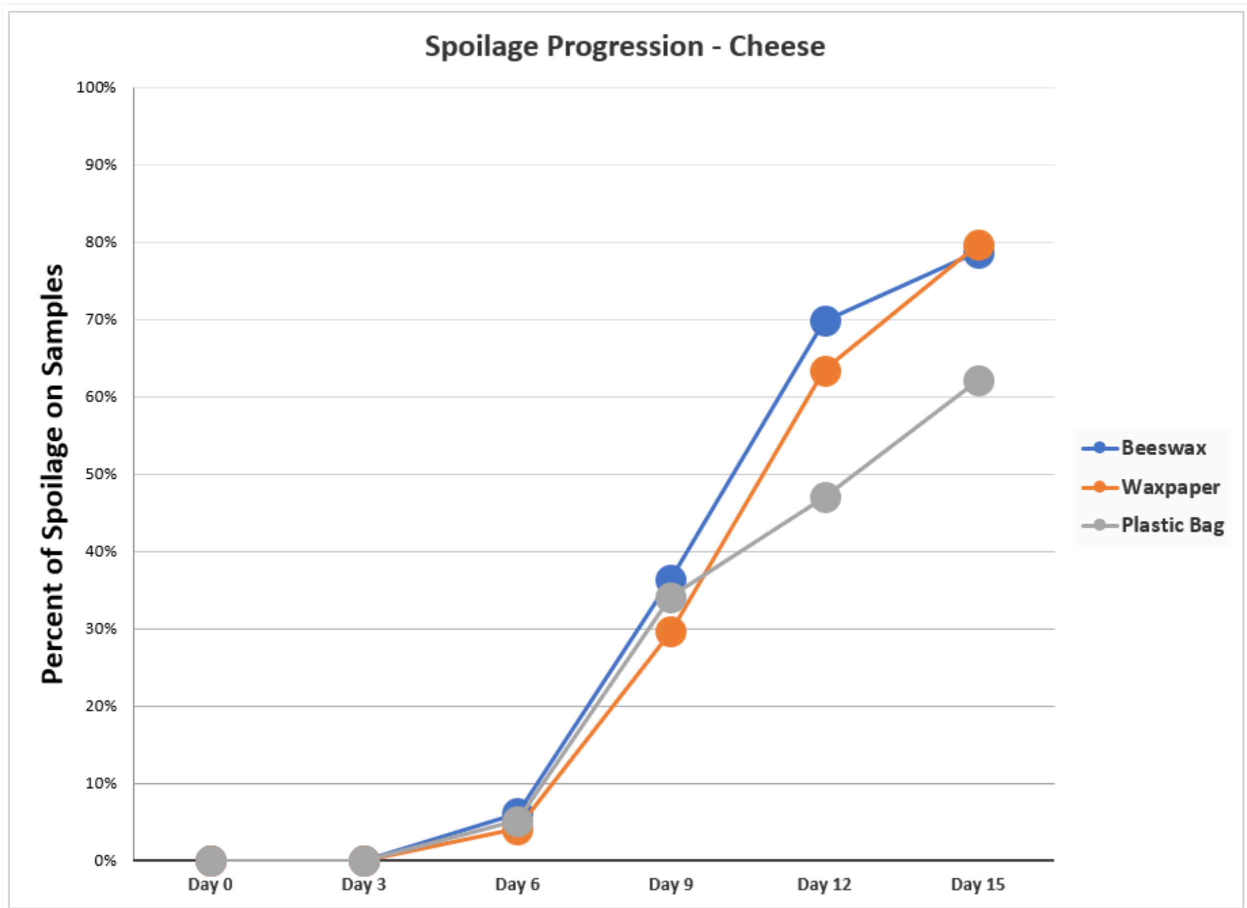
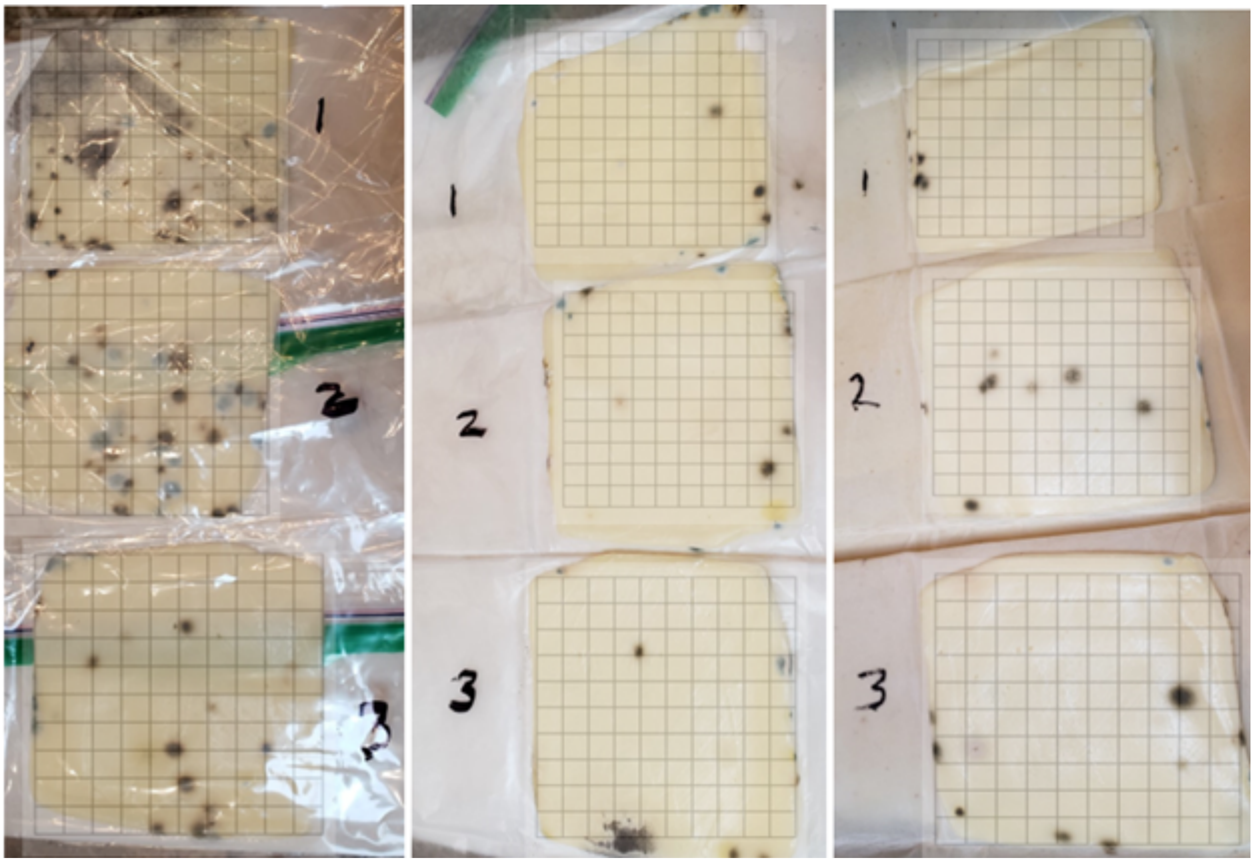


Figure 3: Average progression of spoilage in 27 cheese samples.

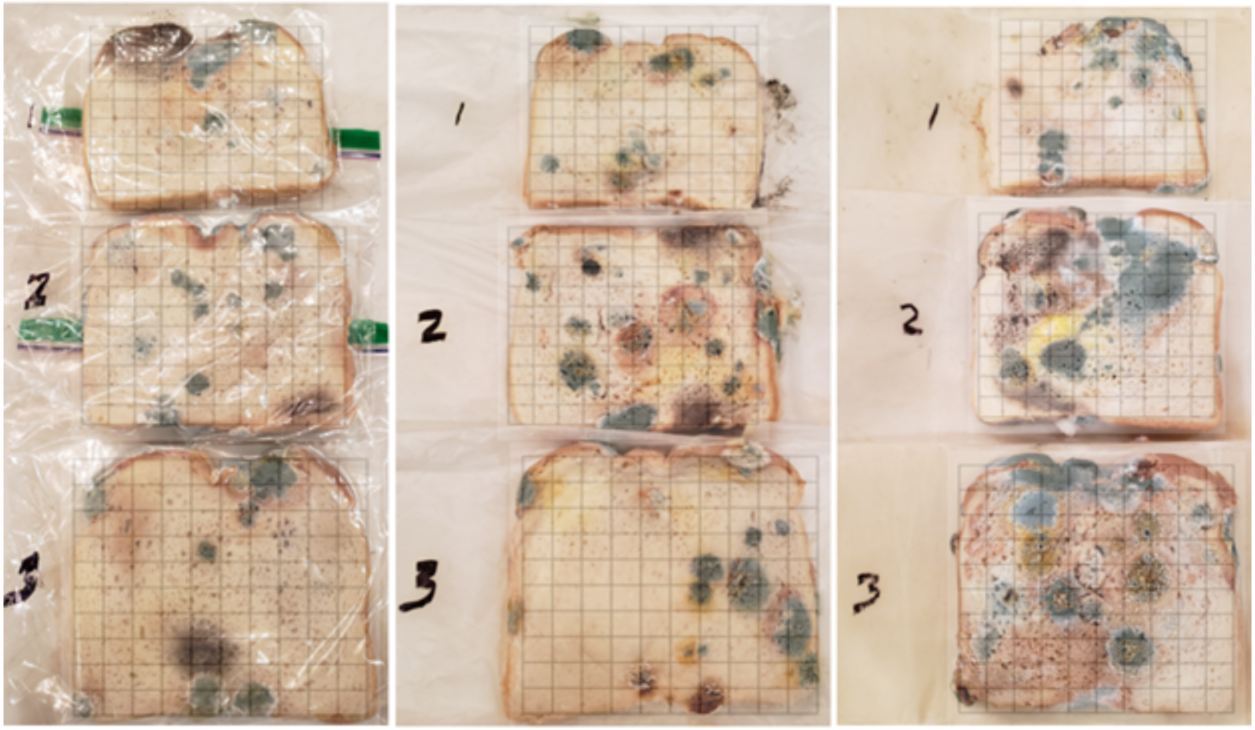
Plastic Bag **Wax Paper** **Beeswax Wrap**

Figure 4: Strawberries showing signs of Botrytis cinerea on day three.



Plastic Bag **Wax Paper** **Beeswax Wrap**

Figure 5: Mold growth on mozzarella cheese slices on day six. Dark spots are Aspergillus niger while the blue areas are Penicillium species.



Plastic Bag **Wax Paper** **Beeswax Wrap**

Figure 6: Bread with mold growth after nine days. Rhizopus stolonifer is represented as blue, green and white and will change to black. Penicillium species may be seen as blue or green. Yellow and brown areas suggest Aspergillus species.