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Effect of Modified Atmosphere Packaging Combined with Potato Starch Coating in Improving the Shelf-Life of Fresh Strawberries

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ABSTRACT

Introduction: Strawberry is a highly perishable fruit because of high water content and susceptibility to fungal spoilage, resulting in rapid post-harvest losses with texture softening, easily spoilage, and physiological changes. The objective of the present study was to investigate the effect of modified atmosphere packaging (MAP) combined with potato starch coating in improving the shelf-life of fresh strawberries for 7 days at refrigerated conditions.

Methods: Fresh strawberries at the red-ripe stage were purchased in a regional market, Kermanshah, Iran. The coated samples with potato starch solution were placed in the stomacher bags, gas flashed through a packaging machine, and sealed with a modified atmosphere containing 10% oxygen, 15% carbon dioxide, and 75% nitrogen. Microbial (total viable count, psychrotrophic bacterial count, and yeast/mold count) and chemical (weight loss and pH) properties of samples were investigated during a storage period of one week.

Results: During the seven-day period, strawberries treated with a potato starch + MAP containing 10% oxygen, 15% carbon dioxide, and 75% nitrogen had the best total viable count, psychrotrophic bacterial count, yeast/mold count, weight loss, and pH values, recorded by 3.93 log CFU/g, 2.89 log CFU/g, 2.31 log CFU/g, 2.05%, and 3.91, respectively, at the end of the experiment period (day 7).

Conclusion: Our findings suggest that potato starch coating + MAP treatment is practical for maintaining the microbial and chemical characteristics of fresh strawberries and increasing their shelf-life, which is critical regarding saleability and exporting.

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Introduction

Strawberry (*Fragaria × ananassa*) is considered one of the major popular fruits among consumers worldwide owing to its delicious taste and appealing appearance along with a diverse range of vitamins, fibers, minerals, and antioxidant compounds, which have anti-cancer and anti-inflammatory properties (1). However, strawberry is a highly perishable fruit because of high water content and susceptibility to fungal spoilage, resulting in rapid post-harvest losses with texture softening, easily spoilage, and physiological changes (2). Preservation at chilled conditions (approximately 0–4 °C) and rapid refrigerating to those temperatures are considered to increase the preservation period of strawberries (3). Given that strawberry is a luxury expensive fruit, can be converted into various types of processed products and marketed scientifically to fetch foreign exchange and to maintain the national economy (4). The modified atmosphere packaging (MAP) changes the gas proportions in the package environment by removing oxygen or altering the atmosphere within the package with a combination of carbon dioxide, oxygen, and nitrogen (2). MAP with the combination of 10% oxygen, 15% carbon dioxide, and 75% nitrogen can slow down the growth of spoilage-related bacteria and food-borne microorganisms, decrease the rate of chemical and biochemical changes, and maintain the overall organoleptic characteristics of easily spoiled fruits for a prolonged time storage (5). Previous studies have reported that storage at refrigerated conditions along with carbon dioxide application might enhance the

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postharvest quality and shelf-life of strawberries (6-8). Other approaches that have been utilized to decrease the postharvest decays of fresh strawberries are using coating and films based edible polymers, irradiation along with antimicrobial and antioxidant constituents (9). From this perspective, potato starch is an economical and renewable biopolymer that can be utilized for the shelf-life preservation of strawberries (10). Starch is considered one of the most commonly utilized food packaging polymers owing to its renewability, availability, cost-effectiveness, appropriate film/coating formation, and well-processivity (11). Several studies have reported the potential coating application of starch biopolymer in bananas (12), guavas (13), mandarin oranges (14), mango (15), plums (16), and strawberries (17). Several studies have also been found on the actual application of MAP in combination with aloe vera gel (18), polylactic acid film (10), aqueous chlorine dioxide (19), and chitosan coating (4) for extending the shelf-life of fresh strawberries. Take into consideration the vulnerability of fresh strawberry to decay caused by environmental and microbiological impacts during chilled storage conditions (1, 2), it is crucial to perform more research on its shelf-life extension. However, according to the knowledge of the author, no previous experiment had been performed with the combining MAP and potato starch to investigate their combined efficacy on the shelf-life of fresh strawberries. Therefore, the objective of the present study was to investigate the effect of MAP combined with potato starch coating on microbial and chemical characteristics of fresh strawberries for one week at cooled conditions.

Materials and Methods

Preparation of Potato Starch Coating

2% potato starch (w/v, high purity powder, purchased from Sigma-Aldrich, UK) was prepared by stirring on the heater stirrer (IKA, Germany) at 70 ± 1 °C for 6 h. After that, 0.75 ml/g of glycerol (Merck, Germany) was added as the plasticizer and stirred for 30 min at room temperature (25 ± 1 °C) (20).

Strawberry Packaging

Fresh strawberries at the red-ripe stage were purchased in a regional market, Kermanshah, Iran. Strawberries of similar size in the lack of physical damage and fungal infection were obtained. An amount of 100 g fresh strawberries was soaked in 200 ml potato starch coating solution for 1 h at 24 ± 1 °C on the shaker (Behdad, Iran). The coated strawberries were allowed to drain for 30 min under a biological safety cabinet. The strawberry control was treated similarly in a sterile distilled water solution without potato starch coating solution. After that, coated samples were placed in the stomacher bags, gas flashed through a packaging machine (Fer plast, FPMV 45 1BFG, Italy), and sealed with a modified atmosphere containing 10% oxygen, 15% carbon dioxide, and 75% nitrogen: strawberry volume ratio of 3:1 in sterile stomacher bags (6). All treatments were then kept at chilled temperature (4 ± 1 ºC) and then microbial and chemical properties were investigated during a seven-day period.

Microbial and Chemical Analysis

At each sampling day, 10 g of untreated and treated strawberries were mixed with 90 ml 0.1% buffered peptone water using the stomacher (BagMixer, France) for 1 min, and then the suspensions were cultured on plate count agar (Merck, Germany) for total viable count (TVC: incubated at 37 ± 1 ºC for 48 h), psychrotrophic bacterial count (PTC: incubated at 7 ± 1 ºC for 10 days), and Dicloran Rose-Bengal Cloranfenicol agar (Merck, Germany) for yeast/mold count (incubated at 25 ± 1 ºC for 5-7 days) (21). Moreover, the determination of weight loss and pH of strawberry samples was conducted based on previous approaches published by Velickova et al., (2013) (22). Weight loss was presented as a loss percentage of strawberries in comparison with the initial weight of samples. To determine the weight loss of the samples, 6 strawberries from each treatment were weighed during storage conditions. To measure the pH of samples, 5 g of each sample was mixed with 45 ml distilled water through the stomacher and then the measurement was conducted using a digital pH meter (Farazbin, Iran).

Statistical Analysis

The study was performed three times. Data analysis was performed by employing a Tukey HSD test (SPSS 23, Chicago, IL, USA). The data were presented as mean value ± standard deviation. $P < 0.05$ was presented as the minimal level of statistical significance.

Results & Discussion

Weight loss is considered one of the main quality parameters of fresh strawberries, which can be associated with the freshness and turgidity of the fruits (4). The result of weight loss of fresh strawberries during 7 days of storage at chilled conditions is presented in figure 1a.

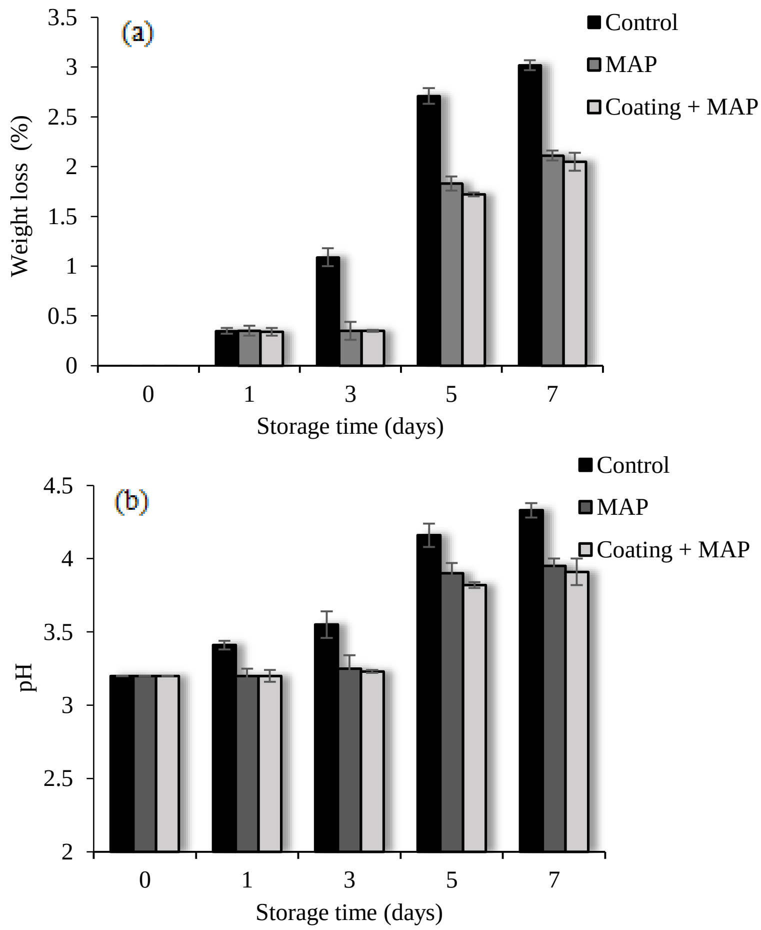

Figure 1. Chemical changes, including weight loss (a) and pH (b), of strawberries during refrigerated storage conditions.

According to our findings, the weight loss percentages of control, uncoated samples treated with MAP, and coated samples treated with MAP reached 3.02%, 2.11%, and 2.05%, respectively after 7 days of cooled storage conditions. The results might be attributed to this fact, the surface coating of strawberries resulted in the reduction of surface pores diameter, respiration, and dehydration (23). The efficacy of chitosan coating on the retarding in weight loss of strawberries comparing with other cellulose derivatives, has been previously found (24). Park et al., (2005) reported that chitosan coating delayed the weight loss of fresh strawberries by approximately 15% in comparison with control samples (25). The utilization of clay nanosilicate packaging has also been reported to retard the weight loss in fresh strawberries (26, 27). The pH was associated with strawberry flavor and maturity (28). According to the results of figure 1b, it can be indicated that in all packaging conditions, the pH changes of coated samples treated with MAP and uncoated samples treated with MAP was lower than the untreated strawberries ($P < 0.05$). In the end of the study period (day 7), the pH values of control, uncoated samples treated with MAP, and coated samples treated with MAP reached 4.33, 3.95, and 3.91, respectively. The chemical changes of treated samples happened lower than untreated samples owing to the decreasing the metabolic processes and reactions as well as microbial activity over post-harvest storage (29).

It has been found that the major spoilage of strawberries was occurred by contamination of yeast/mold and mesophilic bacterial population (9). The results of TVC, PTC, and yeast/mold count of designated strawberry treatments over chilled storage for one week are exhibited in figure 2a-c, respectively.

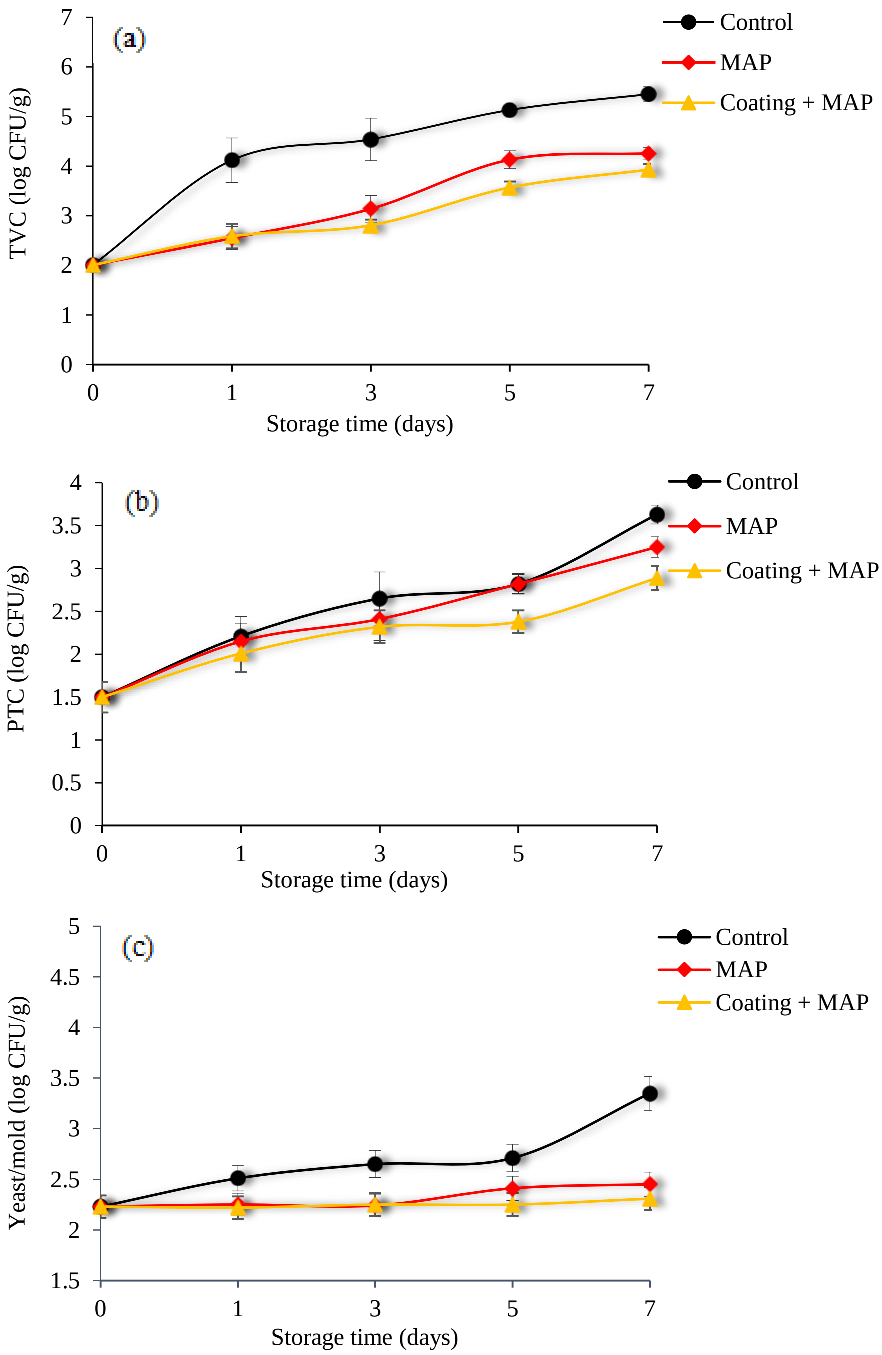

Figure 2. Microbial changes, including TVC (total viable count, a), PTC (psychrotrophic bacterial count, b), and yeast/mold count (c), of strawberries during refrigerated storage conditions.

According to the results of the present study, TVC, PTC, and yeast/mold count of strawberry samples on day 0 were determined to be 2.01, 1.5, and 2.23 log CFU/g, respectively. Our findings presented that TVC, PTC, and yeast/mold count of all strawberries were continuously enhanced with storage time and the microbial population of untreated strawberries was higher than other treatments. Gol et al., (2013) also indicated that strawberries treated with chitosan had remarkably lower TVC, PTC, and yeast/mold count comparing with the uncoated strawberries (27). The lower microbial population of coated samples compared to the control group could be owing to the almost low gas and moisture resistance characteristics of potato starch coating (30). Wu et al., (2023) (28) found that the development of gelatin/zein-based nanofiber film could successfully retard the spoilage process of strawberries stored at room temperature. Li et al., (2021) (9) also reported that poly(lactic acid) nanofibers containing ethyl-dodecanoyl-larginate hydrochloride had antimicrobial activity against *Escherichia coli* O157:H7, *Staphylococcus aureus*, and *Botrytis cinerea* and could also successfully increase the shelf-life of strawberries at room temperature. Moreover, previous studies reported that the application of MAP separately and in combination with biodegradable/edible polymers has no significant adverse effects on the sensory properties of fresh strawberries (27, 31, 32).

Conclusion

In the current experiment, the effect of MAP combined with potato starch coating for 7 days at refrigerated conditions was investigated. Over the experiment period, strawberries treated in a potato starch + MAP containing 10% oxygen, 15% carbon dioxide, and 75% nitrogen had the best TVC, PTC, yeast/mold count, weight loss, and pH values, recorded by 3.93 log CFU/g, 2.89 log CFU/g, 2.31 log CFU/g, 2.05%, and 3.91, respectively after seven days. The results obtained from this experiment hold the potential for extending the shelf-life of fresh strawberries and indicate promising prospects in this field. More studies are essential to investigate the sensory properties and scanning electron microscopy analysis of the coated strawberry surfaces. Further experiments are necessary to improve the productiveness and commercial accessibility of packaged strawberries with MAP.

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