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Effect of Packaging Formats on the Quality of the Seasoned Fried Sajor-caju Mushroom Product during Storage

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Abstract

The study focuses on transforming Sajor-caju mushrooms into snack foods through frying and flavoring. The main objective is to examine how different packaging formats impact the quality of seasoned fried mushroom products. The process involves steaming and drying the mushrooms until the moisture content is below 6 %. Subsequently, the mushrooms are fried in a vacuum fryer at 115 °C under a vacuum pressure of 620 mm Hg for 5 min. The mushrooms obtained were developed into herb-flavored fried mushrooms according to the recipe and method from the model farm project, Than To District, Yala Province of Thailand. The products were packed in 3 different packaging formats; in PP bags (control sample), in polypropylene plastic bags containing oxygen absorber (PP+O_2 absorber), and in aluminum foil bags (AL), stored at room temperature, 29±2 °C for 90 days. The study revealed that different packaging formats resulted in the seasoned fried mushroom product in the color value (L* a* b*), a_w value, moisture content, TBA value, total microbial and fungal counts, and sensory acceptance score ($p < 0.05$) with statistical significance. From the results, it could be concluded that packing in polypropylene plastic bags could store the product for 30 days, and products packed in PP+O_2 absorber could maintain an acceptable sensory quality similar to the one newly prepared for up to 45 days. Packing in aluminum foil bags was the most suitable packing format. It could maintain the product quality in physical, chemical, microbial, and sensory properties for up to 75 days while the product still conformed to the Community Product Standard (303/2004). Moreover, the results from this study can be applied to other snack products and further commercialized.

Keywords: Sajor-caju, Packaging, Mushrooms, Snack foods, Quality, During storage, Seasoned fried mushroom

Introduction

Mushroom is a favorable food due to its good savory flavor and texture features when bitten. The mushrooms typically have broad, thin, oyster- or fan-shaped caps and are white, grey, or tan, with gills lining the underside. In fact, mushrooms receive overwhelming responses from food and pharmaceutical researchers because of their bioactive composition. The biomolecules found in mushrooms, including phenolic compounds, resin structures, steroids, and polysaccharides, have various biological activities [1]. Sajor-caju mushroom (*Lentinus Sajor-cajun* (*Fr.*) *Singers*) is an economically important crop available in Thailand year-round, with a total production of 7,291 tons in 2018. Also known as "Hed Nangpha," this oyster mushroom is highly popular and commercially cultivated in the country. The substrate for Pleurotus Sajor caju is based on sawdust, and rice straw, which are agricultural by-products. The major-cajun mushroom is a medium-sized mushroom with a firm texture and good taste, rich in various nutrients such as protein, iron, calcium, phosphorus, and vitamins (B1, B2, C, A), minerals (P, Na, Ca) and high content of fibers and carbohydrates [2]. Moreover, it is fat-free, can be kept in the refrigerator for several days, and can be cooked in different dishes like other mushrooms. There are many products from Sajor-caju, such as fried Sajor-caju, soup, and chili sauces. The environmental performance of Saju-caju will influence the environmental performance of food having Sajor-caju as an ingredient. Sajor-caju is mainly grown in the middle of Thailand [3]. However, some raw materials such as sawdust have to be transported from the southern part of the country. Therefore, it is currently being widely cultivated and tends to increase steadily. According to the export data of canned and processed vegetables from January to November 2020, processed mushroom products had an export value of $11.7 million, with an 8 % increase compared to the same period of 2019. With this increase in planting and production to the market, mushrooms are processed into products by various methods [4]. However, problems like nutritional loss or natural feature loss such as color and flavor occurred.

Seasoned fried Sajor-caju mushroom is an exciting snack containing mushrooms and spices such as garlic and pepper due to their high nutritional value and crispness. Although this food is widely produced, available in the general markets, and can potentially be an export product that can replace other snack foods, the greasiness occurring in the frying process is still a problem for its stability on crispness. Greasiness causes a rancid smell and results in the product not being stored for a long time; therefore, selecting appropriate packaging and storage conditions can help extend the shelf life. The primary function of the packaging is to protect the product from environmental factors such as light, vapor, gas, or odors during storage, so selecting proper packaging can maintain quality and cause minimal change. Packaging formats commonly used for dry food or snack products should be made of a material that has a sound barrier against moisture and oxygen.

Previous reviews examined extending the shelf life of foods using various innovative packaging technologies for microbial growth control in food products. Packaging acts as a protective barrier that protects food from adulteration by moisture, oxygen, and microorganisms to prolong shelf-life. Many film types are used for food packaging depending on their characteristics. Nylon exhibits good properties as an oxygen, odor and flavor barrier with mechanical strength and high-temperature performance but has a very poor water vapor barrier [5]. Polypropylene (PP) is a non-biodegradable addition to the propylene polymer, and the resins used are mainly isotactic. PP has the lowest density of 0.89 - 0.91 $g\cdot cm^{-3}$ of all the commodity plastics being elastic, more transparent, more effective at bearing water vapor, and has good chemical resistance. An aluminum foil bag is suitable for being a snack food container with the properties of good protection against vapor and gas permeability, being glossy and lightweight [6]. On the other hand, a polypropylene bag is transparent and partially protected from moisture, but the protection against air permeability is better than an Aluminum foil bag. Therefore, it is suitable for hot food, vegetables, and fruits and for making dry sachets. There are some researches to prolong the shelf life of food using oxygen absorbers on the shelf life of Chinese Pastry (Kha-nom-Pia) [7], using aluminum foil in foods baked [8], and using aluminum foil in Aonla and Cereal Based Extruded R-T-E Snack [9].

After visiting the model farm project area in Than To District, Yala Province, which was initiated by Her Majesty Queen Sirikit, it was discovered that the seasoned fried mushroom, a renowned product of a fully integrated mushroom producer group, is facing issues with its shelf life. Therefore, the researchers aimed to study the appropriate packaging formats to be an alternative for entrepreneurs and manufacturers to upgrade these local products.

Materials and methods

Development of the production process of seasoned mushrooms from Sajor-caju mushrooms

Sajor-caju mushrooms in full bloom stage, 4 - 6 cm in diameter from the model farm project, Than To District, Yala Province, were used in this research. The samples were weighed, cleaned, and torn into approximately 5 - 6 cm strips and steamed at 80 °C for 10 min with the water-to-mushroom ratio of 10 to 1 by weight, then used the multipurpose paper to remove the excess water. The sample was dried in a hot air oven at 70 °C for an hour until the final moisture content did not exceed 6 %. The mushrooms obtained were fried in a vacuum fryer (Model VP-10M, Owner Food Machinery) at a temperature of 115 C, and a vacuum pressure of 620 mm Hg for 5 minutes. The excess oil was then removed by the multipurpose paper.

According to the recipe and method of a seasoned fried mushroom from the model farm project, the ingredients used for the seasoning sauce were 130 g of palm sugar, 40 g of soy sauce, 17 g of garlic, 10 g of shredded lemongrass, 40 g of vinegar, 5 g of salt, 3 g of hot peppers, 4.5 g of ground pepper, and 6 g of shredded kaffir lime leaves. All the ingredients were mixed in a pot over low heat, simmering until the seasoning sauce got thick and sticky, then add the fried mushrooms into it at a ratio of fried mushrooms to seasoning sauce 3 to 2.

Quality changes during storage of the seasoned fried mushroom product

The seasoned fried mushrooms were packed in 3 types of packaging; 1) in polypropylene (PP) plastic bags, 2) in polypropylene plastic bags with oxygen absorber (PP+O_2 absorber), and 3) in Aluminum foil bags (AL), then stored at room temperature (29±2 °C). The samples were randomly taken to study the effect of the quality changes in physical, chemical, and microorganisms every 15 days for 90 days or until the samples deteriorated or were unacceptable.

Physical properties

The color L*, a *, b* of the product were measured with a colorimeter (HUNTER LAB, CX 1741, U.S.A.). The CIE system was defined by L * or brightness (0 = black, 100 = white), a * (+ a = red, −a = green) and b * (+b = yellow, −b = Blue). a_w value was determined by a Novasina water activity meter (AG model CH – 8853, USA).

Determination of moisture content

Determination of moisture content followed the method of AOAC [10]. The samples (3 - 5 g) were placed in aluminum dishes and measured for pre-dry and dry weights (dried in an air oven at 105 °C until exhibiting constant weight). After drying, the dish was re-weighed to calculate moisture content using Eq. (1).

$$Mi = WM - WD / WM \quad (1)$$

where WM is the initial weight of the sample and WD is the weight after drying.

Determination of TBA value

Determination of TBA value followed the method of AOAC [10]. TBA (mg malondialdehyde (MDA)/kg) analysis was conducted to determine the lipid oxidation of all test groups. The distillation process was conducted by weighing 10 g of the sample and then homogenizing it with 97.5 mL distilled water and 2.5 mL 4 N HCl. 5 mL was taken from the collected distillate and put into tubes. 5 mL reactive was added on top of it. The sample tubes were kept in a 90 °C water bath for 35 min. After the cooling, the absorbance of the mixture was measured at 532 nm.

Total viable count (TVC)

Determination of total bacterial counts followed the method of AOAC [10]. For total bacterial counts, 0.1 mL of relevant dilutions was inoculated onto sterile nutrient agar plates and spread on the surface using a sterile bent glass rod. Inoculated plates were incubated at 37 °C for 48 h before colonies were counted and reported as colony-forming units/g (CFU/g).

Mold count

Determination of mold count followed the method of AOAC [10]. Mold was enumerated by the surface plate method using potato dextrose agar (PDA). 0.1 mL of appropriate sample dilutions were spread onto PDA agar and incubated at 25 °C for 3 - 5 days. Colonies were counted and reported as colony-forming units/g (CFU/g).

Sensory evaluationper

Sensory evaluation was formed by 50 panelists in terms of appearance, color, smell, crispness, taste, and overall liking based on a 9-point hedonic scale from 1 (extremely unacceptable) to 9 (extremely desirable).

Data analysis

The experiment design was a Completely Randomized Design (CRD) for physical and chemical properties and a Randomized Complete Block Design (RCBD) for the sensory analysis. Analysis of Variance (ANOVA) and Duncan's Multiple Range Tests (DMRT) were performed to compare the differences in samples at the 95 % confidence intervals using the packaged program.

Results and discussion

Results of the quality changes during storage of the seasoned fried mushroom product

Seasoned fried mushroom products were packaged in 3 types of packages: 1) polypropylene (PP) plastic bags, 2) polypropylene plastic bags with oxygen absorbers (PP+O_2 absorber), 3) Aluminum foil bags (AL) and then stored at room temperature (29±2 °C). The physical, chemical, and microbial quality changes, including the sensory acceptance, were studied every 15 days for 90 days or until the samples were of deteriorated/unacceptable quality. The experimental results were as follows:

The color value

Physical parameters, such as color, water activity (a_w), and moisture content, are often measured in snack foods to control the degree of hydration and the qualities of samples during storage time. For the commercially available products, the L* a* b* values were 15.76±0.24, 2.80±0.03, and 4.02±0.29, respectively. The aw values were 0.43±0.02, and the moisture content was 10.94±1.14 %. The color analysis of seasoned fried mushroom products in different packages and storage conditions during storage time was shown in **Figure 1**. The color analysis results in L* a* b* for seasoned fried mushroom products over 90 days showed that different types of packaging resulted in decreased L* and b* values, while a* values increased with time. Retention time on the first day of storage (day 0), seasoned fried mushrooms packed in PP bags had L* a* b* values of 13.19, 3.71, and 4.43, and after 90 days of storage, L* a* b* values changed to 10.11, 6.18, and 2.48, respectively. For the seasoned fried mushrooms packed in PP+O_2 absorber, the L* a* b* values on day 0 were 13.95, 3.93, and 4.55 and changed to 11.45, 6.06, and 3.28 after 90 days while the products packed in Aluminum foil bags (AL) on day 0 had L* a* b* values of 13.34, 3.93, and 4.85 and changed to 12.32, 5.90, and 3.32 after 90 days.

The experimental results showed that the common factors between the storage period and the 3 packaging formats resulted in significantly different L* a* b* ($p < 0.05$) values. Seasoned fried mushrooms in PP bags showed the most significant change in L* a* b* values because PP bags have no protection against light, air, and oxygen. As a result, the fat contained in seasoned fried mushrooms was oxidized during storage, causing aldehyde and ketone compounds to continue the Maillard reaction and give a brown color [11,12]. In addition, it is easy to oxidize in the presence of oxygen, corresponding to the work that found that one of the deterioration factors of dry food is storage conditions. The package without protection against light, air, and oxygen can cause the product to decompose flavonoid compounds or polymerization reactions, resulting in brown compounds that darken the product. Every 10 °C increase accelerates the reaction speed by 2 - 3 times [13].

For fried mushrooms contained in PP+O_2 absorbers and AL bags, there was a slow change in the L* a* b* value since the oxygen absorber acts as a deoxidizer to help absorb oxygen gas inside the package to be less than 0.1 %. This helps prevent oxidation and reduces color changes from the Maillard reaction. However, packing seasoned fried mushrooms in aluminum foil bags in this study had the best protection against the Maillard reaction due to its excellent barrier properties in preventing water, grease, air, and light penetration both in high and low temperatures. Hence, aluminum foil bags are suitable for fried food products [14] (**Figure 1**).

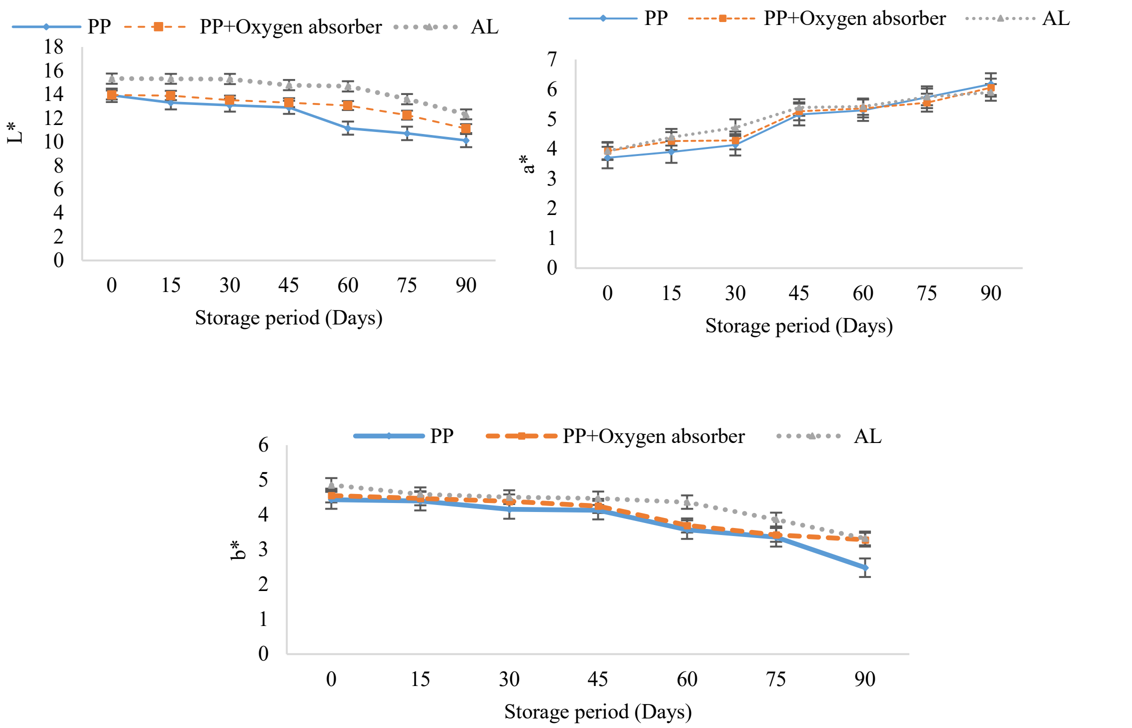

Figure 1 Color change of L* a* b* value in seasoned fried mushroom products under 3 packaging formats stored at room temperature for 90 days.

a_w value and moisture content

One of the most important factors to determine the shelf life of seasoned mushroom products is a_w. In addition, a_w is not only determined by the total quantity of water in products but it is susceptible to microbial spoilage in most food products [15]. The a_w value of seasoned mushroom products within 90 days was as follows; on the first day of storage (day 0), the a_w value of seasoned mushrooms packed in PP bags was 0.413±0.01, and after storage for 90 days, the a_w increased to 0.785±0.01. The a_w value of seasoned fried mushrooms packed in PP+O_2 absorber at day 0 was 0.416±0.02, and after 90 days of storage, the law was 0.687±0.05. For the seasoned mushrooms packed in aluminum foil bags, the a_w value on the first day of storage was 0.404±0.002, while storage for 90 days had an a_w value of 0.547±0.002 (**Figure 2**).

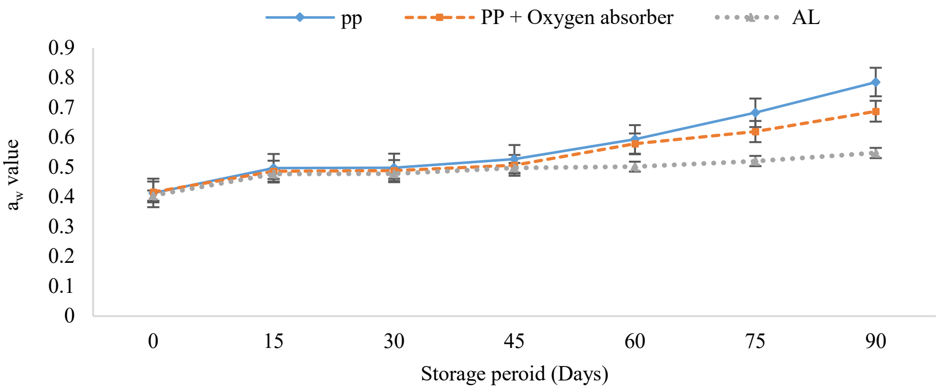

Figure 2 Changes in a_w value in seasoned fried mushroom products under 3 packaging formats stored at room temperature for 90 days.

Regarding the moisture content, it was found that storage of seasoned fried mushroom products in different packages resulted in different moisture content. The initial moisture content (day 0) of seasoned fried mushrooms packed in PP bags was 4.25±0.28 % and increased to 9.39±0.54 % after storage for 90 days. The initial moisture content of seasoned fried mushrooms packed in PP+O_2 absorber bags was 4.22±0.15 % and increased to 8.51±1.01 % after storage for 90 days. The initial moisture content of seasoned fried mushrooms packed in AL bags was 4.22±0.95 % and increased to 7.13±0.57 % after storage for 90 days, respectively (**Figure 3**).

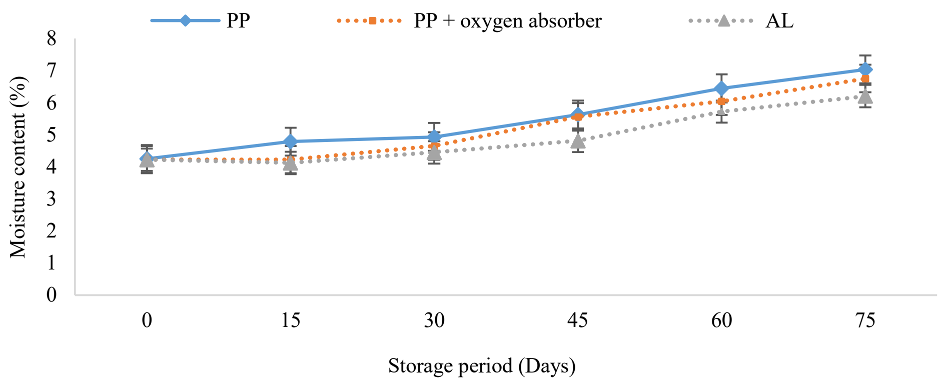

Figure 3 Moisture content changes in seasoned fried mushroom products under 3 packaging formats stored at room temperature for 90 days.

The results from the experiment showed that the common factors of storage time and 3 packaging formats significantly affected a_w and moisture content ($p < 0.05$). Food can absorb moisture from exposure to the residual air in the package; air permeability, including external environment. As a result, the a_w value and the moisture content increase. The study found that products packed in PP bags had the highest change in a_w and moisture content, followed by packing in PP+O_2 absorber. Packing in aluminum foil bags was found to have the slightest change because of its prevention properties of light, air, and moisture [16]. Even though using oxygen absorbers can partially slow down the moisture increase, the main factor in the increase comes from the packaging itself. The single-layer plastic films such as polypropylene and polyethylene have a medium water vapor permeability coefficient between 10 - 12 g m^{-2} day^{-1}. The movement of water vapor occurs in plastic bags better than in foil. Since the foil is a metal foil bag formed from polypropylene film coated on the outer surface with metal vapor, it has better water and gas barrier properties than single-layer polyethylene film bags [17].

The TBA value

The thiobarbituric acid (TBA) value is an important quality indicator indicating fat oxidation, especially in fat-containing products. It measures the number of secondary oxidation products resulting from the decomposition of hydroperoxide compounds, which are primary oxidation products that are more abundant at elevated temperatures. In addition, the oxygen content and a_w are also the catalytic factors of oxidation [18].

The a_w value affected the rate of lipid oxidation. The oxidation rate decreased when the a_w value was 0 - 0.4 and increased when the a_w value was higher than 0.4. Throughout the product's shelf life, 90 days, the a_w value of the product in all 3 formats was in the range of 0.4 - 0.6, which was in the range of high oxidation rates. Hence, it could be another reason for the rancidity [19]. The experiment results found that throughout the shelf life, the TBA value of seasoned fried mushrooms packed in PP bags was higher than those packed in PP+O_2 absorber and AL bags with statistical significance ($p < 0.05$). On day 0, seasoned fried mushrooms in PP bags had an average TBA of 0.25±0.16 mg MDA/kg; after 90 days of storage, it was 4.50±0.61 mg MDA/kg. Seasoned fried mushrooms packed in PP+O_2 absorber had a TBA value on day 0 of 0.23±0.014 mg MDA/kg and changed to 3.30±1.24 mg MDA/ kg after 90 days. The initial TBA value of seasoned fried mushrooms packed in AL bags was 0.23±0.022 mg MDA/kg, and it changed to 2.84±0.55 mg MDA/kg after storage for 90 days, respectively (**Figure 4**). Storage in PP bags affected the highest variation in TBA value due to the oxidation of unsaturated fatty acids in the frying product during storage. Oxidation caused the product to form a volatile malonaldehyde group in the oil, resulting in a higher TBA value. In addition, PP packaging, which has the property of being a transparent bag, can also allow light to stimulate fat oxidation as well. Packing seasoned fried mushrooms in PP+O_2 absorber could delay the product's rancidity because oxygen absorbers can keep the oxygen content in the packaging low, including absorbing oxygen gas that has penetrated during storage [20]. Malonaldehyde formation from oxidation can be accelerated by temperature and light. Therefore, using aluminum foil bags delayed the change in TBA value the most due to its ability to prevent light, air, and water vapor.

The lack of oxygen barrier properties of the PP bag results in continuous oxygen diffusion from the outside into the packaging and accelerates the oxidation reaction. In this case, adding oxygen absorbers can reduce the amount of oxygen in the package to less than 0.1 % of the total concentration. However, oxygen absorbers will only be effective for some time because oxygen from the outside can continuously diffuse into the inside until the effectiveness of the oxygen absorber is exhausted. Eventually, the product will become rancid [21].

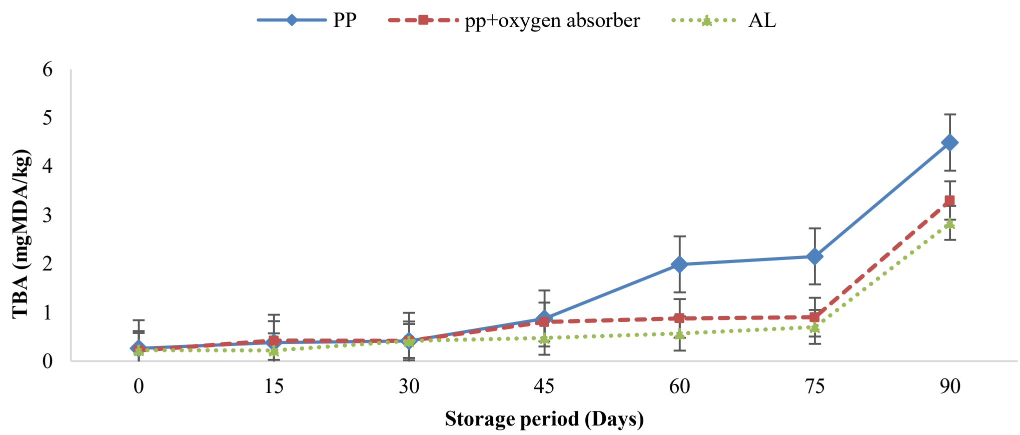

Figure 4 TBA content changes of seasoned fried mushroom products under 3 packaging formats stored at room temperature for 90 days.

Total viable count and mold analysis results

Analysis of the total viable count and mold of seasoned fried mushrooms packed in 3 different packaging formats was randomly examined every 15 days and compared with the standard criteria of ready-to-eat seasoned mushroom community products according to Thai Community Product Standard, 303/2004. According to the standard, the total viable count must be less than 1×10^3 cfu/g, and mold must be less than 1×10^2 cfu/g. The results found that the initial total viable count load of seasoned fried mushrooms packed in PP bags was 2.7×10^1 cfu/g, and the mold load was 1.7×10^1 cfu/g. On day 45, the total viable count was 1.9×10^4 cfu/g, and the fungal load was 1.2×10^2 cfu/g, which exceeded the specified threshold. Therefore, these products could be stored for only 30 days. The initial microbial load for the seasoned fried mushrooms packed in PP+O_2 absorber bags was 1.0×10^1 cfu/g, and the mold was 1.3×10^1 cfu/g. They were found to have exceeded a load of total viable count, and mold count on day 60, with the total viable count and mold load of 2.7×10^3 cfu/g and 1.7×10^2 cfu/g, respectively. Therefore, this package's shelf life of seasoned fried mushrooms was 45 days. Aluminum foil bags seemed to store the product for the longest, with the total viable count and mold load being 1.0×10^1 and 1.3×10^1 cfu/g, respectively. However, on day 90, the total viable count and mold increased higher than the specified threshold; it was 6.4×10^2 and 1.2×10^2 cfu/g, respectively,. Therefore, Aluminum foil bags could store the products for up to 75 days (**Table 1**). The findings were consistent with the a_w value and moisture content analysis results which found that packing in PP bags had the highest a_w value and moisture content. As a result, it greatly affected the growth of microorganisms. Most molds thrive in more acidic conditions and require more oxygen for growth than bacteria, including in areas with a_w values ranging from 0.6 to 0.9. The combination of high barrier packaging, both AL and PP, with an O_2 absorber, had the potential to control aerobic microbial growth, correspondingly with the O_2 absorber may prevent the headspace of O_2 from harboring aerobic microbial activities or may reduce the O_2 permeation rate through the container wall. Aluminum foil functions as a protection from light, and oxygen (prevents the oxidation of fat from turning rancid), keeps the aroma (odor), and moisture, and is anti-bacterial [22] The results showed that removing oxygen and preventing the penetration of oxygen and moisture of packaging could slow down the growth of microorganisms.

Table 1 Total viable count and mold in seasoned fried mushroom products under 3 packaging formats stored at room temperature for 90 days.

Analysis	Packaging	The number of microorganisms during the 90-day storage period (cfu/g)						
		0	15	30	45	60	75	90
Total viable count (cfu/g)	PP bags	2.7×10^1	5.3×10^1	2.2×10^2	1.9×10^4	-	-	-
	PP+O_2 absorber bags	1×10^1	3×10^1	2.2×10^2	7.5×10^2	2.7×10^3	-	-
	AL bags	1×10^1	1.3×10^1	1.4×10^2	2.4×10^2	4.1×10^2	4.1×10^2	6.4×10^3
Mold (cfu/g)	PP bags	1.7×10^1	3×10^1	3×10^1	1.2×10^2	-	-	-
	PP+O_2 absorber bags	1.3×10^1	1.7×10^1	3×10^1	8.7×10^1	1.7×10^2	-	-
	AL bags	1.0×10^1	1.3×10^1	1.5×10^1	$1.7x10^1$	2.8×10^1	8.0×10^1	1.2×10^2

The sensory acceptance test

Throughout the storage time (0 - 90 days), the sensory acceptance test of seasoned fried mushroom products packed in 3 different packaging formats had significant differences in the average liking score of the panelists on appearance, color, odor, texture, taste, and overall liking ($p < 0.05$). The products in Aluminum foil bags were found to get a higher score on a taste test than the others since it has properties to prevent water penetration, gas permeability, and light transmittance in both high temperature and low temperature. Therefore, it helps maintain the crispiness of the product resulting in the texture not changing much, and also helps retain the aroma of spices that were a mixture of seasoned fried mushrooms. In addition, it helps prevent rancidity from oxidation reactions and is used as a container to extend the shelf life of fried food products [23]. The products packed in PP+O_2 absorbers received a sensory preference score after one in AL bags since the properties of oxygen absorbers in controlling and absorb the amount of oxygen in the packaging, thus slowing down the color change, smell, and texture of the product. The packaging that obtained the lowest score from the sensory test was seasoned fried mushrooms in PP bags. Due to the lack of ability to prevent light, air, and oxygen, the fat contained in seasoned fried mushrooms was oxidized and caused changes in color, smell, and texture. Therefore, it was proven that storing products in proper packaging extended their shelf life and minimally changed the product.

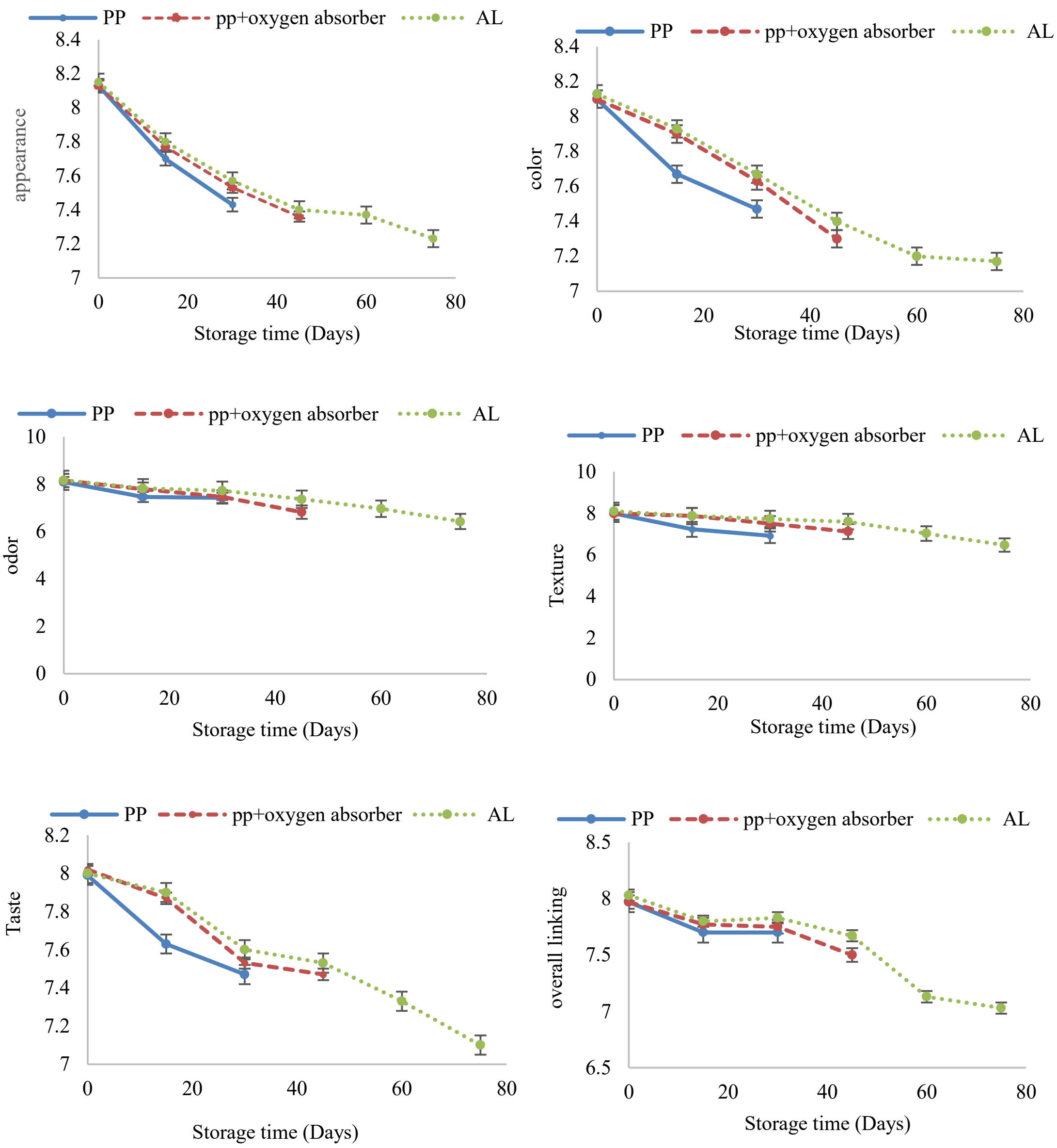

Figure 5 Sensory quality in seasoned fried mushroom products in 3 packaging formats stored at room temperature for 90 days.

Conclusions

The packaging format affected the quality changes of seasoned fried mushroom products during storage time. The quality changes in a_w and TBA values were most suitable for predicting the shelf life of seasoned fried mushroom products. When using the standard criteria for ready-to-eat seasoned mushroom products, it showed that packing in polypropylene bags could be stored for only 30 days. Packing seasoned mushroom products in polypropylene bags containing oxygen absorbers ($PP+O_2$) and aluminum foil bags (AL) could be extended for up to 45 and 75 days, respectively. In addition, packing seasoned fried mushroom products in AL bags can delay changes in the physical, chemical, and microbial qualities. However, quality controls during the production process, packaging, and storage for distribution are also parts that help extend the shelf life of the products.

Acknowledgments

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