# Ảnh hưởng bao bì bảo quản đến chất lượng kẹo dẻo bổ sung phụ phẩm bã chà thịt quả mãng cầu xiêm (*Annona muricata* L.)


## TÓM TẮT

Bao bì hiệu quả có tác dụng mang lại lợi ích sức khỏe và lợi ích cho người tiêu dùng sản phẩm, an toàn hơn với thời hạn sử dụng dài hơn. Bao bì và thời gian bảo quản ảnh hưởng đến chất lượng kẹo dẻo, vì vậy nghiên cứu hiện tại nhằm mục đích khảo sát ảnh hưởng loại bao bì và thời gian bảo quản đến chất lượng kẹo dẻo bổ sung bã thịt quả mãng cầu xiêm. Trong số 3 loại bao bì, bao bì polyethylene (PE) duy trì đặc tính cấu trúc và hạn chế sự tăng trưởng vi sinh vật hiếu khí và nấm mốc, nấm men trong sản phẩm khi so sánh với bao bì polyamide (PA) hoặc polypropylene (PP). Ngoài ra, bao bì PE còn giữ được chất lượng màu sắc, hàm lượng vitamin C, hàm lượng đường tổng, hàm lượng acid tổng, chỉ tiêu cảm quan của sản phẩm sau 6 ngày khảo sát. Hơn nữa, khảo sát thời gian bảo quản kẹo dẻo với bao bì PE trong 5 tuần chỉ ra rằng sản phẩm kẹo dẻo mãng cầu xiêm có màu sắc và hương vị đặc trưng, chất lượng tốt khi được bảo quản trong bao bì PE ở nhiệt độ mát. Bao bì PE có thể là một tùy chọn thích hợp để góp phần duy trì và nâng cao chất lượng sản phẩm kẹo dẻo trong thời gian bảo quản kéo dài.



**Từ khóa:** *Bao bì, kẹo dẻo, mãng cầu xiêm, polyethylene, thịt quả*

# The effect of package material on the quality of gummy candy supplemented with soursop (*Annona muricata* L.) pulp by-product extract


## ABSTRACT

Effective package materials are essential for enhancing consumer welfare by ensuring safety and extending the shelf life of food products. Given that package and storage conditions significantly influence the quality of confectionery, this study evaluated the impact of various package materials on gummy candies supplemented with soursop (*Annona muricata* L.) pulp by-product extract. The results demonstrated that the polyethylene (PE) package was more effective than the polyamide (PA) or polypropylene (PP) ones at maintaining structural integrity and inhibiting the growth of aerobic bacteria, yeasts, and molds. Furthermore, PE successfully preserved the sensory attributes and nutritional profile of the candy, specifically its color and the concentrations of vitamin C, total acids, and total sugars over a six-day observation period. Moreover, the PE package extended the product's shelf life to five weeks while maintaining the characteristic quality, color, and flavor of the soursop-supplemented gummy. Consequently, PE packaging is recommended as a suitable material for preserving the quality of functional gummy candies during prolonged storage.



**Keywords:** *Gummy candy, packaging, polyethylene, pulp, Soursop*


## 1. INTRODUCTION

Soursop (*Annona muricata* L.) is a tropical plant grown in the tropical region of Southeast Asia, South America, Central America, and some Pacific Ocean Islands.[1,2] Soursop has been widely cultivated in the Southern and Central regions of Vietnam due to the favorable soil and climate conditions for its growth.[3,4] It has been known to have a strong flavor and high nutritional content, and to possess health benefits such as anticancer, antimicrobial, antiviral, antiinflammatory, and antidiabetic activities.[5,6] Soursop fruits contain a variety of bioactive compounds with high antioxidant and biological activities, such as phenolic, flavonoid, alkaloid, cyclopeptide, and acetogenin.[7,8,2,4] Moreover, its vitamins and amino acids, such as proline and aminobutyric acid, are comparable to those of bananas, pears, apples, grapes, and pineapples.[9,4] The soursop fruit's vitamin and mineral contents further boost the immune and digestive systems.[2] The pulp contains 29% ascorbic acid, which is higher than in its peels, and abundantly harbors phenolic acids, including gallic acid, benzoic acid, coumaric acid, ferulic acid, and hesperidin.[10] As the soursop fruit is highly perishable and has a short post-harvest life of 3-4 days,[1] it is widely used in the preparation of jams, jellies, dried fruits, syrups, beverages, and wine to produce various nutritious products and increase the economically effective utilization of natural material sources.[1,3,11] However, it is known that a considerable quantity of material sources is underused in its processing; thus, the utilization of the soursop fruit's by-product from the processing can create value-added products, contributing to economic effectiveness and health benefits.

Gummy candy is a popular and favorable food for all people.[12] It is a combination of sugars, gelatin, acid, food coloring, and flavorings.[13] The use of natural juices or purees of orange, strawberry, and other fruits, or even fruit by-products, has been considered for the manufacture of gummy candy. This utilization not only improves gummy's sensory properties (color, flavor, texture), but it also creates more antioxidant and healthier formulations.[14] Several previous studies have demonstrated the effectiveness of utilizing the skins and peels of fruits such as grapes, pineapples, papayas, and lemon peels in the production of gummies.[15,16] Recent group work has utilized soursop pulp by-product from wine production processing to produce gummy candy with highly appreciated texture, color, flavor, and sensory value, meeting the requirements of microbiological safety standards.[17] In continuing with our previous

research, the present study evaluates the effects of the package materials and storage time on the quality of gummy candy supplemented with soursop by-product pulp extract to maintain and improve the quality during the storage period of gummy candy products.

## 2. MATERIALS AND METHODS

### 2.1. Materials

The fruit pulp used is a by-product of soursop wine production. The pulp had a bright white color and good quality.

Saccharose sugar (>99,8%) was originated from TTC Bien Hoa - Dong Nai Sugar One Member Limited Company. Gelatin (bloom 250) and pectin were from TNHH ICFOOD Viet Nam.

Citric acid, ($Pb(CH_3COO)$), 3,5-dinitrosalicylic acid (DNS), hydrochloric acid (HCl), saturated sodium sulfate ($Na_2SO_4$), pectin, and sodium hydroxide (NaOH) were obtained from Xilong Scientific Company, China.

### 2.2. Preparation of gummy candy supplemented with soursop pulp by-product extract

The qualified soursop pulp (50 g) was added to 100 mL of water in a ratio of pulp:water (1:2, w/w). The mixture was minced to obtain the pulp extract, and subsequently, a solution of 150% sugar, 4% citric acid, 0.6% pectin was added. The mixture was heated to 90°C for 7 minutes, and then 35% gelatin was added and heated for an additional 3 minutes to form a uniform mixture. Gelatin was soaked in water for 30 minutes with a ratio of 1:1 (w/w) to fully hydrate and swell prior to use. Next, the mixture was then further heated with the addition of 20% prepared soursop pulp extract for 3 minutes. The cooked mixture was poured into a mold and left at room temperature for 1 hour, and then cooled at 2-4°C for 24 hours to stabilize the structure of the gummy candy mass. Once the candy structure was stabilized after cooling, the mold was removed, and the gummy candy product was obtained.[17]

### 2.3. Investigation of the package materials on the quality of gummy candy supplemented with the soursop pulp by-product

The experiment was laid out following a completely randomized design with triplicate for each treatment. Six samples were stored in three different package treatments, including polypropylene (PP), polyamide (PA), and polyethylene (PE). Afterward, samples were stored in a plastic box and placed at room temperature with natural light. Samples were tested and evaluated for humidity, vitamin C, total sugar content, total acid content, texture, color, and total microorganisms at two-day intervals. Gummy candy samples stored in each corresponding package without sealing were considered the control treatment.

### 2.4. Investigation of storage time on the quality of gummy candy supplemented with the soursop pulp by-product

From the experiment described in the sub-section 2.1.3, we selected the best package material and extended the investigation up to five weeks. The changes of the product during storage time were evaluated once a week, including color, total acid and total sugar content, vitamin C, and total microorganisms, yeast, and mold.

### 2.5. Analysis of physicochemical properties

The product color was analyzed using the ColorLite sph870 portable spectrophotometer to determine the CIE (Commission Internationale de I'Esclairage) color space coordinates through the L*, a*, b* values, in which L* indicates the darkness/lightness of the sample, a* is the measurement of green to red, and b* is the measurement of blue to yellow. The product structure, including hardness, flexibility, toughness, and elasticity, was analyzed using a TMS-Pro texture analyzer with the one-cycle compression method. The maximum compression force parameters were set at 90 N, a height of 15 mm, a speed of 60 seconds, and a compression depth of 50% of the sample's height. The total acid content was determined using a saturated method, as specified in the Vietnamese standard TCVN 4589:1988. Moisture content was measured by the drying method according to the Vietnamese standard TCVN 1867:2001. Reducing sugar content was evaluated by the DNS method.[18] Vitamin C content was determined by the titration method with iodine as described previously.[19]

### 2.6. Analysis of total microorganisms, yeast, and mold (CFU/g)

Aerobic microbial density was measured by the agar-plate counting method. The minced sample (10 g) was added to 9 mL pepton buffer. The sample was thoroughly shaken for 2-3 minutes and diluted to various concentrations. A serial diluted sample (1 mL) was plated on a petri dish of 10 mL of culture medium. After incubation at 37°C for 72 hours, the colonies were counted and

calculated using the formula as follows: N = C/n.d.v, in which N: total colony number in 1 mL sample (CFU: colony forming units), C: number of colonies counted, n: number of plates for one diluted sample, d: dilution factor, and v: volume plated (mL).

### 2.7. Data analysis

Data was analyzed using Statgraphics Centurion XV (Statpoint Technologies Inc., USA). Statistical significance was analyzed by One-way ANOVA. The Least Significant Difference (LSD) was used to test the mean difference between treatments at 5% significance level.

## 3. RESULTS AND DISCUSSION

### 3.1. Effect of package material on the quality of gummy candy supplemented with soursop pulp by-product extract

Package material not only contains the food, but also protects it from the impact of the environment; thus, it is essential in food storage. The effective package offers consumer health benefits, as well as high-quality food with increased safety and a longer usage life.[20] The selection of appropriate package material plays an important role in maintaining the texture, quality, nutritional composition, and sensory properties of the food. The polyester package has been popularly used, providing a barrier against oxygen and carbon dioxide while also regulating humidity in food storage. Moreover, the polyethylene and polypropylene packages have also been used in food storage due to simplicity, low cost, flexibility, strength, lightness, moisture, chemical resistance, and ease of handling.[21] High-density polyethylene is rigid, gas-permeable, and advantageous for processing and shaping.[22,23]

**Table 1.** Effect of packages on the texture of gummy candy supplemented with soursop pulp by-product extract

| Day | Package material | Texture | | | |
|---|---|---|---|---|---|
| | | Hardness (N) | Elasticity (mm) | Flexibility (N) | Toughness (mJ) |
| 2 | PA | $0.38^{bc}$ | $0.25^{ab}$ | $0.35^{b}$ | $0.14^{c}$ |
| | PE | $0.39^{ab}$ | $0.23^{b}$ | $0.35^{b}$ | $0.17^{b}$ |
| | PP | $0.35^{c}$ | $0.26^{a}$ | $0.27^{c}$ | $0.15^{c}$ |
| | *F* | *14.56* | *95.88* | *69.87* | *62.07* |
| | *P* | *0.001* | *0.000* | *0.000* | *0.000* |
| 4 | PA | $0.37^{c}$ | $0.24^{a}$ | $0.33^{b}$ | $0.16^{c}$ |
| | PE | $0.39^{b}$ | $0.23^{a}$ | $0.35^{b}$ | $0.19^{b}$ |
| | PP | $0.33^{d}$ | $0.26^{a}$ | $0.26^{c}$ | $0.15^{c}$ |
| | *F* | *449.00* | *19.56* | *120.31* | *30.00* |
| | *P* | *0.000* | *0.000* | *0.000* | *0.000* |
| 6 | PA | $0.36^{b}$ | $0.23^{c}$ | $0.32^{b}$ | $0.18^{b}$ |
| | PE | $0.39^{a}$ | $0.23^{b}$ | $0.31^{b}$ | $0.21^{a}$ |
| | PP | $0.31^{c}$ | $0.25^{ab}$ | $0.24^{c}$ | $0.16^{b}$ |
| | *F* | *100.25* | *12.47* | *130.33* | *31.76* |
| | *P* | *0.000* | *0.002* | *0.000* | *0.000* |

*Data are the mean of three replicates in each treatment. Different letters in the same column indicate the statistically significant difference between treatments at 5% significance level by the LSD test. PA: polyamide, PE: polyethylene, PP: polypropylene.*

As shown in Table 1, a statistically significant difference was observed between package treatments used to store gummy candy supplemented with soursop pulp by-product extract at six days of investigation. Hardness is one of the important criteria for the quality of gummy candy, and it has a direct relationship with the moisture content of the product in the inverse direction. Toughness reflects the product's flexibility and elasticity. In this investigation, hardness was gradually reduced, and this decrease was found in PA and PP when compared to PE. As for other texture parameters, the elasticity of the product stored in PE package did not show a significant difference after 6 days, remaining at 0.23 mm, while those in PA and PP packages tended to decrease slightly, to 0.25 mm and 0.26 mm on day 2 and to 0.23 mm and 0.25 mm on day 6. Nhi and colleagues identify several factors in the production of gummy candy from soursop pulp, such as toughness and browning, which affect the product life cycle.[24] The toughness of the product showed a significant difference in PA, PE, and PP after 6 days, in which PP had a lower value compared to PE and PA. In terms of the gummy candy's flexibility

characteristic, the flexibility remained at a 0.35N value at day 4 and decreased to 0.31 N at day 6 in the PE package. The flexibility decreased from 0.35N to 0.32N in PA and from 0.27N to 0.24N in PP packages, respectively. This suggests that the product loses its flexibility when kept in these packages.

In addition, the evaluated package types did not significantly affect the color quality, vitamin C content, total sugar content, and total acid content of the product over the 6 days (data not shown).

After six days of storage, the density of aerobic bacteria in PA and PP packages was 1.9 x $10^4$ and 1.8 x $10^4$, respectively, above the allowable limits, whereas the density of aerobic bacteria in the PE package was 4.0 x $10^3$, which was within the allowable limit (The Ministry of Health, 2007) (Table 2). In all three package materials, after six days of storage, the total number of yeast and mold spores was within the allowable limit according to microbial standards (Decision 46/2007/QD-BYT).

**Table 2.** Effect of packages on the microbial parameter after gummy candy's six-day storage**.**

| Day | Parameter | Ministry of Health, 2007 | Package material | | |
|---|---|---|---|---|---|
| | | | PA | PP | PE |
| 2 | Total aerobic bacteria | $\leq 10^4$ | 2.2 x $10^2$ | 2.4 x$10^2$ | 2.0 x $10^2$ |
| | Total yeast and mold | $\leq 10^2$ | ND | ND | ND |
| 4 | Total aerobic bacteria | $\leq 10^4$ | 5.5 x $10^3$ | 3.7 x $10^3$ | 1.4 x $10^3$ |
| | Total yeast and mold | $\leq 10^2$ | ND | ND | ND |
| 6 | Total aerobic bacteria | $\leq 10^4$ | 1.9 x $10^4$ | 1.8 x $10^4$ | 4.0 x $10^3$ |
| | Total yeast and mold | $\leq 10^2$ | <10 | <10 | <10 |

*Data are the mean of three replicates in each treatment. Different letters in the same column indicate the statistically significant difference between treatments at 5% significance level by the LSD test. PA: polyamide, PE: polyethylene, PP: polypropylene. ND: not detected.*

### 3.2. Effect of storage time on the quality of gummy candy supplemented with soursop pulp by-product extract

Because the PE package maintained the stability of structure, color, and quality of gummy candy products better than the PA and PP packages after 6 days. Therefore, we continued to study the impact of the PE package on the quality of gummy candy products during longer storage periods of up to 5 weeks. Color is one of the important characteristics of foods, including candy. It is a parameter that represents the quality and sensory characteristics of consumer tastes. However, it is affected by storage time due to environmental conditions and the type of package used. The results showed that the L* value increased after 5 weeks, from 51.34 in week 1 to 55.50 in week 5. The a* value also increased after 5 weeks, from 3.21 in week 1 to 4.97 in week 5. The b* value decreased after 5 weeks, from -1.48 in week 1 to -1.90 in week 5 (Table 3). The findings showed that the L* and a* values increased, while the b* decreased in the gumy candy product stored in PE after 5 weeks of storage.

**Table 3.** Effect of storage time using PE package on the color parameters of the gummy candy supplemented with soursop pulp by-product extract.

| Time (weeks) | Color values | | |
|---|---|---|---|
| | L* | a* | b* |
| 1 | 51.34$^e$ | 3.21$^e$ | -1.48$^a$ |
| 2 | 52.47$^d$ | 4.84$^d$ | -1.56$^a$ |
| 3 | 53.31$^c$ | 4.25$^c$ | -1.68$^b$ |
| 4 | 54.24$^b$ | 4.74$^b$ | -1.77$^c$ |
| 5 | 55.50$^a$ | 4.97$^a$ | -1.90$^d$ |
| *F* | *563.72* | *229.04* | *96.68* |
| *P* | *0.000* | *0.000* | *0.000* |

*Data are the mean of three replicates in each treatment. Different letters in the same column indicate the statistically significant difference between treatments at 5% significance level by the LSD test.*

**Table 4.** Effect of storage time using PE package on the nutritional composition of the gummy candy supplemented with soursop pulp by-product extract.

| Week | Vitamin C (%mg) | Total acid (%) | Total sugar (%) | Humidity (%) |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| 1 | 16.28 [a] | 1.30[c] | 43.60[a] | 14.47[a] |
| 2 | 15.84[b] | 1.31[c] | 43.35[b] | 13.33[b] |
| 3 | 15.40[c] | 1.33[b] | 42.92[c] | 12.20[c] |
| 4 | 14.96[d] | 1.34[b] | 42.02[d] | 12.13[c] |
| 5 | 14.52[e] | 1.38[a] | 41.15[e] | 11.50[d] |
| *F* | *698.08* | *145.50* | *30776.1* | *1023.64* |
| *P* | *0.000* | *0.000* | *0.000* | *0.000* |

*Data are the mean of three replicates in each treatment. Different letters in the same column indicate the statistically significant difference between treatments at 5% significance level by the LSD test.*

The vitamin C content slightly decreased from 16.28 mg% to 14.52 mg%, while the total acid increased slightly from 1.30% to 1.38% during 5 weeks of storage (Table 4). In addition, the sugar content decreased from 43.6% to 41.15%. The plausible explanation can be due to browning reactions, such as the Maillard reaction, that occurred during storage.[25] This reaction not only reduces the sugar content but can also affect the flavor and color of the gummy candy. Although the total sugar content decreased after 6 days, it was higher than the allowable limit of 40% in accordance with National Standard TCVN 5908:200928. The results also showed that there was an increase in the density of total aerobic microorganisms from $2.0.10^2$ to $4.0 \times 10^3$ after 5 weeks; however, this value was within the allowable limit on microbiological indicator standard according to Decision 46/2007/QĐ-BYT. No yeast and mold spores were detected for 5 weeks (Table 5). Thus, the soursop gummy candy product was well-preserved with the PE package after 5 weeks of storage. The packaging of gummy candy supplemented with soursop pulp by-product extract product was presented in exhibition form (Figure 1).

**Figure 1.** The packaging of gummy candy supplemented with soursop pulp by-product extract product in exhibition form.

**Table 5.** Effect of PE package-based storage on microbial parameters of the gummy candy supplemented with soursop pulp by-product extract.

| Week | Total aerobic microorganism (CFU/g) | | Total yeast and mold (CFU/g) | |
|---|---|---|---|---|
| | Ministry of Health, 2007 | This study | Ministry of Health, 2007 | This study |
| 1 | $\leq 10^4$ | $2.0 \times 10^2$ | $\leq 10^2$ | ND |
| 2 | $\leq 10^4$ | $2.7 \times 10^2$ | $\leq 10^2$ | ND |
| 3 | $\leq 10^4$ | $3.1 \times 10^3$ | $\leq 10^2$ | ND |
| 4 | $\leq 10^4$ | $3.5 \times 10^3$ | $\leq 10^2$ | ND |
| 5 | $\leq 10^4$ | $4.0 \times 10^3$ | $\leq 10^2$ | ND |

*Data are the mean of three replicates in each treatment. Different letters in the same column indicate the statistically significant difference between treatments at 5% significance level by the LSD test. ND: not detected.*

## 4. CONCLUSION

The natural by-products supplemented with food products are a circular strategy to increase economic efficiency and create nutritional value-added products. In this study, among the three storage package types evaluated, the polyethylene (PE) package maintained the quality of the gummy candy product with stable structure, texture, and nutritional content and limited the growth of aerobic bacteria, molds, and yeasts compared to polyamide (PA) and polypropylene (PP) packages. Furthermore, the gummy candy exhibited color and flavor, quality characteristics when stored in the PE package for up to 5 weeks at a cool temperature (4-10°C). The PE package could be a suitable option for maintaining and improving the quality of gummy candy products during long-term storage. To be of commercial value, the effect of the PE package on gummy candy product storage needs to be investigated over a longer period. At the same time, the research results provide scientific values to evaluate and forecast the product's change trend. Further studies should be conducted to determine other factors, such as humidity, light intensity, and others, that can affect the product quality; thereby, diversifying the forms of preservation and circulation of products on the market.

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