Effects of Storage Conditions on the Astaxanthin, Moisture, and Aerobic Microorganisms of Spiced Sergestid Shrimp

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ABSTRACT

Each food product has distinct characteristics, and selecting appropriate storage conditions for each product is essential to minimize quality degradation and extend its shelf life. This study focused on understanding how different packaging materials and storage temperatures influence the quality and longevity of spiced *Sergestid* shrimp, as well as determining the optimal conditions to inhibit microbial activity, prevent moisture absorption, and preserve maximum astaxanthin content. Poethylene bags with an aluminum film (Al/PE), PET bottles (polyethylene terephthalate), paper bags with a polyethylene film (Paper/PE), and glass bottles were used for packaging. Storage was carried out at four different temperatures: 5, 15, 25, and 35°C. The moisture content, astaxanthin content, and total aerobic microorganisms were determined at least once every 3 to 7 days and continuously monitored for 77 days. The findings indicated that PET bottles effectively prevent moisture absorption and protect astaxanthin from degradation over time. However, transparent packaging, such as glass bottles that allow direct exposure of the product to light, negatively affects the stability of astaxanthin. The optimal temperature range for storing this product was identified as being between 5 and 15°C, which helped stabilize moisture content (5.55-6.34%) and inhibit the growth of aerobic microorganisms (2.42-2.58 LogCFU/g). These findings provide crucial insights for the seafood industry, particularly in choosing the right packaging materials and storage conditions to enhance the shelf life and maintain the quality of spiced *Sergestid* shrimp products. This study contributes to the existing knowledge and aids stakeholders in making informed decisions regarding product packaging and storage strategies.

Keywords: packaging; storage conditions; spiced *Sergestid* shrimp; Acetes

Introduction

Dried food items are a popular product category in Vietnam in particular and globally in general due to the convenience of the drying process, which effectively extends the shelf life of food by inhibiting the growth of harmful microorganisms. Among these, dried Sergestid shrimp (*Acetes* species) have become a favored product in the Vietnamese market (Shaikh et al., 2017). Enhancing such products by adding spices not only increases convenience but also improves their sensory and overall perceived value (Brown, 2009). However, spiced products face significant challenges in packaging preservation and maintaining freshness (Devi et al., 2015). These products often contain high levels of salt, sugar, and spices, which can accelerate spoilage compared to other food items (Sahu & Bala, 2017).

Astaxanthin is the key pigment responsible for the vibrant red color of spiced *Sergestid* shrimp, a crucial quality parameter that strongly influences consumer preference. The color serves as an indicator of freshness and product quality, making the preservation of astaxanthin essential for both visual appeal and nutritional value. Additionally, astaxanthin is a powerful antioxidant with various health benefits, including anti-inflammatory, anticancer, anti-aging, and eye health properties (Starska, 2022). However, it is highly susceptible to degradation during storage due to exposure to light, high temperatures, and oxygen (Anarjan & Tan, 2013). Once degraded, astaxanthin loses its antioxidant efficacy and other beneficial properties. In the production and storage of spiced *Sergestid* shrimp, astaxanthin plays a dual role. It not only imparts the shrimp's characteristic red color but also contributes to its antioxidant properties, aiding in product storage (Nicol et al., 2000). Therefore, protecting and maintaining astaxanthin throughout production and storage is critical to ensure the product's quality and nutritional value.

Previous studies have demonstrated that packaging and storage conditions significantly influence the quality and freshness of food products (Shao et al., 2021). Temperature and storage duration are particularly critical factors affecting product quality (Nilsen et al., 2021). For instance, the use of low-quality packaging materials has been shown to increase the moisture content of products leading to reduced freshness (Rojas et al., 2009). Temperature and storage duration also play a crucial role in regulating the moisture content of food. Improper storage conditions can cause the product to lose or absorb excess moisture, negatively impacting its quality. Furthermore, astaxanthin, an essential antioxidant in food products, is susceptible to degradation under unsuitable storage conditions, leading to diminished antioxidant properties and nutritional value. The total amount of anaerobic microorganisms serves as another critical indicator of food quality. These microorganisms can cause spoilage and degrade product quality over time (Christy et al., 2014). Temperature and storage duration have been shown to directly impact the growth of anaerobic microorganisms in food products (Zhang et al., 2021). As such, packaging, temperature, and storage duration are integral to maintaining the quality and freshness of food products. Although numerous studies have investigated food preservation strategies, there remains a lack of comprehensive research on the quality changes of spiced Sergestid shrimp over time and the comparative effects of different packaging materials.

This study aims to determine the optimal storage conditions for spiced Sergestid shrimp. The product was stored at temperatures ranging from 5°C to 35°C in four different types of packaging materials, including PET bottles (polyethylene terephthalate), Al/PE bags (polyethylene bags with an aluminum film), glass bottles, and paper/PE bags (paper bags with a polyethylene film). Throughout the storage period, the study measured key quality parameters, including moisture content, astaxanthin content, and total aerobic microbial content. The findings provided valuable recommendations for ideal storage conditions that minimize the degradation of astaxanthin and limit the growth of aerobic microorganisms. These results can assist businesses in selecting appropriate packaging materials and storage conditions that align with their commercial objectives, ensuring product quality and extending shelf life.

Material and Methods

Material

Green Seafood Company, located in Ben Tre province, Vietnam (9°56'53"N 106°30'51"E), supplies fresh *Sergestid* shrimp (*Acetes*). The raw materials (Grade II) meet the following quality criteria: moisture content ranging from 84.22% to 87.92%, an average length of 6.43 to 10.89 mm, and the absence of large impurities visible to the naked eye. The Sergestid shrimp may appear bruised or broken in half, with a pinkish-white body and a pink spot on the tail. The production of spiced Sergestid shrimp was carried out at Nguyen Tat Thanh University.

The process began with filtered grade II *Sergestid* shrimp, which was placed into a mixing device equipped with stirring blades. The Sergestid shrimp was heated to 90 ± 2!, after which various seasonings were added in the following proportions: 2% annatto color, 1.5% sugar, 2.5% salt, 0.5% monosodium glutamate, 0.2% chili powder, 0.2% garlic powder, 2% vegetable oil, 2.25% sorbitol, 3.83% water, and 0.02% preservative E211. After mixing, spiced *Sergestid* shrimp proceeded to the roasting phase, also conducted at 90 ± 2! until the moisture content reduces to 5-10%. Finally, the mixture was allowed to cool to room temperature before packaging or further processing.

Chemicals

The chemical reagents utilized are as follows: Astaxanthin (e" 97%, Merck, Germany), butylhydroxytoluol (> 99%, Merck, Germany), dichloromethane (> 99.5%, Merck, Germany), and n-hexane (> 95%, Merck, Germany). Biological materials include peptone from animal tissue (Himedia, India), NaCl (> 99%, Xilong, China), $Na_2HPO_4.12H_2O$ (> 98%, Xilong, China), KH_2PO_4 (> 99%, Xilong, China), and plate count agar (Himedia, India).

Processing and storage

Approximately 20kg of spiced Sergestid shrimp were allocated into four different types of packaging. A total of 96 packages were prepared, each containing 200g of spiced *Sergestid* shrimp. These packages were evenly distributed for evaluation across 12 sessions and stored at four temperature levels: 5, 15, 25, and 35°C. The types of packaging used included PET bottles (thickness: 1.41 mm, diameter: 70 mm, and height: 100 mm), Al/PE (thickness PE:0.04 mm, thickness Al: 0.04 mm, length: 148 mm, and width: 220 mm), paper/PE (thickness PE: 0.04 mm, thickness paper: 0.1 mm, length: 148 mm, and width: 220 mm), and glass bottles (thickness: 3.36 mm, length: 80 mm, width: 80 mm, and height: 100 mm). The storage experiment was conducted over a maximum period of 77 days with the support of a multi-room incubator (LI-BM850, LKLAB company, Seoul, Korea). The investigation of packaging types was carried out at a temperature of 5°C, and the investigation of storage temperature was conducted using the optimal packaging determined in the previous investigation. Throughout this period, the quality of the spiced *Sergestid* shrimp was monitored by measuring the moisture content, astaxanthin content, and the total aerobic microorganisms.

Determination of moisture content

The moisture content was determined based on the weight difference of the material before and after the drying process at 105 °C until the weight stabilized across three separate weighings. For this purpose, 0.5 g sample was weighed and dried at 105 °C by using a moisture analyzer (MB90, Ohaus, New Jersey, USA) (Vu et al., 2022).

Determination of total aerobic microogranism (TAM)

The total aerobic microorganism (TAM) was referring to Vu et al., (2024). First, the Salt Peptone Water (SPW) prepared by mixing 10 g of peptone from animal sources, 5 g of NaCl, 9 g of hydrated Na_2HPO_4, and 1.5 g of KH_2PO_4 in 1000 mL of hot water until fully dissolved. Then, 9 mL of mixing solution was poured into each test tube. For the Plate Count Agar (PCA) medium, 23.5 g of PCA was dissolved in 1 L of warm distilled water. The solution was sterilized at 121°C for 15 min, and then it is left to cool to a low temperature in the range of 44-47 °C until use. The preparation of initial sample was beginning with the mixing of 10 g sample with 90 mL of SPW in a sterile Erlenmeyer flask. The flask was shaked vigorously for 2-3 min until homogeny. The serial dilutions were proceeded by making a dilution at 10-fold increments (10^{-1} to 10^{-5}) until the bacteria count is manageable. In each plate, 15 mL of PCA at a temperature of 44 to 47°C was combined with 1 mL of the diluted sample. After vortexing, the PCA was stayed to harden. The plates were incubated at 37°C for 24 hours. The colony was counted.

Determination of astaxanthin content (AC)

The standard curve for astaxanthin was created by carefully pipetting precise volumes of the stock solution - 0.1, 0.5, 1.0, 1.5, and 2.0 mL - into 10 mL flasks. Each flask was then filled to the marked level with a solvent mixture of n-hexane, acetone, and water in a 40:120:100 (mL) ratio. The photometric properties of each solution were measured immediately after preparation. A blend of hexane, acetone, and water was used as the blank for these measurements. For the extraction, approximately 40 mL of mixture B (comprising 40 mL n-hexane, 120 mL acetone, and 100 mL water) was used to extract 5 g of sample (msample). The extract was filtered through Whatman No. 1 filter paper, transferred to a 50 mL flask, and the volume was brought up to the mark (V_1) using mixture B. Each 1 mL (V_2) of the extract was analyzed using UV-Vis spectrophotometry at a wavelength of 470 nm (Sukarman et al., 2023).

Statistical and data analysis

Means resulted for three replications were analyzed by using IMB® SPSS® Statistics software version 25. The significant value was determined by using Tukey test (Vu et al., 2022).

Results and Discussion

The impact of packaging and storage time on the moisture content of spiced Sergestid shrimp

Figure 1 showed the statistically significant impact of different packaging materials and storage duration on the moisture content of spiced *Sergestid* shrimp ($p<0.05$). Different packaging materials, due to their unique structures and properties, significantly influenced the moisture content of the product (Lee, 2010). For PE/paper bags, which combined paper with a thin PE coating and used interlocking C-shaped plastic strips for closure, an increase in moisture content was observed. While the interlocking mechanism provides some barrier against moisture migration, it is not entirely effective. Moisture content rose to 6.21 ± 0.11% after 14 days and continued increasing, reaching 6.66 ± 0.16% by day 77. In the case of Al/PE bags, constructed from a thick PE layer combined with aluminum, the material provides a stronger air seal. However, the similar interlocking closure mechanism resulted in moisture content ingress. Moisture content increased to 6.76 ± 0.17% after 21 days and reached 7.62 ± 0.17% by day 77. Glass bottles, sealed with an aluminum sheet, welded at the seam and topped with a tightly screwed with a metal cap featuring a foam pad, proved more effective in mitigating moisture transfer. The results showed a slow increase in moisture content during the first 42 days, reaching 6.44 ± 0.21%, and stability thereafter until day 77. The most effective packaging was PET bottles, designed with thick, hard plastic, a seam-welded aluminum sheet, and a foam layer to enhance the seal between the cap and the body. This opaque brown packaging effectively stabilized the moisture content, maintaining it below 6.26% throughout storage. Interestingly, moisture content showed a slight decrease by day 77, possibly due to the heat and light-absorbing properties of the PET material, which may enhance moisture evaporation. In summary, based on moisture content transformations, PET bottles are the most effective packaging for in stabilizing the moisture content of spiced *Sergestid* shrimp. Previous studies have emphasized the importance of packaging material properties in managing moisture the exchange and extending food shelf life (Ibrahim, 2023). Environmental factors like humidity and the intrinsic characteristics of the packaging materials such as concentration, density, solubility, and permeability which play critical roles in this process. Effective management of these factors is essential for optimizing the shelf life and quality of packaged foods (Ibrahim, 2023). A report on the storage of dried *Sergestid* shrimp supports these findings, highlighting that PET bottles prevent moisture absorption more effectively than PE-coated paper bags, with a recorded moisture content of approximately 2.6% after 110 days of storage (Thuy et al., 2024).

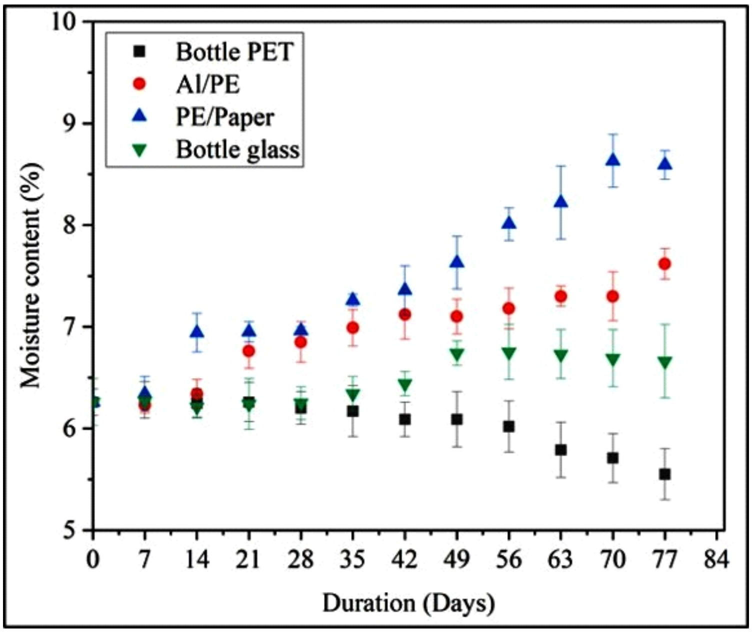

Fig. 1. Moisture content of spiced *Sergestid* shrimp with different packaging and time storage.

The impact of packaging and storage time on the growth of TAM in spiced Sergestid shrimp

Microorganisms can easily invade nutrient-rich environments through the air. Loose packaging increases the likelihood of microbial invasion (Elsas et al., 2011). Figure 2 showed that all four types of packaging significantly influenced the growth of aerobic microorganisms ($p<0.05$). Packaging that allowed greater moisture exchange led to higher moisture content, which in turn accelerated the growth of aerobic microorganisms (Pereira et al., 2012; Wason et al., 2021). The fastest appearance and growth of aerobic microorganisms in spiced Sergestid shrimp was observed in PE/Paper bags. After just 7 days of storage, the total aerobic microorganisms had increased to 2.37 ± 0.04 logCFU/g, which was higher than other packaging types. Extending the storage time to day 35, the count rose to 2.7 ± 0.03 logCFU/g and continued to increase slowly until day 77. This rapid growth was attributed to the initial rise in moisture content and high air permeability of the packaging, which created a favorable environment for microbial proliferation. A similar trend was observed in Al/PE bags. During the first 21 days of storage, the total aerobic microorganisms increased to 2.37 ± 0.03 logCFU/g, remained stable until day 42, and then rose rapidly until day 77. The increased moisture content in this packaging contributed to the accelerated microbial growth. In contrast, PET bottles performed better in limiting microbial growth. During the first 7 days of of storage, the total aerobic microorganisms rose to 2.09 ± 0.06 logCFU/g, after which it stabilized for the next 35 days. The very slow increase in microbial counts over the entire 77-day storage period indicated the effectiveness of PET bottles in controlling moisture and inhibiting microbial growth. Among the four packaging types, PET bottles proved to be the most effective in maintaining the quality of spiced *Sergestid* shrimp by preventing moisture increase and suppressing aerobic microorganism growth. These findings aligned with previous studies that showed reducing oxygen levels in vacuum-sealed packaging significantly inhibited the growth of aerobic bacteria, molds, and yeasts, thereby extending the shelf life and preserving their sensory characteristics (Czerwiñski et al., 2021). Another report confirmed that reducing oxygen levels within the packaging, these systems helped to prevent the growth of aerobic microorganisms (Souza et al., 2012). Similarly, PET bottles were shown to effectively inhibit aerobic microorganism growth during the storage of dried *Sergestid* shrimp in PET bottles (Thuy et al., 2024).

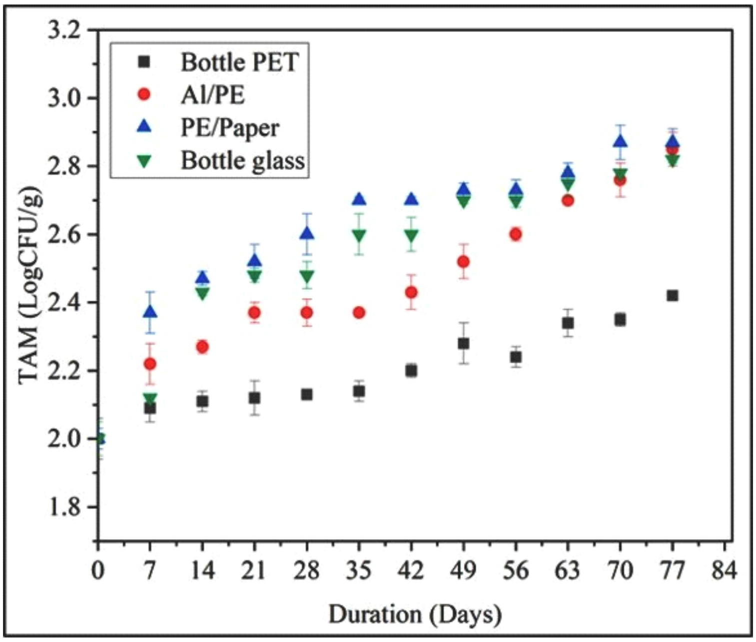

Fig. 2. Total aerobic microorganism of spiced Sergestid shrimp with different packaging and time storage

The impact of packaging and storage time on the Astaxanthin content of spiced Sergestid shrimp

Astaxanthin is a natural carotenoid known for its strong antioxidant properties that can help reduce the risk of cardiovascular disease, cancer, arthritis, and improve skin health (Yuan et al., 2011). However, astaxanthin can degrade during storage (Martínez et al., 2017). Figure 3 showed that the astaxanthin content in spiced Sergestid shrimp significantly varies among different packaging types over a storage period from 0 to 15 days ($p<0.05$). Among the packaging types, glass bottles showed the highest reduction in astaxanthin content from 14.47 to 13.36 mg/gDW. Al/PE bags, PET bottles, and PE/paper bags did not show significant reduction or difference in astaxanthin content. However, after 15 days of storage, the astaxanthin content decreased from 14.47 to 13.91 mg/gDW. It can be concluded that these three types of packaging impact the astaxanthin content in spiced Sergestid shrimp. This may be due to the effect of temperature during storage due to direct exposure of light on the packaging surface (Vasile & Baican, 2021). A previous report indicated that polyethylene packaging, which allows light to pass through, further increases the degradation of astaxanthin (Duncan & Chang, 2012). Additionally, glass bottle packaging significantly affects the astaxanthin content in spiced Sergestid shrimp ($p<0.05$). Glass packaging allows direct light transmission into the product, directly impacting the astaxanthin content. After 15 days of storage, the remaining astaxanthin content was 13.36 ± 0.05 mg/gDW. The combination of moisture retention, microbial growth, and astaxanthin degradation showed that PET bottles are effective in ensuring moisture content, nutrition, and inhibiting microbial growth. A similar previous report also agreed on the degradation of astaxanthin in shrimp over extended storage time (Niamnuy et al., 2008). Another report also revealed a reduction of approximately 43% in astaxanthin content after 15 days and 86% after 40 days of storage of ready-to-eat shrimp preserved in polyethylene packaging (Cui et al., 2013). The variation between packaging types, including PET bottles, Al/PE bags, and paper/PE bags, was also reported to have differing impacts on the astaxanthin of dried Sergestid shrimp during storage (Thuy et al., 2024).

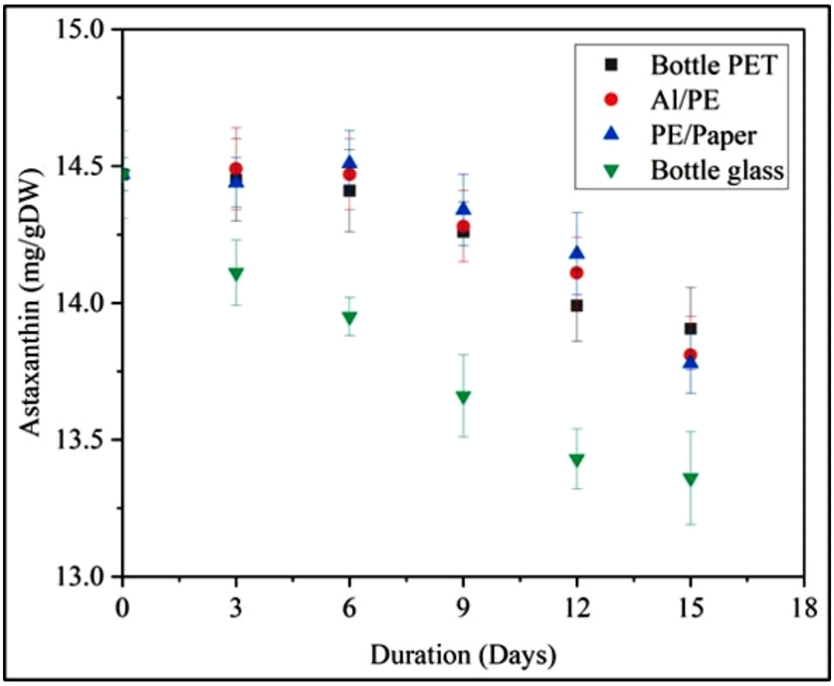

Fig. 3. Astaxanthin content of spiced Sergestid shrimp with different packaging and time storage

The impact of temperature and storage time on the moisture content of spiced Sergestid shrimp

Figure 4 showed the impact of different temperatures and durations on the moisture content of spiced Sergestid shrimp ($p<0.05$). The findings demonstrated that lower storage temperatures resulted in a smaller increase in moisture content over time (Hofmann & Borchert, 2022). At 5°C, the moisture content tended to decrease during the storage period. While no significant reduction was observed within the first 42 days, extending the storage period to 77 days results in a significant reduction, with the moisture content reaching 5.55 ± 0.11%. This reduction was due to the activity of the cooling equipment, which reduced ambient moisture, facilitating moisture migration from the shrimp to the air. As the temperature increases, the separation of moisture in the cooling environment diminishes, and a balance between the moisture content of the spiced Sergestid shrimp and the environment is achieved. Therefore, no significant change is observed when stored at 15°C. At higher temperatures, such as 25°C and 35°C, the moisture content increased. At 25°C, the moisture content rose from 6.26 to 7.04% over 77 days, indicating that elevated temperatures and higher ambient humidity promoted moisture absorption into the product. Similarly, at 35°C, the moisture content increased further, reaching 7.10 ± 0.07% by day 77, due to higher ambient moisture facilitating greater moisture uptake facilitated by the higher temperature and humidity. In summary, both temperature and storage duration critically influenced the moisture content of spiced Sergestid shrimp. Lower temperatures, particularly 5°C, were effective in reducing or stabilizing moisture content, thereby preserving the nutritional and quality attributes of the product. The previous study discussed the importance of optimal temperature and moisture conditions for prolonging the shelf life of food products. It emphasized that inappropriate conditions can lead to increased microbial growth, leading to spoilage and reduced food quality (Hammond et al., 2015). The previous article highlighted that temperature management is crucial for maintaining the desired moisture levels in preserved foods, particularly fruits and vegetables (Amit et al., 2017).

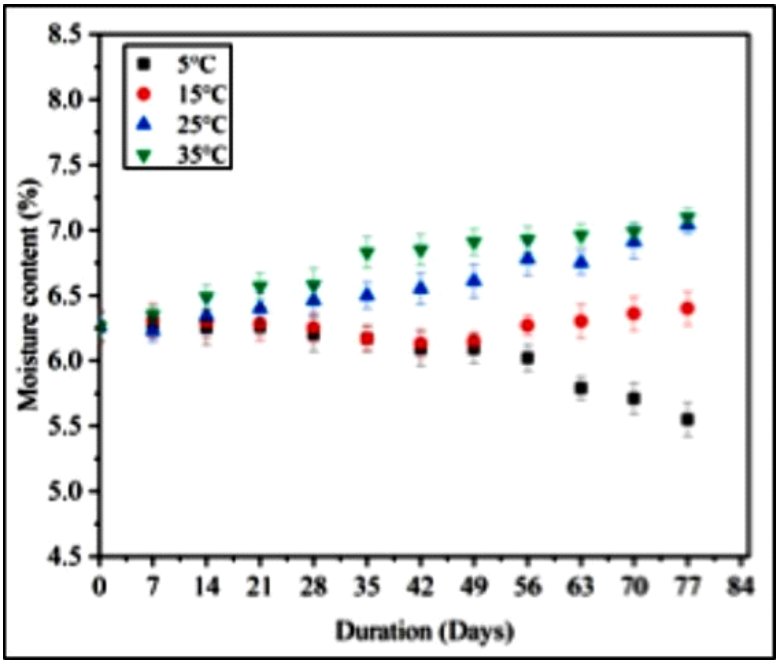

Fig. 4. Moisture content of spiced Sergestid shrimp with different temperatures and time storage

The impact of temperature and storage time on the growth of TAM in spiced Sergestid shrimp

The statistical analysis results indicated a significant effect of temperature on the growth of aerobic microorganisms ($p<0.05$) (Figure 5). At colder temperatures within the surveyed range, there was a notable decrease in the growth of aerobic microorganisms. Specifically, a slow increase in total aerobic microorganisms was observed during storage after 77 days at 5°C, with the total aerobic microorganisms on day 77 reaching 2.42 ± 0.02 LogCFU/g. Additionally, a significant increase was noted during the first 7 days, with the total aerobic microorganisms on day 7 measured at 2.09 ± 0.06 LogCFU/g, followed by a slower growth rate in subsequent days. This pattern attributed to the aerobic microorganisms' initial resistance to the harsh environment at 5°C, followed by a gradual adaptation and development in this challenging setting. When the storage temperature was increased to 15°C, aerobic microorganism activity was facilitated, leading to a more uniform and rapid growth compared to samples stored at 5°C. After 77 days of storage at 15°C, the total aerobic microorganisms reached 2.58 ± 0.05 LogCFU/g. Further increasing the storage temperature closer to standard conditions made it easier for microorganisms to invade and proliferate. Consequently, spiced Sergestid shrimp stored at 35°C saw the highest increase, with total aerobic microorganisms reaching 2.95 ± 0.06 LogCFU/g – the product met food safety standards in accordance with Decision No. 46/2007/QĐ-BYT of Vietnam, with the maximum allowable limit being 5 LogCFU/g. These findings align with prior studies emphasizing the importance of maintaining proper cold chain management to inhibit aerobic microbial growth, which can grow even at refrigeration temperatures commonly used in food storage (Silvestri et al., 2018). Another study examined the role of various factors, including temperature, in influencing microbial growth in food, highlighting how these factors can inhibit or promote growth depending on their levels and interactions (Kim & Ndegwa, 2018). Additionally, research has demonstrated that microbial population growth rates depend on environmental conditions, particularly temperature, which directly affects metabolic rates. Between 0°C and 40°C, temperature increases typically result in sees exponential growth rates of food-spoiling microorganisms (Hammond et al., 2015).

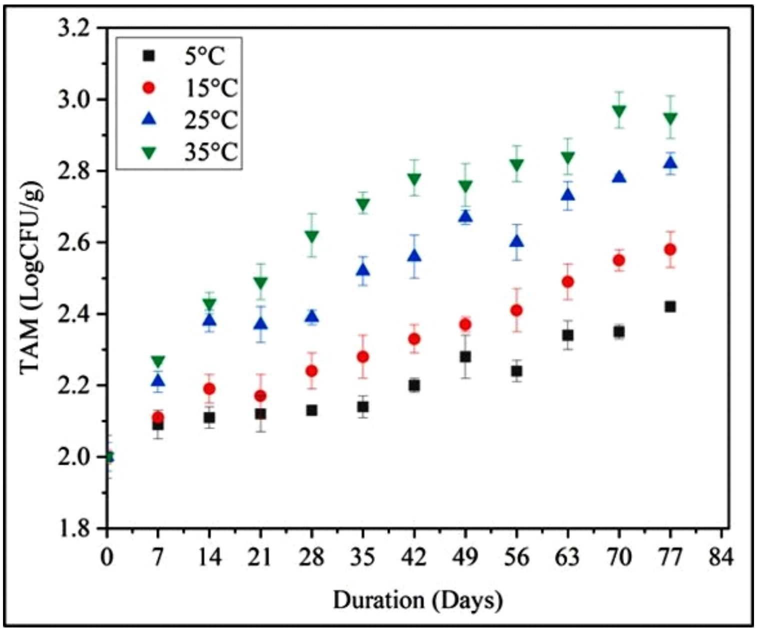

Fig. 5. Total aerobic microorganism of spiced Sergestid shrimp with different temperatures and time storage

The impact of temperature and storage time on the Astaxanthin content of spiced Sergestid shrimp

Astaxanthin is a carotenoid with strong antioxidant properties widely used in functional foods and health supplements. However, it is highly sensitive to temperature extremes, as both low and high temperatures can reduce its concentration due to solidification and degradation processes (Ambati et al., 2014; Liu et al., 2016). Figure 6 showed the impact of different storage temperatures and durations on the astaxanthin content of spiced *Sergestid* shrimp. Over a 15-day observation period, a clear trend emerged: astaxanthin content decreased over time, with the rate of decline varying significantly across temperatures. At a cooler temperature of 5°C, the reduction in astaxanthin content was the most gradual, with a modest decline of approximately 2.48%. In contrast, at higher temperature of 45°C, the astaxanthin content dropped substantially faster, by approximately 17.67%. Temperatures within the intermediate range - 15°C, 25°C, and 35°C - showed reductions in astaxanthin content ranging from 10.41% to 13.84%. These findings indicated that astaxanthin is more stable at lower temperatures, while higher temperatures accelerate its degradation. The reduction in astaxanthin content is primarily attributed to oxidation, which is exacerbated by exposure to light and higher temperatures. Elevated temperatures increase the kinetic energy of molecules, thereby accelerating chemical reactions, including oxidative processes that lead to the degradation of astaxanthin. Therefore, managing temperature is crucial for preserving the content of astaxanthin during storage, especially to mitigate the adverse effects of oxidation and heat exposure. A previous study evaluated astaxanthin's stability in different films under storage conditions. It noted that astaxanthin's color and antioxidant properties could change when stored at higher temperatures, indicating a decrease in stability with increased temperature (£upina et al., 2022). A similar study focused on enhancing astaxanthin's stability through microencapsulation. It reported that astaxanthin encapsulated in alginate beads showed varying degrees of stability under different temperatures, highlighting a significant loss at higher temperatures, which supports the notion that higher temperatures can accelerate the degradation of astaxanthin (Lin et al., 2016). Another relevant study tested astaxanthin nanodispersions and observed that they are highly sensitive to storage conditions, including temperature (Anarjan & Tan, 2013).

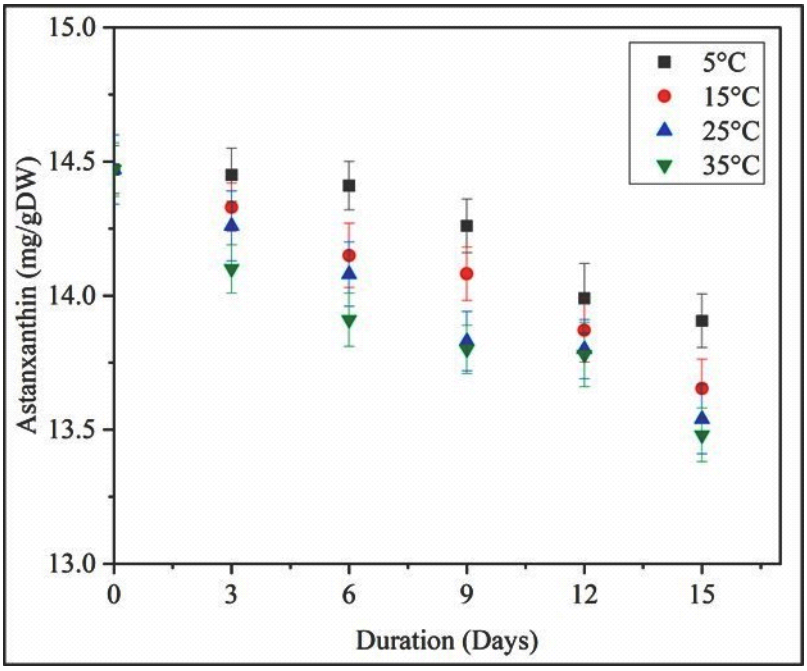

Fig. 6. Astaxanthin content of spiced Sergestid shrimp with different temperatures and time storage

Changes in appearance over time at a suitable storage condition for spiced Sergestid shrimp

Figure 7 illustrated the changes in the appearance of spiced Sergestid shrimp over the storage period. The stages of processing, from harvest to post-storage, significantly influenced the color and appearance of the product. At harvest, *Sergestid* shrimp exhibited a natural, bright pink-white color, with distinct details such as clear eyes and intact shells. Following processing, the product transitioned to a deep orange-yellow hue due to the effects of seasoning and cooking. The texture of the Sergestid shrimp became firmer, and the surface appeared drier, indicating that the processing steps had altered the moisture content and original state of the Sergestid shrimp. After 35 days of storage, the product retained most of its orange-yellow color. However, the surface appeared noticeably drier and less shiny compared to the freshly processed product. This was due to dehydration during storage. Despite these changes, the texture and sensory quality of the product remained largely unaffected. By 49 days of storage, more pronounced changes in appearance were observed. The color of the Sergestid shrimp darkened and intensified, due to continued moisture loss. The texture also became drier, with visible signs of shrinkage and textural changes resulting from prolonged storage. At 77 days of storage, the Sergestid shrimp's color became paler in previous stages, and the surface showed increased dryness and porosity, suggesting further moisture loss. These changes may have resulted in a crisper texture. This change in color may be the result of oxidation astaxanthin compounds, although the product may still be within safe limits for consumption, there is clearly a deterioration in sensory quality.

Fig. 7. Description of the appearance of the product from harvest to post-storage.

Conclusion

This study was designed to assess the effects of four distinct packaging types on the biochemical quality of spiced *Sergestid* shrimp, as well as to identify optimal storage temperatures and analyze how the duration of storage affects product quality. Results showed that all tested packaging types were effective in inhibiting bacterial growth and contamination. Among them, glass bottles proved to be the most effective in preventing moisture absorption and the degradation of astaxanthin. However, this type of packaging also allowed light exposure, which caused photodegradation of astaxanthin. Besides, PET bottle packaging is recommended as suitable packaging to preserve spiced Sergestid shrimp products. The study found that maintaining a temperature range between 5°C and 15°C was most conducive for preserving astaxanthin, ensuring stable moisture content, and preventing microbial growth, without causing significant structural damage to the *Sergestid* shrimp. Storage temperatures from 5°C to 35°C were also explored. Additionally, the data evaluated under different storage conditions indicated that the product has a minimum shelf life of 77 days. These insights are crucial for choosing the right packaging and storage conditions to enhance the shelf life of spiced *Sergestid* shrimp and similar food products. At the same time, the results provided a foundation for developing kinetic models that can accurately predict the product's shelf life in the future.

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