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Effect of packaging method and storage temperature on the sensory quality and lipid stability of fresh snakehead fish (*Channa striata*) fillets

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Abstract

The objective of the present study was to investigate the effect of packaging methods (i.e., air-packaging and vacuum-packaging) and storage temperatures (i.e., chilled temperature of 3 ± 1.0 °C and superchilled temperature of -2.5 ± 0.5 °C) on the sensory quality and lipid stability of fresh snakehead fish fillets. The results indicated that vacuum packaging and superchilled storage significantly improved the quality of fresh snakehead fillets, resulting in lower free fatty acids (FFA), hydroperoxide (PV), and thiobarbituric acid-reactive substances (TBARS) values and higher phospholipid (PL) content compared to other groups. Sensory analysis using the quality index method (QIM) and Torry scores rejected the air-packaged and vacuum-packaged fillets on days 9 and 13 at chilled storage, respectively. Meanwhile, the shelf-lives of air-packaged and vacuum-packaged fillets stored at superchilled temperature of -2.5 ± 0.5 °C were 15 and 25 days, respectively. Strong linear correlations (r^2 = 0.9871 for chilled-air-packaged fillets, r^2 = 0.9605 for chilled-vacuum-packaged fillets, r^2 = 0.9797 for superchilled-air-packaged fillets and r^2 = 0.9132 for superchilled-vacuum-packaged fillets) were found between the QI values and storage time of each fillet group. It can be reasonably concluded that vacuum packaging and storage at -2.5 ± 0.5 °C was more efficient in preserving the fresh quality of the snakehead fish fillets.

Keywords: packaging method; sensory quality; snakehead fish; superchilled storage; lipid stability.

Practical Application: Vacuum packaging in combination with superchilled storage at -2.5 ± 0.5 °C is an effective means to extend the shelf life of fresh snakehead fish fillets to 25 days. This technique has a great potential application in snakehead fish processing industry to ensure sustainable production.

1 Introduction

Fish and seafood products are nutritionally valuable as they contain proteins, lipids, minerals, and vitamins that are beneficial for health. Consumption of fish and seafood products is linked to a lower incidence of cardiovascular diseases and obesity (Tacon & Metian, 2013). Fish consumption accounts for approximately 70% of animal protein intake in Vietnam (Sinh et al., 2014). Snakehead fish is considered to be a noteworthy candidate for global aquaculture as fish farmers choose it for a higher profit over other species (Nen et al., 2018). Snakehead fish is one of the most cultivated fish species in Asia and Vietnam at large. In the Mekong delta, Vietnam, snakehead fish production increased from 5,300 tons in 2004 to 40,000 tons in 2010 (Sinh et al., 2014).

However, fish is prone to oxidation and development of off-flavors resulting from improper handling, incorrect storage, and temperature abuse. Freshness is one of the vital attributes when assessing fish quality and consumer acceptance (Alasalvar et al., 2001). Therefore, the extension of the shelf life of fish is vital to prevent food waste and allow transportation to distant locations. The need to extend the shelf life of fish has led to the optimization of handling, packaging, and storage practices to ensure the freshness and quality of fish. Preserving the natural quality parameters of fish requires the use of temperature, packaging, and chemical additives to delay, reduce, or inhibit spoilage reactions. Low-temperature processing is extensively used to extend the shelf life of aquatic food through its interference with normal physiological processes in bacteria and enzymes (Georlette et al., 2004). The use of low temperatures to preserve fish can be achieved through chilling, superchilling, and freezing. Chilling maintains fish freshness but does not kill, eliminate microorganisms or stop enzymatic activity. Chilling brings the temperature close to but not below the freezing point of the fish muscle. This can be achieved using ice flakes, slurry ice, and cooling air. The shelf life of rainbow trout (*Oncorhynchus mykiss*) increased to 13- and 16-day using flow ice (a mixture of 40% ice and 60% water) alone or with injected ozone respectively from 8 days when stored on normal ice (Ortiz et al., 2008). Superchilling brings the temperature of the fish just below the initial freezing point which is usually between -0.5 °C to -2.8 °C (Kaale et al., 2011). The low temperature and ice crystal formation inhibit bacterial growth and enzymatic activities. Superchilling has been employed to extend the shelf life of seafood like cod (*Gadus morhua*) and salmon (*Salmo salar*) (Duun & Rustad, 2007, 2008). Chilling and superchilling have also been combined with different packaging methods to extend the shelf life of fish. Stamatis & Arkoudelos (2007) found lower bacterial counts in sardines stored in modified atmosphere packaging compared to those in air and vacuum packaging at 3 °C. Wang et al. (2008)

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found that a combination of modified atmosphere packaging and superchilled storage extended the shelf life of fresh cod loins (*Gadus morhua*) from 9 to 21 days while chilled modified atmosphere packaging extended the shelf life to 14 days. Duun & Rustad (2008) found that a combination of vacuum packaging and superchilled storage extended the shelf life of iced salmon samples to 21 days at -1.4 or 3.6 °C. Chowdhury et al. (2017) assessed the quality changes in air-packaged and vacuum-packaged Asian Sea-Bass fillets under 5 ± 1 °C storage temperature. Microbial, biochemical, textural, and sensory properties investigations after 15 days showed that vacuum packaging had better preservative effects. The influence of the packaging technique and storage temperature on the sensory properties and quality of the fish differs from species to species as each has its spoilage patterns and indicators (Sampels, 2015).

Freshness is one of the most important quality indicators of fresh fishery products. The principal method to evaluate the freshness of fishery products is sensory evaluation. Quality Index Method (QIM) and Torry score are reliable methods and have been used for assessment of the freshness of different fishery products (Martinsdottir et al., 2001; Cyprian et al., 2013; Nguyen et al., 2021; Nga & Diem, 2019). The Quality Index Method (QIM) is based on significant, well-defined characteristics of appearance, odor, and texture attributes changing through storage time. A score from 0 to 3 demerit (index) points is given for each quality parameter according to the specific parameter descriptions. The scores are summarized to give an overall sensory score, the Quality Index (QI). The QI is linearly correlated with the storage time at a specific storage condition; thus, the QI can be used to estimate the past and remaining shelf life of the fishery products (Martinsdottir et al., 2001; Cyprian et al., 2013). The Torry score is a systematic scoring system which is based on an objective sensory method to assess the state of the fish or the freshness of the cooked fish (Shewan et al., 1953). It is a descriptive 10-point scale that has been developed for lean, medium-fatty and fatty fish species. When the average Torry score is around 5.5, which indicates that the product is approaching the end of shelf life (Martinsdottir et al., 2001).

The objective of this present study was to compare the shelf life and lipid stability of snakehead fish during storage under chilled or superchilled conditions and air or vacuum packaged conditions. The changes in sensory quality of fresh snakehead fish fillets were evaluated by QIM and Torry schemes. The lipid quality of snakehead fish fillets was assessed by determinations of lipid content, lipid hydrolysis (FFA and PL) as well as lipid oxidation (PV and TBARS).

2 Materials and methods

2.1 Materials

All snakehead fish samples used in this research were bought from a local fish farm in Nha Trang city, Khanh Hoa province, Vietnam. The average weight of the snakehead fish was 700-800 g. The fish were transported to the laboratory alive in water containers.

2.2 Chemicals

All chemicals used were of analytical grade (Sigma-Aldrich, USA) and purchased from Asia Laboratory Instruments Company Limited, 594/23 Au Co Street, Tan Binh District, Ho Chi Minh City, Vietnam.

2.3 Sample preparation and sampling

At the laboratory, fish were rested for 2 h before bleeding and filleting following the procedure described by Nguyen et al. (2021). The fillets were divided into four groups (40 fillets in each group) for different packaging methods and storage temperatures (Table 1). Each fillet was placed on a Styrofoam tray and packaged in a Polyethylene bag for air-packaging and in a Polyamide bag for vacuum-packaging. After packaging, fillets were chilled to 2 °C and superchilled to -2.5 °C in an air blast freezer at a temperature of -35 °C. Chilled samples were stored in a refrigerator at a temperature of 3 ± 1.0 °C. Superchilled samples were stored in a refrigerator at the temperature of -2.5 ± 0.5 °C. The temperature of the refrigerators was controlled using a temperature controller (Conotec FOX-1004, Korea). Five fillets in each group were randomly taken for sensory evaluations (QIM and Torry) and chemical determinations. All measurements were done in triplicate.

2.4 Sensory analysis using QIM scheme

Sensory analyses were carried out by five panelists from the Faculty of Food Technology of Nha Trang University. These panelists were selected for their expertise in the descriptive analysis of food sensory parameters. Before the main evaluation, training sessions were conducted to train the panelists on how to use the QIM and Torry Schemes developed for the freshness analysis of snakehead fish fillets (Nguyen et al., 2021).

The QIM based on a total of 12 demerit points described five attributes including color of the skin side, color of the flesh side, texture, odor, and stickiness of the fillets. Each panelist assessed the fillets from day 0 until spoiled.

2.5 Evaluation of cooked snakehead fillets with Torry scheme

For the analysis of the odor and flavor of the snakehead fish fillets, six slices (2 × 6 cm) were cut from two fillets, wrapped in aluminum foil paper, placed in a perforated stainless-steel pan, and steam-cooked for 10 minutes at 95-100 °C. After cooking, the samples were blind coded with a 3-digit random number and served to the panelists for evaluation and grading using

Table 1. Definition of treatments and sampling schemes.

Treatment Code	Treatment	Storage temperature	Sampling days
Fresh fish			0
CAP	Air-packaged & Chilled storage	3 ± 1.0 °C	3, 6, 9, 10
CVP	Vacuum-packaged & Chilled storage	3 ± 1.0 °C	3, 6, 9, 10, 11, 12, 13, 14
SAP	Air packaged & Superchilled storage	-2.5 ± 0.5 °C	3, 6, 9, 12, 15
SVP	Vacuum-packaged & Superchilled storage	-2.5 ± 0.5 °C	3, 6, 10, 14, 17, 20, 23, 25

CAP: Air-packaged & Chilled storage; CVP: Vacuum-packaged & Chilled storage; SAP: Air-packaged & Superchilled storage; SVP: Vacuum-packaged & Superchilled storage.

Torry Scheme developed by Shewan et al. (1953) with some modifications made by Martinsdottir et al. (2001) for medium fatty fish. An average score of ≤ 5.5 was used as the sensory rejection point. Torry Scheme ranged from 3-10 with higher scores reflecting premium quality.

2.6 Total lipid determination

Lipids of fish muscle were extracted from a sample with methanol/chloroform/0.88% KCl (/1/0.5, v/v/v) according to the method of Bligh & Dyer (1959). The lipid content was determined gravimetrically after evaporation of all chloroform and the results were expressed as a percentage of the wet-weight samples.

2.7 Lipid hydrolysis determinations

Free fatty acid (FFA) content was determined on lipid extract according to the method of Bernárdez et al. (2005), based on complex formation with cupric acetate-pyridine, followed by absorbance reading at 715 nm (Libra S50 UV/VIS spectrophotometer, Biochrom, UK). The results were expressed as grams FFA/100g of lipid using a standard curve prepared from oleic acid.

Phospholipid content of the fish muscle was determined according to the method of Stewart (1980), based on the complex formation of phospholipid with ammonium ferrothiocyanate, followed by absorbance reading at 488 nm (Libra S50 UV/VIS spectrophotometer, Biochrom, UK). The results were expressed as a percentage of total lipid content and calculated using a standard curve prepared from phosphatidylcholine.

2.8 Lipid oxidation measurements

Lipid hydroperoxide (PV) was determined by the ferric thiocyanate method of Shantha & Decker (1994). The results were expressed as μmol lipid hydroperoxides per g of sample (μM CPO/g).

Thiobarbituric acid-reactive substances (TBARS) were determined according to the method of Lemon (1975) with adjustments described by Nguyen & Phan (2018). The results were expressed as μmol malondialdehyde per kg (μM MDA/kg) calculated using a standard curve constructed from MDA equivalence in tetraethoxypropane (TEP).

2.9 Statistical analysis

Microsoft Excel 2021 was used to generate graphs and tables (Microsoft Corporation, USA). The results were analyzed using one-way ANOVA and the mean was statistically evaluated using Duncan's multiple range test (DMRT) to obtain the conservative differences with multiple comparisons with the level of significance set at $P < 0.05$. All the statistical analyses were carried out using the SPSS (version 26) software (SPSS Inc., Chicago, Illinois). The results were presented as means ± SD.

3 Results and discussion

3.1 Quality Index Method (QIM)

Changes in the freshness of air-packaged and vacuum-packaged snakehead fish fillets at chilled and superchilled storage evaluated using the QIM scheme are shown in Figure 1.

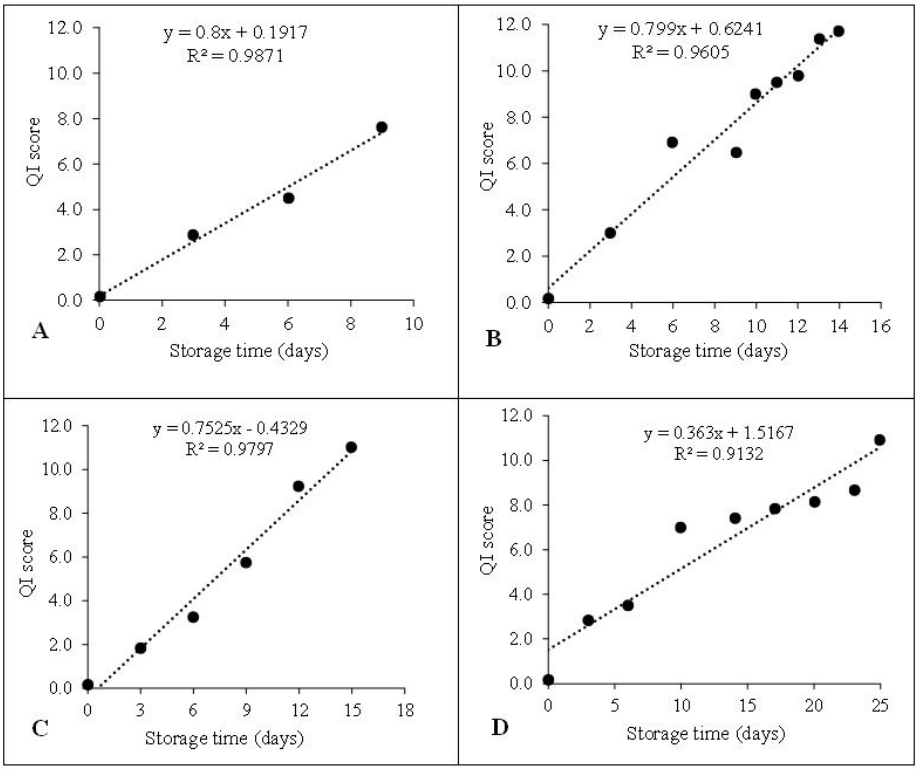

Figure 1. Changes in Quality Index (QI) score of fresh snakehead fillets as functions of packaging method and storage temperature. (A) air-packaged and chilled storage; (B) vacuum-packaged and chilled storage; (C) air-packaged and superchilled storage; (D) vacuum-packaged and superchilled storage.

Sensory quality in all the treatment groups reduced with storage time. At the beginning of storage (day 0), the quality of the fish was characterized by a uniform white color on both sides of the flesh and skin of the fillets with a fresh seaweed odor and elastic texture with no shredded meat stickiness. These fresh quality attributes were given a score of zero from the QIM scheme. During storage, the QIM scores (QI) for the chilled air-packaged fillets were relatively low from day 0 to day 6. However, spoilage was evidenced by a change in the color of the skin side and odor of the air-packaged group after day 9. The uneven pale-yellow color, rancid odor, and viscous texture of the fillets on day10 rendered the chilled air-packaged fillets unfit for human consumption. Therefore, the shelf life of the air-packaged fillets stored at 3 ± 1 °C was 9 days. Change in the odor of the chilled air-packaged fillet was in correlation (r^2 = -0.964) with its Torry score. Unlike the air-packaged fillet group, changes in the attributes of vacuum-packaged fillets at chilled storage were comparatively slow up to day 9. On day 10, a pale-yellow color was observed on the flesh side of the vacuum-packaged fillets. This was not conclusive of the end of storage life as subsequent evaluation on day 11 could not verify spoilage. However, from day 11 onward, fluctuation in most of the attributes continued above the critical limit. The panelists finally judged the CVP fillet group to be unfit for consumption on day 14. The packaging method had a significant effect ($P < 0.05$) on the quality of the snakehead fish fillets stored at chilled conditions. Vacuum packaging at chilled temperatures extended the shelf life of the fillets from 9 to 13 days. Similar results have been reported in previous studies. A shelf life of 9 days for air packaged and 15 days for vacuum-packaged Silver Pomfret (*Pampus argenteus*) fillets stored at 4 °C was revealed in an earlier study by Chowdhury et al. (2017). It is reported by Frau et al. (2021) that vacuum packaging of artisanal goat cheeses represents the possibility of preserving the cheeses for a longer time and thus increasing their shelf life. The shelf life of vacuum packaged fish balls prepared from *Capoeta trutta* was extended to two weeks on average during chilled storage at 4 °C (Özpolat, 2022).

The end of storage for the superchilled air-packaged group was signaled by the appearance of a pale-yellow color on the flesh side, a soft texture, and an off-odor on day 15. A similar pattern of spoilage was also noticed in the superchilled vacuum-packaged fillets. A sharp increase in all the attribute scores from day 0 to day 3 was observed. After day 3, the attributes remained comparatively stable until an off-odor and an opaque yellowish color were observed on the flesh side on day 17. An early indication of spoilage frequently observed in the odor and color parameters is thought to be due to the degradation of certain proteins that produce volatile compounds in the fish muscles. The accumulation of secondary lipid oxidation products such as aldehydes, ketones, and carbonyls, is responsible for off-odor and off-flavor development as well as discoloration (Yin et al., 2014).

From regression analysis (Figure 1), a strong positive correlation was found between the QI for each fillet group and storage time. The correlation coefficients (r^2 = 0.9871 for CAP, 0.9605 for CVP, 0.9797 for SAP, and 0.9132 for SVP) indicate the adequacy of the QIM scheme used to examine quality changes in the raw snakehead fish fillets at chilled and superchilled temperatures. The results of this study show that the shelf life of raw air-packaged and vacuum-packaged snakehead fish fillets is 9 and 13 days at chilled storage (3 ± 1 °C) and 15 and 25 days at superchilled storage at -2.5 ± 0.5 °C respectively. Vacuum packaging extended the shelf life of the fresh snakehead fish fillet by 66.7% in both chilled and superchilled storages. This is higher than the 6-day and 10-day shelf life reported for air-packaged and vacuum-packaged Salmo (*Trutta macrostigma*) stored at 5 ± 1 °C by Karakaya & Duman (2016) but slightly lower than the 28-day shelf life reported for common carp (*Cyprinus carpio)* stored at -12 °C (Raj et al., 2016). The results of the present study were not in agreement with Oliveira et al. (2022) who reported that vacuum packaging did not influence in the shelf life of Brazil nut kernels. This might be attributed to the differences in chemical compositions and properties of different products. Storage temperature is considered vital to the efficacy of the packaging method as the superchilled fillet group had a prolonged shelf life than its counterpart in chilled storage.

3.2 Torry score of cooked snakehead fish muscle

Changes in the odor and flavor of the snakehead fish fillets during chilled (3 ± 1.0 °C) and superchilled (-2.5 ± 0.5 °C) storages are presented in Figure 2. The mean Torry scores for all the fillet groups generally declined in a linear pattern throughout the chilled and superchilled storage time. The average Torry score of 5.5 has been used as the limit for human consumption. Torry scores appeared below 5.5 on days 10 and 14 for air and vacuum-packaged fillets stored at chilling temperature. Whereas at superchilled storage, Torry scores remained well above 5.5 up to days 15 and 25 for air and vacuum-packaged fillet groups. Initially (from day 0 to day 6), air-packaged fillets showed a higher Torry score than vacuum-packaged fillets in both storages.

The odor and flavor of all the fillet groups on day 0 were characterized by a fresh oily and boiled milk smell. As storage time progressed, deviation from the fresh state of the fish was observed especially in the air-packaged group which presented a

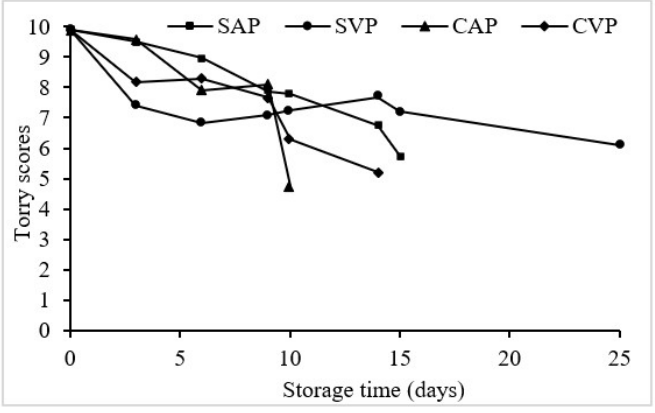

Figure 2. Changes in Torry scores of cooked snakehead fish muscle during storage as functions of packaging method and storage temperature (CAP: Air-packaged & Chilled storage; CVP: Vacuum-packaged & Chilled storage; SAP: Air-packaged & Superchilled storage; SVP: Vacuum-packaged & Superchilled storage).

rancid odor and a bitter taste that marked the end of its shelf life on day 10 in chilled storage and day 15 in superchilled storage. Variability between fillet groups of the same temperature history is said to be due to a fast rate of chemical deterioration in the fish muscles in the air-packaged group. A similar observation was recorded from the analysis of air-packaged redfish fillets that deteriorated after 11 days of chilled storage at 2 °C (Githu, 2013). A rancid flavor was noticed in air-packaged Nile tilapia (*Oreochromis niloticus*) fillets after 9 days of chilling at 1 °C in a study by Cyprian et al. (2013) similar to the present study. There was no significant difference ($P > 0.05$) in the Torry scores between groups of packaged fillets (chilled vs. superchilled storage) as well as within groups (air-packaged vs. Vacuum-packaged). A similar result was reported by Nga & Diem (2019) when Torry Scheme did not differentiate between Nile Tilapia fillet groups stored at 1, 4, 9, 15, and 19 ± 1 °C. However, more fluctuations were observed in the Torry scores of fillets from chilled storage than its superchilled counterparts regardless of the packaging methods. The relative stability of scores from the superchilled storage may be attributed to the preservative effect of low temperature with ice crystal formation. Torry scores from superchilled fillet group slightly outstrip fillets from chilled storage only at the end of storage time with 5.8 and 5.6 scores recorded for SAP and SVP as compared to 4.8 and 5.2 for CAP and CVP, respectively. This indicated that superchilled fillet groups were still in an acceptable range for consumption at the end of storage. Torry Score used in this work could not vividly distinguish the effect of the packaging method on the flavor and odor of cooked snakehead fish fillets.

3.3 Lipid content

Changes in the lipid content of snakehead fish fillets during storage for the four treatment groups are shown in Figure 3. The lipid content of all the samples slightly decreased at the end of storage. At the end of the storage period, the lipid content of the fillets stored at superchilled temperatures was significantly ($P < 0.05$) higher than that of the fillets stored at chilled temperatures. There was no significant difference in the lipid content at the end of storage of fillets under different packaging methods stored at the same temperature. Storage temperature had a greater effect on the final lipid content than the packaging method. In a similar manner, the lipid content of chilled snakehead fish fillets at the end of storage was significantly ($P < 0.05$) lower than the initial lipid content at day 0. The decrease in the lipid content of snakehead fish fillets at chilled storage was in accordance with the higher lipid oxidation products (i.e., PV and TBARS) obtained in these fillets. The decrease in the lipid content is thought to be due to lipid oxidation.

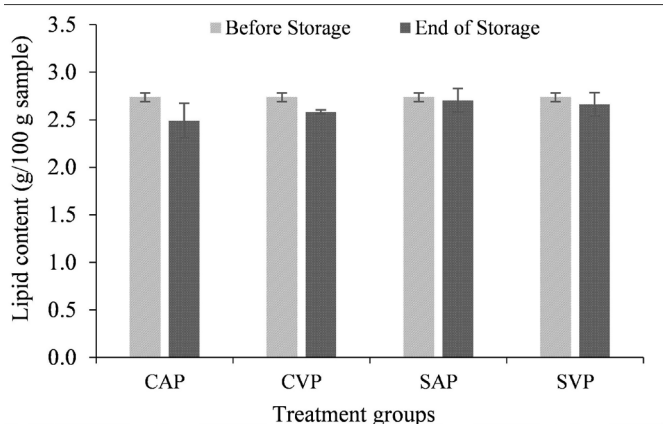

Figure 3. Changes in lipid content of snakehead fish fillets during storage as functions of packaging method and storage temperature (CAP: Air-packaged & Chilled storage; CVP: Vacuum-packaged & Chilled storage; SAP: Air-packaged & Superchilled storage; SVP: Vacuum-packaged & Superchilled storage).

3.4 Lipid hydrolysis

Changes in the free fatty acid (FFA) and phospholipid (PL) contents of snakehead fish fillets as affected by the packaging method and storage temperature are shown in Figure 4A, 4B, respectively. The FFA content of all the samples significantly increased at the end of storage except SVP samples (Figure 4A). At the end of the storage period, a higher FFA content was observed in fillets stored at chilled conditions and was significantly different ($P < 0.05$) from that of superchilled fillets. A similar increase in the FFA content was reported by Ozyurt et al. (2009) for red mullet and goldband goatfish stored in ice for 11 days. The FFA content at the end of storage was 1.12% oleic acid for red mullet and 1.40% oleic acid for goldband goatfish. The PL content of the samples was significantly decreased at the end of the storage period (Figure 4B). The PL content of the chilled samples was significantly lower than that of the superchilled samples. Vacuum packaging in combination with superchilled storage was effective at retarding lipid hydrolysis as evidenced by the lower FFA content and higher PL content in comparison with other groups. The increased FFA content was in negative correlation with the decrease in PL content, showing that phospholipids are preferentially hydrolyzed. During storage, lipids in fish are hydrolyzed by microbial enzymes, natural lipases in fish muscles, and spontaneous lipid hydrolysis (Hwang & Regenstein, 1993). The increase in FFA content and decrease in PL content with time observed in this study can be used to indicate loss of freshness in snakehead fish fillets.

3.5 Lipid oxidation

The extent of lipid oxidation in both chilled and superchilled storage is shown in Figure 5. Generally, the hydroperoxide value (PV) for all the fillet groups significantly ($P < 0.05$) increased at the end of storage (Figure 5A). The PV detected in the fresh fish on day 0 was 0.05 μmol CPO/g of the sample. At the end of storage, PV increased to 0.16, and 0.13 μmol CPO/g on days 10 and 14 in fillets stored at chilled conditions for CAP and CVP, respectively. Low PV of 0.10 and 0.07 μmol CPO/g were obtained in SAP and SVP from superchilled storage, respectively. In the same way, a significant increase ($P < 0.05$) was observed in the TBARS value from 1.1 μm/g on day 0 to 4.3, 8.5, 4.0, and 2.5 μM MDA/kg in CAP, CVP, SAP, and SVP respectively at the end of storage period (Figure 5B). TBARS of snakehead fish fillets stored at superchilled conditions were lower than those for chilled storage. At the same storage temperature, vacuum-packaged snakehead fish fillets had lower TBARS values

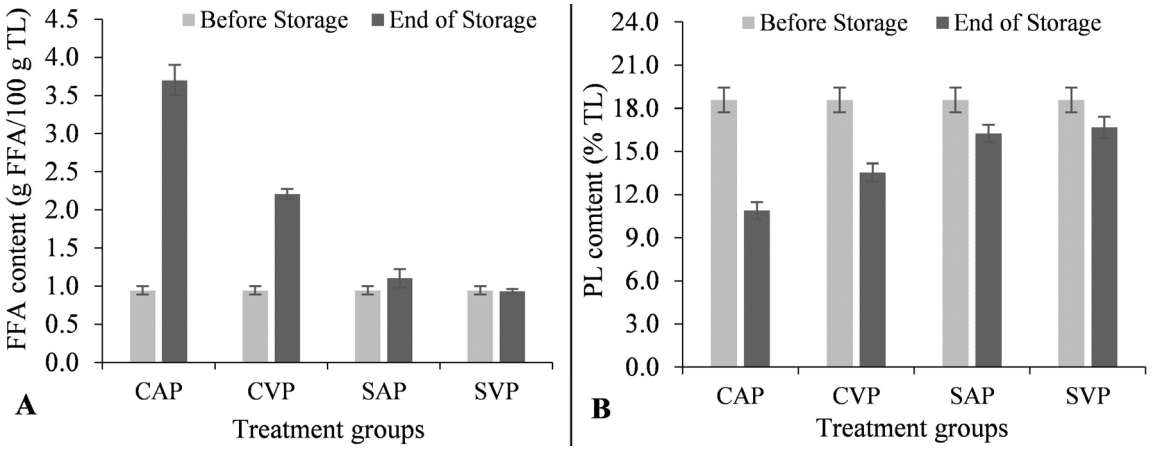

Figure 4. Changes in FFA content (A) and PL content (B) of snakehead fish muscle after storage as functions of packaging method and storage temperature (CAP: Air-packaged & Chilled storage; CVP: Vacuum-packaged & Chilled storage; SAP: Air-packaged & Superchilled storage; SVP: Vacuum-packaged & Superchilled storage).

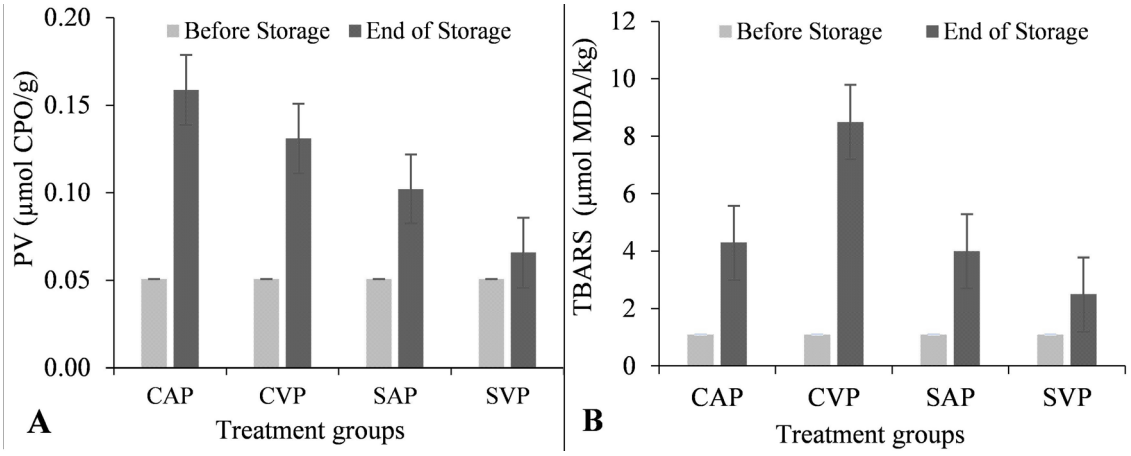

Figure 5. Changes in PV content (A) and TBARS content (B) of snakehead fish muscle after storage as functions of packaging method and storage temperature (CAP: Air-packaged & Chilled storage; CVP: Vacuum-packaged & Chilled storage; SAP: Air-packaged & Superchilled storage; SVP: Vacuum-packaged & Superchilled storage).

compared to air-packaged samples. A similar increase in lipid PV and TBARS values was reported from the frozen storage of cobia fillets (Nguyen & Phan, 2018). The lowest value of TBARS recorded for superchilled vacuum-packaged snakehead fish fillet in our result was comparable to that obtained for superchilled Golden rainbow trout (Kitanovski et al., 2017). Özpola (2022) reported that the TBA content of vacuum-packaged fish ball was lower than air-packaged fish ball during chilled storage at 4 °C for 35 days. The elevation of the peroxide value in CAP and CVP indicated a higher extent of lipid oxidation that occurred in these fillet groups during chilled storage. Lipid hydroperoxide is an unstable primary lipid oxidation product, its content in fish muscle depends on the rate of formation and decomposition. The decomposition of hydroperoxide in the CAP and CVP was indicated by their increasing values in TBA-reactive substances. The accumulation of aldehydes in fish muscle can further damage protein and release rancid flavors (Taheri & Motallebi, 2012). The spoilage indication due to increased TBARS value in the snakehead fish fillets stored at chilled temperature is in agreement with the rancid odor and off-flavor indicated by the QIM scheme and Torry scores. Based on this result, it can be judged that vacuum packaging in combination with superchilling temperature efficiently enhanced the fresh quality of the snakehead fish than air packaging at chilled or superchilled storage temperature.

4 Conclusion

The results of the present study indicated that storage temperature and packaging method strongly affected the sensory quality and lipid stability of fresh snakehead fish fillets during storage. Vacuum packaging and superchilled storage significantly improved the sensory quality and retarded the lipid degradation of fresh snakehead fillets. Based on the QI scores and Torry scores, the shelf-lives of air-packaged and vacuum-packaged fillets at chilled storage of 3 ± 1.0 °C were 9 days and 13 days, respectively. Meanwhile, the shelf-lives of air-packaged and vacuum-packaged fillets stored at superchilled temperature of -2.5 ± 0.5 °C were 15 and 25 days, respectively. Vacuum packaging

in combination with superchilled storage is an effective means to extend the shelf life of snakehead fish fillets. This new technique has the potential to extend the intrinsic freshness of snakehead fish fillets and ensure sustainable production.

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