International Journal of Food Studies | IJFS May 2024 | Volume 13 | pages 36–45

Effect of Salt (Nacl) and Vacuum Packaging on Some of the Quality Attributes of Snakehead Fish

Eka Andriani[a], Hendrik Septiana[a], and Al Mukhlas Fikri[a*]

[a] Department of Nutrition, Faculty of Health Sciences, University of Singaperbangsa Karawang, Karawang, Indonesia, 41361
[*]Corresponding author
mukhlas.fikri@fikes.unsika.ac.id

Received: 24 December 2022; Published online: 1 May 2024

Abstract

Snakehead fish (*Chana striata*) is one of the important protein sources among Indonesian people. However, the shelf life is short leading to limited use of fresh snakehead fish. This study aimed to analyse the effect of vacuum packaging and addition of salt on the sensory properties, total plate count, water activity and pH of fresh snakehead fish. The fish was salted (NaCl) at various concentrations, including 0, 5, 10 and 15%, and kept for 14 days at refrigeration temperature (± 3 °C). Sensory evaluation, TPC and a_w measurements, and pH analysis were performed at day 0, 7 and 14. All groups with salt addition exhibited a significantly slower decrease in the mean scores (9-point hedonic scale) of color, aroma, appearance and texture ($p < 0.05$), with the decrease for all sensory properties detected at day 7 of storage. In microbial tests, a significant increase in TPC was observed in the groups with 0% and 5% salt addition ($p < 0.05$). The group with 15% salt addition showed the lowest water activity. Also, the group without salt addition had the highest pH value. This study demonstrated that addition of salt to snakehead fish might gives beneficial effects on the shelf life of a vacuum packaged product. However, the optimum shelf life using vacuum packaging and salt addition needs further study.

Keywords: Salted fish; Shelf life; Snakehead fish; Vacuum packaging

1 Introduction

Snakehead fish is an important source of protein among Asian people (Jr. & Williams, 2004). It is a freshwater fish that contains a high content of protein (16.2%) (Widodo et al., 2012). Snakehead fish is also a great source of albumin which is important in wound healing and immune system modulation (Herumuryawan & Hardaningsih, 2017; Tungadi, 2019; Widodo et al., 2012). Additionally, It has been reported to have several biological activities, including anti-inflammatory Suhendi et al. (2019) and antidiabetic Suhendi et al. (2020) effects, and lowering oxidative stress (Abdulgani et al., 2020). It has greater economic value, due to the higher meat proportion, than other freshwater fish (Ren et al., 2022). However, like other types of freshwater fish, the snakehead fish is very perishable, causing a very short shelf life of no longer than three days at refrigeration temperature (Leng et al., 2022).

Snakehead fish is commonly found in traditional menus and offers potential for the development of economic products in the culinary industry (Ren et al., 2022; Widodo et al., 2012). Snakehead fish has been extensively used in many local menus, namely fish soup (Ren et al., 2022), grilled fish and fried fish (Marimuthu et al., 2012), smoked fish (Omoruyi et al., 2017), *pempek* (Jayanti et al., 2017), *seruit* (Bertalina et al., 2023) and *koya* (Anandito et al., 2019). In addition to good taste

 10.7455/ijfs/13.1.2024.a3

and consumer acceptance, snakehead fish is a nutritious food containing high values of protein (16.2%) and minerals (Tungadi, 2019; Widodo et al., 2012). However, due to its very short shelf life, distribution of snakehead fish becomes challenging (Rodgers, 2006). Extending the shelf life of fresh snakehead fish is important as fresh fish is mainly needed in food processing. Furthermore, food packaging can be used in preservation to extend the shelf life (Qi et al., 2014; Susan et al., 2018).

Vacuum packaging is a simple technology that is popularly used to extend the shelf life of a food product (Aberoumand & Baesi, 2020). This technology removes air from the pack, causing very low oxygen levels which can inhibit the activity of enzymes and microorganisms (Patil et al., 2020). Vacuum packaging has been used to preserve some foodstuffs, including meat, dairy products and even condiments up to 4 weeks (Bindu et al., 2002; Korkeala & Björkroth, 1997; Semjon et al., 2018). Also, other studies have preserved fish and fish products using the vacuum packaging method in combination with atmosphere modification (Goulas & Kontominas, 2007; Nasution et al., 2017; Özogul et al., 2004). A very recent study evaluated the effect of vacuum packaging and cold storage on the sensory quality and lipid stability of snakehead fish fillets, and it found the shelf life could reach 25 days (Nguyen et al., 2023). Besides cold storage and atmosphere modification, vacuum packaging with the addition of preservatives to the foodstuff is also effective for inhibiting microbial growth (Patil et al., 2020).

Salt (NaCl) has been used for centuries as a food preservative (Awuchi et al., 2020). Salt can cause a reduction of water activity in the food and shrinkage of microbial cells due to the hypertonic environment ("Preservation and Physical Property Roles of Sodium in Foods," 2010). Salt is considered a cheap preservative which can be used by households and micro, small and medium enterprises (MSMEs). Moreover, investigations that combine vacuum packaging and salting in food preservation are still limited. Therefore, by looking at the current sales potential where production may only be limited to regions with rivers, lakes, ponds and swamps, vacuum packaging can also be utilized to prolong the shelf life of snakehead fish and improve its economic potential (Ren et al., 2022). Therefore, this study aimed to evaluate the effect of vacuum packaging on the sensory quality, total plate count, water activity and pH of snakehead fish. In addition, to optimally extend the shelf life, the fish was salted at various concentrations.

2 Materials and methods

2.1 Material preparation and vacuum packaging

The fresh snakehead fish (*Chana striata*) used in this study was sourced from the traditional market of Karawang, Indonesia. The fish was cleaned and then cut, by an incision along the back of the fish to its tail, into several pieces (2.5 x 2.5 x 2.5 cm) to obtain the fillets. During cutting, the head, skin, guts, fins and bones were removed. Table salt (NaCl) was added to the fillets, at concentration of 0, 5, 10 and 15%, and the resulting fillets were immediately vacuum-packed (Sinbo, Turkey) (voltage: 220 V; power: 150 W; vacuum pressure: 0,045 kPa; sealing length: 28 cm; sealing width 50 cm). Vacuum packaging was performed at room temperature, using polythene bags. Then, the vacuum-packed snakehead fish fillets were stored at refrigeration temperature ($\pm$ 3 ^{o}C).

2.2 Total plate count, pH and water activity

Total bacteria were measured using the Total Plate Count (TPC) method for fishery products as specified in the Indonesian National Standard (INS) No. 01-2332.3-2006 (Indonesian National Standard, 2006). The pH of fish was measured using a pH meter (GLP 21 Crison, USA) as specified in the INS No. 06-6989.11-2004 (Indonesian National Standard, 2004). Water activity (a_w) was measured using a a_w meter (Rotronic-Hygrolab, USA), following the procedure of Ahmad et al. (2005). Measurements were made on days 0, 7 and 14.

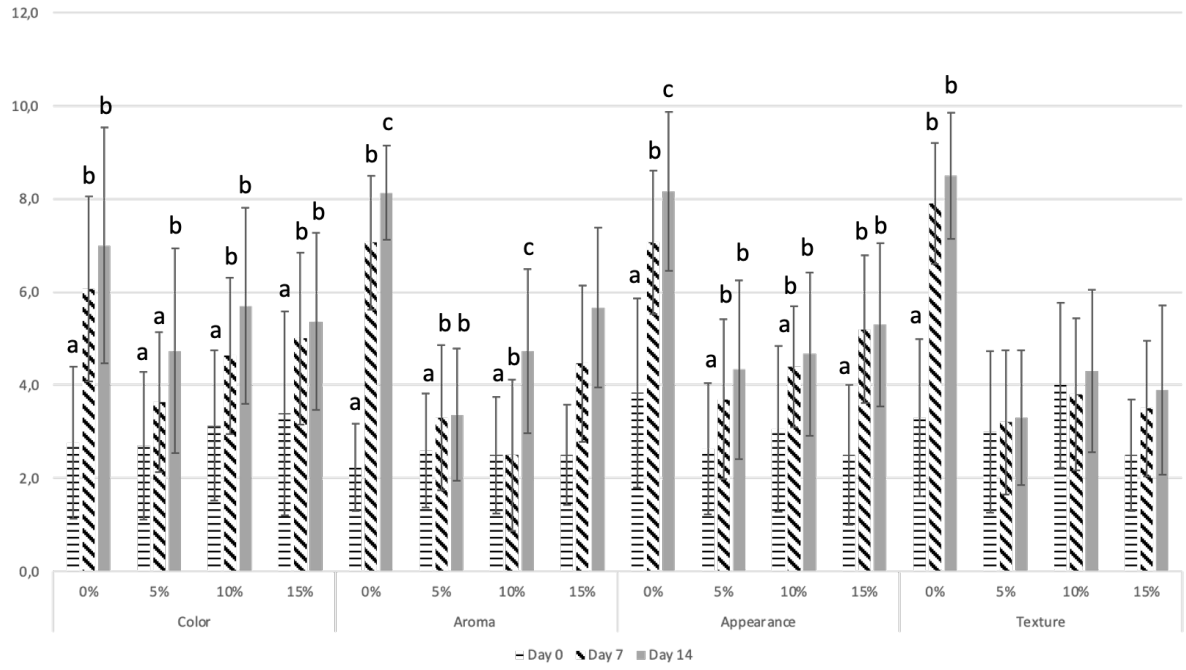

Figure 1: Comparison of the sensory properties of snakehead fish between the groups of salt addition at day 0, 7 and 14.

2.3 Sensory evaluation

Sensory properties of the vacuum-packed fish including color (visual observation), aroma (smelling), appearance (visual observation) and texture (finger pressing) were evaluated. Sensory tests, using a 9-point hedonic scale (1= the lowest intensity; 9- the highest intensity), were performed by 30 semi-trained panelists (12 men and 18 women; age between 19-21 years) (Anamika & Vishakha, 2017). The panelists were nutrition students who had passed a sensory evaluation course. The tests were carried out on days 0, 7 and 14 to evaluate the sensory changes during storage.

2.4 Proximate analysis

Proximate analysis of snakehead fish was carried out according to the AOAC method (AOAC, 2005). Protein and fat analysis used the Kjeldhal (AOAC 975.17) and Soxhlet (AOAC 973.22) methods, respectively. Water content was analysed by gravimetry (AOAC 9292.02). Ash was determined using a muffle furnace (AOAC 922.02). Fibre was analysed by gravimetry (AOAC 2011.25), and carbohydrates were determined by the difference method (AOAC, 2006). Assessment of chemical composition was conducted using a snakehead fish fillet sample with no salt addition on day 0 of packaging.

2.5 Data analysis

Descriptive statistics of data were reported as the mean and standard deviation. Differences between the groups on the days of observation of the sensory properties, TPC, a_w and pH were evaluated using two-way ANOVA, with Tukey post-hoc test. The significant difference was determined at p-value < 0.05.

Table 1: Proximate composition of snakehead fish

Proximate composition	%
Water	81.03 ± 0.93
Ash	0.62 ± 0.08
Fat	1.08 ± 0.05
Protein	17.27 ± 1.84
Carbohydrate	0

3 Results and Discussion

The water, protein, fat and ash contents of the snakehead fish were 81.03 ± 0.93%, 17.27 ± 1.84%, 1.08 ± 0.05% and 0.62 ± 0.08%, respectively (Table 1). Our proximate analysis showed comparable results with previous studies (Paul et al., 2013; Widodo et al., 2012). High protein content in snakehead fish shows this food is a good source of protein and has the potential to address malnutrition (Marsella et al., 2021; Saleh & Bukhari, 2022). Compared to other freshwater fish including goldfish, three spot gurami, Hemibagrus fish and mackerel, this study showed the snakehead fish contained higher protein and lower fat (Widodo et al., 2012). Several other studies used snakehead fish as part of the diet to help consumers manage health conditions, including wounds, compromised immune system, diabetes, neurological diseases and tuberculosis (Kong et al., 2021; Permatasari et al., 2021; Prastari et al., 2017; Rahman et al., 2018; Sahid et al., 2018; Sunarno et al., 2018).

The mean scores for all sensory properties did not differ significantly ($p > 0.05$) between the groups of salt addition at day 0. However, there was a significant decrease in the mean score for color at day 7 in the 0%, 10% and 15% groups, where the 0% group had the dullest color compared to other groups ($p < 0.05$). Meanwhile, a significant decrease in mean score for color in the 5% group was only seen at day 14 ($p < 0.05$). During 14 days of refrigerated storage, only the 5% group did not show any changes in the mean score for aroma ($p > 0.05$). A significant difference in the mean score for aroma in the 0% group, which could be characterised as the least fresh aroma, was observed ($p < 0.05$). It was also observed that the addition of salt at day 0 affected the appearance of the snakehead fish. There was a significant difference in the mean scores for appearance between the groups with salt addition and the group without salt ($p < 0.05$), with salted snakehead fish looking fresher. Furthermore, the mean scores for appearance in all groups significantly decreased at day 7 ($p < 0.05$). However, the appearance in groups with salt addition showed a slightly clear mucus, while a lumpy mucus was observed in the group without salt addition. Acceptable appearance could be maintained until day 14 in all groups with salt addition. A significant decrease in the mean score for texture was found in the group without salt addition at day 7 ($p < 0.05$). In this group, the texture became very soft, while the texture in the salt-treated groups was still slightly elastic. Other groups showed no significant changes in the mean scores for texture over the period of study ($p > 0.05$). A comparison of the sensory properties of snakehead fish between the groups of salt addition at days 0, 7 and 14 is shown in Figure 1.

Although Patil et al. (2020) proposed that vacuum packaging may become a tool for shelf-life extension of fish, the present study revealed that vacuum packaging alone might not be effective in preserving the sensory quality of snakehead fish. After 7 days of storage, the quality of vacuum-packed snakehead fish without salt addition decreased dramatically in terms of the mean scores for sensory properties. Although vacuum packaging eliminates the air content which may inhibit a decrease in quality of fish, the present study did not find this to be the case. Addition of salt to snakehead fish, in addition to vacuum packaging, could help to preserve the sensory quality. By adding 5% of salt, the color and aroma of the snakehead fish could be maintained for at least 7 days. A previous study found that the addition of salt could preserve the sensory quality of sardinella fish, giving it a whiter color, more compact texture and fresher odour (Tumbelaka et al., 2013). However, Sipahutar et al. (2021) reported that a concentration of more than 10% salt made the fish look dry and hard. Salt has a property to attract water which makes fish look more compact and as salt may crystalise on the surface of fish this could make the color whiter (Albarracín

Table 2: TPC, a_w, and pH of snakehead fish

Parameters [NaCl] (%)	Day 0	Day 7	Day 14
	TPC (CFU/g)		
0	$3.9 \pm 0.2 \times 10^{6a*}$	$1.1 \pm 0.1 \times 10^{8b*}$	$2.5 \pm 0.2 \times 10^{9c*}$
5	$1.2 \pm 0.1 \times 10^{5a\blacklozenge}$	$1.4 \pm 0.1 \times 10^{6ba\blacklozenge}$	$1.5 \pm 0.2 \times 10^{7ca\blacklozenge}$
10	$1.6 \pm 0.1 \times 10^{4\triangledown}$	$2.1 \pm 0.2 \times 10^{3\triangledown}$	$2.8 \pm 0.3 \times 10^{4\triangledown}$
15	$1.5 \pm 0.2 \times 10^{3\triangledown}$	$2.7 \pm 0.2 \times 10^{3\triangledown}$	$6.6 \pm 0.1 \times 10^{3\triangledown}$
	a_w		
0	$1.016 \pm 0.02^{\blacklozenge}$	$1.018 \pm 0.01^{*}$	$1.002 \pm 0.03^{*}$
5	$0.923 \pm 0.08^{a\triangledown}$	$0.916 \pm 0.01^{a\blacklozenge}$	$1.012 \pm 0.03^{b*}$
10	$0.907 \pm 0.04^{a\triangledown}$	$0.921 \pm 0.06^{a\blacklozenge}$	$0.949 \pm 0.09^{b\blacklozenge}$
15	$0.907 \pm 0.02^{a\triangledown}$	$0.886 \pm 0.02^{b\triangledown}$	$0.854 \pm 0.03^{b\triangledown}$
	pH		
0	6.75 ± 0.3	6.31 ± 0.1	6.96 ± 0.3
5	6.39 ± 0.4	6.57 ± 0.4	6.72 ± 0.2
10	6.37 ± 0.2	6.58 ± 0.9	6.74 ± 0.8
15	6.20 ± 0.7	6.60 ± 0.6	6.79 ± 0.7

Different symbols indicate significant differences between the groups on the same day, while different letters indicate significant differences within the groups on different observation days.

et al., 2011). In addition, salt inhibits the activity of proteolytic enzymes in fish leading to lower degradation of fish muscle and higher sensory quality (Toldrá, 2019). Moreover, the present study revealed that there were high total bacteria counts, especially in vacuum-packed snakehead fish without salt addition. After 14 days of refrigerated storage, there was a significant increase in the total bacteria in that snakehead fish without salt addition group where the TPC value reached $2.5 \pm 0.2 \times 10^9$. In contrast, addition of 10% and 15% salt to snakehead fish could inhibit bacterial growth for 14 days. Whereas a slight increase of total bacteria was found in the 5% salt addition group after 14 days. The microbial data aligns with a_w data, where a_w was significantly constant for 7 days among all groups with salt addition and notably increased after 14 days only in the group with 5% salt addition. In addition, we did not find remarkable changes in pH among all the groups. Chemical and microbial properties of vacuum-packed snakehead fish are shown in Table 2. Normally, without any treatment, the microbial shelf life of fish is around 15 h at 25 ^{o}C (Humaid & Jamal, 2014). Moreover, previous research showed the shelf life of fish could be extended up to 13 days with vacuum packaging and under cold temperature (Nguyen et al., 2023). Sivertsvik et al. (2002) summarised the shelf life of vacuum-packed fishery products and reported that the shelf life ranged from 3 to 38 days. Whilst vacuum reduces air in the pack, several other factors may also affect the shelf life, including packaging material, quality of raw material, type of atmosphere, species of fish and storage conditions (Sivertsvik et al., 2002). Moreover, some spoilage organisms that do not require air may grow in vacuum-packed foodstuffs, such as *C. botulinum, C. perfringens and C. bifermentans, or Actinomyces and Eubacterium tarentallus* which are found in fish (Abdelsalam, 2017). In addition, vacuum packaging may produce carbonic acid which could desaturate muscle protein (Masniyom et al., 2013).

Salt, a natural preservative, has been used for many decades in the preservation of food (Wijnker et al., 2006). The addition of salt helped to retain the quality of snakehead fish. TPC values were below the standard (5.0 x 10^5) for fresh fish in the groups with 10 and 15% salt addition, whereas the TPC value in the 5% salt addition group slightly exceeded the abovementioned standard at day 7. The TPC values were relatively like those reported by (Carol et al., 2013) for fresh fish which ranged from 1.5 to 7.2 x 10^6 CFU/g. Salt can preserve snakehead fish by reducing the water activity due to the association between sodium and chloride ions and water molecules ("Preservation and Physical Property Roles of Sodium in Foods," 2010). This can be seen in our a_w data which was below 0.1 after 14 days of refrigerated storage, except for the 5% salt addition group at day 14. High a_w values provide an environment for bacteria to grow (Troller & Christian, 2012). Combination of vacuum packaging and the addition of a preservative such as salt is recommended to give an optimum shelf life (Patil et al., 2020). The findings are supported by some previous studies that showed the shelf life of fish balls (Noordin et al., 2014), trout fillets (Frangos et al., 2010) and beef (Gök et al., 2009) were prolonged due to this combination.

4 Conclusions

The present study demonstrates that vacuum packaging, combined with salt addition to fresh snakehead fish, may be beneficial to preserve the product. The addition of 5% salt maintained the sensory properties (color, aroma and texture) of snakehead fish, while 10 and 15% salt addition demonstrated better total microbial load and a_w values. Further study is needed to perform a shelf-life optimisation, with various refrigeration temperatures.

Acknowledgements

We acknowledge the Institute of Research and Community Service of the University of Singaperbangsa Karawang for funding this research.

References

Abdelsalam, M. (2017). Potential role of anaerobic bacteria as fish pathogens. *Journal of Aquaculture Research and Development*, *08*. https://doi.org/10.4172/2155-9546.1000500

Abdulgani, N., Hidayati, D., Adinovitasary, R., Oliviatie, V., & Sekartaji, A. D. (2020). Mda levels in the pancreas, testes, liver, and plasma of diabetic rats: The effect of snakehead (channa striata) extract. *Nusantara Bioscience*, *12*. https://doi.org/10.13057/nusbiosci/n120109

Aberoumand, A., & Baesi, F. (2020). Effects of vacuum packaging in freezer on oxidative spoilage indexes of fish ¡i¿lethrinus atkinsoni¡/i¿. *Food Science and Nutrition*, *8*, 4145–4150. https://doi.org/10.1002/fsn3.1704

Ahmad, S., Anzar, A., Srivastava, A. K., & Srivastava, P. K. (2005). Effect of curing, antioxidant treatment, and smoking of buffalo meat on ph, total plate count, sensory characteristics, and shelf life during refrigerated storage. *International Journal of Food Properties*, *8*, 139–150. https://doi.org/10.1081/JFP-200048028

Albarracín, W., Sánchez, I. C., Grau, R., & Barat, J. M. (2011). Salt in food processing; usage and reduction: A review. *International Journal of Food Science and Technology*, *46*, 1329–1336. https://doi.org/10.1111/j.1365-2621.2010.02492.x

Anamika, G., & Vishakha, S. (2017). Organoleptic evaluation of nutritious biscuits developed from amaranth seeds. *International Journal Of Science Environment and Technology*, *6*, 98–103. www.ijset.net

Anandito, R. B. K., Siswanti, Saputro, R. E., & Purnamayati, L. (2019). Sensory and chemical characteristics of koya made from snakehead fish (channa striata) and soybean flour (glysine max). *IOP Conference Series: Earth and Environmental Science*, *246*, 12037. https://doi.org/10.1088/1755-1315/246/1/012037

AOAC. (2005). Official methods of analysis of aoac international (17th ed.).

AOAC. (2006). Official methods of analysis of aoac international (W. Horwitz & G. W. Latimer, Eds.; 18th ed.).

Awuchi, C. G., Twinomuhwezi, H., & Amagwula, I. O. (2020). Food additives and food preservatives for domestic and industrial food applications. *Journal of Animal Health*, *2*, 1–16. www.iprjb.org

Badan Standardisasi Nasional. (2013). Standar-nasional indonesia (sni) 01- 2729.1-2013 tentang spesifikasi ikan segar. badan standarisasi nasional. jakarta.

Bertalina, B., Sudarmi, S., & Indriyani, R. (2023). The formula for making seruit (local food) based on snakehead fish as a food source of high protein. *Jurnal Kesehatan*, *14*, 88. https://doi.org/10.26630/jk.v14i1.3657

Bindu, J., Gopal, T. S., Joseph, A. C., & Nair, T. S. U. (2002). Effect of vacuum packaging on the shelf life of. *Fishery Technology*, *39*(2), 137–141.

Carol, G. R., Jeyasanta, K. I., Mani, A. E., & Patterson, J. (2013). Prevalence of pseudomonas sp. in fin fishes and their antibiotic susceptibility. *Journal of pure and applied microbiology*, *7*, 677–681.

Frangos, L., Pyrgotou, N., Giatrakou, V., Ntzimani, A., & Savvaidis, I. N. (2010). Combined effects of salting, oregano oil and vacuum-packaging on the shelf-life of refrigerated trout fillets. *Food Microbiology*, *27*, 115–121. https://doi.org/10.1016/j.fm.2009.09.002

Gök, V., Kayaardi, S., & Obuz, E. (2009). Extending the chilled shelf life of vacuum-packaged ground beef using ascorbic acid, nitrite or salt. *Journal of Muscle Foods*, *20*, 211–226. https://doi.org/10.1111/j.1745-4573.2009.00144.x

Goulas, A. E., & Kontominas, M. G. (2007). Effect of modified atmosphere packaging and vacuum packaging on the shelf-life of refrigerated chub mackerel (scomber japonicus): Biochemical and sensory attributes. *European Food Research and Technology*, *224*, 545–553. https://doi.org/10.1007/s00217-006-0316-y

Herumuryawan, M., & Hardaningsih, G. (2017). Effect of striped snakehead fish (ophiocephalusstriatus) extract supplement pills compared to human albumin infusion on albumin serum, lipid profile, malondialdehyde and il-8 serum level on nephrotic syndrome. *Pakistan Journal of Medical and Health Sciences*, *11*, 1601–1606.

Humaid, S. A., & Jamal, M. T. (2014). The effect of storage temperature (4°c, 15°c and 25°c) on the shelf life of whole marine fish (rastrelliger kanagurta). *IOSR Journal of Environmental Science*, *8*, 46–51. www.iosrjournals.orgwww.iosrjournals.org46%7C

Indonesian National Standard. (2004). Air dan air limbah –bagian 11: Cara uji derajat keasaman (ph)dengan menggunakan alat ph meter.

Indonesian National Standard. (2006). Cara uji mikrobiologi-bagian 3: Penentuan angka lempeng total (alt) pada produk perikanan standar nasional indonesia.

Jayanti, U., Dasir, D., & Idealistuti, I. (2017). Kajian penggunaan tepung tapioka dari berbagai varietas ubi kayu (manihot esculenta crantz.) dan jenis ikan terhadap sifat sensoris pempek. *Edible*, *6*, 59–62. https://doi.org/10.32502/jedb.v6i1.633

Jr., W. R. C., & Williams, J. D. (2004). Snakeheads (pisces, channidae): A biological synopsis and risk assessment. https://doi.org/10.3133/cir1251

Kong, Y., Li, M., Shan, X., Wang, G., & Han, G. (2021). Effects of deltamethrin subacute exposure in snakehead fish, channa argus: Biochemicals, antioxidants and immune responses. *Ecotoxicology and Environmental Safety*, *209*, 111821. https://doi.org/10.1016/j.ecoenv.2020.111821

Korkeala, H. J., & Björkroth, K. J. (1997). Microbiological spoilage and contamination of vacuum-packaged cooked sausages. *Journal of Food Protection*, *60*, 724–731. https://doi.org/10.4315/0362-028X-60.6.724

Leng, W., Wu, X., Xiong, Z., Shi, T., Sun, Q., Yuan, L., & Gao, R. (2022). Study on antibacterial properties of mucus extract

of snakehead (channa argus) against escherichia coli and its application in chilled fish fillets preservation. *LWT*, *167*, 113840. https://doi.org/10.1016/j.lwt.2022.113840

Marimuthu, K., Thilaga, M., Kathiresan, S., Xavier, R., & Mas, R. H. M. H. (2012). Effect of different cooking methods on proximate and mineral composition of striped snakehead fish (channa striatus, bloch). *Journal of Food Science and Technology*, *49*, 373–377. https://doi.org/10.1007/s13197-011-0418-9

Marsella, C. P., Taslim, N. A., Syam, N., & Syauki, A. Y. (2021). Medical nutrition therapy in hemodynamically unstable patients due to cardiogenic shock with infected bronchiectasis and severe protein-energy malnutrition. *Gaceta Sanitaria*, *35*, S506–S509. https://doi.org/10.1016/j.gaceta.2021.10.081

Masniyom, P., Benjama, O., & Maneesri. (2013). Effect of modified atmosphere and vacuum packaging on quality changes of refrigerated tilapia (oreochromis niloticus) fillets. *International Food Research Journal*, *20*, 1401–1408.

Nasution, Z., Ilza, M., & Sari, N. I. (2017). Study vacuum and non vacuum packaging on the quality of fish balls malong (muaresox talabon) during cold storage temperature (±50c). *Jurnal Online Mahasiswa Fakultas Perikanan dan Ilmu Kelautan Universitas Riau*, *4*, 1–8.

Nguyen, M. V., Karnue, S., & Kakooza, D. (2023). Effect of packaging method and storage temperature on the sensory quality and lipid stability of fresh snakehead fish (channa striata) fillets. *Food Science and Technology*, *43*. https://doi.org/10.1590/fst.116222

Noordin, W. N. M., Shunmugam, N., & Huda, N. (2014). Application of salt solution and vacuum packaging in extending the shelf life of cooked fish balls for home and retail uses. *Journal of Food Quality*, *37*, 444–452. https://doi.org/10.1111/jfq.12105

Omoruyi, K., Okpeva, O., & Abdullahi, M. M. (2017). Effects of oven-drying and smoke-drying on the nutritional quality of snakehead (parachanna obscura) and upside-down-catfish (synodontis clarias) in delta state. *FUW Trends in Science and Technology Journal*, *2*, 239–243. www.ftstjournal.com

Özogul, F., Polat, A., & Özogul, Y. (2004). The effects of modified atmosphere packaging and vacuum packaging on chemical, sensory and microbiological changes of sardines (sardina pilchardus). *Food Chemistry*, *85*, 49–57. https://doi.org/10.1016/j.foodchem.2003.05.006

Patil, A. R., Chogale, N. D., Pagarkar, A. U., Koli, J. M., Bhosale, B. P., Sharangdhar, S. T., Gaikwad, B. V., & Kulkarni, G. N. (2020). Vacuum packaging is a tool for shelf life extension of fish product: A review. *Article in Journal of Experimental Zoology*, *23*, 807–810. https://www.researchgate.net/publication/339842514

Paul, D. K., Islam, R., & Sattar, A. (2013). Physico-chemical studies of lipids and nutrient contents of channa striatus and channa marulius. *Turkish Journal of Fisheries and Aquatic Sciences*, *13*. https://doi.org/10.4194/1303-2712-v13_3_11

Permatasari, T. A. E., Ernirita, E., Kurniaty, I., & Widakdo, G. (2021). Nutritional and microbiological characteristics of snakehead fish flour (channa striata) and its modification as weight enhancing supplements for children with tuberculosis. *Food Science and Technology*, *9*, 45–57. https://doi.org/10.13189/fst.2021.090301

Prastari, C., Yasni, S., & Nurilmala, M. (2017). Characterization of snakehead fish protein that's potential as antihyperglikemik. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *20*, 413. https://doi.org/10.17844/jphpi.v20i2.18109

Preservation and physical property roles of sodium in foods. (2010). In J. E. Henney, C. L. Taylor, & C. S. Boon (Eds.). National Academies Press.

Qi, L., Xu, M., Fu, Z., Mira, T., & Zhang, X. (2014). C2slds: A wsn-based perishable food shelf-life prediction and lsfo

strategy decision support system in cold chain logistics. *Food Control*, *38*, 19–29. https://doi.org/10.1016/j.foodcont.2013.09.023

Rahman, M. A., Ma, R., Mhr, M., Mk, S., Sh, C., & Mm, S. (2018). Snakehead fish (channa striata) and its biochemical properties for therapeutics and health benefits open access. https://scienceforecastoa.com/

Ren, M., Yin, T., You, J., Liu, R., Huang, Q., & Xiong, S. (2022). Comparative study of the nutritional composition and antioxidant ability of soups made from wild and farmed snakehead fish (channa argus). *Foods*, *11*, 3294. https://doi.org/10.3390/foods11203294

Rodgers, S. (2006). Deriving strategic advantages from extended shelf-life foods in the hospitality sector. *Journal of Culinary Science and Technology*, *5*, 111–129. https://doi.org/10.1300/J385v05n02_10

Sahid, N. A., Hayati, F., Rao, C. V., Ramely, R., Sani, I., Dzulkarnaen, A., Zakaria, Z., Hassan, S., Zahari, A., & Ali, A. A. (2018). Snakehead consumption enhances wound healing? from tradition to modern clinical practice: A prospective randomized controlled trial. *Evidence-Based Complementary and Alternative Medicine*, *2018*, 1–9. https://doi.org/10.1155/2018/3032790

Saleh, M., & Bukhari, A. (2022). Medical nutrition therapy in patient with multiple fractures, and liver injury with hypoalbuminemia complications and moderate protein energy malnutrition: A case report. *Current Developments in Nutrition*, *6*, 752. https://doi.org/10.1093/cdn/nzac062.021

Semjon, B., Král, M., Pospiech, M., Reitznerová, A., Maľová, J., Tremlová, B., & Dudriková, E. (2018). Application of multiple factor analysis for the descriptive sensory evaluation and instrumental measurements of bryndza cheese as affected by vacuum packaging. *International Journal of Food Properties*, *21*, 1508–1522. https://doi.org/10.1080/10942912.2018.1494194

Sipahutar, Y. H., Yuniarti, T., Bertiantoro, A., & Perceka, M. L. (2021). Sensory characteristics and moisture content of salted sardinella (sardinella fimbriata) in different salt concentration. *IOP Conference Series: Earth and Environmental Science*, *860*, 012077. https://doi.org/10.1088/1755-1315/860/1/012077

Sivertsvik, M., Jeksrud, W. K., & Rosnes, J. T. (2002). A review of modified atmosphere packaging of fish and fishery products – significance of microbial growth, activities and safety. *International Journal of Food Science and Technology*, *37*, 107–127. https://doi.org/10.1046/j.1365-2621.2002.00548.x

Suhendi, A., Pawarti, H., Rohman, A., Wahyono, D., & Nurrochmad, A. (2020). Snakehead fish extract (channa striata): A review of pharmacological activity.

Suhendi, A., Sutrisna, E. E., Muhtadi, M., & Sutrisna, E. (2019). Anti-inflammatory and antidiabetic of channa striata powder and nephelium lappaceum fruit peel ethanolic extracts on albino wistar mice.

Sunarno, S., Mardiati, S. M., & Rahadian, R. (2018). Applications of bioactive material from snakehead fish (channa striata) for repairing of learning-memory capability and motoric activity: A case study of physiological aging and aging-caused oxidative stress in rats. *Journal of Physics: Conference Series*, *1025*. https://doi.org/10.1088/1742-6596/1025/1/012078

Susan, A. I., Sasmita, E., Yulianto, E., Arianto, F., Restiwijaya, M., Kinandana, A. W., & Nur, M. (2018). Ozone application to extend shelf life of vegetables by microbial growth inhibition. *MATEC Web of Conferences*, *197*, 02004. https://doi.org/10.1051/matecconf/201819702004

Toldrá, F. (Ed.). (2019). *Advances in food and nutrition research* (Vol. 87). Academic Press.

Troller, J. A., & Christian, J. H. B. (2012). *Water activity and food*. Academic Press.

Tumbelaka, R. A., Naiu, A. S., & Dali, F. A. (2013). Pengaruh konsentrasi garam dan lama penggaraman terhadap nilai hedo-

nik ikan bandeng (chanos chanos) asin kering. *Nike: Jurnal Ilmiah Perikanan dan Kelautan*, *1*.

Tungadi, R. (2019). Potential of snakehead fish (ophiocephalus striatus) in accelerating wound healing. *Universal Journal of Pharmaceutical Research*, *4*. https://doi.org/10.22270/ujpr.v4i5.316

Widodo, M. A., Mustafa, A., Widodo, M. A., & Kristianto, Y. (2012). Yohanes kristianto poltekkes kemenkes malang albumin and zinc content of snakehead fish (channa striata) extract and its role in health. *IEESE International Journal of Science and Technology (IJSTE)*, *1*, 1–8.

Wijnker, J. J., Koop, G., & Lipman, L. J. A. (2006). Antimicrobial properties of salt (nacl) used for the preservation of natural casings. *Food Microbiology*, *23*, 657–662. https://doi.org/10.1016/j.fm.2005.11.004