Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 26(1): 639 – 653 (2022)
www.ejabf.journals.ekb.eg

Combined Effect of Moringa (*Moringa oleifera*) Water Extracts and Vacuum Packaging on the Quality and Lipid Oxidation of the Sun-Dried Punti (*Puntius sophore*) During Storage

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ARTICLE INFO

Article History:
Received: Dec. 13, 2021
Accepted: Jan.7, 2022
Online: Feb. 27, 2022

Keywords:
Moringa extracts;
Puntius sophore;
Vacuum packaging;
Quality;
Lipid oxidation

ABSTRACT

Due to lipid oxidation, sun-dried products have a distinct off-flavor, which discourages product usage and limits variety. In addition, there is a frequent complaint about the quality of dried fish available in the market. This research aimed to investigate the effect of moringa water extracts pretreatment (1.5%, 2.5%, and 3.5%) and vacuum packaging on the quality and lipid oxidation of sun-dried punti (*Puntius sophore*) during storage at ambient temperature for 7 months. Biochemical, aerobic plate count and sensory changes of dried *P. sophore* were monthly analyzed. Total phenolic content, total flavonoid content, and 1,1-diphenyl-2-picrylhydrazil (DPPH) radical scavenging activity of moringa water extracts were also evaluated. Moringa extract-treated and vacuum-packed dried fishes showed lower aerobic plate count, total volatile base nitrogen than the untreated vacuum packed samples. Vacuum packaging and moringa treatment reduced significantly the lipolysis (acid value) and oxidation of lipid (peroxide value and thiobarbituric acid reactive substance) in *P. sophore*. The application of moringa water extracts did not affect significantly the sensory properties of the product. Results demonstrated that pre-treatment with moringa water extract (2.5%) and vacuum packaging could be an alternative to reduce the quality deterioration and lipid oxidation and improve the quality as well as the shelf life of this dried product during processing and storage.

INTRODUCTION

Dried fish is one of the most important sources of animal protein and other essential nutrients for attaining a healthy body **(Rasul *et al*., 2021b)**. Moreover, Bangladeshi people highly prefer this dried fish due to its characteristic taste and flavor. Nowadays, people are more aware about their health and food quality, as well as safety of the food

they consume. However, the physical, biochemical, and sensory qualities of many sun-dried fishery products available in the local market are not satisfactory for human consumption for the unhygienic processing of fish, use of harmful insecticides and pesticides to prevent insect infestation **(Rasul *et al.*, 2020; Rasul *et al.*, 2021a)** and improper storage of dried fishery products **(Remya *et al.*, 2018)**. In Bangladesh, dried fish is usually packed in different plastic and jute bags for storage and transportation. It is generally sold in an open market without any packaging **(Rabbanee *et al.*, 2012; Chowdhury *et al.*, 2020)**. Another major problem of dried fish products is microbial and fungal growths that reduce the product value and acceptance of dried fish products.

Dried punti (*P. sophore*) is a popular and available in dried fish markets in Bangladesh **(Hasan *et al.*, 2016)**, which is highly nutritious. However, sun-dried punti and other dried fish are prone to lipid oxidation due to the presence of omega-3 fatty acids, which causes loss of nutritional value, undesirable smell and off flavor, and nonenzymatic browning during processing and subsequent storage **(Rasul *et al.*, 2019; Qiu *et al.*, 2019)**. Lipid oxidation products have toxic effects on human health **(Bellanti *et al.*, 2017)**. To overcome those problems, various synthetic antioxidants are used by the fish processors **(Tran *et al.*, 2020)**. Nevertheless, the excessive use of the synthetic antioxidants has proved to be carcinogenic and potential health hazards of consumers **(Zheng & Wang, 2001)**. Therefore, consumers have expected for using natural products as an alternative to additives for improving food quality **(Hernández *et al.*, 2016)**. There has been a particular interest in the application of natural food additives for dried fish instead of classical synthetic preservatives **(Slavin *et al.*, 2016; Lithi *et al.*, 2019)**. **Jadhav *et al.* (2018)** reported that the moringa leaf (locally known as *Sojne*) powder is a natural preservative for extending the shelf life of the Nile tilapia during ice storage. Moringa leaf powder lowers the lipid oxidation significantly in dry pork sausages **(Mukumbo *et al.*, 2019)**. Besides, vacuum packaging has better effect in extending the shelf life of processed fish products **(Chowdhury *et al.*, 2020)**. It is necessary to improve the quality by adding certain natural preservatives along with vacuum packaging which would help in providing better quality and extending the shelf- life of dried punti as well. Related research on lipid oxidation progress for this dried fish product during storage is scarce. Therefore, this study aimed to investigate the effect of moringa (*Moringa oleifera*) water extracts and vacuum packaging in improving the quality and oxidative stability of dried punti during storage.

MATERIALS AND METHODS

Collection of moringa leaves

Moringa leaves were collected from local cultivers of Gazipur Sadar, Bangladesh. The plant materials were brought to the Fish Processing Laboratory of BSMRAU,

Gazipur. Moringa leaves were washed in running tap water and the excess water was drained. Then, they were left to dry under the sun in open air for two consecutive days to gain constant weight.

Preparation of moringa water extracts

Moringa water extracts were prepared according to the method of **Chaula *et al.* (2019)**. Doses of moringa extracts were prepared at 1.5% (T1), 2.5% (T2), and 3.5% (T3) (basis of preliminary evidence of **Adeyemi *et al*. (2013**) by weighing 15, 25, and 35 g of ground moringa, respectively. They were mixed with 1.0 L of boiling water. The mixture was let to simmer for 10 min and subsequently was cooled in a refrigerator, and was then gravity filtered to remove the solid particles.

Preparation of dried punti

Fresh punti (*Puntius sophore*) (25.23 ± 5.64 g) were collected from local market of Gazipur, gutted and washed with clean water. Then, the fish were soaked in cooled moringa water extracts for 30 min at room temperature. Treated and untreated (control) fish were spread separately on the drying rack (improved drying method of **Rasul *et al*. (2018**) and dried for 4 consecutive days in order to reduce the moisture content to <16%. After the drying process was completed, treated and control dried fishes were vacuum packed (using machine PAXX model, Germany) in high-barrier film bags (40 PA/70 LDPE) separately to prevent absorption of moisture and kept in room temperature (21-28ºC) for 7 months. At every one month interval, samples were analyzed.

Extraction of total lipid

Total lipid from dried fish samples were extracted following **Bligh and Dyer (1959)** method**,** using a solvent mixture of chloroform: methanol: distilled water (10:5:3). The extracted lipid was re-dissolved in chloroform and kept at –26°C for further use.

Chemical analysis

Proximate composition (moisture, crude protein, crude lipid, and ash) was determined following **AOAC (2002)** method. Total volatile basic nitrogen (TVB-N) was determined according to the method of **Antonacopoulos and Vyncke (1989)** and expressed as mg TVB-N per 100 g muscle. Acid value was measured using **AOAC (2002)** method. The results were reported as mg KOH/g lipid. The peroxide value (PV) of total lipid was measured using **AOAC (2002)** method. The PV value was stated as meq/kg of lipid. The thiobarbituric acid reactive substance (TBARS) was measured according to the method of **Buege and Aust (1978)**, and value was expressed as mg malonaldehyde (MDA)/kg fish sample.

Microbiological analysis

Aerobic plate count (APC) of bacteria in dried punti was estimated using spread plate count technique. Briefly, an amount of 25 g of dried fish sample was properly blended with 225 mL of physiological saline (0.85% NaCl) for preparing consecutive decimal dilution, and each dilution of fish homogenate was cultured in sterile plate count agar, following spread plate method and incubated at 37°C for 30 hours. Bacterial colonies (30-300 colonies) were counted as CFU (colony forming unit)/g and converted it as log CFU/g **(Barraw & Feltheam, 1993)**.

Antioxidant activity of moringa water extracts

Total phenolic contents (TPC) in the moringa leaf extracts were assessed using Folin–Ciocalteau reagent using the method defined in the study of **Farvin and Jacobsen (2013)**. Total phenolic contents were calculated using a standard curve, and values were expressed as gallic acid equivalent in mg GAE/g of moringa extracts. Additionally, total flavonoid contents (TFC) were extracted and estimated by the method of **Zhishen *et al.* (1999)** and the values were expressed as mg QE/g of moringa extracts. The DPPH free radical scavenging activities of moringa water extracts were determined by the stable radical, 2, 2-diphenyl-1-picrylhydrazyl (DPPH) **(Cheng *et al*., 2006)**.

Sensory analysis

Sensory characteristics of dried punti were evaluated following the method of **Rasul *et al.* (2018)**. Individual sensory booths were used to perform sensory evaluation. Representative dried fish were served to assess the physical characteristics by a panel of 10 members (ages from 22 to 36 years) from the Department of Fisheries Technology of BSMRAU.

Statistical analysis

All the data were reported as mean ± standard deviation (SD). Data were analyzed using ANOVA followed by Duncan's multiple range test using Statistix 10 (Analytical Software, Tallahassee, FL, USA). A significant difference was considered at the level of $P < 0.05$.

RESULTS AND DISCUSSION

Antioxidant activity of moringa water extract

Phenolic and flavonoid compounds are antioxidant, which have great impact on the lipid stability and inhibit the deterioration through reducing radical reactions that occur in lipid oxidation process **(Koski *et al*., 2003; Tenyang *et al*., 2020)**. The TPC and TFC in the moringa water extracts varied from 72.46 to 78.33 mgGAE/g, and 55.73 to 62.42 mg QE/g, respectively (Table 1). The highest TPC and TFC were found in 3.5% extract,

while the lowest values were observed in 1.5% extract. With the increase of concentration, TPC and TFC were increased, which indicate that the antioxidant power of moringa extract is dose dependent. However, no significant differences were detected with regard to either TPC and TFC of 2.5% or 3.5% of moringa extract. Moreover, it is assumed that when larger amount of dried moringa was used, more extraction time was needed to get efficient phenolic compounds. More or less similar results are observed in the study of **Ilyas *et al.* (2015)** who found that, the amount of TPC and TFC of moringa leaves extracts were 95.35 mg GAE/g and 65.43 mg TE/g, respectively.

Table 1. Antioxidant capacity of different concentrations of moringa water extract[1]

Extract (g/L)	Total phenolic content (mg GAE/g)	Total flavonoid content (mg QE/g)	DPPH scavenging activity (% inhibition)
1.5% moringa	72.46 ± 1.21^{b}	55.73 ± 1.2^{b}	68.40 ± 0.91^{c}
2.5% moringa	76.54 ± 1.10^{a}	60.08 ± 1.6^{a}	77.47 ± 1.73^{b}
3.5% moringa	78.33 ± 1.70^{a}	62.42 ± 1.8^{a}	81.73 ± 1.54^{a}

[1]Value expressed as mean ± SD (n = 6). Means having different superscript letters within a column are significantly different ($p < 0.05$)

DPPH has been used extensively as a free radical to evaluate reducing substances and is a useful reagent for investigating the free radical scavenging activities of compounds **(Duan *et al*., 2006)**. In this study, the DPPH radical scavenging activity of 1.5%, 2.5%, and 3.5% moringa extract were 68.40%, 77.47%, and 81.73%, respectively. Similarly, 72.88% and 76.61% DPPH activity was found in the moringa seeds and leaves of aqueous extracts **(Hameid *et al*., 2018)**. Furthermore, **Chumark *et al.* (2008)** noted that the aqueous extract of moringa showed 78.15% DPPH radical scavenging activity. Many studies showed that aqueous extraction's success in recovering phenolic compounds from plant matrices is dependent on a number of parameters such as temperature, extraction time, and solvent to solid ratio, nature of the soil, geographical locations and season of cultivation **(Cam & Aaby, 2010; Ilyas *et al*., 2015)**.

Proximate composition of dried *P. sophore*

The moisture, protein, lipid, and ash content of control, T1, T2, and T3 treatments were ranged from 15.73 to 13.31%; 47.33 to 49.03%; 9.78 to 11.01%, and 19.52 to 21.99%, respectively (Table 2). All the treated samples showed comparatively higher nutritional composition than that of the control samples. On the other hand, the highest protein (49.03%) and lipid (11.01%) were found in T3; whereas, the lowest protein, lipid, and ash contents were observed in the control samples (Table 2). More or less similar result reported that the use of *Cinnamomum tamala* Nee leaves extract showed the higher nutritional composition than the control dried *Corica soborna* **(Begum *et al*., 2013)**. Another study showed that the use of 1%, 2%, and 3% *Moringa oleifera* marinades retained less moisture and higher protein, lipid, and ash content than the control sample of smoked dried African catfish during storage for 2 months **(Adeyemi *et al*., 2013)**.

Table 2. Proximate composition of dried *P. sophore* after drying[1]

Treatment	Moisture (%)	Protein (%)	Lipid (%)	Ash (%)
Control	15.73±0.23^{a}	47.33±0.47^{c}	9.78±0.33^{b}	19.52±0.62^{b}
T1	14.83±0.40^{b}	48.27±0.42b^{c}	10.21±0.44^{b}	19.51±0.47^{b}
T2	13.52±0.35^{c}	48.81±0.51^{ab}	10.66±0.53^{b}	21.99±0.51^{a}
T3	13.31±0.21^{c}	49.03±0.21^{a}	11.01±0.20^{a}	21.73±0.37^{a}

[1]Value expressed as mean ± SD (n = 6). Means having different superscript letters within a column are significantly different ($p < 0.05$)

Lipid oxidation

The formation of hydroperoxides resulted from early stage of lipid oxidation is determined by peroxide value and acid value. Peroxide value (PA) and acid value (AV) are very important indicators for determining the primary lipid oxidation of fishery product. The PV increased from 9.33 to 28.12 meq/kg oil; 7.78 to 25.52 meq/kg oil; 5.52 to 23.44 meq/kg oil and 5.31 to 22.79 meq/kg oil in the control, T1, T2 and T3 samples, respectively (Fig. 1) during the storage time. Significantly lower PV was observed in moringa treated samples when compared to untreated samples. This is due to the higher amount of TPC, TFC, and DPPH radical scavenging activity of moringa, which inhibited the lipid oxidation. The control, T1, T2, and T3 samples were acceptable up to 4, 5, 6, and 6 months, respectively, based on the acceptable limit (up to 20 meq/kg oil) of PV in case of dried fishery products **(Connell, 1995)**. The peroxide value increased from 13.84 to 27.87 meq/kg oil in dried *T. fasciata* during 90 days storage in ambient temperature in airtight polythene bag **(Rasul *et al.*, 2019)**. Our results are in line with the finding of **Tenyang *et al.* (2020)**, who reported lower peroxide value (7.92 to 17.09 meq/kg oil) in dried *Orochromis niloticus* treated with moringa aqueous extract compared to untreated sample (20.63 meq/kg oil). Another study suggested the use of clove (*Syzygium aromaticum*) and seaweed (*Kappaphycus alvarezii*) water extracts to impede lipid oxidation in sun-dried sardines and results revealed that 5, 10, and 20 g/L clove extracts reduced significantly lipid peroxidation in sun-dried sardines by 38.7%, 54.6%, and 56%, respectively **(Chaula *et al.*, 2019)**.

The AV increased from 6.52 to 27.32 mg KOH/g of lipid; 4.02 to 24.01 mg KOH/g of lipid; 3.73 to 22.21 mg KOH/g of lipid, and 3.60 to 22.06 mg KOH/g of lipid in the control, T1, T2, and T3 samples, respectively (Table 3) during the storage time. Compared to the untreated samples, significantly lower AV were observed in moringa treated samples, indicating that moringa extract prevented the lipid oxidation in dried fish during drying and storage period. However, no significant differences were observed in acid values between T2 (2.5%) and T3 (3.5%) samples. **Song and Kim (2018)** found that pre-application of *Hutgae* fruit and green tea extracts on eels before drying was effective in delaying peroxidation during the drying process and refrigeration storage. Increment of

acid value was comparatively lower in green tea extract treated semi dried eel than that of the control during frozen storage for 9 months **(Song, 2021)**. More or less similar trend of acid values reported using green tea extract in salted mackerel **(Nam *et al.*, 2011)** and pitcher (*Nepenthes*) extract on sun-dried squid **(Minh, 2021)**.

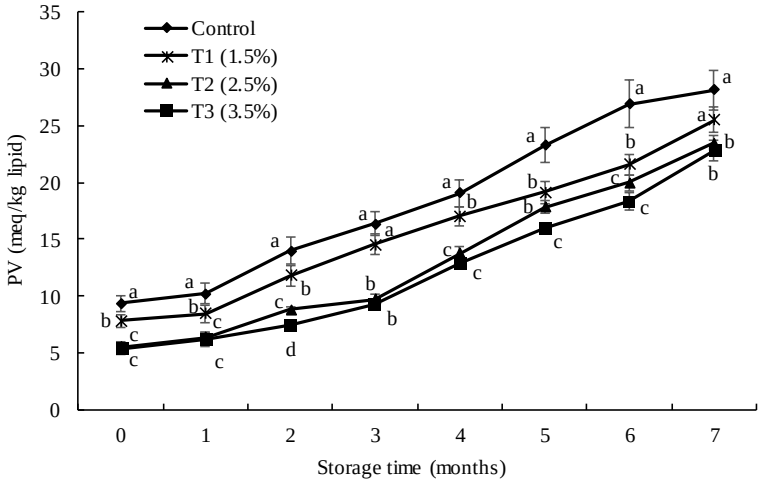

Fig. 1. Peroxide value (meq/kg lipid) of dried *P. sophore* during storage

Different letters indicate significant ($p < 0.05$) differences of means within the treatments at the same storage time. The error bars indicate means ± standard deviation (n = 6)

Table 3. Acid value (mg KOH/g of lipid) of dried fish during storage[1]

Treatment	Storage (months)							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Control	6.52± 0.87^{a}	8.12± 0.74^{a}	11.3± 0.65^{a}	13.57± 0.58^{a}	17.41± 0.55^{a}	20.32± 0.85^{a}	23.71± 1.01^{a}	27.32± 1.51^{a}
T1	4.02± 0.52^{b}	7.45±0.58^{abc}	10.21 ±0.52^{ab}	13.47± 0.71^{a}	16.33± 0.48^{b}	18.78± 0.67^{b}	20.67± 0.68^{b}	24.01± 1.02^{b}
T2	3.73± 0.47^{b}	6.54± 0.9b^{c}	9.49± 0.47^{b}	12.88± 0.50^{a}	15.92± 0.44^{b}	18.03± 0.49^{bc}	19.66± 0.55^{bc}	22.21± 0.67^{c}
T3	3.60± 0.82^{b}	6.47± 0.80^{c}	8.58± 0.50^{b}	11.39± 0.61^{b}	14.81± 0.61^{c}	17.29± 0.42^{c}	19.43± 0.49^{c}	22.06± 0.91^{c}

[1]Value expressed as mean ± SD (n = 6). Means having different superscript letters within a column are significantly different ($p < 0.05$)

The TBARS values measure the degree of oxidative rancidity in fats. Figure 2 shows the changes in TBARS value of dried *P. sophore* in various treatments. The TBARS value of untreated sample at 0 days was 0.79 mg MDA/kg and moringa treated dried fish were 0.77 to 0.76 mg MDA/kg. The control sample showed comparatively higher amount of TBARS value compared to that of moringa treated samples during storage at ambient temperature. Since moringa leaves extract have high TPC, TFC, and DPPH activity, they react rapidly with the free radicals to inhibit the lipid oxidation, which causes lower TBARS values **(Sreelatha & Padma, 2009)**. Additionally, vacuum

packaging interrupts the lipid oxidation of fishery products by limiting the availability of oxygen **(Etemadian *et al.*, 2012)**. In this study, the TBARS value exceeded the acceptable range (2 mg MDA/kg for dried fish) **(Connel, 1990)** after 5 months, 6 months, 7 months and 7 months for the control, T1, T2, and T3 samples, respectively. Recent research concluded that Pitcher (*Nepenthes*) extract showed excellent antioxidant potential to delay the lipid oxidation in the dried squid **(Minh, 2021)**. **Slavin *et al.* (2016)** found that 1% clove water extract significantly reduced the TBARS and peroxide value in oven dried omena fish by 77% and 79%, respectively. Moreover, rosemary extract combined with vacuum packing inhibited the lipid oxidation in Atlantic mackerel fish burgers **(Ucak *et al*., 2011)**.

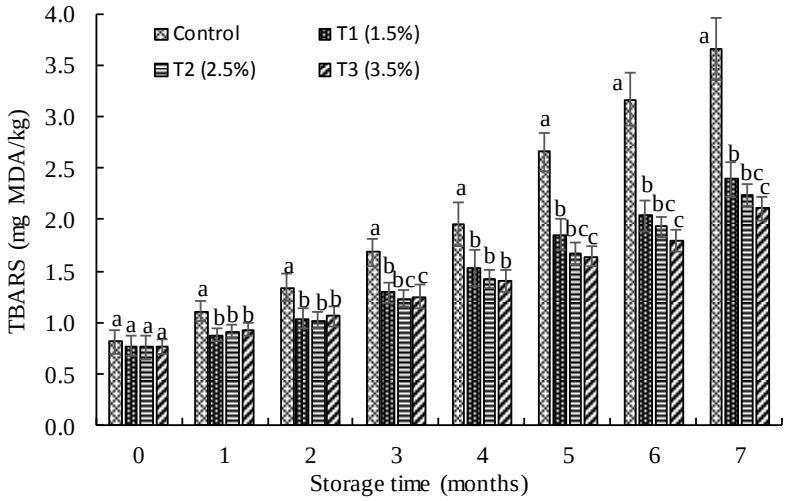

Fig. 2. TBARS value of dried *P. sophore* during storage

Different letters indicate significant ($p < 0.05$) differences of means within the treatments at the same storage time. The error bars indicate means ± standard deviation (n = 6)

Total volatile base nitrogen (TVBN)

The TVBN indicates the degree of spoilage of fishery product mainly composed of ammonia, primary, secondary and tertiary amines **(Ochieng *et al*., 2015)**. TVBN value increased from 11.78 to 72.76 mg/100g, 10.78 to 49.29 mg/100g, 10.34 to 44.78 mg/100g, 10.24 to 43.74 mg/100g for the control, T1, T2, and T3 samples, respectively (Fig. 3). The control sample showed higher TVBN value than moringa treated samples during seven months of storage at ambient temperature. Nonetheless, there was no significant variation recorded between T2 and T3 samples. The products were acceptable up to 4, 6, 6, and 6 months in the case of the control, T1, T2, and T3 sample, respectively, based on the acceptable range of TVBN value (40 mg/100g; **Kimura and Kiamukura, 1934**). However, TVBN values of T1 sample was very near to the rejection limit at 6 month of storage. It has been reported that the lowest TVBN value (5.6 to 19.5 mg/100g)

was recorded in vacuum-packaged dried sardine compared to the treated samples during 90 days of storage **(Ochieng *et al.*, 2015)**. Moringa water extract combined with vacuum packaging showed synergistic effect in reducing TVBN value, which reduces the bacterial number or the bacterial deamination property on non-protein nitrogenous compound due to the presence of phenolic compounds in moringa.

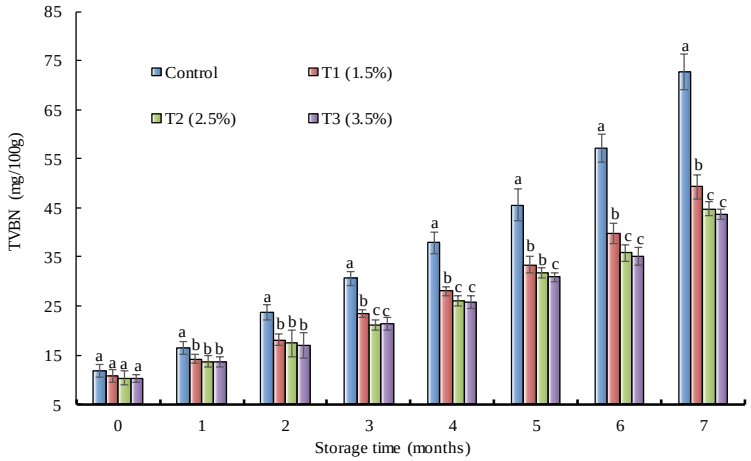

Fig. 3. TVBN value of dried *P. sophore* during storage

Different letters indicate significant ($p < 0.05$) differences of means within the treatments at the same storage time. The error bars indicate means ± standard deviation (n = 6)

Changes in APC of dried *P. sophore*

The APC is a significant measure for the evaluation of the microbial quality of a product, as well as for the shelf life assessment **(Chowdhury *et al.*, 2020; Rasul *et al.*, 2021a)**. The initial APC just after dying were recorded as 3.81, 3.57, 3.35, and 3.29 log CFU/g for the control, T1, T2, and T3 samples, respectively (Fig. 4). The APC increased with the increasing of the storage period. The acceptable limit of APC in dried fishery products is below 6 log CFU/g **(ICMSF, 2002)**. Considering this limit, the control, T1, T2, and T3 samples showed the acceptable range up to 5, 6, 6, and 6 months, respectively. However, the APC of T1 sample was very near to the rejection limit after 6 months of storage. Compared to the control samples, the moringa treated samples significantly retarded the bacterial growth, which might be due to moringa water extract possessing antimicrobial property **(Gupta *et al.*, 2018)**. Higher bacterial growth inhibition was observed with the increasing of moringa concentrations along with vacuum packaging. Nevertheless, no significant variation was observed in APC between T2 and T3 samples. Similarly, 1.0% moringa extracts effectively reduced the bacterial growth and retained the chemical quality of *M. rosenbergii* when stored at chilling temperature **(Karim *et al.*, 2018)**. It has been reported that the addition of 1% bay leaf, rosemary, black cumin seed, and lemon oil extracts with vacuum packaging decreased microbiological activity of hot smoked rainbow trout during storage **(Erkan *et al.*, 2011)**.

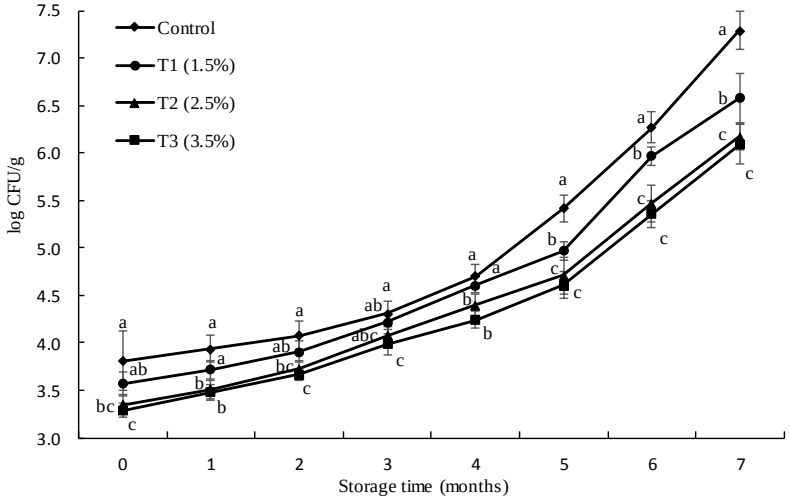

Fig. 4. Aerobic plate count of dried *P. sophore* during storage

Different letters indicate significant ($p < 0.05$) differences of means within the treatments at the same storage time. The error bars indicate means ± standard deviation (n = 6)

Sensory evaluation

Sensory score prepared using mean score of sensory attributes, such as color, odor, and texture of dried *P. sophore* (Table 4). The initial quality of dried fish had characteristic silvery color, characteristic fishy odor and firm, and flexible texture. The value of sensory attributes were increased with the increasing of the storage period. The color value of dried fish was increased in all the samples with the increasing of storage period due to non-enzymatic browning reactions **(Majumdar *et al.*, 2018)**. The more the sensory scores are obtained, the less the quality indicates. Initially, the control sample showed comparatively better attributes in sensory quality (color, odor, texture) than the moringa treated samples. After the 7 month storage period, the control sample showed higher scores than the treated samples.

According to **Rasul *et al.* (2018)**, the acceptable ranges of color, odor, and texture are less than 6 and overall acceptability's permissible limit is less than 18. Based on this limit, control samples and treated samples were acceptable up to 5 and 6 months which did not quite agree with chemical and microbial results. However, moringa treated samples showed lower results than the control samples, indicating comparatively good quality, though there were no significant differences. Similarly, 1%, 2%, and 3% of *Moringa oleifera* marinades did not show any significant differences in sensory attributes in case of smoke dried African catfish **(Adeyemi *et al.*, 2013)**. Additionally, it has been reported that, the use of 5% (v/v) and 10% (v/v) of *Moringa oleifera* leaf extract increased the shelf life without adversely affecting the sensory properties of vacuum packed *Pangasianodon hypophthalmus* fillets during chilled storage **(Greeshma *et al.*,**

2019). The present finding coincides with that of **Muthukumar *et al.* (2014)** in the use of moringa leaves in pork patties.

Table 4. Sensory scores of dried *P. sophore* during storage[1]

Attribute	Treatment	Storage (months)							
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Color	Control	1.16± 0.10^{b}	1.29± 0.05^{b}	1.72± 0.12^{a}	2.25± 0.12^{a}	3.36± 0.10^{a}	4.86± 0.22^{a}	6.10± 0.20^{a}	7.41± 0.14^{a}
	T1 (1.5%)	1.27± 0.09^{ab}	1.41± 0.08^{ab}	1.75± 0.09^{a}	2.27± 0.06^{a}	3.06± 0.07^{b}	4.26± 0.21^{b}	5.93± 0.22^{a}	6.89± 0.21^{b}
	T2 (2.5%)	1.34± 0.10^{a}	1.46± 0.09^{a}	1.83± 0.12^{a}	2.39± 0.08^{a}	3.17± 0.09^{ab}	4.16± 0.16^{b}	5.86± 0.20^{a}	6.66± 0.19^{b}
	T3 (3.5%)	1.38± 0.07^{a}	1.52± 0.09^{a}	1.89± 0.10^{a}	2.43± 0.11^{a}	3.25± 0.10^{a}	4.07± 0.20^{b}	5.81± 0.31^{a}	6.61± 0.27^{b}
Odor	Control	1.11± 0.1^{a}	1.26± 0.12^{b}	1.70± 0.15^{b}	2.32± 0.07^{b}	3.61± 0.13^{a}	5.19± 0.11^{a}	6.04± 0.25^{a}	6.88± 0.15^{a}
	T1 (1.5%)	1.23± 0.12^{a}	1.39± 0.08^{ab}	1.65± 0.10^{b}	2.41± 0.1^{ab}	3.11± 0.11^{c}	4.93± 0.12^{b}	5.95± 0.17^{a}	6.62± 0.14^{a}
	T2 (2.5%)	1.28± 0.07^{a}	1.57± 0.14^{a}	2.27± 0.07^{a}	2.50± 0.1^{a}	3.36± 0.11^{bc}	4.65± 0.10^{bc}	5.56± 0.14^{b}	6.44± 0.3^{a}
	T3 (3.5%)	1.31± 0.16^{a}	1.56± 0.10^{a}	2.25± 0.12^{a}	2.59± 0.13^{a}	3.42± 0.19^{ab}	4.47± 0.1^{c}	5.44± 0.26^{b}	6.36± 0.37^{a}
Texture	Control	1.23± 0.08^{b}	1.55± 0.11^{a}	2.20± 0.20^{b}	2.79± 0.10^{b}	3.51± 0.21^{a}	5.36± 0.14^{a}	6.34± 0.20^{a}	7.22± 0.24^{a}
	T1 (1.5%)	1.32± 0.09^{a}	1.59± 0.15^{a}	2.42± 0.15^{a}	2.87± 0.07^{a}	3.36± 0.1^{a}	4.87± 0.07^{b}	5.84± 0.11^{b}	6.46± 0.18^{b}
	T2 (2.5%)	1.38± 0.11^{a}	1.64± 0.13^{a}	2.48± 0.20^{a}	2.95± 0.09^{a}	3.27± 0.13^{a}	4.78± 0.10^{b}	5.55± 0.16^{c}	6.32± 0.21^{b}
	T3 (3.5%)	1.41± 0.09^{a}	1.69± 0.12^{a}	2.55± 0.12^{a}	3.04± 0.17^{a}	3.28± 0.10^{a}	4.72± 0.19^{b}	5.44± 0.22^{c}	6.28± 0.3^{b}
Overall acceptability	Control	3.50± 0.14^{b}	4.10± 0.17^{b}	5.62± 0.41^{b}	7.36± 0.37^{a}	10.48± 0.31^{a}	15.41± 0.66^{a}	18.48± 0.69^{a}	21.51± 0.64^{a}
	T1 (1.5%)	3.82± 0.16^{a}	4.39± 0.11^{a}	5.82± 0.28^{b}	7.55± 0.26^{a}	9.53± 0.52^{b}	14.06± 0.62^{b}	17.72± 0.66^{ab}	19.97± 0.53^{b}
	T2 (2.5%)	4.0± 0.15^{a}	4.67± 0.13^{a}	6.58± 0.18^{a}	7.84± 0.51^{a}	9.80± 0.46^{ab}	13.59± 0.68^{b}	16.97± 0.60^{b}	19.42± 0.63^{b}
	T3 (3.5%)	4.10± 0.2^{a}	4.77± 0.16^{a}	6.69± 0.24^{a}	8.06± 0.44^{a}	9.95± 0.60^{a}	13.26± 0.58^{b}	16.69± 0.75^{b}	19.25± 0.68^{b}

[1]Value expressed as mean ± SD (n = 10). Means having different superscript letters within a column are significantly different ($p < 0.05$)

CONCLUSION

In this study, moringa water extracts showed substantial amount of total phenolic content, total falvanoid content and they have high DPPH radical scavenging activity. In addition, pretreatment with moringa water extracts effectively inhibit the lipid oxidation, improve the quality and shelf life of *P. sophore* during drying and storage at ambient temperature. However, 2.5% and 3.5% of moringa water extract showed better results

than 1.5% and untreated samples in terms of peroxide value, acid value, thiobarbituric acid reactive substance value, TVBN, and aerobic plate count. Moringa water extract (2.5%) showed better sensory attributes than other treated and untreated samples. Therefore, processors can apply 2.5% moringa water extract pretreatment and vacuum packaging in improving quality and oxidative stability of dried fishery product.

ACKNOWLEDGEMENT

The authors are grateful to the Research Management Wing of BSMRAU and University Grant Commission, Bangladesh for providing the research grant.

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