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Effects of vacuum and modified atmosphere packaging on the biochemical and microbiological quality of sliced goonch fish (*Bagarius bagarius*) stored at refrigerated condition

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Abstract

Vacuum packaging and modified atmosphere packaging (MAP) are widely applied packaging methods for displaying refrigerated fish and fish products. This study evaluated the biochemical and microbiological quality of sliced goonch fish (*Bagarius bagarius*) by analysing different parameters under not sealed pack (control), vacuum pack, and MAP-1 (50% CO_2 / 50% N_2), and MAP-2 (50% CO_2 / 50% O_2) at three days interval in 15 days of refrigerated storage at 4±1°C. The total volatile base nitrogen (TVB-N), peroxide value (PV) and thiobarbituric acid reactive substances (TBARS) values of the samples in four packaging systems did not cross the acceptable limit in the entire storage time. The total viable count (TVC) progressively increased with time in all packaging systems. However, TVCs were significantly ($p<0.05$) lower on 9^{th} and 12^{th} storage day in all samples compared to the control sample. Based on the bacterial counts of 7 log CFU/g, the shelf-life was determined at about 6, 10, 12, and 9 days for control, vacuum, MAP-1, and MAP-2 sample, respectively. All treatments offered satisfactory results during the storage period, except for the control in terms of shelf life. However, MAP-1 with 50% CO_2 and 50% N_2 demonstrated the promising result for shelf life extension, which can be utilised by the retail superstores for displaying the fishes.

1. Introduction

Goonch fish (*Bagarius bagarius*) is a Sisoridae catfish, locally called *baghair* fish in Bangladesh. This voracious and predatory catfish termed as 'freshwater shark' is quite attractively marked greyish or light yellowish with large irregular black bands and markings (Rahman, 1989). Goonch fish has a unique taste and flavour that attracts the consumers in Bangladesh. The proximate composition of this fish was determined as moisture 73.20%, ash 0.5%, fat 8.25%, and protein 18.05% (Memon *et al.,* 2010). It has a high demand and value in the country, though the abundance has been declining in River ecosystem of Bangladesh (Sarker *et al*., 2008).

In Bangladesh, the transport and storage facilities of fish for both the retail and wholesale market are inadequate (Rahman *et al.,* 2009). For these inadequate facilities, each year, a vast quantity of fishes cannot be utilised appropriately. The quality loss mainly takes place owing to prolonged exposure of fish at a higher temperature, followed by rough and excessive handling. However, there was no systematic study conducted to reduce the loss in the past (Rahman *et al.,* 2009). In the local market, fishes are sold as a whole without proper storage and display facilities. However, in retail superstores of the country, fresh fishes are displayed under icing condition as a whole, sometimes as a whole dressed and hardly as portions. As a result, consumers are restricted to buy the affordable pieces of fishes, particularly for larger popular fishes. This icing condition cannot substantially prolong the shelf-life adequately for display and retail purposes (Amanullah, 2019). Eventually, the quality of the fishes deteriorates, and a considerable amount of fishes spoils, which is one of the reasons for high pricing in those superstores.

Fresh fish is an extremely perishable food item for its biological composition. For this reason, even at regular iced or chilled storage, the shelf life of fresh fish remains short for the enzymatic reaction, oxidation, and microbiological spoilage. In the early stages of deterioration, textural quality is reduced by the autolytic enzymes (Hansen *et al.,* 1996). The extensive autolysis occurs by digestive enzymes resulting in softening and rupture the belly wall and discharge the blood water

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containing both lipid and protein (FAO, 1986). Lipid oxidation is another accounted for the cause of spoilage of pelagic fishes such as herring and mackerel have high-fat content in the flesh (Fraser and Sumar, 1998). Typically, oxidation occurs while oxygen reacts with the double bonds of different fatty acids. Hence, fish lipids having polyunsaturated fatty acids are very prone to oxidation (Hultin, 1994). Microbial growth and metabolic activity are another crucial cause of spoilage, producing amines, biogenic amines, sulphides, organic acids, alcohols, ketones, and aldehydes which produce unpleasant and undesirable off-flavours (Gram and Dalgaard, 2002; Dalgaard *et al.,* 2006).

The consumer demands are growing for fresh products with prolonged shelf-life. In contrast, the energy cost is increasing for freezing and frozen storage of food. In these circumstances, the fish processing factories and retail superstores are keenly searching an alternative method for shelf-life prolongation and marketability of chilled fish as well as saving the energy costs at the same time (Ashie *et al.,* 1996). At present, more than 200 outlets from around 30 enterprises have been functioning in Bangladesh, where a steady 15-20 per cent annual sales growth is observed. The popular companies are Swapno, Agora, Meena Bazaar, Nandan, and others (Alam and Rana, 2013). The vacuum packaging and modified atmosphere packaging (MAP) could be used in combination with chilling or refrigeration for keeping quality as well as increasing the shelf life of fresh fish and shellfish.

Vacuum packaging is the placement of a product inside a packaging material with low permeability to oxygen, followed by air exhaustion and sealing (Smith *et al.,* 1990). On the other hand, MAP is a preservation technique that involves alteration of the atmospheric environment around food by the replacement of one or a mixture of gases (Arashisar *et al.,* 2004). This type of packaging is widely used packaging technique for shelf-life elongation (25-400%) of fish, meat, and various products in developed countries (Reddy *et al.,* 1991). The extension of shelf-life for fish products in a vacuum packaging and MAP depends on the type of raw materials, gas mixtures, temperature, and packaging materials. Effects of gases used in packaging have been studied mostly in marine fish (Reddy *et al.,* 1991; Ruiz-Capillas and Moral, 2001). However, few studies have been found on MAP packaging of freshwater fishes such as tilapia, sutchi catfish, and carps (Noseda *et al.,* 2012; Masniyom *et al.,* 2013; Li *et al*., 2017). This type of packaging technique has not developed yet in the market of developing countries like Bangladesh. Therefore, the study was aimed to develop a proper vacuum packaging and MAP for this freshwater fish to extend the shelf-life, which can ensure the supply of quality fishes conveniently.

2. Materials and methods

2.1 Collection and preparation of samples

The goonch fishes (*Bagarius bagarius*) with the weight of 8±2 kg was bought from Shaheeb Bazar (a local fish market) in Rajshahi city of Bangladesh. The fishes were brought in icing condition to the Quality Control Laboratory of Department of Fisheries under the Rajshahi University, Bangladesh. After the arrival, fishes were washed under running tap water at room temperature, dressed, and cut into around 2 cm thick slices with a weight of 100±10 g. Then the sliced goonch fishes were washed with running tap water for two times, and the last wash was performed with distilled water (room temperature).

2.2 Packaging and storage of sliced fishes

Around 200 g of sliced goonch fishes were packed under vacuum packaging and MAP in plastic pouch having low moisture and gas permeability. Multilayered (Polythene/Polyamide/Polythene) transparent pouch with 100 µm density was used as packaging material. Four types of packaging were applied using different gas mixture following the method of Noseda *et al*. (2012). These four types packaging was regarded as treatments namely, (1) aerobic, not sealed pack as control, (2) vacuum pack as treatment-1, (3) MAP-1 (50% CO_2/ 50% N_2) as treatment-2, and (4) MAP-2 (50% CO_2/ 50% O_2) as treatment-3. Vacuum packaging and MAP were done by a packaging machine (C100, MULTIVAC, Germany) which was attached to a gas mixer (KM100-3MEM, WITT, Germany) via a buffer tank following the guidelines of the manufacturer. Particular gas ratios were set according to the treatments on the panel of gas mixer which was attached with three gas (O_2, N_2 and CO_2) cylinders. In this way, gas with a specific ratio was transferred to the pack and sealed automatically inside the packaging machine. The O_2, N_2, and CO_2 gas levels inside the packaged samples were monitored with a gas analyser (OXYBABY M+, WITT, Germany). All packaged samples were stored in a refrigerator at 4±1°C. Samples of three (as replications) from each of the treatments were analysed at three days interval during the 15 days storage period.

2.3 Biochemical and microbiological analysis

Total volatile base nitrogen (TVB-N) was measured according to the EC (2005) method. Exactly 10 g of the ground fish sample was mixed with 90.0 mL of 6%

perchloric acid, homogenised for 2 mins with a blender (Bajaj, India), and then filtered. A 50 mL of the extract with 4-6 drops phenolphthalein were put in a Kjeldahl flask, and then some glass-beads and 6.5 mL of 20% NaOH has added the flask after placing on the distillation unit (JSGW, Haryana, India). The distillation process was continued for about 10 mins. The distillate was collected in a conical flask containing 100 mL of 3% H_3BO_3, and 3-5 drops of the mixed indicator. Distillation was confirmed by changing the colour of the mixed indicator (violet to greenish). The distillate was titrated with 0.05N HCl, and the endpoint was determined by gaining the pH as 5.0±0.1. The TVB-N value was calculated using the following equation:

$$\text{TVB} - \text{N (mg/100 g)} = \frac{(\text{mL titrant of sample} - \text{mL titrant of blank}) \times 0.14 \times 2 \times 100}{\text{sample wt in g}}$$

Peroxide value (PV) was determined based on international IDF (International Dairy Federation) standard described by Shantha and Decker, (1994) using fish oil. For this purpose, firstly the oil was extracted utilising Soxhlet extraction by following standard AOAC (1995) method. At first, 0.01-0.30 g sample fish oil was taken in a test tube and added 9.8 mL chloroform: methanol (7:3) and vortexed for 2-4 s. A 50 µL ammonium thiocyanate solution was added and vortexed for 2-4 s. Then 50 µL iron (II) chloride solution was added and again vortexed for 2-4 s. After incubating at room temperature for 5 mins, the absorbance of the sample was determined at 500 nm against a blank using UV-visible spectrophotometer (UV-1601PC, Shimadzu, Japan). The entire procedure was conducted in subdued light. The PV was calculated by using the following formula:

$$PV\ (\text{mEq/kg}) = \frac{(\text{sample Abs} - \text{blank Abs}) \times 41.52}{\text{atomic wt of iron} \times \text{sample wt in g} \times 2}$$

Thiobarbituric acid reactive substance (TBARS) was estimated by a colourimetric method of Witte *et al.* (1970). Exactly 20 g of fish sample was homogenized with 50 mL of 20% trichloroacetic acid (in 2M phosphoric acid) at 1000 × *g* for 2 mins using a homogenizer (IKA-T18, Staufen, Germany). The resulting mixture was diluted to 100 mL with dd water and homogenized again. The mixture was filtered through a filter paper (Whatman No-1, 110 mm). A 5 mL of filtrate was taken into a test tube containing 5 mL of 2 -thiobarbituric acid (0.005 M in dd water). The test tube was shaken well and kept in the dark for 15 hrs at the room temperature. The reactive substances were quantified at 530 nm using UV visible spectrophotometer (UV-1601PC, Shimadzu, Japan). TBARS value was calculated as follows: TBARS value (mg malonaldehyde/kg) = optical density × 5.2.

Total viable count (TVC) expressed as colony forming units (CFU/g) were determined by a standard plate count method following the decimal dilution technique by (APHA, 1992). At first, 1 mL of prepared and well shaken diluted sample was transferred to an empty plate using a micropipette. Then around 15 mL of prepared plate count agar (Sigma-Aldrich, USA) was poured to the plate after cooling to 45±1°C. The plates were incubated at 35°C for 48 hrs in an incubator (Poleko, Poland) and counted the colonies. Bacterial counts were converted into logarithms.

2.4 Statistical analysis

Analyses of variances were done using one-way ANOVA. The differences among mean values of various treatments were performed by post hoc Tukey's test using SPSS-20 (IBM, Chicago, USA), and a significant difference was defined as $p<0.05$.

3. Results

3.1 Total volatile base nitrogen (TVB-N) value

The initial TVB-N value of sliced goonch fish was observed 1.26 mg/100 g and then the TVB-N values gradually risen with the progress of storage period during the storage under all packaging systems. The highest TVB-N value was 6.75 mg/100 g on 15th day of storage for vacuum pack sample. However, there were significantly ($p<0.05$) lower TVB-N values recorded on the 9th and 12th storage day under all packaging systems in comparison to the control sample. Besides, no significant ($p<0.05$) differences were observed in samples between vacuum and MAP during the storage period. Comparatively lower TVB-N values were observed in MAP samples than the control sample in the entire storage period (Table 1).

3.2 Peroxide value (PV)

The PV fluctuated between 0.86 and 4.89 mEq/kg fish oil under all packaging systems during the storage period. A gradual increasing trend was observed until the 6th day of storage of samples under all the packaging systems followed by a sharp decline and then increased again in PV (Table 2). However, there were no such significant ($p>0.05$) differences observed among the treatments in the storage period (Table 2).

3.3 Thiobarbituric acid reactive substances (TBARS) value

In the current study, the initial TBARS values of sliced goonch fish were found 0.51 mg malonaldehyde (MDA)/kg. The TBARS values fluctuated between 0.24 and 4.35 mg MDA/kg in samples of all packaging types

Table 1. Total volatile base nitrogen (TVB-N) value (mg/100 g) of sliced goonch fish (*Bagarius bagarius*) under vacuum and MAP packaging conditions during storage at refrigerated temperature (4°C)

Treatments	Storage Period					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Not sealed pack (control)	1.26±0.20^{a}	2.80±0.40^{a}	5.72±0.57^{a}	6.30±0.59^{b}	6.12±1.13^{b}	-
Vacuum pack	1.26±0.20^{a}	2.94±0.20^{a}	3.24±0.62^{a}	5.74±0.59^{a}	6.25±1.23^{a}	6.75±0.83
MAP-1 (50% CO_2 /50% N_2)	1.26±0.20^{a}	3.08±0.57^{a}	4.20±0.57^{a}	4.06±0.76^{a}	4.48±0.40^{a}	5.74±0.20
MAP-2 (50% CO_2 /50% O_2)	1.26±0.20^{a}	2.52±0.40^{a}	4.12±1.07^{a}	4.20±0.00^{a}	5.80±1.07^{a}	6.52±1.07

Values are expressed as mean±SD, taken from three replicates. Values in the same column bearing different superscript letters indicate the significant difference at $p<0.05$.

Table 2. Peroxide value (PV) (mEq/kg fish oil) of sliced goonch fish (*Bagarius bagarius*) under vacuum and MAP packaging conditions during storage at refrigerated temperature (4°C)

Treatments	Storage Period					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Not sealed pack (control)	0.86±0.32^{a}	1.79±0.3^{a}	3.20±0.3^{a}	1.07±0.37^{a}	1.65±0.17^{a}	-
Vacuum pack	0.86±0.32^{a}	1.87±0.5^{a}	4.89±0.8^{a}	2.17±0.17^{b}	2.68±0.32^{a}	3.28±0.63
MAP-1 (50% CO_2 /50% N_2)	0.86±0.32^{a}	1.90±0.9^{b}	3.45±0.9^{a}	2.07±0.38^{b}	4.42±1.08^{a}	3.05±0.35
MAP-2 (50% CO_2 /50% O_2)	0.86±0.32^{a}	2.66±0.5^{ab}	4.55±0.5^{a}	1.12±0.14^{a}	2.31±0.55^{b}	4.14±0.34

Values are expressed as mean±SD, taken from three replicates. Values in the same column bearing different superscript letters indicate the significant difference at $p<0.05$.

in the storage period. TBARS values were observed in an increasing trend until the end for the control sample, 9th day for vacuum and MAP-2 sample, and 15th day for MAP-1 sample and then started to decline (Table 3). There were significantly ($p<0.05$) lower TBARS values found in vacuum and MAP-1 on the 9th and 12th storage day in comparison to the control. Moreover, significantly ($p<0.05$) higher TBARS values were found in MAP-2 sample on the 6th, 9th and 12th storage day in comparison to other samples (Table 3).

3.4 Total viable count (TVC)

The initial TVC of sliced goonch fish was 5.22 log CFU/g, and then the TVCs steadily increased with the progress of time in all packaging systems during the storage period. However, there were significantly ($p<0.05$) lower TVCs recorded on the 9th and 12th storage day in all packaged samples in comparison to the control. Comparatively lower TVCs were recorded in the case of MAP-1 sample throughout the storage period (Table 4).

4. Discussion

Information on the vacuum packaging and MAP of

Table 3. Thiobarbituric acid reactive substances (TBARS) value (mg malonaldehyde/kg) of sliced goonch fish (*Bagarius bagarius*) under vacuum and MAP packaging conditions during storage at refrigerated temperature (4°C)

Treatments	Storage Period					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Not sealed pack (control)	0.51±0.06^{a}	0.40±0.01^{b}	1.03±0.10^{a}	1.22±0.03^{b}	1.51±0.04^{c}	-
Vacuum pack	0.51±0.06^{a}	0.24±0.09^{a}	0.82±0.06^{a}	0.97±0.07^{a}	0.42±0.16^{a}	0.49±0.09
MAP-1 (50% CO_2 /50% N_2)	0.51±0.06^{a}	0.60±0.08^{c}	0.82±0.06^{a}	1.05±0.05^{a}	1.15±0.03^{b}	1.40±0.16
MAP-2 (50% CO_2 /50% O_2)	0.51±0.06^{a}	0.47±0.03^{bc}	2.00±0.18^{c}	4.35±0.09^{c}	2.91±0.18^{d}	2.45±0.09

Values are expressed as mean±SD, taken from three replicates. Values in the same column bearing different superscript letters indicate the significant difference at $p<0.05$.

Table 4. Total viable counts (TVCs) (Log CFU/g) of sliced goonch fish (*Bagarius bagarius*) under vacuum and MAP packaging conditions during storage at refrigerated temperature (4°C)

Treatments	Storage Period					
	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Not sealed pack (control)	5.22±0.04^{a}	6.32±0.18^{b}	6.93±0.22^{a}	8.03±0.07^{c}	8.81±0.04^{b}	-
Vacuum pack	5.22±0.04^{a}	5.26±0.11^{a}	5.62±0.24^{a}	6.63±0.10^{ab}	7.78±0.32^{a}	8.22±0.05
MAP-1 (50% CO_2 /50% N_2)	5.22±0.04^{a}	5.21±0.15^{a}	6.62±0.36^{b}	6.42±0.11^{a}	7.03±0.32^{a}	7.70±0.28
MAP-2 (50% CO_2 /50% O_2)	5.22±0.04^{a}	5.91±0.15^{ab}	6.22±0.08^{b}	6.99±0.19^{b}	7.79±0.06^{a}	7.85±0.07

Values are expressed as mean±SD, taken from three replicates. Values in the same column bearing different superscript letters indicate the significant difference at $p<0.05$.

goonch fish is not available. However, the current study focuses on the biochemical and microbiological quality as well as the shelf life of sliced goonch (*Bagarius bagarius*) fish under vacuum packaging and MAP at refrigerated (4°C) storage condition.

TVB-N is termed as the sum of ammonia (NH_3), dimethylamine (DMA), and trimethylamine (TMA) in fish as a whole (Wu and Bechtel, 2008). It is commonly used as an indicator of the bacterial spoilage of fish. TVB-N value depends on several factors such as feeding, season, size, and other environment parameters (Binsi *et al*., 2015). In the current study, the TVB-N values of samples of four packaging systems were within the safe limit for human consumption, based on the acceptable limit of TVB-N at 30-35 mg/100 g for fish and fishery products set by Connell (1995). In another study of the same laboratory, TVB-N values did not cross the limit of acceptability in 20 storage days at 4°C for ready-to-cook (RTC) pangas fish curry in not sealed pack, MAP-1 with 50% CO_2 and 50% N_2, and MAP-2 with 75% CO_2 and 25%N_2 (Nayma *et al.,* 2020). In the current study, the initial TVB-N value of 1.26 mg/100 g in goonch fish was nearly similar to the findings of Thai pangas (Islami *et al.,* 2015) and is better than the results of Seer fish observed by Mohan *et al*. (2018). Several studies showed that the TVB-N value of freshly harvested fish was in a range from 5 to 20 mg/100 g (Huss, 1988; Connell, 1995). The TVB-N value in the current study peaked to 6.75 mg/100 g on 15th day of storage for vacuum pack sample (Table 1). The gradual increase of TVB-N value in the storage period is due to the increase in bacterial growth and some endogenous enzymes (Ruiz-Capillas and Moral, 2001; Islami *et al.,* 2015). This result is similar to other studies, in which a correlation was observed between quality deterioration and risen TVB-N values of MAP seafood, but the levels, which were not always below from acceptable limit at the end of shelf-life for the product (Ozogul *et al*., 2004; Nayma *et al.,* 2020). Several others found significantly lower production of volatile compounds in products under MA pack in comparison to air pack which seems to be supportive to the findings of the current study (Wang *et al.,* 2008; Yesudhason *et al.,* 2014).

PV is commonly used as a vital indicator to assess the degree of primary oxidation of lipid (Masoud *et al.,* 2008). Fish lipid is very much prone to oxidation as it contains high levels of unsaturated fatty acids. PV measures the quantity of hydroperoxides formed in the fish body. The acceptable limit of PV is 10-20 mEq/kg of fish oil (Connell, 1995). Based on the stated limit, the PV of the samples under all packaging systems in the current study did not cross the acceptable limit (Table 2). Clarification of the PV as a quality indicator is not straightforward. As the hydroperoxides are flavourless and odourless, the PV cannot indicate the real sensory quality of any product. However, it may indicate a possible formation of sensorial and objectionable compounds at a later stage. Besides, the lipid hydroperoxides break down with the progress of time. A low PV at a defined point during the storage of any product can indicate both an early stage of autoxidation and a late phase of heavily oxidised products such as in dried, salted fish (Smith *et al.,* 1990; Kanner and Rosenthal, 1992).

In the current study, the initial rise of PV was due to the development of hydroperoxides. It increased at the initial stage of oxidation but decrease at the later stage when the degree of cleavage and reactions surpass the hydroperoxides formation (Underland *et al*., 1999; Cyprian *et al*., 2015). The formation of hydroperoxides is significantly affected by the lipid content and packaging methods, which might be the reason for the variations of the PV in the current study. It was reported that gutting increased the peroxides formation during storage of fatty fishes, e.g., mackerel (Lehmann and Aubourg, 2008). The reason behind that is the gutting exposes the cut surfaces and belly area to air, thus making the lipid more prone to oxidation. It is evident for a higher PV in gutted sutchi catfish (Viji *et al.,* 2015).

TBARS is a procedure which evaluates the level of secondary lipid oxidation and thus the quality of food. TBARS index is used to measure the MDA amount, which is a secondary product of the oxidation of polyunsaturated fatty acids (Mohan *et al.,* 2008). The acceptable limit of TBARS value is 2 mg MDA/kg fish sample, and when this limit exceeds, an obnoxious odour and taste build up in fish (Connell, 1990). In the current study, the TBARS values did not exceed the limit of acceptability in all packaged samples except the MAP-2 sample, where it exceeded the acceptable limit on the 9th storage day (Table 3). The higher TBARS value in MAP -2 samples can be explained for the higher degree of secondary lipid oxidation in the presence of 50% O_2 compared to that of other samples. Ruiz-capillas and Moral (2001) also found higher TBARS value for CO_2 rich atmosphere.

Oxidative rancidity might be the primary concern for the shelf-life of MAP seafood, particularly for fatty fishes (Sivertsvik *et al.,* 2002). Mohan *et al.* (2018) observed the initial TBARS value of seer fish as 0.32 mg MDA/kg, and then the values increased with storage time, which is nearly similar to the current study. On the other hand, Viji *et al.* (2015) found that fresh pangas fish *(Pangasiandon hypophthalmus)* provided a TBARS value of 0.038 mg MDA/kg sample, which is much

lower than that of the fresh goonch fish sample of the current study. However, the TBARS value may not disclose the actual degree of lipid oxidation as MDA sometimes interacts with other compounds of fish flesh (Aubourg, 1993). Oxidative rancidity is a great problem for O_2 rich MAP packaging. O_2 reacts with the fatty acids to produce hydroperoxide without degrading the odoriferous components (Church, 1998). The usefulness of TBA value and TBARS for utilizing as shelf-life indicator depends on the type of food products (DeWitt and Oliveira, 2016). For instance, the TBA was not a suitable indicator for shelf-life estimation of Atlantic horse mackerel under MAP (Alfaro *et al*., 2013), while Torrieri *et al*. (2011) establish TBARS to be a critical indicator for shelf-life determination of Bluefin tuna under MAP.

Total bacterial count is an important measure for the assessment of the microbial quality of a product as well as for shelf-life estimation. It was evident that freshwater fishes that are freshly harvested (tilapia, rainbow trout, silver perch, and sea bass) have bacterial counts around 2 -6 log CFU/g (Gelman *et al.,* 2001). Based on this study, the initial TVC of sliced goonch fish was 5.22 log CFU/ g, indicated a satisfactory quality of fresh fish in the current study. According to ICMSF (1986), the upper acceptable limit of aerobic plate counts (APC) for frozen and fresh fish is 7 log CFU/g. In the current study, the TVCs exceeded the 7 log CFU/g on approximately 6th for not sealed pack, 10th for vacuum, 12th for MAP-1, and 9th storage day for MAP-2 sample (Figure 1). Based on the bacterial counts, the shelf-life was determined at around 6, 10, 12, and 9 days for not sealed pack, vacuum pack, MAP-1, and MAP-2 sample, respectively. Nearly similar shelf-life except for MAP-2 (50% CO_2/50% O_2) sample was observed by Noseda *et al.* (2012) in case of frozen-thawed Vietnamese pangas fillets stored at 4°C in air, vacuum, MAP-1 (50% CO_2/ 50% N_2), and MAP-2 (50% CO_2/ 50% O_2) at approximately 7, 10, 12 and 14 days, respectively.

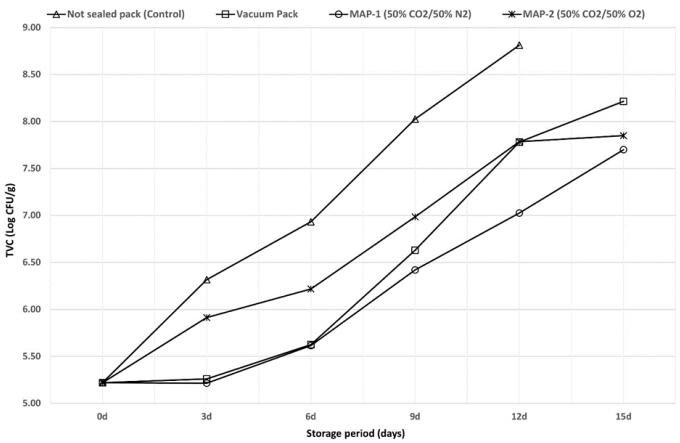

Figure 1. Changes in the total viable counts (TVCs) (Log CFU/g) of sliced goonch fish (*Bagarius bagarius*) under vacuum and MAP packaging conditions during storage at refrigerated temperature (4°C)

Various factors such as species, storage temperature, initial bacterial contamination, and packaging systems can affect the shelf-life of fish (Sivertsvik *et al*., 2002). Application of MAP with CO_2 was reported to extend the shelf-life of food products because it delayed the microbial growth (Ozogul *et al.,* 2004; Chen and Xiong, 2008). Ozogul *et al*. (2004) observed almost similar findings to the current study, where lower TVCs in MAP (CO_2/N_2:60/40) samples compared to vacuum and air pack samples was observed in sardines (*Sardina pilchardus*) fish kept at 4°C. In the current study, the vacuum pack sample showed lower TVCs compared to that of MAP-2 (50% CO_2 / 50% O_2) pack sample throughout the entire storage period. There is a disagreement with the study of Noseda *et al*. (2012) where MAP-2 (50% CO_2 / 50% O_2) of frozen-thawed Vietnamese pangas fillets stored at 4°C showed longer shelf-life (14 days) than vacuum pack (10 days). Moreover, quality assessment of *Scombercolias japonicas* under vacuum and modified atmosphere (CO_2/ N_2: 50/50) packaging at 3 and 6°C have been studied by Stamatis and Arkoudelos (2007). After 15 days of storage, the TVC for MAP samples was 6.6 log CFU/g stored at 3°C and 6.7 Log CFU/g stored at 6°C, which is lower than that of the current study.

In terms of costs, it was observed that the price for packaging materials and gases was about 0.18–0.24 USD per pack of 500 g, which is reasonable for this kind of quality products. Therefore, this information could be useful for the processors to introduce this kind of packaging technology even in developing countries like Bangladesh.

5. Conclusion

The vacuum packaging and MAP have been demonstrated as an effective packaging technique to extend the shelf-life of fishes. These packaging systems render the growth of many spoilage and pathogenic microorganisms and inhibit their toxin production for ensuring the safety of fish and fishery products. However, the requirement of skilled staff, high initial cost, and chemical and microbial hazards associated with the end products are some of the drawbacks of MAP. In the current study, all the treatment presented satisfactory results during the storage period, except for the control, which showed total bacterial counts above the acceptable levels on the 6th day of the storage. Vacuum packaging extended the shelf life by 10 days, MAP-1 (50% CO_2 and 50% N_2) increased the shelf life by 12 days, and MAP-2 (50% CO_2 and 50% O_2) increased the shelf life by 9 days. Therefore, MAP-1 demonstrated highest shelf life based on bacterial counts. This MAP packaging can be

utilised in combination with refrigerated storage by the superstores to store and display the fishes with extended shelf life, which can ensure the supply of larger fishes as an affordable size pack. However, further research needs to be conducted on other fish species and their value-added products with different gas mixtures to get sufficient shelf life, which eventually increases the value, price, and convenience of fish and fishery products.

Conflict of interest

There is no conflict of interest to declare.

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