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Quality Characteristics of Cuttlefish (*Sepia officinalis*) Treated with Different Additives During Iced Storage

A. Jeyakumari, L. Narasimha Murthy and S. J. Laly
ICAR-Central Institute of Fisheries Technology, Cochin - 682 029

Abstract

Cuttlefish is considered as one of the most important seafood items, which is rich in essential nutrients. Different additives and salt are widely used during chilling to improve the texture and quality of cuttlefish. In the present study, cuttlefish (*Sepia officinalis*) was treated with a commercially used additive (CA), and its quality was compared with trisodium phosphate (TSP) (2.5 % & 5 %) treated samples. Fresh cuttlefish before treatment had 83.02 % moisture, 13.89 % protein, 1.2 % fat and 2.3 % ash. TVB-N value showed an increasing trend in all the samples during storage with the highest increase in control (1.4-9.2 mg 100 g^{-1}). The *L** values showed a decreasing trend in control and TSP-treated samples. The *a** values of control and CA samples didn't follow any trend during iced storage. Moreover, *a** value showed a decreasing trend in the TSP sample up to the 7^{th} day and thereafter didn't follow any trend. The *b** value was found to increase in TSP-treated samples. However, the CA and control samples did not follow any trend for *b** values during iced storage. Texture analysis revealed that the hardness value showed a decreasing trend in cuttlefish during iced storage. The aerobic plate count (APC) in the 5 % TSP sample reached 6.98 log cfu g^{-1} on the 14^{th} day. However, the APC of the control crossed acceptability limit and reached a value of 7.2 log cfu g^{-1} on the 12^{th} day. A similar trend was also observed for the psychrophilic count during storage. Moreover, a significant reduction in H_2S forming bacteria was observed in TSP treated sample. Based on the aerobic plate count and psychrophilic count, the cuttlefish treated with CA and TSP 2.5 % had a shelf life of up to 14 days. Control samples had a shelf life of only 12 days and TSP 5 % treatment extended the shelf life of cuttlefish to more than 14 days. The present study revealed that 5 % TSP supresses microbial activity and extends the shelf life of cuttlefish under ice storage.

Keywords: Cuttlefish, additives, iced storage, quality, shelf life

Introduction

Cuttlefish is one of the most important seafood export items among the cephalopods. It is rich in essential nutrients and is considered as a highly favoured seafood delicacy in European and Asian markets. Cuttlefish is exported mainly in frozen blocks or as IQF products to countries like Japan, the USA, Spain, Italy, etc. Frozen cuttlefish exports contributed 16.38 % of the total exports for the year 2020-2021 in India (MPEDA, 2021). Freshness is the most important attribute, which influences the quality and consumer acceptance of seafood. Cuttlefish are prone to spoilage due to biochemical and microbial activities. Hence, the cuttlefishes are to be kept under chilled conditions (0 °C– 4 °C) or frozen till it reaches the consumer. The yellow discolouration of the mantle is another important problem in frozen cephalopods and it has led to the rejection of cuttlefish by the importing countries. Different additives and salt are widely used during chilling to improve the texture and quality of cuttlefish. But very few studies have been focused on the quality of cephalopods stored under ice storage treated with or without commercial additives (Ganesan et al. 2005; Dhananjaya, 2006; Sungsri-in et al., 2011; Manimaran et al., 2016; Sengor et al., 2018). Moreover, additives used for treating the cephalopods in the seafood Industry are mostly imported and it normally consists of phosphate, citric acid, potassium carbonate, etc. Polyphosphates are commonly used as additives in fish and shellfish processing for moisture retention, improving colour and texture and delaying oxida-

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*Email: jeya131@gmail.com

tive spoilage. It is one of the food additives approved by the European Union and the Joint FAO/WHO expert committee. The phosphates used in foods can be phosphates, diphosphates (two phosphate units), tripolyphosphates (three units), or polyphosphates (more than three) (FAO, 2006). Phosphates (diphosphates, tripolyphosphates, or polyphosphates) are used in foods as additives and are reported to have antimicrobial effects. Trisodium phosphate has a superior antimicrobial effect compared to other phosphates (Lorencova et al., 2012). Generally, cuttlefish is subjected to chilled conditions with or without additives prior to freezing. As per the buyer's requirements, imported additives are used for improving the quality of cuttlefish before freezing by the seafood processor. However, there is a lack of information on the biochemical and microbial quality of cuttlefish treated with imported additives. Hence, the present study was conducted to evaluate the effect of a commercially used additive on the quality of cuttlefish and to compare its quality with cuttlefish treated with trisodium phosphate.

Materials and Methods

Fresh whole cleaned cuttlefish were procured from VKM Foods Pvt. Ltd. at Vashi, Navi Mumbai, and brought to the laboratory in iced condition. Then the samples were divided into four lots. The first lot was treated with commercially used additives namely PEARL C580A and PEARL LQ54. A solution that contains 1.2 % of PEARL C580A and 1.6 % of PEARL LQ54 along with 2 % salt and was used for treating the cuttlefish (as per the seafood industry practice) and named as CA. The second lot was treated with 2.5 % TSP and 2 % salt, the third lot was treated with 5 % TSP and 2 % salt and the fourth lot was treated with only 2 % salt. Since all other treatments had 2 % salt (as per industry practice) in their composition, the fourth lot treated with 2 % salt was kept as control. All the samples were kept under chilled condition (2 °C) for 18 h (duration of treatment was followed as per industry practice). After 18 h treatment, all the samples were kept in ice and quality analysis was carried out for up to 14 days.

The proximate composition was analyzed as per the AOAC (2019). Total volatile base nitrogen (TVB-N) values were evaluated by the method followed by Conway (1950). Peroxide value (PV) and nonprotein nitrogen (NPN) were evaluated as per AOAC (2019) method. Alpha-amino nitrogen (AAN) content of the sample was determined by the method of Pope & Stevens (1939). The sensory evaluation of cuttlefish was done by a trained panel. The panel members were asked to evaluate of the treated cuttlefish samples for their appearance, colour, texture, flavour and overall acceptability. A score between 7.0 and 9.0 indicated, "extremely liked," scores between 5 and 7 indicated "liked" and a score below 5 was kept as the limit of acceptability (Ganesan et al., 2005). Colour [L^* (lightness), a^* (redness), b^* (yellowness)] analysis of cuttlefish was carried out using a hunter–Lab scan colourimeter (Hunter Associates Laboratory, Reston, USA). Textural Profile Analysis (TPA) was performed by a texture analyzer (Lloyd Instruments, TA plus, UK). Nexygen software was used for the tabulation of texture parameters.

The microbial quality parameters analyzed included Total plate count (FAO, 1992), psychrophilic bacterial count (FAO, 1992) and Hydrogen sulphide (H_2S) producing bacteria (Jeyakumari et al., 2020). The statistical analyses were carried out at a significance level of 5 % by using SPSS software (version 16.0).

Results and Discussion

The proximate composition of fresh cuttlefish before treatment showed 83.02 % moisture, 13.89 % protein, 1.2 % fat and 2.3 % ash. Sengor et al. (2018) observed 75.88 % moisture content in fresh cuttlefish. It has been reported that the proximate composition of seafood is influenced by various factors including season, age, sex and environmental conditions (Albrecht-Ruiz et al., 2017; Rasul et al., 2021). Changes in the biochemical quality of cuttlefish during iced storage are given in Table 1. During iced storage, the moisture content of the samples ranged from 87.97 % to 92.69 %. Sengor et al. (2018) observed an increasing trend in the moisture content of cuttlefish on 9th and 10th day of storage at 2 °C. In the present study, control and TSP 5 % samples followed a similar trend. However, TSP 2.5 % and CA did not follow any trend during iced storage. pH measurement indicates the freshness of the seafood. Fresh cuttlefish had a pH of 6.74 (data not shown). There was a significant difference ($P<0.05$) in the pH values between the control (6.74) and TSP samples (8.8 for TSP 2.5 % & 10.25 for TSP 5 %) on the 0th day. In the present study, CA samples had a pH ranging from 7.1-7.5 during iced storage. The higher pH in TSP samples might be due to the alkaline properties of TSP. A similar result was observed by earlier researchers for a phosphate-treated fish fillet (Etemadian et al., 2013). Sungsri-in et al. (2011) observed an increasing trend for the pH of squid stored under ice and reported that an increase in pH during storage might be due to the production of volatile basic compounds by microbial activity. However, in the present study, pH did not follow any trend during iced storage. TVB-N showed a gradual increase in cuttlefish during iced storage (Table 1). TSP samples had lower TVB-N values (TSP 2.5 %: 7.0 mg 100 g^{-1}; TSP 5 %:6.8 mg 100 g^{-1}) than control (8.5 mg 100 g^{-1}) and CA samples (9.2 mg 100 g^{-1}) on 14th day. It has been reported that TVB-N content less than 30 mg 100 g^{-1} is considered as grade A, 30-45 mg 100 g^{-1} for grade B and higher than 45 mg 100 g^{-1} is considered unacceptable for cuttlefish (Ke et al., 1984). Accordingly, none of the samples crossed the acceptable limit of TVB-N during iced storage even after reject on by the sensory panel. Ganesan et al. (2005) reported that cuttlefish fillets stored in the ice had an acceptable level of TVB-N up to the 19th day. Manimaran et al. (2016) observed a TVB-N value of below 20 mg 100 g^{-1} at the time of rejection of octopus stored under the ice. Alpha-amino nitrogen showed a decreasing trend during storage. The decrease in Alpha-amino nitrogen might have occurred due to the depletion of free amino acids by microbial activity (Manimaran et al., 2016). The highest alpha amino nitrogen content was observed in CA (16.55 mg %) samples on the 14th day. Control had lower alpha amino nitrogen content (9.52 mg %) than TSP samples (TSP 2.5 %:12.40 mg %; TSP 5%:11.76 mg %) on the 14th day of iced storage. NPN compounds content showed a decreasing trend during iced storage. The highest values for NPN compounds were observed in TSP 2.5 % samples (90.2-161.5 mg %) followed by CA (85-147 mg %), control (52.5-138.5 mg %,) and TSP 5 % (71.4-123.5 mg %). There are previous reports on the decrease in NPN content during iced storage for squid,

Table 1. Changes in the biochemical quality of cuttlefish during iced storage

Samples/Days	0	3	5	7	9	12	14
Moisture							
CA	88.76 ± 0.10	88.22 ± 0.15	86.98 ± 0.05	87.22 ± 0.25	86.92 ± 0.10	87.28 ± 0.22	87.28 ± 0.22
TSP 2.5 %	89.32 ± 0.25	88.2 ± 0.20	90.08 ± 0.10	91.05 ± 0.10	89.49 ± 0.30	88.75 ± 0.15	90.8 ± 0.30
TSP 5 %	90.2 ± 0.20	91.17 ± 0.10	91.28 ± 0.25	91.39 ± 0.30	91.44 ± 0.25	91.85 ± 0.18	92.69 ± 0.45
Control	87.97 ± 0.15	88.03 ± 0.30	89.99 ± 0.22	89.15 ± 0.28	90.63 ± 0.15	91.72 ± 0.25	91.72 ± 0.30
TVB-N (mg 100 g^{-1})							
CA	1.4 ± 0.15	2.8 ± 0.05	5.6 ± 0.20	6.4 ± 0.02	7.5 ± 0.02	8.4 ± 0.02	9.2 ± 0.04
TSP 2.5 %	1.4 ± 0.05	1.4 ± 0.08	2.8 ± 0.15	2.8 ± 0.08	4.5 ± 0.12	5.8 ± 0.20	7 ± 0.12
TSP 5 %	1.4 ± 0.08	1.4 ± 0.10	1.4 ± 0.05	2.8 ± 0.08	4.2 ± 0.05	4.8 ± 0.08	6.8 ± 0.05
Control	1.4 ± 0.10	1.4 ± 0.10	4.2 ± 0.05	4.2 ± 0.10	5.2 ± 0.08	6.5 ± 0.08	8.5 ± 0.10
AAN (mg %)							
CA	34.44 ± 1.5	29.4 ± 1.2	28 ± 0.88	24.08 ± 1.5	19.6 ± 0.75	19.6 ± 0.80	16.55 ± 0.80
TSP 2.5 %	28.56 ± 0.55	26.88 ± 0.60	23.52 ± 0.65	17.36 ± 0.80	16.8 ± 0.55	15.12 ± 0.60	12.40 ± 0.80
TSP 5 %	24.5 ± 0.65	19.84 ± 0.55	14.6 ± 1.25	12.2 ± 0.66	12.32 ± 1.2	11.76 ± 0.12	11.76 ± 0.65
Control	24.08 ± 1.2	15.6 ± 1.5	12.72 ± 1.2	10.96 ± 0.55	10.52 ± 0.80	10.52 ± 0.20	9.52 ± 0.20
NPN (mg %)							
CA	147 ± 1.2	139 ± 0.80	129.5 ± 0.80	107.1 ± 0.90	99.4 ± 1.2	90.3 ± 0.90	85 ± 1.50
TSP 2.5 %	161.5 ± 0.80	136.5 ± 0.65	130.2 ± 0.95	127.4 ± 0.65	108.5 ± 0.80	95.2 ± 0.95	90.2 ± 0.80
TSP 5 %	123.5 ± 1.5	107.1 ± 1.2	106.4 ± 1.5	94.5 ± 1.20	83.3 ± 0.95	76.3 ± 0.80	71.4 ± 0.65
Control	138.5 ± 0.68	124.2 ± 1.5	112.1 ± 1.2	79.1 ± 0.90	72.1 ± 1.5	70.7 ± 1.2	52.5 ± 0.55

Mean ± SD (n-3); CA- Treated with commercial additive; TSP- 2.5 %- Treated with 2.5 % trisodium phosphate; TSP- 5.0 %- Treated with 5.0 % trisodium phosphate; Control– Without any additives cuttlefish and octopus. It was reported that it might be due to the utilization of the NPN compounds by pseudomonas bacteria under iced condition (Joseph & Sherief, 2003; Manimaran et al., 2016). In the current work, peroxide values were found to be nil up to 3rd day in all samples and thereafter there was a gradual increase in PV during iced storage (Data not shown). Control had a higher peroxide value (3.3-18.5 milleq. O_2 kg^{-1} of meat) than others (TSP 2.5 %: 2.6-12.5 milleq.O_2 kg^{-1} of meat; TSP 5 %: 3.7-16.8 milleq. O_2 kg^{-1} of meat; CA: 1.12 – 9.5 milleq. O_2 kg^{-1} of meat). However, all the samples had an acceptable limit (less than 20 milleq. O_2kg^{-1} of meat) of peroxide value during iced storage.

Table 2. Changes in the colour (*L**, *a** and *b** values) and texture of cuttlefish during iced storage

Samples/Days	0	3	5	7	9	12	14
*L**							
CA	69.94 ± 0.30	70.73 ± 0.35	71.20 ± 0.22	71.41 ± 0.55	71.53 ± 0.44	71.55 ± 0.75	74.11 ± 0.40
TSP 2.5 %	70.73 ± 0.20	68.87 ± 0.55	67.58 ± 0.15	64.83 ± 0.38	64.14 ± 0.15	64.09 ± 0.80	63.55 ± 0.25
TSP 5 %	68.66 ± 0.40	66.05 ± 0.20	66.05 ± 0.20	61.76 ± 0.30	60.8 ± 0.35	60.80 ± 0.55	59.22 ± 0.40
Control	70.87 ± 0.15	67.17 ± 0.55	64.91 ± 0.60	63.81 ± 0.40	61.86 ± 0.60	59.40 ± 0.15	59.40 ± 0.20
*a**							
CA	2.54 ± 0.05	3.21 ± 0.02	1.01 ± 0.05	3.14 ± 0.15	1.52 ± 0.06	2.27 ± 0.25	2.09 ± 0.10
TSP 2.5 %	4.28 ± 0.08	3.48 ± 0.05	3.22 ± 0.08	2.38 ± 0.20	2.45 ± 0.55	2.0 ± 0.30	2.09 ± 0.15
TSP 5 %	5.13 ± 0.10	4.39 ± 0.15	4.29 ± 0.10	2.6 ± 0.08	2.16 ± 0.40	2.2 ± 0.25	2.60.7 ± 0.20
Control	0.72 ± 0.04	0.73 ± 0.05	0.67 ± 0.05	1.54 ± 0.05	1.62 ± 0.10	0.59 ± 0.35	2.0 ± 0.25
*b**							
CA	1.82 ± 0.05	1.49 ± 0.02	1.39 ± 0.05	0.80 ± 0.01	0.95 ± 0.04	0.55 ± 0.10	3.2 ± 0.05
TSP 2.5 %	1.55 ± 0.02	1.86 ± 0.04	2.12 ± 0.03	2.39 ± 0.02	2.5 ± 0.02	2.5 ± 0.08	3.2 ± 0.02
TSP 5 %	1.65 ± 0.04	1.85 ± 0.05	2.2 ± 0.02	3.2 ± 0.05	3.8 ± 0.08	4.2 ± 0.06	4.5 ± 0.06
Control	1.90 ± 0.02	1.98 ± 0.03	1.7 ± 0.04	2.76 ± 0.02	1.47 ± 0.10	2.73 ± 0.02	4.5 ± 0.04
Hardness (N)							
CA	29.44 ± 1.25	28.5 ± 0.45	24.27 ± 0.55	22.42 ± 0.25	19.80 ± 0.65	18.5 ± 0.15	16.25 ± 0.20
TSP 2.5 %	27.44 ± 0.60	26.47 ± 0.80	25.87 ± 0.68	20.65 ± 0.30	18.60 ± 0.40	15.81 ± 0.25	15.80 ± 0.08
TSP 5 %	26.47 ± 0.20	25.6 ± 0.25	22.3 ± 0.50	19.6 ± 0.40	15.97 ± 0.25	10.73 ± 0.40	10.65 ± 0.25
Control	25.65 ± 0.80	22.65 ± 0.45	18.20 ± 0.55	17.62 ± 0.25	15.65 ± 0.55	15.15 ± 0.55	14.80 ± 0.15
Springiness (mm)							
CA	0.9 ± 0.01	0.9 ± 0.02	0.89 ± 0.01	0.96 ± 0.02	0.90 ± 0.01	0.99 ± 0.03	0.90 ± 0.01
TSP 2.5 %	0.9 ± 0.01	0.9 ± 0.01	0.85 ± 0.03	0.98 ± 0.03	0.52 ± 0.03	0.77 ± 0.02	0.77 ± 0.02
TSP 5 %	0.9 ± 0.00	0.9 ± 0.00	0.88 ± 0.02	0.88 ± 0.01	0.85 ± 0.02	0.64 ± 0.01	0.64 ± 0.01
Control	0.95 ± 0.02	0.90 ± 0.01	0.45 ± 0.01	0.58 ± 0.01	0.26 ± 0.01	0.75 ± 0.02	0.75 ± 0.02
Chewiness (kgf.mm)							
CA	13.8 ± 0.40	12.5 ± 0.66	12.5 ± 0.60	11 ± 0.55	8.61 ± 0.80	7.8 ± 0.20	5.03 ± 0.40
TSP 2.5 %	12.8 ± 0.60	12.4 ± 0.55	11 ± 0.55	9.5 ± 0.40	8.2 ± 0.70	7.27 ± 0.35	6.72 ± 0.55
TSP 5 %	10.3 ± 0.25	9.5 ± 0.45	8.5 ± 0.20	7.8 ± 0.55	6.5 ± 0.65	5.24 ± 0.44	5.03 ± 0.25
Control	13 ± 0.40	10.9 ± 0.25	10.9 ± 0.30	8.5 ± 0.60	7.6 ± 0.55	5.8 ± 0.65	5.03 ± 0.30

Mean ± SD (n-3); CA- Treated with commercial additive; TSP- 2.5 %- Treated with 2.5 % trisodium phosphate; TSP- 5.0 %- Treated with 5.0 % trisodium phosphate; Control– Without any additives

In the present study, L^* values showed a decreasing trend in control and TSP-treated samples. Tantasuttikul et al. (2011) and Sengor et al. (2018) observed similar results for cuttlefish stored under 2 ºC and reported that a decrease in L^* value during iced storage was a sign of quality deterioration. Moreover, CA samples showed an increasing trend in L^* value during iced storage. Kumar et al. (2015) observed improved color and textural quality for squid treated with imported commercial additives. a^* value of control and CA samples did not follow any trend during iced storage. Moreover, a^* value showed decreasing trend in the TSP sample up to the 7th day and thereafter did not follow any trend. b^* value was found to increase in TSP treated sample. However, the control and CA sample did not follow any trend in b^* values during iced storage (Table 2). Hardness and chewiness showed a gradual decrease during storage. Results indicated that the TSP 5 % sample had lower hardness than TSP 2.5 % (Table 2). It may be due to a higher concentration (5 %) of TSP weakening the textural properties of cuttlefish. Springiness values did not follow any trend during iced storage.

Sensory evaluation revealed that cuttlefish had a very bright, fresh sea odour and firm texture on the 0th day. Overall acceptability showed a decreasing trend in all samples from the 5th day onwards (Fig. 1). Vaz-Pires et al. (2008); Ganesan et al. (2005) observed an unpleasant odour on the 8th day for cuttlefish stored under iced conditions. Sengor et al. (2018) observed a 6-day shelf life for the whole cuttlefish stored under 2 ºC. In the present study, all the samples had an acceptable sensory score ranging between 5.5-6.8 on the 9th day. On the 12th day, the control and CA samples had an off odour, which reduced their acceptability. However, the APC count was within the limit for the CA sample. In the case of both the TSP samples, the sensory scores were within the acceptable limit on the 12th day.

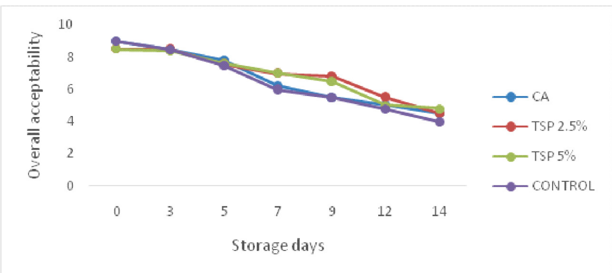

Fig. 1. Changes in the overall acceptability of cuttlefish during iced storage

The level of aerobic plate count (APC) gives an indication of the quality as well as the shelf life of seafood. The initial APC of cuttlefish was 3.5 log cfug^{-1} and increased to 6.2 log cfug^{-1} on the 9th day and crossed the acceptable limit on the 12th day (7.2 log cfug^{-1}) for control (Fig. 2). In the case of CA and 2.5 % TSP samples, APC reached 6.99 log cfug^{-1} and 6.89 log cfug^{-1}, respectively on the 12th day and crossed the acceptable limit on the 14th day (CA: 7.65 log cfug^{-1}; TSP 2.5 %: 7.25 log cfug^{-1}). However, APC of the TSP 5 % treated sample was within the acceptability limit up to the 14th day (6.98 log cfug^{-1}) indicating the antimicrobial effect of TSP (Smyth et al., 2018). Tantasuttikul et al. (2011) observed squid and cuttlefish stored under the ice without any additive treatment reached the rejection limit of APC after the 12th day. Similar results were observed by Ganesan et al. (2005) for cuttlefish stored under the ice. Kumar et al. (2015) observed a lower aerobic plate count for cuttlefish treated with commercial additives.

The psychrophilic bacterial count showed a gradual increase in cuttlefish during iced storage. Sengor et al. (2018) reported the rejection limit of psychrophiles on the 9th day for cuttlefish stored at 4°C. In the present study, the count of psychrophiles crossed the rejection limit of 7 log cfug^{-1} on the 12th day for control (Fig. 3). In the case of CA and TSP 2.5 %, the psychrophilic count crossed the rejection limit with values of 7.2 log cfug^{-1} and 7.5 log cfug^{-1} on the 14 day (Fig. 3). TSP 5 % had a psychrophilic

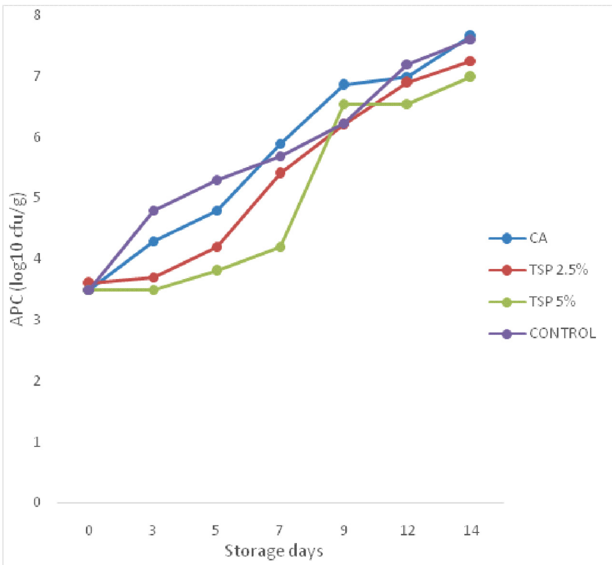

Fig. 2. Changes in the APC of cuttlefish during iced storage

count of 6.9 log cfug^{-1} on 14th day. The spoilage of seafood, when stored in ice, is mainly caused by psychrophilic bacteria, which easily grow and multiply at low temperatures. Most of the previous researchers studied only the changes in aerobic plate count in cephalopods under iced storage and reported that APC could serve as a good indicator for spoilage (Ganesan et al., 2005; Vaz-Pires et al., 2008; Kumar et al., 2015). In the present study, APC and psychrophilic count were checked and the counts of both showed an increase in cuttlefish during iced storage. Sengor et al. (2018) also observed similar results for cuttlefish stored under the ice.

H_2S forming bacteria is one of the most important microbial quality indices in cephalopods (Vaz-Pires et al., 2008). H_2S formers showed an increasing trend during iced storage. However, it was observed that there was a significant ($P<0.05$) reduction in H_2S producing bacterial count in the TSP sample than other (Fig. 4). H_2S forming bacterial count was absent in TSP 5 % up to the 9th day and reached 5.5 log cfug^{-1} on the 14th day.

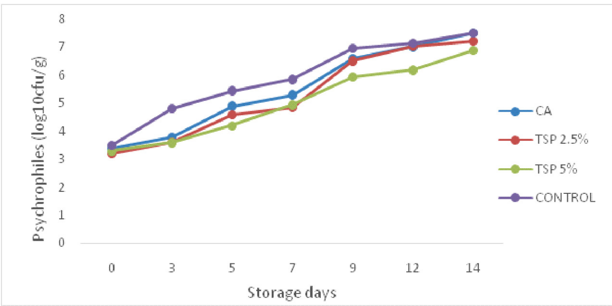

Fig. 3. Changes in the Psychrophilic count of cuttlefish during iced storage

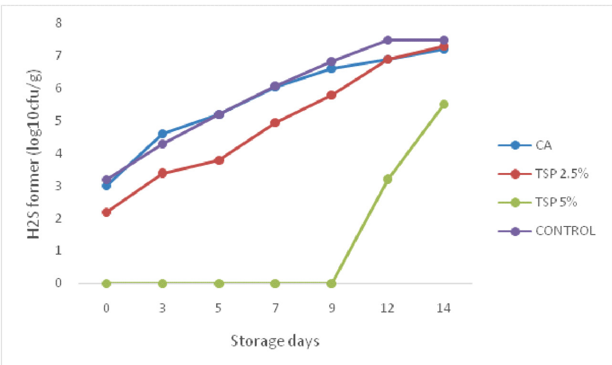

Fig. 4. Changes in the H_2S forming bacterial count of cuttlefish during iced storage

The results from the study indicated that the commercial additive used in the present work increased the hardness/tenderness compared to the control. Among the biochemical indices, alpha-amino nitrogen, and NPN content well correlated with the sensory scores. Based on the aerobic plate count and psychrophilic count, the cuttlefish treated with CA and TSP 2.5 % had a shelf life of up to 14 days. Control samples had a shelf life of only 12 days and TSP 5 % treatment extended the shelf life of cuttlefish to more than 14 days. Results indicated that TSP could prolong the shelf life of cuttlefish under ice storage. However, it could not improve the texture and color as compared to the imported commercial additive used in the study.

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