DEVELOPMENT OF A SMOKED TUNA (*Thunnus albacares*) WITH MANGO FLAVORINGS AND CINNAMON WOOD AS SMOKING AGENT

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Abstract

Among the preservation methods used, smoking is a good method for yellowfin tuna (Thunnus albacares). The objective was to identify the most suitable fruit flavoring to be incorporated with cinnamon wood smoking under different storage conditions (4 and -20 °C). Sensory analysis was carried out with 30 untrained panelists using a 7-point hedonic scale to determine the best fruit flavoring. Accordingly, cinnamon wood smoked, mango flavored tuna produced with 1.0% (w/w) salt and 1.5% (w/w) white pepper levels recorded as the best in all organoleptic properties checked (p<0.05). The final smoked tuna was vacuum packed and stored under chilled and frozen conditions for further analysis. The presence or absence of E. coli and Salmonella was examined at the date of production, and total plate count, lipid oxidation, pH, colour and texture were detected up to 42 days. Moisture and fat contents were reduced, while protein levels increased (p<0.05). E. coli and Salmonella were absent in the final product and pH, and lipid oxidation was within the acceptable limits up to 14 days under both storage conditions. The hardness, chewiness and gumminess changed with storage time. In conclusion, cinnamon wood smoked, mango flavored tuna produced can be selected as the most suitable fruit flavoring..

Keywords:_Smoked yellowfin tuna; Vacuum packaging; Cinnamon; Mango_

INTRODUCTION

Humans consume fish in a variety of ways by making different dishes because of their nutritive value and the characteristic flavor compounds present (Balami et al., 2019). Fish are prominent among highly nutritious foods, which are comprised of proteins and essential amino acids (Karunarathna & Attygalle, 2010; Lelwela et al., 2021), fatty acids, minerals and vitamins (Karunarathna & Attygalle, 2010; Peng et al., 2013). The tuna fish industry comprises six principal market species, and yellowfin tuna (*Thunnus albacares*) is one of the prominent species. Karunarathna & Attyalle (2019) reported that the moisture, protein, lipid and ash contents of yellowfin tuna white muscle were 72.44%, 21.42%, 0.88% and 1.12%, respectively. Yellowfin tuna is considered a good source of amino acids and fatty acids. Tuna muscles are rich in docosahexaenoic acid (DHA) (16.91%) and eicosapentanoic acid (EPA) (2.39%). DHA and EPA health beneficial fatty acids, especially for cardiovascular diseases. The n-3/n-6 ratio can be used as an indicator for comparing the relative nutritive values of different fish oils (Peng et al., 2013). Due to their high nutritional content and moisture content, fish are considered highly perishable (Ojutiku et al., 2009). Therefore, preservation is important to reduce the deterioration of food, and such food can be preserved by many processes, such as salting, sun drying, freezing, canning and smoking (Shajil et al., 2018).

Smoking is an ancient method of preservation of fish (Adeyeye, 2019). Currently, smoking of fish is used to impart organoleptic characteristics of fish while extending the shelf life (Arvanitoyannis & Kotsanopoulos, 2012). Smoke is a typical aerosol of pyrolysis of wood materials with solid and liquid particles dispersed in a gaseous medium (Adeyeye, 2019). Wood smoke consists of alcohols, aldehydes, ketones, esters, furans, phenols and acids (Toldrá, 2017). The smoking procedure inhibits the growth of many microorganisms and limits oxidative reactions (Muratore et al., 2007). The fish smoking process comprised of two main types, cold smoking and hot smoking, and the main difference between these two types is the temperature used for smoking. During cold smoking,the nutritive quality of the final product will be preserved since the core temperature reaches 33 °C, but the final product will not be protected against harmful microorganisms, whereas in hot smoking (70–80 °C),the shelf life of the product will be increased, but the nutritive quality will be diminished (Arvanitoyannis & Kotsanopoulos, 2012).

In many countries, there is a significant potential to increase the per capita consumption of fish and fish products (Amarasinghe, 2014). This will lead to enhancing the nutritional status of people and enhancing the profits of the fisheries industry. Value addition increases the usability and culinary attributes of food products. Smoking is a cost-beneficial method of value addition to fish, and it will increase the per capita fish consumption due to its unique taste (Lofstedt et al., 2021). However, among Sri Lankans, the preference for smoked fish products is very low (Jinadasa et al., 2020). Viji et al., (2017) shows importance of production of pineapple and orange flavored smoked *Catlacatla.* The development of new value-added smoked products with different flavors will be benefitted to have a variety of smoked products in the market. Therefore, the objective of this research was to develop ready-to-eat, fruit-flavored smoked tuna fish product using *Cinnamomum zeylanicum* and *Swietenia macrophylla* wood chunks as smoking agents along with suitable fruit flavorings.

MATERIALS AND METHODS

Sample collection and product development

Equal-sized loin cuts of yellowfin tuna (*Thunnus albacares*) were received from a commercial tuna processing factory located in Ja-Ela, Sri Lanka, and transported to the laboratory in sealed polystyrene form boxes containing ice. White pepper *(Piper nigrum)* powder, salt and fruits were purchased from a local market. Cinnamon (*Cinnamomum zeylanicum*) wood was collected from a cinnamon processing station in Galle, Sri Lanka. Smoked tuna were prepared by marinating with 1% (w/w) salt, 1.5% (w/w) white pepper and smoked at93.33 °C (200 °F) for 100 minutes. Mango juice was identified as best fruit flavor according to preliminary trails. Smoked tuna with mango juice showed higher acceptance among tomato juice and orange juice. Well ripened pealed ‘petti amba’ (*Mangifera indica* L) cut in to blender jar (Panasonic MX GM-1011) blended with fresh water (1:1). Then the separated, freshly prepared mango juice was introduced to the liquid tray of the smoker (MASTERBUILT Bluetooth digital electronic smoker, Model no. MB 20076419), and water was introduced to the liquid tray of the smoker to produce the control. Moisture content, crude protein content, crude fat content and ash content were determined according to AOAC, 2016. After product development, samples of the final product were stored under two different storage conditions: chilled (4 °C) and frozen (-20 °C) for further analysis until 42 days. Moisture content, crude protein content, crude fat content and ash content were determined according to AOAC, 2016.

Recipe development

The best salt level, white pepper level and best fruit flavor were identified by conducting sensory evaluation programs with 30 untrained panelists in the age group 23 – 25 years representing both sexes. For the identification of best fruit, flavor three samples were smoked with mango juice, orange juice and tomato juice accordingly.

Keeping quality analysis of the smoked tuna fish

Determination of pH

The pH value was determined according to the method of Goulas&Kontominas (2005). A 10 g sample of the product was homogenized in 100 ml of distilled water, and the pH of the slurry was measured using a digital pH meter (PL-700PV, Gemmy Industrial Corp., Taiwan) at ambient temperature. Measurements of pH were made in triplicate for both 4 °C and -20 °C storage conditions.

Lipid Oxidation

Lipid oxidation of smoked fish samples was measured during chilled and frozen storage using a 2-thiobarbituric acid reactive substances assay, as described by Stalikas&Konidari (2001) with minor modifications. The sample (3 g) was mixed with 9 mL of 1 N NaOH and 100 µl of 7.2% butylated hydroxyl toluene. Then, the samples were allowed to hydrolyze in a shaking water bath (CW3-10, JEIO TECH, Korea) at 60 °C for 1 hour. The hydrolysate was filtered after mixing with 6 mL of 40% trichloroacetic acid (TCA) by vortexing for 30 seconds. The filtrate (1 mL) was mixed with 6 mL of 20 mM 2-thiobutric acid, and the mixture was kept in a boiling water bath at 90 °C for 40 minutes and cooled. Then, the samples were centrifuged (Thermo Scientific™ Sorvall™ ST 16) at 2090 x g for 15 minutes. The absorbance of the supernatant was measured at 532 nm with a spectrophotometer (UV-2005, Selecta, Abrera, Spain). The amount of malonaldehyde was calculated using the standard curve prepared from 1,1,3,3-tetraethoxy propane.The TBARS value was reported as mg monoaldehyde (MDA) per kg of fish.

Microbial analysis

The presence or absence of *E. coli* and *Salmonella* was identified at the initial date of production. Then, at 7, 14, 28 and 42 days, the total aerobic bacteria were measured. All microbial analyses were carried out according to AOAC (2016) using triplicates.

Analysis of Physical Properties

Color of the smoked fish (L*, a*, b* Values)

The outer coat of the smoked tuna loin was removed, and a uniform surface was selected to measure the color. The intensity of the internal color of the product was determined as L* (lightness), a* (redness), and b* (yellowness) values by using a colorimeter (Spectrophotometer CM-3500d, Konica Minolta Sensing, Inc., Japan).Measurements were made in triplicate for both storage conditions throughout the storage period of 1 day, 7 days, 14 days, 28 days and 42 days.

Texture

The texture profile of the smoked tuna fish was measured with a sample (20x20x30 mm) using a load cell of 500 N (Model TA-XT 2i, Stable Micro System Ltd., UK). The samples were compressed by 80% at a compression speed of 5.0 mm/s.

Statistical analysis

Statistical analysis was conducted using the Minitab 19 software package. The nonparametric Freidman test was used to analyze the subjective quality measures and determine the median values of sensory evaluations. Data related to physical, chemical and microbial analyses were analyzed using one-way ANOVA. The level of statistical significance was taken as 0.05.

RESULTS AND DISCUSSION

The best salt and white paper levels weredetermined by conducting several preliminary trials.Accordingly, there was no significant difference among all checked parameters, such as taste, aroma, colour, appearance and overall acceptability ($p > 0.05$). Therefore, 1% (w/w) salt and 1.5 (w/w) white paper powder levels were identified as the best. Sodium chloride has been identified as a good in-activator of autolytic enzymes and reduces lipid oxidation in marine species (Ghaly et al., 2010; Guizani et al., 2014; Lelwela et al., 2021).However, in some research findings shows that sodium chloride induces lipid oxidation of raw chicken meat and beef (Gheisari et al., 2010). Sodium chloride also control microorganismes as *Listeria monocytogenes* (Hosseini et al., 2021) as well. Therefore, adding salt can extend the shelf life with increasing the taste. Pepper (*Piper nigrum*) is identified as an important part of the human diet, and it enhances the sensory attributes of colour, pungency and flavour(Sanatombi & Rajkumari, 2020). Past studies revealed that the seeds of *P. nigrum* consist of flavonoids, alkaloids, tannins and saponins like phytochemicals. These phytochemicals can inhibit the growth of *Escherichia coli* and *Staphylococcus aureus* in food products (Kalunta, 2017).

For the determination of the best fruit flavor for “hot smoked tuna”, 1% (w/w) salt and 1.5% (w/w) pepper treated samples were smoked at 93.3°C for 100 minutes without any liquid (dry), with water, orange juice, mango juice and tomato juice separately. The smoked samples were presented to the sensory panel to select the best. High acceptance was recorded in mango treated sample accordance with parameters such as appearance, colour, aroma, texture, juiciness, taste and overall acceptability ($p < 0.05$) (Figure 1). When considering the Sri Lankan situation, 185,335 metric tons of mango were produced in 2021 (Industry Capability Report, 2022), and high fiber content mango has low market demand. However, these fruits contain polyphenols, flavonoids, carotenoids and ascorbic acid, which have different beneficial properties because of their antioxidant activities (Muralidhara et al., 2019). Therefore, there is a new potential to use mango for new product development.

Comparison of proximate composition of raw and smoked tuna

The moisture content, crude protein and crude fat content of mango flavored smoked tuna were 63.77 ± 1.11, 26.89 ± 0.69 and 3.77 ± 0.09%, respectively, while in raw fish,they were 74.38 ± 0.72, 20.82 ± 0.42 and 1.19 ± 0.06%, respectively. Significant differences were observed in the proximate composition of raw and smoked tuna loins ($p < 0.05$). The reduction in the moisture content of the smoked product is due to the removal of free water during the smoking process. The crude protein level and crude fat level were elevated because of weight loss due to the reduction in moisture content. Past research reported that the moisture, protein and fat contents of tuna fish were 70.83, 20.22 and 1.01%, respectively (Karunarathna & Attygalle, 2019). Variations in these values are due to factors such as the season of the catch, environment and feed. The industrial specification for the moisture content of smoked final fish products generally recommends a water content less than 65% (Cardinal et al., 2001), and the moisture content of the final smoked tuna was within the acceptable range. These values are in complete agreement with those of who reported that the mean moisture content of smoked mackerel was 56.7% (Kolodziejska et al., 2002).

Physical property analysis of smoked tuna

Determination of color during storage conditions

Table 1 shows the changes in lightness (L*), redness (a*) and yellowness (b*) of tuna smoked with water and tuna smoked with mango juice stored in chill and frozen storage. With the storage of fish fillets under frozen conditions (-20 °C), lightness (L*) decreased, while redness (a*) and yellowness (b*) increased (Sriket& La-ongnual, 2018). In a trial performed with hot smoked Atlantic mackerel (*Scomberscombrus*), all color parameters decreased after 6 weeks of refrigerated vacuum storage, leading to darker and less red and yellow color. The present study showed an increasing pattern of yellowness in both treatments stored at chill and frozen storage. This may be due to the reaction between a mixture of phenolic compounds such as quaiacylpropane and syringylpropane present in wood smoke and proteins such as myoglobin present in fish muscle (Huda et al., 2010). These results comply with the reports, but lightness and yellowness values show a constant pattern during storage due to inhibited oxidation of muscle myoglobin (Gutiérrez Guzmán et al., 2015;Adeyeye et al., 2017).

Texture profile analysis of the smoked product

Texture is an important sensory characteristic that determines the quality or acceptability of fisheries products. Texture of a product highly related to lipid and water content present (Jittinandana et al., 2002). Hardness, gumminess and chewiness are primary mechanical parameters that can be used to characterize the texture properties of fruit-flavored smoked products. The hardness showed an increasing pattern of stored products under frozen conditions (Table 2). However, this increase was lower in mango-flavored smoked tuna than in the control (p<0.05). Water-treated and mango-treated samples stored frozen and chilled showed increasing patterns for gumminess and chewiness (Table 2).

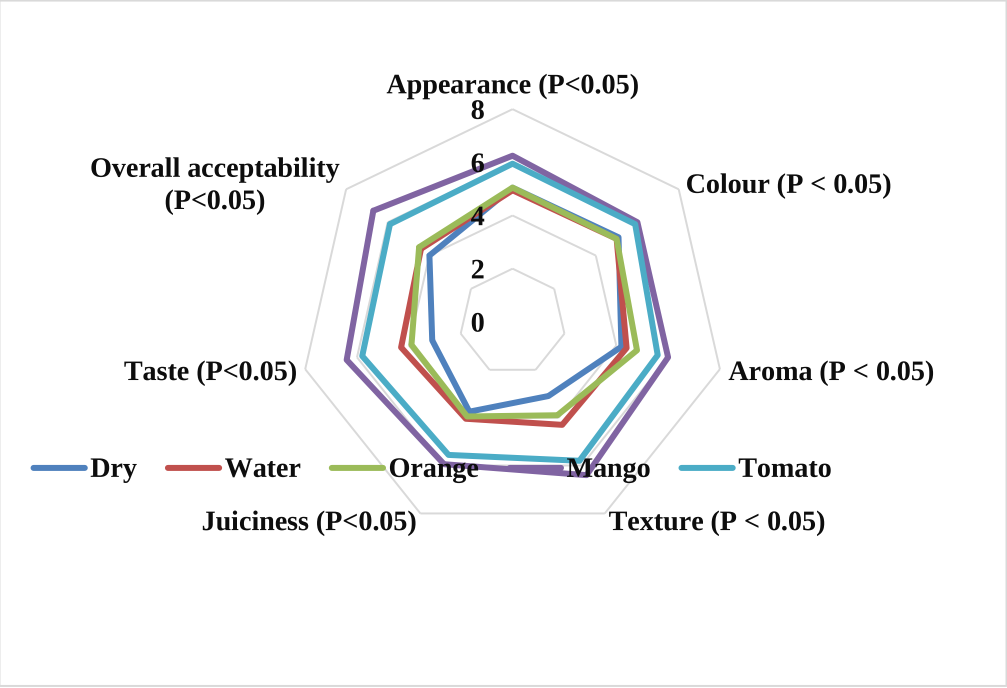

Figure 1. Identification of best fruit flavor for the smoked tuna fillets smoked at 200 ^{0}F for 100 minutes with Cinnamon wood smoke

Table 1 Change of color in smoked tuna fish stored at 4 and -20 °C

		Chilled Storage (4 °C)		Frozen Storage (-20 °C)	
Texture analysis	Storage (day)	Tuna smoked with water	Tuna smoked with mango juice	Tuna smoked with water	Tuna smoked with mango juice
"L" value	1	66.22 ± 2.43 [a]	68.21 ± 1.37 [a]	66.22 ± 2.43	68.21 ± 1.38
	7	62.98 ± 3.19 [a]	70.06 ± 1.35 [b]	64.66 ± 2.36	68.19 ± 2.88
	14	67.46 ± 6.14 [a]	66.05 ± 1.72 [a]	66.80 ± 4.47	69.95 ± 0.44
	28	65.16 ± 1.89 [a]	66.26 ± 2.56 [a]	68.50 ± 1.72	69.52 ± 1.86
	42	65.15 ± 3.48 [a]	66.39 ± 1.59 [a]	67.59 ± 3.52	68.21 ± 2.32
"a" value	1	6.48 ± 0.87 [a]	6.11 ± 0.65 [a]	6.48 ± 0.87	6.11 ± 0.65
	7	7.27 ± 1.15 [a]	6.49 ± 0.49 [a]	7.2 ± 0.84	6.86 ± 0.89
	14	6.07 ± 1.64 [a]	6.06 ± 0.52 [a]	5.59 ± 0.88	5.57 ± 0.28
	28	6.59 ± 0.53 [a]	7.34 ± 1.06 [a]	7.02 ± 0.69	5.61 ± 0.58
	42	6.31 ±1.13 [a]	6.03 ± 0.65 [a]	6.57 ± 0.76	5.93 ± 0.51
"b" value	1	12.02 ± 0.06 [a]	12.42 ± 0.44 [a]	12.02 ± 0.06 [a]	12.42 ± 0.44 [a]
	7	13.85 ± 0.65 [a]	14.30 ± 0.84 [a]	13.54 ± 0.71 [a]	13.15 ± 0.57 [a]
	14	13.45 ± 0.29 [a]	13.57 ± 0.31 [a]	13.05 ± 0.91 [a]	13.93 ± 0.45 [a]
	28	14.12 ± 0.40 [a]	13.96 ± 0.28 [a]	13.74 ± 0.72 [a]	13.67 ± 0.41 [a]
	42	14.53 ± 0.65 [a]	14.48 ± 0.46 [a]	13.57 ± 0.48 [a]	13.22 ± 0.36 [a]

[a-b] Different superscripts in the same row represent a significant ($P < 0.05$) difference between means. Values are mean ± SD (n = 3).

Table 2 Change of texture profile in smoked tuna fish stored at 4 and -20 °C

		Chilled Storage (4 °C)		Frozen Storage (-20 °C)	
Texture analysis	Storage (day)	Tuna smoked with water	Tuna smoked with mango juice	Tuna smoked with water	Tuna smoked with mango juice
Hardness (g)	1	2918 ± 1037	2051 ± 592	2918 ± 1037	2051 ± 592
	7	3713 ± 831	3261 ± 497	2751 ± 258 [a]	2167± 74.7 [b]
	14	3137 ± 1121	3157 ± 1958	3787 ± 247	2992 ± 481
	28	2714 ± 485	3377 ± 129	2792 ± 348 [a]	4398 ± 367 [b]
	42	3596 ± 1055	2887 ± 1753	4220 ± 2540	3710 ± 446
Gumminess (g)	1	258 ± 50.6	195.3 ± 22.3	258.0 ± 50.6	195.3 ± 22.3
	7	88.8 ± 78.3	58.6 ± 13.5	460.7 ± 117.4	392.0 ± 186
	14	313.7 ± 58.7	200.0 ± 91.0	451.7 ± 53.7	644.0 ± 296
	28	242 ± 138.6	340.3 ± 40.1	422.3 ± 66.6	438.0 ± 52
	42	675 ± 498	978 ± 517	1213 ± 676	1124.3 ± 126.3
Chewiness (mJ)	1	31.6 ± 23.5	23.9 ± 08.2	31.6 ± 23.5	23.9 ± 8.2
	7	88.8 ± 78.3	48.6 ± 27.5	171.9 ± 169.9	49.7 ± 35.8
	14	50.9 ± 03.3	15.0 ± 03.6	57.9 ± 16.9	97.2 ± 40.6
	28	65.8 ± 80.0	47.9 ± 15.7	56.6 ± 54.9	176.9 ± 107.4
	42	94.2 ± 69.5	132.3 ± 89.4	133.8 ± 72.6	120.1 ± 16.6

[a-b] Different superscripts in the same row represent a significant ($P < 0.05$) difference between means. Values are mean ± SD (n=3).

However,Nithin et al., (2015) reported that the gumminess and chewiness of tuna-incorporated sausage showed decreased values because of increased phenol content during storage.

Chemical analysis of smoked tuna during storage

Determination of pH of smoked tuna with storage

Changes in the pH of water-treated and mango flavored tuna stored at 4°C and -20°C for 42 days of storage are shown in Figure 2. Accordingly, the pH values of both products stored under chilled storage and frozen storage showed a reducing pattern ($p > 0.05$). This result may be due to the development of acid-producing microorganisms with storage (Maeda et al., 2014.) The value of the pH slightly decreased in chilled storage rather than frozen storage. Significant differences ($p < 0.05$) were observed between samples smoked with treated and the control samples. Mango flavored samples showed a lower level of pH reduction. According to Muralidhara et al. (2019),a lower pH reduction of mango-treated samples reflects the antimicrobial activity of mango pulp. However, some other studies showed a significant increase in pH with the storage of smoked fish products (Kayan et al., 2015). This increase in pH may be attributed to the production of volatile basic components, such as ammonia and trimethylamine, by fish spoiling bacteria (Goulas & Kontominas, 2005).

Determination of lipid oxidation of smoked tuna with storage

The malondialdehyde content of fish is identified as a good parameter to detect the freshness of fish products (Cheng et al., 2015). Changes in the malondialdehyde of water treated and mongo flavored tuna stored at 4°C and -20°C for 42 days of storage are shown in Figure 3. There were significant differences in the malondialdehyde content under both storage conditions ($p < 0.05$), but no significant difference was observed between the mango and water treated samples on the same day ($p > 0.05$) from day 07 to day 28. From day 28 and day 42, there was a sudden drop in the malondialdehyde content due to the conversion of malondialdehyde into other organic compounds (Draper & Hadley, 1990). However, the 1–2 mg MDA/kg level is usually considered the limit for fish products (Guizani et al., 2014). Elevated levels of malondialdehyde make off odors and off flavors within the product, and it is known to be mutagenic to humans because it can form adducts with proteins and DNA (Papastergiadis et al., 2012).

Microbial analysis during storage of smoked tuna

Harvested fish can be contaminated in the marine environment and during processing. Microbial contamination is a major problem in the fish processing industry (Iwamoto et al., 2010). *E. coli* and *Salmonella sp.* are two indicator microorganisms for food spoilage that show biofilm formation (Frozi et al., 2017). Therefore, they can survive in extream conditions for extended time periods. Bacterial contamination in food often results in food spoilage as well as life-threatening health hazards such as food poisoning to humans (Dutta et al., 2018). Most of the time, food products are contaminated with these pathogenic microorganisms through inappropriate processing steps and storage conditions (Mugampoza et al., 2013). The final smoked products were free from these pathogenic microorganisms, showing the safety of the product for consumers. The total plate count of mongo flavored tuna was reduced up to day 14 in both storage conditions and an increasing pattern after 14 days.

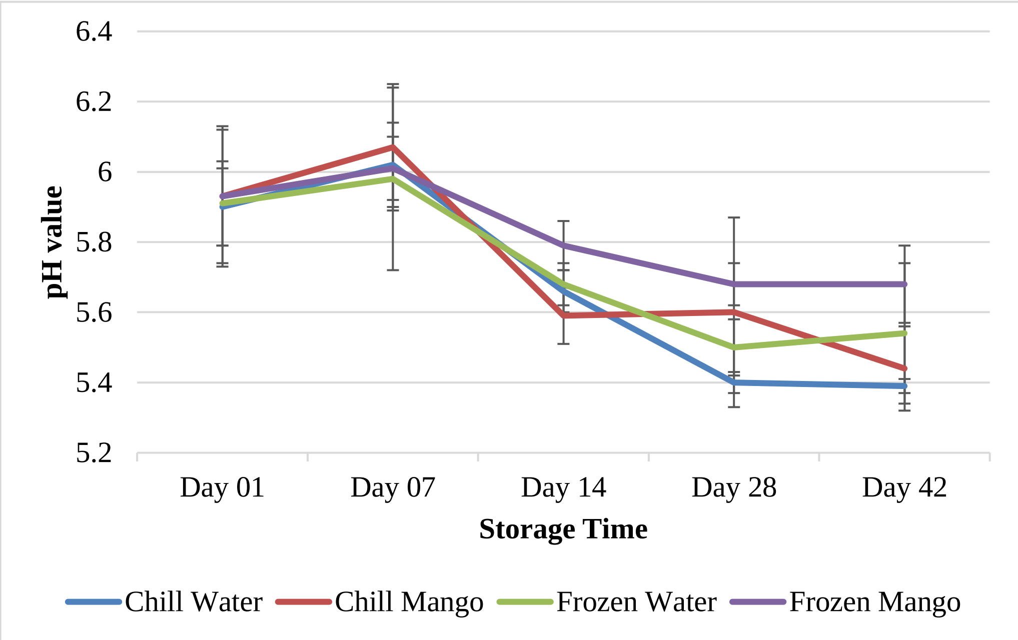

Figure 2. Changes of pH in smoked tuna stored at chill (4 °C) and frozen (-20 °C) temperatures.

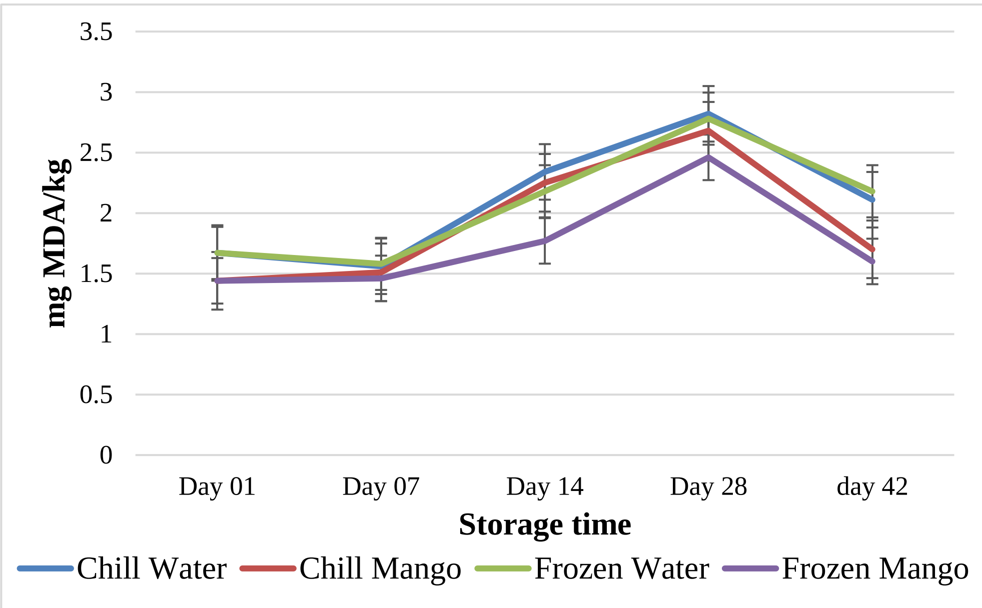

Figure 3. Changes of malonedialdehyde content in smoked tuna stored at chill (4 °C) and frozen (-20 °C) temperatures.

The reduction in TPC was due to the phenolic compounds found in the mango pulp. This may be due to the antibacterial property of mango fruit described by Hannan (Hannan et al., 2013; Hoogendoorn et al., 2021).

Conflicts of Interest Statement

Authors state that there are no conflicts of interest exist.

CONCLUSIONS

Based on the results obtained for mango flavored, cinnamon wood smoked tuna with 1% (w/w) salt and 1.5% (w/w) white paper, smoked at 200 ^{o}F (93.33 °C) for 100 minutes selected as the most suitable fruit flavoring and smoking condition. The developed product can be kept under refrigerated (4 °C) condition up to 14 days without reducing its physiochemical and microbial properties.

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