

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693

ISSN Online: 2617-4707

NAAS Rating (2026): 5.29

IJABR 2026; 10(5): 30-43

www.biochemjournal.com

Received: 21-02-2026

Accepted: 24-03-2026

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Standardization of various food ingredients for salt cured Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1816)

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i5a.8308>

Abstract

Fish preservation is a crucial component of post-harvest technology to extend shelf life, ensure food safety, and retain nutritional and sensory quality. The present study aimed to standardize ingredients such as ginger, garlic, turmeric and onion for salt cured Indian mackerel (*Rastrelliger kanagurta*). The proximate composition of fresh Indian mackerel revealed moisture contents of $71.09 \pm 0.96\%$, protein $19.11 \pm 0.01\%$, fat $8.10 \pm 0.09\%$, and ash $1.45 \pm 0.04\%$, respectively. Biochemical analysis showed low initial spoilage indicators such as TMA 2.34 ± 0.03 mg/100 g; TVB-N 7.30 mg/100 g; PV 1.7 meq O_2 /kg; pH 6.57 ± 0.07 and FFA $0.13 \pm 0.01\%$ as oleic acid, while microbial loads were within safe limits (3.32 log cfu/g). The optimized ingredient concentrations for Indian mackerel including salt 30%; ginger 25.5%; garlic 18.5%; turmeric 4%; and onion 26% yielding the best score. The sensory acceptability fish was recorded as 9.0. The study fills an important research gap by defining precise curing ingredient ratios that can improve sensory quality, supporting sustainable fish preservation and quality retention.

Keywords: Salt curing, standardization, fish preservation, sensory evaluation and shelf-life extension

1. Introduction

Fish is an integral part of food that can help in subsisting and dealing with issues of starvation and malnutrition in developing or under-developed countries. It is an excellent source of high-quality protein and provides all the essential amino acids that the body cannot generate on its own, thus making it complete protein source and fats including long-chain omega-3 fatty acids like EPA (Eicosapentaenoic acid) and DHA (Docosahexaenoic acid) (Hosomi *et al.* 2012; Barik *et al.*, 2017; Mohanty *et al.*, 2019) [33, 13, 50]. More than 20% of the animal protein consumed by about 3.1 billion people that obtained from fish. In the year 2022-23, global fish production has reached 185.4 million tonnes from capture and culture fisheries. Among this, the capture fish sector contributed 91 million tonnes whereas the culture fish sector contributed about 94.4 million tonnes (FAO 2024) [24].

In India during 2022-23, the total fish production of India was 175.45 lakh tones, among which marine fish production was 44.32 lakh tones and 131.13 lakh tones from inland fisheries. Maharashtra state contributed a share of 5.90 lakh tones, including marine sector 4.46 lakh tones and the inland sector 1.44 lakh tones. In India and Maharashtra state Indian mackerel (*Rastrelliger kanagurta*) contributed to about 3.94 lakh tonnes and 43,353 tonnes, respectively during the year 2022-23 (Handbook of Fisheries Statistics 2023 and CMFRI 2023). Out of the total marine landings, 65% of the fish are consumed fresh, 7% are frozen, 20% are cured, and 0.2% are canned (Annual Report, MOFPI, 2021-22), [48]. A total of 1,63,298.5 tonnes of dried items were exported (CMFRI 2023), with mackerel about 79,767 tonnes (CMFRI 2023) [20].

The salted and dried fish products, developed through sun drying or air drying, are prevalent in Asian countries. In India, the dry fish sector plays a crucial role in the fisheries industry, accounting for approximately 20% of the nation's total fish production.

This significant contribution highlights its importance in the country's economy. Johnson *et al.*, (2018) ^[39], reported that dried fish serve as an excellent source of micronutrients, particularly for underprivileged populations across South and Southeast Asia. Dried fish remains a nutritionally rich product, retaining the omega-3 fatty acids and antioxidant properties of fresh fish. According to Siddhanth *et al.*, (2022) ^[63] 100 grams of dried fish contains approximately 80% proteins and 300 calories, while equivalent amounts of animal meat would provide double the calories and considerably less protein. This makes dried fish an efficient, low-calorie alternative to other protein sources. Because of their shelf-stable nature, dried fish products are stored and transported without refrigeration, making them accessible even in remote areas which are having fewer cooling methods (Banna *et al.*, 2022) ^[12].

Salting is one of the oldest methods for the preservation and extension of the shelf life of fish, and it was used long before other processes such as smoking, drying, canning, marinating, *etc* (Fuentes *et al.*, 2007) ^[27]. The common methods for salting of fish are dry salting, wet salting and a combination of the two methods. The salting duration and concentration are determined by the final product characteristics. Salt uptake depends on many factors including the quality and chemical composition of raw material, species, muscle type, fish size, fillet thickness, weight, physiological state, salting method, brine concentration, duration of the salting process and fish-to-salt ratio (Gallart-Jornet *et al.*, 2007) ^[28].

Studies on preserved fish products also indicated spices such as garlic, ginger, and some citrus fruits to improve the stabilities of such products during storage (Mah *et al.*, 2009) ^[45]. Several studies have focused on the effect of ginger extract on fish products such as fillets, sausage, surimi, *etc*. (Ahmed *et al.*, 2019; Ranendra *et al.*, 2017) ^[1, 56]. Recently, consumers prefer increased towards processed foods with natural preservatives instead of chemical additives (Holley & Patel, 2005) ^[32]. Onions contain omega-3 fatty acids, carotenoids and polyphenols which help the body to regulate blood fat level, sugar level as well as the cholesterol level of blood. According to Arias *et al.*, (2022) ^[8] onion is also a good source of biotin, manganese, vitamin B6, copper, vitamin C, fibre, phosphorus, potassium, folate and vitamin B1. In addition to this, fruits, vegetables and greens can also be added to cereals and other foods, to nutritionally enrich them with micronutrients and bioactive compounds, such as lycopene (Bick *et al.*, 2014) ^[15]. Turmeric is a colouring, flavouring and agent anti-bacterial ingredient used in different food products (Farid *et al.*, 2016) ^[25]. A study was conducted to examine the effect of turmeric powder and salt (dry) along with sun-drying process on physico-chemical, mineral and bacteriological quality of fresh water fish (Farid *et al.*, 2016) ^[25].

Therefore, the aim of the present study is to standardise various ingredients such as ginger, garlic, turmeric and onion for development of dried salt cured Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1816).

2. Materials and Methods

Freshly caught Indian mackerel, *Rastrelliger kanagurta* were procured from commercial catch of trawler of Mirkarwada Jetty, Ratnagiri, Maharashtra, in a polyurethane ice box with a 1:1 ratio of fish and ice and was brought to the laboratory of Fish Processing Technology, College of

Fisheries, Shirgaon, Ratnagiri. Later the fish were washed with potable water repeatedly to remove the blood and filth attached to it. Then fish was dressed to remove the scales and visceral content and was repeatedly washed to remove the blood, scales adhered to the fish.

2.1 Preparation of ingredients

2.1.1 Ginger extract

Ginger was brought from local market, Shirgaon, Ratnagiri. Ginger was washed and outer layer was peeled. Then ginger was cut into small pieces and blended in a domestic mixture to prepare extract by slightly adding water. Then the obtained extract was used to prepare various concentrations with slight modifications during standardisation according to the method given by Alhassan *et al.*, (2023) ^[2].

2.2.2 Garlic extract

Garlic was brought from local market, Shirgaon, Ratnagiri. Garlic cloves were separated and blended in domestic mixture and slightly water was added to prepared extract. This extract was used to prepare various concentrations with slight modifications during standardisation according to the method given by Kindossi *et al.*, (2023) ^[42].

2.3.3 Turmeric paste

Turmeric was brought from local market, Shirgaon, Ratnagiri. Water was added to prepare a thick consistent paste of turmeric. This paste was used to prepare various concentrations with slight modifications during standardisation according to the method given by Imtiaz *et al.*, (2017).

2.4.4 Onion extract

Onions were brought from local market, Shirgaon, Ratnagiri. Onions were washed and outer layer was peeled and chopped into small pieces. Then the chopped pieces were blended in domestic mixture to prepare extract by slightly adding water. This extract was used to prepare various concentrations with slight modifications during standardisation according to the method given by Sule *et al.*, (2023) ^[67].

2.2 Standardization of ingredients:

2.2.1 Standardization of salt for Indian mackerel

Fish was salt cured according to the method given by various researchers, Bureau of Indian Standards and local method was also followed. Various concentrations of salt were taken and fish and salt were arranged in alternate layers and kept for overnight. Treatment of salt were designated as T₁ (20%) (Kolli and Setty, 1996) ^[57], T₂ (25%) (Chavan *et al.*, 2008) ^[19], T₃ (30%) (Bureau of Indian Standards, 2001) ^[17], T₄ (33.33%) (Murali *et al.*, 2019) ^[51] and T₅ (33.33%) (Local Method) (Table 1). Sensory analysis of salt cured fish was done using hedonic scale for best concentration of salt.

Table 1: Optimization of salt concentrations for the standardization of curing process in Indian mackerel (*Rastrelliger kanagurta*)

Treatment	T ₁	T ₂	T ₃	T ₄	T ₅
Salt concentration (%)	20	25	30	33.33	33.33

T₁: 20% salt concentration as per Kolli and Setty, (1996),
T₂: 25% of salt concentration as per Chavan *et al.*, (2008),

T₃: 30% salt concentration as per Bureau of Indian Standards, (2001), T₄: 33.33% salt concentration as per Murali *et al.*, (2019) [57, 19, 17, 51] and T₅:33.33% salt concentration was followed according to Local Method.

2.2.2 Standardization of initial concentration of ginger for Indian mackerel

For the initial standardization of ginger for Indian mackerel, the fish was first salt cured with 30% salt concentration. Later it was washed with potable water to remove excess salt and initial standardization ginger for Indian mackerel was carried out by dipping the fish in various concentrations of ginger extract such as 20% (Alhassan *et al.*, 2023) [2] as control, T₁ (21%), T₂ (22%), T₃ (23%), T₄ (24%) and T₅ (25%) (Table 2). Sensory analysis of salt cured ginger treated fish of various concentrations were carried out using hedonic scale for selecting the best concentration of ginger.

Table 2: Optimization of initial ginger concentrations for the standardization of salt cured Indian mackerel

Treatment	Control	T ₁	T ₂	T ₃	T ₄	T ₅
Ginger concentration (%)	20	21	22	23	24	25

Control 20% ginger extract as per Alhassan *et al.*, (2023) [2], T₁:21% ginger extract, T₂:22% ginger extract, T₃:23% ginger extract, T₄:24% ginger extract, T₅:25% ginger extract

2.2.3 Standardization of final concentration of ginger for Indian mackerel

For the final standardization of ginger for Indian mackerel, the fish was salt cured with 30% salt concentration and later it was washed with potable water to remove excess salt and final standardization ginger for Indian mackerel was carried out by taking concentrations of 20% (Alhassan *et al.*, 2023) [2] as control, T₁ (23.5%), T₂ (24%), T₃ (24.5%), T₄ (25%) and T₅ (25.5%) (Table 3) according to the suggestions given by panellists from initial standardisation of ginger. Sensory analysis of salt cured ginger treated fish of various concentrations were carried out using hedonic scale for selecting the best concentration of ginger.

Table 3: Optimization of final ginger concentrations for the standardization of salt cured Indian mackerel

Treatment	Control	T ₁	T ₂	T ₃	T ₄	T ₅
Ginger concentration (%)	20	23.5	24	24.5	25	25.5

Control 20% ginger extract as per Alhassan *et al.*, (2023) [2], T₁:23.5% ginger extract, T₂:24% ginger extract, T₃:24.5% ginger extract, T₄:25% ginger extract, T₅:25.5% ginger extract

2.2.4 Standardization of initial concentration of garlic for Indian mackerel

For the initial standardization of garlic for Indian mackerel, the fish was firstly salt cured with 30% salt concentration. Later it was washed with potable water to remove excess salt and initial standardization garlic for Indian mackerel was carried out by dipping the fish in various concentrations of garlic extract such as 8% (Kindossi *et al.*, 2023) [42] as control, T₁ (10%), T₂ (12%), T₃ (14%), T₄ (16%) and T₅ (18%) (Table 4). Sensory analysis of salt cured garlic treated fish of various concentrations were carried out using hedonic scale for selecting the best concentration of garlic.

Table 4: Optimization of initial garlic concentrations for the standardization of salt cured Indian mackerel

Treatment	Control	T ₁	T ₂	T ₃	T ₄	T ₅
Garlic concentration (%)	8	10	12	14	16	18

Control 8% garlic extract as per Kindossi *et al.*, (2023) [42], T₁:10% garlic extract, T₂:12% garlic extract, T₃:14% garlic extract, T₄:16% garlic extract, T₅:18% garlic extract

2.2.5 Standardization of final concentration of garlic for Indian mackerel

For the final standardization of garlic for Indian mackerel, the fish was salt cured with 30% salt concentration and later it was washed with potable water to remove excess salt the final standardization ginger for Indian mackerel was carried out by taking concentrations of 8% (Kindossi *et al.*, 2023) [42] as control, T₁ (17%), T₂ (17.5%), T₃ (18%), T₄ (18.5%) and T₅ (19%) (Table 5) according to the suggestions given by panellists from initial standardisation of garlic. Sensory analysis of salt cured garlic treated fish of various concentrations were carried out using hedonic scale for selecting the best concentration of garlic.

Table 5: Optimization of final garlic concentrations for the standardization of salt cured Indian mackerel

Treatment	Control	T ₁	T ₂	T ₃	T ₄	T ₅
Garlic concentration (%)	8	17	17.5	18	18.5	19

Control 8% garlic extract as per Kindossi *et al.*, (2023) [42], T₁:17% garlic extract, T₂:17.5% garlic extract, T₃:18% garlic extract, T₄:18.5% garlic extract, T₅:19% garlic extract

2.2.6 Standardization of initial concentration of turmeric for Indian mackerel

For the initial standardization of turmeric for Indian mackerel, the fish was firstly salt cured with 30% salt concentration. Later it was washed with potable water to remove excess salt and initial standardization turmeric for Indian mackerel was carried out by dipping the fish in various concentrations of turmeric extract such as 1% (Farid *et al.*, 2016) [25] as control, T₁ (3%), T₂ (5%), T₃ (7%), T₄ (9%) and T₅ (11%) (Table 6). Sensory analysis of salt cured turmeric treated fish of various concentrations were carried out using hedonic scale for selecting the best concentration of turmeric.

Table 6: Optimization of initial turmeric concentrations for the standardization of salt cured Indian mackerel

Treatment	Control	T ₁	T ₂	T ₃	T ₄	T ₅
Turmeric concentration (%)	1	3	5	7	9	11

Control 1% turmeric extract as per Farid *et al.*, (2016) [25], T₁:3% turmeric extract, T₂:5% turmeric extract, T₃:7% turmeric extract, T₄:9% turmeric extract, T₅:11% turmeric extract

2.2.7 Standardization of final concentration of turmeric for Indian mackerel

For the final standardization of turmeric for Indian mackerel, the fish was salt cured with 30% salt concentration and later it was washed with potable water to remove excess salt the final standardization turmeric for Indian mackerel was carried out by taking concentrations of 1% (Farid *et al.*, 2016) [25] as control, T₁ (3.5%), T₂ (4%), T₃

(4.5%), T₄ (5%) and T₅ (5.5%) (Table 7) according to the suggestions given by panellists from initial standardisation of turmeric. Sensory analysis of salt cured turmeric treated fish of various concentrations were carried out using hedonic scale for selecting the best concentration of turmeric.

Table 7: Optimization of final turmeric concentrations for the standardization of salt cured Indian mackerel

Treatment	Control	T ₁	T ₂	T ₃	T ₄	T ₅
Turmeric concentration (%)	1	3.5	4	4.5	5	5.5

Control 1% turmeric extract as per Farid *et al.*, (2014) ^[16], T₁:3.5% turmeric extract, T₂:4% turmeric extract, T₃:4.5% turmeric extract, T₄:5% turmeric extract, T₅:5.5% turmeric extract

2.2.8 Standardization of initial concentration of onion for Indian mackerel

For the initial standardization of onion for Indian mackerel, the fish was firstly salt cured with 30% salt concentration. Later it was washed with potable water to remove excess salt and initial standardization onion for Indian mackerel was carried out by dipping the fish in various concentrations of onion extract such as 5% (Sule *et al.*, 2023) ^[67] as control, T₁ (10%), T₂ (15%), T₃ (20%), T₄ (25%) and T₅ (30%) (Table 8). Sensory analysis of salt cured onion treated fish of various concentrations were carried out using hedonic scale for selecting the best concentration of onion.

Table 8: Optimization of initial onion concentrations for the standardization of salt cured Indian mackerel

Treatment	Control	T ₁	T ₂	T ₃	T ₄	T ₅
Onion concentration (%)	5	10	15	20	25	30

Control 5% onion extract as per Sule *et al.*, (2023) ^[67], T₁:10% onion extract, T₂:15% onion extract, T₃:20% onion extract, T₄:25% onion extract, T₅:30% onion extract

2.2.9 Standardization of final concentration of onion for Indian mackerel

For the final standardization of onion for Indian mackerel, the fish was salt cured with 30% salt concentration and later it was washed with potable water to remove excess salt the final standardization onion for Indian mackerel was carried out by taking concentrations as 5% (Sule *et al.*, 2023) ^[67] as control, T₁ (20%), T₂ (22%), T₃ (24%), T₄ (26%) and T₅ (28%) (Table 9) according to the suggestions given by panellists from initial standardisation of onion. Sensory analysis of salt cured onion treated fish of various concentrations were carried out using hedonic scale for selecting the best concentration of onion.

Table 9: Optimization of final onion concentrations for the standardization of salt cured Indian mackerel

Treatment	Control	T ₁	T ₂	T ₃	T ₄	T ₅
Onion concentration (%)	5	20	22	24	26	28

Control 5% onion extract as per Sule *et al.*, (2023) ^[67], T₁:20% onion extract, T₂:22% onion extract, T₃:24% onion extract, T₄:26% onion extract, T₅:26% onion extract

2.3 Proximate composition

2.3.1 Moisture

Moisture was estimated according to AOAC (2006) ^[6]. Sample (2 g) was taken in a glass dish which was previously

dried in an oven and weighed and kept in oven at 100±2 °C for 5 hours, cooled in desiccators and weighed. The process of cooling and weighing was repeated until the difference between two successive weights was less than 1 milligram. The lowest weight was recorded accurately. Moisture content of the samples was estimated using the formula,

$$\text{Moisture}(\%) = \frac{W_1 - W_2}{W_1 - W} \times 100$$

Where,

W₁ = Weight (g) of the dish with sample before drying

W₂ = Weight (g) of the dish with sample after drying

W = Weight (g) of empty dish

2.3.2 Protein

Protein in the samples was estimated according to the method given by AOAC (2006) ^[6].

2.3.2.1 Digestion

Sample (1 g) was taken and transferred into Kjeldhal digestion flask. 0.5 g of digestion mixture (K₂SO₄: CuSO₄: 5:1) was added to it. Then 20 ml concentrated sulphuric acid was added and mixed. The solution was heated at 420 °C until it become clear.

2.3.2.2 Distillation

The digested sample was put into a volumetric flask measuring 250 ml, and the volume was filled with distilled water. A volumetric pipette was used to measure 10 ml of the sample, which was then attached to the distillation unit along with 10 ml of a 40% NaOH solution. The top of the digesting tube was sealed and partially filled with distilled water. A 100 ml conical flask was filled with a 10 ml solution of boric acid (2%) and two drops of mixed indicator using a volumetric pipette. The water was heated, producing steam. Then the sample was distilled for around 15 minutes. Boric acid changes from a blue violet to a green colour when 30 to 40 ml of distillate have been collected. Distillate was titrated with 0.143 N H₂SO₄ until the blue violet color persists.

$$\text{Protein}(\%) = \frac{V \times 0.002 \times 6.25 \times 100}{W \times A}$$

V = Volume of 0.143 N of H₂SO₄

D = Volume of digested sample

W = Weight of sample

A = Aliquot taken for distillation

2.3.3 Fat

Fat was estimated as per the method given by AOAC (2006) ^[6]. The flask of Soxhlet apparatus was cleaned, dried and weighed accurately. The dried sample (2 g) was weighed into a thimble made of filter paper. The thimble was placed in extraction tube, which was then connected with the weighed flask containing sufficient ether and also with the condenser. The apparatus was used to heat the chemicals to 55-60 °C. The heat vaporized the volatile solvent, which passed up through side arm and was condensed in the condenser. The condenser solvent felled drop by drop into the porous thimble. When sufficient solvent has been transferred to the extraction tube to fill the siphon arm, it siphons back over into the weighed flask. This process was continued until the extraction was completed in 8-10 hours.

The flask was removed and the volatile solvent was evaporated. The flask with the fatty material was dried in a hot air oven till the weight remained constant.

$$\text{Fat content (\%)} = \frac{w_1 - w_2}{w} \times 100$$

W = Weight of sample in gm

W₁ = Final weight of sample with flask (g)

W₂ = Weight of empty flask (g)

2.3.4 Ash

Ash in sample was estimated according to AOAC (2006) [6]. Ash content in Sample was carried out by weighing about 2 g sample in a porcelain crucible. Then, it was placed in muffle furnace for about 5 hours at 550 °C. Then it was cooled in desiccator and weighed. The ash content of the samples was estimated by given formula.

$$\text{Ash content (\%)} = \frac{W_1 - W_2}{W_1 - W}$$

Where,

W = Weight (g) of empty crucible

W₁ = Weight (g) of crucible + dried sample

W₂ = Lowest weight (g) of crucible with sample

2.4 Biochemical parameters

2.4.1 pH measurement

Estimation of pH was carried out by the protocol laid down by AOAC (2006) [6]. About 5 g sample was ground with 45 ml of distilled water and filtered using a filter paper. The pH of the filtrate was recorded using a digital pH meter.

2.4.2 Estimation of Total Volatile Base Nitrogen (TVB-N)

The TVB-N content was analyzed as per the method given by Beatty and Gibbons (1937) [14].

2.4.2.1 Preparation of TCA (Trichloroacetic acid)

About 10 g of sample was blended with 90 ml of distilled water for 2 min, then added 5 ml of 10% TCA (w/v in distilled water). The mixture was ground well and filtered through Whatman's filter paper no.1.

2.4.2.2 Preparation of Reagent

About 92 ml of 2% boric acid, 4 ml of 0.1% of alcoholic solution of bromocresol green and 4 ml of 0.1% of alcoholic methyl red were mixed to make 100 ml of reagent.

2.4.2.3 Procedure

The Conway unit was washed with distilled water. 1 ml of reagent was added in to the inner chamber of Conway unit. TCA extract (1 ml) and saturated potassium carbonate (0.5 ml) were taken in the unit's outer chamber, then grease was applied on the edges of the Conway unit. Conway unit was rotated clockwise and anticlock wise and incubated at ambient temperature for 3 hours. The reagent (inner chamber) was titrated with 0.02 N sulphuric acid (H₂SO₄) till the blue colour turned in to pink. TVB-N was calculated as mg/100 g of sample as follows:

$$\text{TVB-N mg\%} = \frac{T \cdot v \times 14 \times N \times 100 \times D \cdot F}{w}$$

Where

T.V = Titre value

N = Normality

W = Weight of sample

D.F = Dilution factor

TMA values are expressed as mg%

TMA values are expressed as mg%.

2.4.3 Estimation of Trimethylamine Nitrogen (TMA-N)

Estimation of TMA content was carried out by using the same procedure as TVBN except that 1 ml of 10% formaldehyde was added to fix ammonia in the outer chamber with the following 1 ml TCA extract and 0.5 ml saturated potassium carbonate (K₂CO₄).

$$\text{TMA-N mg\%} = \frac{T \cdot V \times 0.02 \times 50 \times 100}{w}$$

Where

T.V = Titre value

W = Weight of sample

TMA values are expressed as mg%

2.4.4 Peroxide Value (PV)

The peroxide value was calculated in milliequivalents of oxygen per kilogram of fat. Sample was ground using a mortar and pestle. Fat was extracted by adding 50 ml of chloroform and filtering the mixture. This filtrate was then passed through filter paper containing anhydrous sodium sulphate and collected in a stoppered flask. For fat content estimation, 20 ml of the filtrate was transferred to a pre-weighed evaporating dish. The chloroform was evaporated using a water bath, and the dish was then dried in a hot air oven at 100 °C for 3 hours. Once dried, the dish was cooled in a desiccator and weighed to determine the fat content. To measure the peroxide value, 10 ml of the same filtrate was taken in a conical flask, followed by the addition of 10 ml glacial acetic acid and 1 ml of 10% potassium iodide. The flask was sealed with a stopper and shaken gently, allowing the solution to stand for exactly one minute. Then, 50 ml of distilled water and 1 ml of 1% starch indicator were added. The solution was titrated with 0.01 N sodium thiosulphate, added gradually while shaking constantly. As the end point neared, vigorous shaking was done to ensure complete release of iodine from the chloroform layer. The titration was continued drop by drop until the blue color disappeared. A blank sample was also prepared using 10 ml of the chloroform extract, and its titre value was recorded (AOAC, 2006) [6].

$$\text{PV (Milli equivalent of O}_2\text{/kg of fat)} = \frac{T \cdot v \times N \times 1000}{w}$$

Where,

T.V. = Sample titer value PV (Milli equivalent of O₂/kg fat)

N = Normality of sodium thiosulphate

W = Weight of fat (g)

2.4.5 Free Fatty Acid (FFA)

The FFA content of the sample was estimated following the AOAC (2006) [6] method. About 25 g of sample was placed in a mortar and a sufficient amount of anhydrous sodium sulphate was added to ensure complete dehydration. The mixture was ground thoroughly and transferred to a dry conical flask. Chloroform was then added, the contents were

mixed well, and the solution was filtered. For FFA analysis, 20 ml of the chloroform extract was taken in a conical flask and evaporated to dryness using a water bath. After cooling, 10 ml of neutral alcohol was added, followed by a drop of phenolphthalein indicator. The solution was titrated with N/100 sodium hydroxide until a light pink color appeared and remained stable for at least one minute. To determine the fat content in the 20 ml extract, the same volume of extract was taken in a pre-weighed Petri dish, evaporated to dryness, and the weight difference was recorded. Free fatty acid as oleic acid percentage in sample was expressed as:

$$\text{Free fatty acid (\% as oleic acid)} = \frac{v \times 0.001 \times 0.28 \times 100}{w}$$

Here,

W = Weight of fat present in 10 ml chloroform extract

V = Volume in ml of N/100 NaOH used for titration

2.5 Microbiological parameters

2.5.1 Enumeration of Total Plate Count (TPC)

Total plate count (TPC) was carried out by the method of APHA (1992). Physiological saline solution (0.85% NaCl) was used as a diluent for preparing the homogenate. About 25 gm sample was weighed and transferred to 225 ml of physiological saline in a homogenizer. Tryptone Glucose Beef Extract Agar (TGBE) was used as a media for plating. Inoculum dilutions of 0.1ml of 10^{-1} , 10^{-2} , 10^{-3} and 10^{-4} were taken in the petri dishes. The sample-containing petri dishes were incubated at 37 °C for 24-48 hours. The colonies developed on agar were counted. Plates giving colonies between 30-300 ranges were selected. Plates with crowded or spread colonies, which could not be counted, were discarded. The TPC was counted with the below formula. Total plate count (CFU/ml) = Average counts of colonies × Dilution factor

2.6 Sensory analysis

Sensory analysis of fish was evaluated using '1 to 9' point hedonic). In that characteristic such as appearance, colour, odour, texture, and overall acceptability was evaluated by

group of semi-trained panellist during organoleptic evaluation (Hough, 2010) [34].

2.7 Statistical Analysis

All experiments were performed in triplicate and a completely randomized design were used. Analysis of variance (ANOVA) was performed and mean comparisons were done by Tukey test. Analysis was performed using a SPSS package (SPSS 16.0 for windows, SPSS Inc, Chicago, IL, USA). P values less than 0.05 were considered statistically significant.

3. Results

3.1 Length and weight of fish

In the present study the average length of Indian mackerel was recorded as 22.16±0.14 cm and the average weight was 104.36±0.01gm.

The present study was conducted to investigate the quality of fresh fish Indian mackerel and to standardise ingredients of salt cured Indian mackerel. The proximate composition, biochemical, microbiological and sensory quality characteristics of fresh Indian mackerel was carried out and present in Table 10, 11 and Fig 1. The results obtained are presented and discussed below.

3.2 Proximate composition of Indian mackerel

In the present study the proximate composition of Indian mackerel was observed as Moisture 71.09±0.96%, Protein 19.11±0.01%, Fat 8.10±0.09% and Ash 1.45±0.04% (Table 10 and Fig 1).

Table 10: Proximate composition of fresh Indian mackerel fish (*Rastrelliger kanagurta*)

Sr. No.	Attributes	Composition (%)
1	Moisture	71.09±0.96
2	Protein	19.11±0.01
3	Fat	8.10±0.09
4	Ash	1.45±0.04
5	Others	0.25±0.08

Mean ± SD for each attribute represent percentage composition of three determinations.

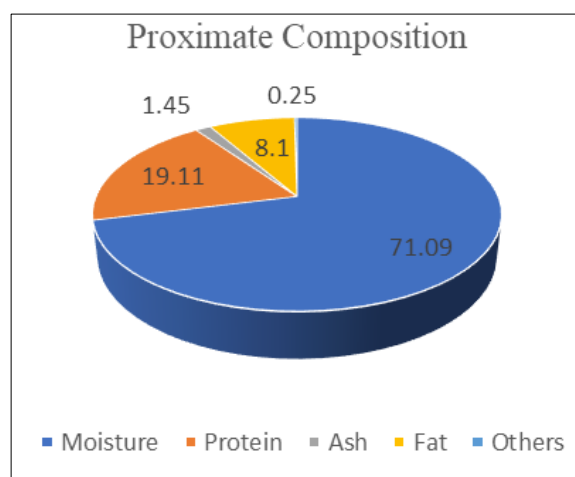


Fig 1: Proximate composition of fresh Indian mackerel fish (*Rastrelliger kanagurta*)

3.3 Quality of fresh fish

The sensory, biochemical and microbiological quality characteristics of fresh fish are summarized in Table 11. The sensory evaluation score of Indian mackerel showed on appearance was high (9.0). Biochemical assessments

revealed low values of TVBN (7.30±0.08mg/100 g), TMA-N (2.34±0.03mg/100 g), PV (1.7±0.17 meq O₂/kg, pH (6.57±0.07) and FFA (0.13±0.01% as oleic acid). The total plate counts of fresh Indian mackerel was recorded as 3.32±0.07 log cfu/g.

Table 11: Quality of fresh Indian mackerel fish (*Rastrelliger kanagurta*) meat

Quality parameter	Observed values
A. Biochemical quality	
pH	6.57±0.07
TVB-N (mg/100 g)	7.30±0.08
TMA-N (mg/100 g)	2.34±0.03
PV (meq of O ₂ /kg)	1.7±0.17
FFA (% as oleic acid)	0.13±0.01
B. Microbiological analysis	
Total plate count (log cfu/g)	3.32±0.07
C. Sensory evaluation	
Organoleptic score	9.00

Observed values for each quality parameter represent Mean ± SD of three determinations.

Table 12: Mean results of sensory characteristics for standardizing the concentration of salt for mackerel fish

Treatment	Appearance	Colour	Odour	Texture	Overall Acceptability
T ₁ (20%)	6.22±1.09 ^a	6.56±0.88 ^a	7.00±0.87 ^{ab}	6.56±0.73 ^a	6.56±0.88 ^a
T ₂ (25%)	6.60±0.97 ^{abc}	6.70±0.67 ^a	7.10±0.88 ^{abc}	7.20±0.92 ^{ab}	6.50±0.97 ^a
T ₃ (30%)	7.50±0.85 ^{bc}	7.50±0.97 ^{ab}	8.00±0.82 ^{bc}	7.70±0.82 ^b	7.90±0.99 ^b
T ₄ (33.33%)	7.60±0.52 ^c	7.80±0.42 ^b	8.10±0.57 ^c	7.50±0.71 ^{ab}	7.70±0.67 ^b
T ₅ (33.33%) (L.M)	6.50±0.71 ^{ab}	6.60±0.84 ^a	6.50±0.97 ^a	6.56±1.01 ^a	6.60±0.70 ^a

Organoleptic scores are written as means ± SD of nine-point hedonic scale given by organoleptic panel (n = 10). Means ± SD^{a-c} in the same row followed by different superscript is

significantly different ($p < 0.05$), according to Tukey test. T₁: 20%, T₂: 25%, T₃: 30%, T₄: 33.33%, T₅: 33% (Local Method)

Table 13: Mean results of sensory characteristics for standardizing the initial concentration of ginger for mackerel fish

Treatment	Appearance	Colour	Odour	Texture	Overall Acceptability
Control (20%)	6.70±1.06 ^a	6.60±0.84 ^a	6.40±0.70 ^a	7.00±0.94 ^a	6.50±0.71 ^a
T ₁ (21%)	7.40±0.70 ^{ab}	7.20±0.42 ^{ab}	7.10±0.57 ^{ab}	7.40±0.70 ^a	6.90±0.57 ^a
T ₂ (22%)	8.00±0.71 ^b	7.56±0.88 ^b	7.56±0.73 ^b	7.67±0.87 ^a	7.33±0.71 ^{ab}
T ₃ (23%)	8.36±0.67 ^b	7.73±0.65 ^b	7.55±0.69 ^b	7.64±0.81 ^a	8.00±0.89 ^{bc}
T ₄ (24%)	8.20±0.92 ^b	7.70±0.48 ^b	7.90±0.74 ^{bc}	7.90±0.57 ^a	8.20±0.63 ^{bc}
T ₅ (25%)	8.40±0.70 ^b	7.50±0.71 ^{ab}	8.50±0.71 ^b	8.00±0.67 ^a	8.30±0.67 ^c

Organoleptic scores are written as means ± SD of nine-point hedonic scale given by organoleptic panel (n = 10). Means ± SD^{a-c} in the same row followed by different superscript is

significantly different ($p < 0.05$), according to Tukey test. Control: 20%, T₁: 21%, T₂: 22%, T₃: 23%, T₄: 24%, T₅: 25%

Table 14: Mean results of sensory characteristics for standardizing the final concentration of ginger for mackerel fish

Treatment	Appearance	Colour	Odour	Texture	Overall Acceptability
Control (20%)	6.80±0.42 ^a	7.60±0.84 ^a	6.00±0.00 ^a	7.80±0.42 ^a	6.00±0.00 ^a
T ₁ (23.5%)	6.80±0.42 ^b	7.60±0.84 ^b	6.70±0.48 ^a	7.80±0.42 ^{ab}	6.00±0.00 ^b
T ₂ (24%)	6.80±0.42 ^{bc}	7.80±0.42 ^c	7.30±0.82 ^{ab}	7.90±0.57 ^{abc}	7.10±0.32 ^{bc}
T ₃ (24.5%)	7.10±0.32 ^{bc}	8.00±0.00 ^c	7.80±0.42 ^{bc}	8.30±0.48 ^{abc}	7.80±0.92 ^{bc}
T ₄ (25%)	8.90±0.32 ^{bc}	8.80±0.42 ^c	8.90±0.32 ^c	8.90±0.32 ^{bc}	8.60±0.52 ^c
T ₅ (25.5%)	7.50±0.53 ^c	7.80±0.79 ^c	8.00±0.00 ^d	9.00±0.00 ^c	7.90±0.32 ^d

Organoleptic scores are written as means ± SD of nine-point hedonic scale given by organoleptic panel (n = 10). Means ± SD^{a-d} in the same row followed by different superscript is

significantly different ($p < 0.05$), according to Tukey test. Control: 20%, T₁: 23.5%, T₂: 24%, T₃: 24.5%, T₄: 25%, T₅: 25.5%.

Table 15: Mean results of sensory characteristics for standardizing the initial concentration of garlic for mackerel fish

Treatment	Appearance	Colour	Odour	Texture	Overall Acceptability
Control (8%)	7.10±0.74 ^a	7.20±0.92 ^a	6.50±0.53 ^a	7.30±1.06 ^a	6.50±0.53 ^a
T ₁ (10%)	7.80±0.84 ^{ab}	7.60±1.07 ^{ab}	7.00±0.00 ^b	7.80±0.79 ^{ab}	7.20±0.79 ^{ab}
T ₂ (12%)	7.80±0.42 ^{abc}	7.70±1.16 ^{ab}	7.00±0.00 ^b	8.00±0.69 ^{ab}	7.20±0.79 ^{ab}
T ₃ (14%)	8.00±0.00 ^{bc}	8.10±0.74 ^{ab}	7.60±0.52 ^c	7.80±0.79 ^{ab}	7.70±0.52 ^{bc}
T ₄ (16%)	8.00±0.00 ^{bc}	8.30±0.48 ^{ab}	8.00±0.00 ^d	8.00±0.69 ^{ab}	8.00±0.00 ^c
T ₅ (18%)	8.40±0.52 ^c	8.50±0.53 ^b	9.00±0.00 ^e	8.50±0.53 ^b	9.00±0.00 ^d

Organoleptic scores are written as means $\pm$ SD of nine-point hedonic scale given by organoleptic panel (n = 10). Means $\pm$ SD^{a-d} in the same row followed by different superscript is

significantly different ($p < 0.05$), according to Tukey test. Control: 8%, T₁: 10%, T₂: 12%, T₃: 14%, T₄: 16%, T₅: 18%.

Table 16: Mean results of sensory characteristics for standardizing the final concentration of garlic for mackerel fish

Treatment	Appearance	Colour	Odour	Texture	Overall Acceptability
Control (8%)	6.80 $\pm$ 0.42 ^a	7.60 $\pm$ 0.84 ^a	6.00 $\pm$ 0.00 ^a	7.80 $\pm$ 0.42 ^a	6.80 $\pm$ 0.42 ^a
T ₁ (17%)	6.80 $\pm$ 0.42 ^a	7.70 $\pm$ 0.67 ^a	7.30 $\pm$ 0.82 ^b	7.80 $\pm$ 0.42 ^a	6.80 $\pm$ 0.42 ^a
T ₂ (17.5%)	6.80 $\pm$ 0.42 ^a	7.80 $\pm$ 0.42 ^a	7.30 $\pm$ 0.42 ^c	7.80 $\pm$ 0.42 ^a	7.10 $\pm$ 0.32 ^b
T ₃ (18%)	7.10 $\pm$ 0.32 ^{ab}	8.00 $\pm$ 0.00 ^{ab}	8.00 $\pm$ 0.42 ^{cd}	8.30 $\pm$ 0.48 ^a	7.90 $\pm$ 0.52 ^c
T ₄ (18.5%)	8.90 $\pm$ 0.32 ^c	8.80 $\pm$ 0.42 ^b	8.90 $\pm$ 0.32 ^e	8.90 $\pm$ 0.32 ^b	8.30 $\pm$ 0.52 ^d
T ₅ (19%)	7.60 $\pm$ 0.52 ^b	7.80 $\pm$ 0.79 ^a	8.00 $\pm$ 0.00 ^d	8.10 $\pm$ 0.32 ^b	7.90 $\pm$ 0.52 ^c

Organoleptic scores are written as means $\pm$ SD of nine-point hedonic scale given by organoleptic panel (n = 10). Means $\pm$ SD^{a-d} in the same row followed by different superscript is

significantly different ($p < 0.05$), according to Tukey test. Control: 8%, T₁: 17%, T₂: 17.5%, T₃: 18%, T₄: 18.5%, T₅: 19%.

Table 17: Mean results of sensory characteristics for standardizing the initial concentration of turmeric mackerel fish

Treatment	Appearance	Colour	Odour	Texture	Overall Acceptability
Control (1%)	7.70 $\pm$ 1.25 ^{ab}	7.80 $\pm$ 1.32 ^{ab}	7.00 $\pm$ 1.05 ^a	8.00 $\pm$ 1.25 ^a	7.80 $\pm$ 1.32 ^{ab}
T ₁ (3%)	8.30 $\pm$ 1.06 ^b	8.30 $\pm$ 1.06 ^b	7.70 $\pm$ 0.95 ^a	8.30 $\pm$ 1.06 ^a	8.10 $\pm$ 0.99 ^b
T ₂ (5%)	8.20 $\pm$ 0.83 ^b	7.90 $\pm$ 0.74 ^{ab}	7.60 $\pm$ 0.52 ^a	7.90 $\pm$ 0.74 ^a	7.90 $\pm$ 0.74 ^{ab}
T ₃ (7%)	7.30 $\pm$ 0.48 ^{ab}	7.60 $\pm$ 0.52 ^{ab}	7.50 $\pm$ 0.53 ^a	7.90 $\pm$ 0.57 ^a	7.40 $\pm$ 0.52 ^{ab}
T ₄ (9%)	7.10 $\pm$ 0.73 ^{ab}	6.80 $\pm$ 0.79 ^a	7.70 $\pm$ 0.67 ^a	7.80 $\pm$ 0.97 ^a	7.00 $\pm$ 0.69 ^{ab}
T ₅ (11%)	6.70 $\pm$ 1.06 ^a	6.70 $\pm$ 1.06 ^a	7.80 $\pm$ 0.79 ^a	7.80 $\pm$ 1.03 ^a	6.80 $\pm$ 1.03 ^a

Organoleptic scores are written as means $\pm$ SD of nine-point hedonic scale given by organoleptic panel (n = 10). Means $\pm$ SD^{a-b} in the same row followed by different superscript is

significantly different ($p < 0.05$), according to Tukey test. Control: 1%, T₁: 3%, T₂: 5%, T₃: 7%, T₄: 9%, T₅: 11%.

Table 18: Mean results of sensory characteristics for standardizing the final concentration of turmeric for mackerel fish

Treatment	Appearance	Colour	Odour	Texture	Overall Acceptability
Control (1%)	6.50 $\pm$ 0.53 ^a	6.50 $\pm$ 0.53 ^a	6.50 $\pm$ 0.53 ^a	7.50 $\pm$ 0.53 ^a	7.00 $\pm$ 0.00 ^a
T ₁ (3.5%)	7.40 $\pm$ 0.84 ^b	7.10 $\pm$ 0.32 ^b	7.90 $\pm$ 0.32 ^c	7.80 $\pm$ 0.63 ^a	7.90 $\pm$ 0.32 ^b
T ₂ (4%)	9.00 $\pm$ 0.00 ^c	7.70 $\pm$ 0.48 ^c	8.80 $\pm$ 0.42 ^d	8.00 $\pm$ 0.67 ^a	8.90 $\pm$ 0.32 ^c
T ₃ (4.5%)	7.70 $\pm$ 0.67 ^b	7.20 $\pm$ 0.42 ^{bc}	7.40 $\pm$ 0.70 ^{bc}	7.80 $\pm$ 0.63 ^a	7.20 $\pm$ 0.63 ^a
T ₄ (5%)	7.60 $\pm$ 0.52 ^b	7.60 $\pm$ 0.52 ^{bc}	7.60 $\pm$ 0.52 ^{bc}	7.90 $\pm$ 0.57 ^a	7.20 $\pm$ 0.42 ^a
T ₅ (5.5%)	7.60 $\pm$ 0.52 ^b	7.10 $\pm$ 0.32 ^b	7.10 $\pm$ 0.32 ^{ab}	8.00 $\pm$ 0.47 ^a	7.10 $\pm$ 0.32 ^a

Organoleptic scores are written as means $\pm$ SD of nine-point hedonic scale given by organoleptic panel (n = 10). Means $\pm$ SD^{a-d} in the same row followed by different superscript is

significantly different ($p < 0.05$), according to Tukey test. Control: 1%, T₁: 3.5%, T₂: 4%, T₃: 4.5%, T₄: 5%, T₅: 5.5%.

Table 19: Mean results of sensory characteristics for standardizing the initial concentrations of onion for mackerel fish

Treatment	Appearance	Colour	Odour	Texture	Overall Acceptability
Control (5%)	6.30 $\pm$ 0.67 ^a	6.30 $\pm$ 0.67 ^a	6.40 $\pm$ 0.70 ^a	6.90 $\pm$ 0.99 ^a	6.10 $\pm$ 0.32 ^a
T ₁ (10%)	7.10 $\pm$ 0.57 ^{ab}	7.00 $\pm$ 0.94 ^{ab}	6.70 $\pm$ 0.67 ^{ab}	7.40 $\pm$ 0.84 ^a	6.70 $\pm$ 0.48 ^{ab}
T ₂ (15%)	7.10 $\pm$ 0.88 ^{ab}	7.10 $\pm$ 0.99 ^{ab}	7.00 $\pm$ 0.82 ^{ab}	7.40 $\pm$ 0.84 ^a	7.00 $\pm$ 0.47 ^{ab}
T ₃ (20%)	7.70 $\pm$ 0.95 ^b	7.70 $\pm$ 1.06 ^b	7.40 $\pm$ 1.35 ^{ab}	7.80 $\pm$ 1.03 ^a	7.50 $\pm$ 1.18 ^{bc}
T ₄ (25%)	8.10 $\pm$ 1.20 ^b	8.20 $\pm$ 1.23 ^b	7.90 $\pm$ 1.45 ^b	7.60 $\pm$ 1.07 ^a	8.20 $\pm$ 1.23 ^c
T ₅ (30%)	7.50 $\pm$ 0.97 ^b	7.50 $\pm$ 0.97 ^{ab}	7.50 $\pm$ 0.97 ^{ab}	7.60 $\pm$ 1.07 ^a	7.60 $\pm$ 0.97 ^{bc}

Organoleptic scores are written as means $\pm$ SD of nine-point hedonic scale given by organoleptic panel (n = 10). Means $\pm$ SD^{a-c} in the same row followed by different superscript is

significantly different ($p < 0.05$), according to Tukey test. Control: 5%, T₁: 10%, T₂: 15%, T₃: 20%, T₄: 25%, T₅: 30%.

Table 20: Mean results of sensory characteristics for standardizing the final concentration of onion for mackerel fish

Treatment	Appearance	Colour	Odour	Texture	Overall Acceptability
Control (5%)	6.20 $\pm$ 0.63 ^a	6.40 $\pm$ 0.52 ^a	6.30 $\pm$ 0.4 ^a	6.40 $\pm$ 0.70 ^a	6.10 $\pm$ 0.32 ^a
T ₁ (20%)	6.80 $\pm$ 0.63 ^{ab}	7.10 $\pm$ 0.32 ^b	6.90 $\pm$ 0.74 ^{ab}	7.20 $\pm$ 0.79 ^{ab}	7.20 $\pm$ 0.63 ^b
T ₂ (22%)	7.50 $\pm$ 0.71 ^{bc}	7.70 $\pm$ 0.67 ^b	7.60 $\pm$ 0.70 ^{bc}	7.90 $\pm$ 0.57 ^{bc}	7.90 $\pm$ 0.57 ^c
T ₃ (24%)	7.80 $\pm$ 0.63 ^c	8.00 $\pm$ 0.47 ^b	8.00 $\pm$ 0.47 ^{cd}	8.00 $\pm$ 0.79 ^{bc}	8.00 $\pm$ 0.32 ^c
T ₄ (26%)	8.00 $\pm$ 0.42 ^d	8.90 $\pm$ 0.32 ^c	8.50 $\pm$ 0.53 ^d	8.80 $\pm$ 0.42 ^d	8.70 $\pm$ 0.48 ^d
T ₅ (28%)	8.00 $\pm$ 0.00 ^c	8.40 $\pm$ 0.52 ^c	8.40 $\pm$ 0.52 ^d	8.20 $\pm$ 0.42 ^{cd}	8.30 $\pm$ 0.48 ^{cd}

Organoleptic scores are written as means $\pm$ SD of nine-point hedonic scale given by organoleptic panel ($n = 10$). Means $\pm$ SD^{a-d} in the same row followed by different superscript is significantly different ($p < 0.05$), according to Tukey test. Control: 5%, T₁: 20%, T₂: 22%, T₃: 24%, T₄: 26%, T₅: 28%.

4. Discussion

4.1 Standardization of salt for Indian mackerel

In the present study Indian mackerel with 30% salt concentration has received overall acceptability score of 8.10 ± 0.57 and accepted by the panellists as compared to other treatments (Table 12). The results showed that the concentration of salt for Indian mackerel were significantly different at ($p < 0.05$). Further Tukey test confirmed that salt concentration of 30% was better than those with other concentrations. Similar concentration of salt was used by Chavan *et al.*, 2008^[19] during salting of fish based on optimal microbial inhibition, sensory quality, and moisture reduction efficiency under local climatic conditions. Other researchers have reported varying concentrations typically 20-30% depending on fish size, salting duration, and ambient temperature, which influence salt penetration and osmotic dehydration rates. Thus, differences in salting media composition, regional preferences, and preservation objectives explain the variation across studies (Chavan, 2008; Gopakumar, 2002)^[19].

4.2 Standardization of ginger for Indian mackerel

In the present study, the initial experiment showed that 25% ginger extract was best according to the panellist score 8.30 ± 0.67 as compared to other treatments (Table 13.) The final ginger concentrations of 25.5% was standardised for Indian mackerel which was more acceptable with overall acceptability score of 7.90 ± 0.32 (Table 14). The results showed that the final concentrations of ginger for salt cured for Indian mackerel were significantly different at ($p < 0.05$). Further Tukey test confirmed that final ginger concentration of 25.5% was better than those with other concentrations. The variation in the optimized ginger concentration (25.5%) observed in the present study compared to the differing concentrations reported in earlier literature can be primarily attributed to differences in fish species, muscle composition, lipid content, and processing conditions. Salt-cured and dried mackerel is a fatty fish with dark muscle fibres, higher oxidative susceptibility, and elevated endogenous enzyme activity, which significantly influences the interaction and efficacy of ginger bioactive compounds such as gingerols and shogaols. These compounds exhibit antioxidant and antimicrobial activity that is strongly affected by lipid matrix interactions and reduced water activity resulting from salt curing and drying. In contrast, studies reporting higher or variable ginger concentrations often involve lean fish species, where higher moisture content, active microbial metabolism, and protein degradation necessitate greater levels of plant-based preservatives. Therefore, the standardized ginger concentration of 25.5% identified in this study reflects a species-specific and process-dependent optimization, ensuring effective oxidative stability and microbial control in salt-cured and dried mackerel rather than indicating inconsistency with previous findings of Alhassan *et al.*, (2023)^[2].

4.3 Standardization of garlic for Indian mackerel

In the present study, the initial experiment showed that 18% garlic extract was best according to the panellist score 9.00 ± 0.00 as compared to other treatments (Table 15). The final garlic concentrations of 18.5% was standardised for Indian mackerel which was more acceptable with overall acceptability score of 8.90 ± 0.32 (Table 16). The results showed that the final concentrations of garlic for salt cured for Indian mackerel were significantly different at ($p < 0.05$). Further Tukey test confirmed that final garlic concentrations of 25.5% was better than those with other concentrations. The difference in the optimized garlic concentration between the present study and earlier reports (8%) can be attributed to variations in fish species, muscle composition, processing method, and product characteristics. Salt-cured and dried mackerel (*Scomber* spp.) possesses a higher lipid content, darker muscle fibers, and stronger endogenous enzymatic activity compared to lean or semi-lean species such as cassava fish (*Pseudotolithus* sp.) used in previous studies. These intrinsic differences influence the diffusion, retention, and efficacy of bioactive compounds from garlic, particularly sulfur-containing compounds such as allicin, which interact differently with lipid-rich matrices. Additionally, the salt-curing and drying process applied to mackerel alters water activity, protein denaturation, and surface permeability, thereby modifying the antimicrobial effectiveness of garlic at lower concentrations. Therefore, the lower garlic concentration standardized in the present study reflects species-specific responses, processing-induced structural changes, and optimized antimicrobial efficiency rather than a reduction in preservative efficacy (Kindossi *et al.*, 2023)^[42].

4.4 Standardization of turmeric for Indian mackerel

As compared to other treatments the final turmeric concentrations of 4% was standardised for Indian mackerel which was more acceptable with overall acceptability score of 9.00 ± 0.00 (Table 18). The results showed that the final concentrations of turmeric for Indian mackerel were significantly different at ($p < 0.05$). Further Tukey test confirmed that final turmeric concentrations of 4% was better than those with other concentrations. The difference in turmeric concentration standardized in the present study compared to the 1% level reported in earlier literature can be attributed to variations in fish species, muscle composition, lipid content, and processing methodology. The previous study utilized ribbon fish (*Trichiurus haumela*), a relatively lean species with lower lipid content and lighter muscle structure, processed primarily through sun drying with minimal prior salt curing. In contrast, mackerel used in the present study is a fatty fish characterized by dark muscle fibers, higher polyunsaturated fatty acid content, and greater susceptibility to oxidative rancidity during salt curing and drying. Turmeric bioactive compounds, particularly curcuminoids, exhibit strong antioxidant and antimicrobial activities, but their effectiveness is influenced by lipid matrix interactions, salt-induced protein denaturation, and reduced water activity. Consequently, salt-cured and dried mackerel requires a different turmeric concentration to achieve comparable oxidative stability and microbial inhibition. Therefore, the variation in turmeric percentage reflects species-specific physicochemical properties and processing-induced differences.

4.5 Standardization of onion for Indian mackerel

In the present study, the initial experiment showed that 25% onion extract was best according to the panellist score 8.20 ± 1.23 (Table 19). The final onion concentrations of 28% was standardised for both Indian mackerel which was more acceptable with overall acceptability score of 8.30 ± 0.48 (Table 20). The results showed that the final concentrations of onion for salt cured for Indian mackerel were significantly different at ($p < 0.05$). Further Tukey test confirmed that final onion concentrations of 25.5% was better than those with other concentrations. The observed difference in the optimized onion concentration between the present study (26%) and the earlier report employing a 5% level can be attributed to variations in fish species, form of onion used, and processing methodology. The previous study was conducted on smoked African catfish (*Clarias gariepinus*), a freshwater, lean fish species, using onion peel waste powder, which is highly concentrated in flavonoids such as quercetin and another phenolic compounds onion. In contrast, the present study utilized salt-cured and dried mackerel (*Scomber spp.*), a marine fatty fish characterized by dark muscle fibers, higher polyunsaturated fatty acid content, and greater susceptibility to lipid oxidation during curing and drying. Additionally, fresh onion or onion paste used in the present work contains higher moisture and lower phenolic concentration per unit weight compared to dried onion peel powder, necessitating a higher inclusion level to achieve effective antimicrobial and antioxidant activity. Furthermore, salt curing alters protein structure and water activity, influencing the diffusion and efficacy of onion bioactive compounds. Therefore, the higher onion concentration standardized in the present study reflects species-specific physicochemical properties, differences in onion form, and processing methods (Sule *et al.*, 2023) [67].

4.6 Proximate composition of Indian mackerel

The proximate composition of Indian mackerel, viz., moisture, protein, fat, ash and carbohydrate contents are given in Table 10 and the values are expressed in% of wet-weight basis. Evaluating proximate composition is the most important aspect for determining the nutritional status of fish.

4.6.1 Moisture content of Indian mackerel

Moisture is a measure of total amount of chemically unbound water in a sample (Balachandran, 2020) [11]. In the present study moisture content of fresh Indian mackerel was recorded as $71.09 \pm 0.96\%$. The obtained results of moisture content of fresh Indian mackerel are completely agreed with the observations reported by Tsighe *et al.*, (2018) [71] as $71.25 \pm 0.62\%$ and $71.84 \pm 0.52\%$ from the Indian mackerel and spotted sardine respectively. Similar results of moisture but slightly higher than the former observations in Indian mackerel were reported by Jora *et al.*, (2020) [40], Alkuraieef *et al.*, (2021) [4], Sunil *et al.*, (2023) [68] and Uchoi *et al.*, (2020) [72], as $76.2 \pm 0.15\%$, $74.33 \pm 0.39\%$, 76.19% and $74.83 \pm 0.00\%$ for Indian mackerel and spotted sardine respectively. According to Ali *et al.*, (2013), Sonavane *et al.*, (2017) [13, 66] differences in habitat, fishing ground, and environmental conditions such as temperature and food availability further influence moisture content in *R. kanagurta*.

4.6.2 Protein content of Indian mackerel

Fish protein has high nutritional value because essential amino acids serve as antioxidant elements in various nutraceutical industries. These amino acids possess many properties such as gel formation, oil adsorption, water-holding capacity and health-related properties. Amino acids also have antihypertensive, blood quality maintenance, muscle tissue repairing and system-regulating properties in humans (Ghaly *et al.*, 2013) [29]. In the present study protein content of Indian mackerel was recorded as $19.11 \pm 0.01\%$. The obtained results of protein content of Indian mackerel are completely agreed with the observations reported by Tsighe *et al.*, (2018) [71] as $19.76 \pm 0.65\%$ in spotted sardine, 19.12% in *Rastrelliger kanagurta*, 19.14% in *Rastrelliger kanagurta* from from Eritrea Red Sea waters and India. Other researchers Alkuraieef *et al.*, (2021) [4], Tsighe *et al.*, (2018) [71], have documented protein content in the range of $20.89 \pm 0.07\%$, $21.29 \pm 1.06\%$ and $22.94 \pm 0.26\%$ in *Rastrelliger kanagurta*. Protein levels in *R. kanagurta* tend to decrease during spawning periods due to the mobilization of muscle protein for gonadal development, while higher values are reported during active growth phases (Sonavane *et al.*, 2017) [66]. Differences in size, age, and feeding intensity also influence muscle protein concentration across studies. Additionally, environmental factors and fishing grounds affect food availability, which in turn alters protein deposition in fish muscle (Nisa & Asadullah, 2012) [52]. Hence, the protein value obtained in the present study falls within the biologically acceptable range reported for the species.

4.6.3 Fat content of Indian mackerel

Fish is often classified as lean, semi-fatty and fatty depending on the lipid content in the muscle. Fish with less than 0.5% muscle lipids is categorised as lean fish, those with lipids in the range 0.5-2% is semi-fatty and fish with more than 2 percent lipids in the muscle is fatty fish. Unlike lean or semi-fatty fish, fat content in the fatty fishes exhibit wide fluctuations (Balachandran, 2020) [11]. In the present study fat content of Indian mackerel was recorded as $8.10 \pm 0.09\%$. Various researchers Sunil *et al.*, (2023) [68], Jora *et al.*, (2020) [40], Alkuraieef *et al.*, (2021) [4] and Tsighe *et al.*, (2018) [71] reported fat content of Indian mackerel in the range of 2.99%, $7.58 \pm 0.17\%$, $5.00 \pm 0.10\%$, $3.23 \pm 0.26\%$ and $3.85 \pm 0.52\%$ respectively. The fat content variation in Indian mackerel is associated with seasonal lipid deposition associated with feeding intensity and reproductive cycle of the species. Indian mackerel is known to accumulate muscle lipids during pre-spawning and active feeding periods, whereas lower fat values are reported during post-spawning or lean seasons (Sonavane *et al.*, 2017; Nisa & Asadullah, 2012) [66, 52]. Fat content also varies with size, age, and availability of lipid-rich prey in different fishing grounds. Environmental factors such as water temperature and primary productivity further influence lipid metabolism in pelagic fishes. Therefore, the fat content recorded in the present study lies within the natural biological variation reported for *R. kanagurta*.

4.6.4 Ash content of Indian mackerel

Ash content is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals without a food. Ash content

range of fish is between 0.2% to 4% (Balachandran, 2020)^[11]. In the present study, ash content of Indian mackerel was recorded as $1.45 \pm 0.04\%$. In agreement with our findings, Sunil *et al.*, (2023)^[68], Sonavane *et al.*, (2017)^[66], Tsighe *et al.*, (2018)^[71] and Alkuraieef *et al.*, (2021)^[4] estimated ash content in the range of 1.70%, 1.42%, $1.46 \pm 0.01\%$, $1.75 \pm 0.25\%$ and $1.26 \pm 0.14\%$ from Indian mackerel. Slight lower value of ash content $0.92 \pm 0.14\%$ was recorded by Jora *et al.*, (2020)^[40]. Ash content variation in *R. kanagurta* can be attributed to differences in habitat-specific mineral availability and feeding ecology of the species. Ash content reflects the total mineral composition of muscle, which is influenced by environmental factors such as water chemistry, salinity, and sediment characteristics of the fishing ground (Sonavane *et al.*, 2017)^[66]. Variations may also arise due to seasonal physiological changes and growth stage, as mineral deposition fluctuates with metabolic activity (Nisa & Asadullah, 2012)^[52]. Additionally, differences in sample preparation and analytical procedures adopted across studies can contribute to slight difference in ash values.

4.7 Biochemical analysis content of Indian mackerel

4.7.1 TMA-N content of Indian mackerel

TMA-N can also be used as a spoilage indicator, and they are considered unreliable for use in fresh fish because they reflect the later stages of spoilage rather than freshness (Ross and Smith, 2006)^[58]. Trimethylamine can be converted from TMAO by psychrotolerant *Enterobacteriaceae*, *Vibrio* spp., *Aeromonas* spp., *P. phosphoreum* and *S. putrefaciens* (Gram and Dalgaard, 2002)^[30]. In the present study, TMA-N content of Indian mackerel was recorded as 2.34 ± 0.03 mg/100 g. Similar value of TMA-N content of Indian mackerel was reported as 2.8 mg/100 g by Pandey *et al.*, (2018)^[54]. TMA produced in early stages of deterioration and may be lost throughout the spoilage (Balachandran, 2020)^[11]. TMA interacts with muscle lipids and, in conjunction with volatile fatty acids, contributes to the stale fishy smell (Gram and Dalgaard, 2002)^[30]. For fish, the maximum acceptable limit of TMA was 10-15 mg/100 g, respectively (Connell, 1995)^[21]. In the present study, the TMA values in Indian mackerel were significantly low and this indicates the good quality of the samples.

4.7.2 TVB-N content of Indian mackerel

Total volatile bases (TVB-N) are used measurements of seafood quality. It is a general term, which includes the measurement of trimethylamine (Produced by spoilage bacteria), dimethylamine (Produced by autolytic enzymes during frozen storage), ammonia (Produced by deamination of amino acids and nucleotide catabolites) and other volatile basic nitrogenous compounds associated with seafood spoilage (Huss, 1995)^[35]. In the present study, TVB-N content Indian mackerel was observed as 7.30 ± 0.08 mg/100 g. Pandey *et al.*, (2018)^[54] have documented TVB-N content of Indian mackerel as 15.87 mg/100 g. TVB-N exhibits a great difference between species and seems to be a better index of spoilage for marine fish than for freshwater fish, since marine fish have a higher content of trimethylamine oxide (TMAO). Several authors reported that TVB-N was a poor quality index for fresh water fish, (Erkan & Özden, 2006)^[23] while it was considered a good index to assess the spoilage of marine fish (Hernández-Herrero *et al.*,

1999, Ruiz-Capillas & Moral, 2001 & Antoine *et al.*, 2002)^[31, 59, 5].

4.7.3 Free Fatty Acid (FFA) content of Indian mackerel

The post-mortem alterations in fish lipids can be witnessed by the FFA determination (Chaijan *et al.*, 2006)^[18]. Accumulation of free fatty acids causes quality to further deteriorate and speeds up protein denaturation (Balachandran, 2020)^[11]. In the present study FFA content of Indian mackerel was $0.13 \pm 0.01\%$ as oleic acid. Various researchers Tsighe *et al.*, (2018)^[71] have reported that FFA content of Indian mackerel in the range of $0.09 \pm 1.10\%$ as oleic acid and $3.86 \pm 0.71\%$ as oleic acid. An increase in free fatty acid (FFA) is a well-established post-mortem feature in fish tissue (Koizum *et al.*, 1985, Shewfelt, 1981)^[43, 62] resulting from the enzymatic hydrolysis of esterified lipids (Hwang & Regenstien, 1993) & Bosund & Ganrot, 1969)^[36, 16]. FFA and their oxidation products would have an effect on fish muscle texture and functionality since they interact with myofibrillar proteins and promote protein aggregation (Pacheco-Aguilar *et al.*, 2000)^[53].

4.7.4 Peroxide Value (PV) content of Indian mackerel

Primary lipid oxidation was measured using hydroperoxides and is expressed as peroxide value (PV). PV is an excellent quality indicator of primary lipid oxidation during the initial stage of spoilage, because in later stages, PV value decreases by the result of hydroperoxide decomposition (Aubourg, 1999)^[9]. In the present study ash content of Indian mackerel was recorded as 1.7 ± 0.17 meqO₂/kg fat. Tsighe *et al.*, (2018)^[71] reported peroxide values of Indian mackerel and spotted sardine as 9.65 ± 0.28 meqO₂/kg fat and 6.54 ± 0.23 meqO₂/kg fat. The peroxide value (PV) gives the initial evidence of rancidity in unsaturated fats and oils (Karimi *et al.*, 2017)^[41]. The maximum allowable levels of the primary lipid degradation products, as indicated by the PV, are in the range of 10-20 mEq O₂/kg fish fat (Connell, 1995)^[21].

4.7.5 pH content of Indian mackerel

The pH of fresh fish muscle is close to the value 6.5-7. Post mortem pH can vary from 6.0 to 7.1 depending on season, species and other factors (Simeonidou *et al.*, 1997)^[64]. The pH of flesh is one of the important factors governing the quality of fish. Fish muscle with a low pH is tough where microbial growth is also controlled (Love, 1997)^[44]. In the present study, pH of Indian mackerel was recorded as 6.57 ± 0.07 . The obtained results of pH for Indian mackerel are completely agreed with the observations reported by Uchoi *et al.*, (2020) as 6.44 ± 0.00 . Several researchers have indicated that the pH value of fresh fish samples is in the range of 6.7-7.03 (Azam *et al.*, 2004)^[10]. A post-mortem pH of 7 or above is an indication of starvation with depleted carbohydrate stores. The mean pH increases in pH indicate the accumulation of alkaline compounds, such as ammonia compounds and trimethylamine, mainly derived from microbial action (Schormüller, 1968)^[60].

4.8 Microbiological analysis of Indian mackerel

4.8.4 Total Plate count

Fish and fish products have its own microflora at any given time along the value chain. This is particularly true because of the fish flora, processing methods, preservation and storage conditions (Singini *et al.*, 2013)^[65]. In the present

study, total plate count of Indian mackerel was recorded as 3.32 ± 0.07 log cfu/g. Various researchers Tsighe *et al.*, (2018) ^[71] reported total plate count in Indian mackerel as 4.96 log cfu/g and 2.61 log 2.66 log cfu/g. Factors like improper handling, uncontrolled temperature at processing points cross contamination from fish contact surfaces and driers, poor processing methods, lack of hygiene habits of the handlers as well as lack of habits of cleaning the processing area may be behind the contamination (Svanevik *et al.*, 2015) ^[69]. According to Mailoa *et al.*, (2017) ^[46], the microbiological quality of fresh fish with maximum total plate 5.0×10^5 cfu/g.

4.9 Sensory analysis

In the present study overall acceptability of Indian mackerel was recorded as 9.00 ± 0.0 . Similar results of 9.00 ± 0.0 was observed by Sharifian *et al.*, (2011) ^[61]. The overall acceptability points scored by Indian mackerel respectively, which indicated high degree of acceptance of the products by the panellists. Differences in sensory scores reported by other researchers are mainly due to variations in raw material freshness, post-harvest handling, storage temperature, and duration of storage, which strongly influence sensory perception during evaluation (Huss, 1995) ^[35]. Pandey *et al.*, (2018) ^[54] reported higher sensory scores because the fish were evaluated immediately after procurement and stored under strict refrigerated conditions, whereas studies reporting lower values often involved delayed analysis or extended storage periods. In the present study, the score of 9.0 reflects proper handling, minimal biochemical deterioration, and controlled experimental conditions.

5. Conclusion

The present study standardized the proportions of key curing ingredients such as salt, ginger, garlic, onion, and turmeric for Indian mackerel (*Rastrelliger kanagurta*). The optimal formulation for Indian mackerel was 30% salt, 25.5% ginger, 18.5% garlic, 26% onion, and 4% turmeric. These standardized concentrations yielded excellent sensory scores (8.8 on the nine-point hedonic scale) and significantly ($p < 0.05$) improved biochemical and microbial stability during drying and subsequent storage. This systematic ingredient standardization fills an existing research gap in traditional fish curing practices by providing reproducible, quantitative guidelines for natural preservative use and process optimization. The findings thus contribute to the development of nutritionally stable, microbiologically safe, and sensorially acceptable dried fish products suitable for sustainable commercial processing and extended storage under tropical conditions.

6. Acknowledgment

The authors are grateful to the authorities of college of fisheries and department of fish processing technology or providing facilities to conduct the research.

7. Funding

The authors didn't receive any financial assistance during the conduction of research.

8. Conflicts of interest

The authors declare that there are no conflicts of interest.

References

1. Ahmed ES, Shehata MG, Abd-Rabou HS, El-Menshawly H. Extend the shelf life of vacuum-packaged herring fish fillets using garlic and ginger extracts. *Journal of Pure and Applied Microbiology*. 2019;13(3):1571-1581.
2. Alhassan EH, Akongyuure DN, Dandi SO, Tamakloe H. Preservative effect of ginger (*Zingiber officinale*) paste on fresh Nile tilapia, *Oreochromis niloticus* at room temperature. *UDS Int J Dev*. 2023;10(1):45-51.
3. Ali A, Al-Abri ES, Goddard JS, Ahmed SI. Seasonal variability in the chemical composition of ten commonly consumed fish species from Oman. *J Anim Plant Sci*. 2013;23(3):805-812.
4. Alkuraieef AN, Alsuhailani AM, Alshawhi AH, Aljahani AH, Aljobair MO, Albaridi NA. Proximate chemical composition and lipid profile of Indian mackerel fish. *Food Sci Technol*. 2021;42:2-4.
5. Antoine FR, Wei CI, Otwell WS, Sims CA, Littell RC, Hogle AD, *et al.* TVB-N correlation with odor evaluation and aerobic plate count in Mahi-Mahi (*Coryphaena hippurus*). *J Food Sci*. 2002;67(9):3210-3214.
6. AOAC. Official methods of analysis. 18th ed. Association of Official Analytical Chemists; 2006.
7. APHA. Standard methods for the examination of water and wastewater. 18th ed. American Public Health Association; 1992.
8. Arias A, Feijoo G, Moreira MT. Exploring the potential of antioxidants from fruits and vegetables and strategies for their recovery. *Innov Food Sci Emerg Technol*. 2022;77:102974-102979.
9. Aubourg SP. Lipid damage detection during the frozen storage of an underutilized fish species. *Food Res Int*. 1999;32(7):497-502.
10. Azam K, Ali MY, Asaduzzaman M, Basher MZ, Hossain MM. Biochemical assessment of selected fresh fish. *J Biol Sci*. 2004;4(1):9-10.
11. Balachandran KK. Post-harvest technology of fish and fisheries products. Daya Publishing House; 2020.
12. Banna MHA, Al Zaber A, Rahman N, Siddique MAM, Siddique MAB, Hagan JE, *et al.* Nutritional value of dry fish in Bangladesh and its potential contribution to addressing malnutrition: a narrative review. *Fishes*. 2022;7(5):240-242.
13. Barik NK. Freshwater fish for nutrition security in India: evidence from FAO data. *Aquac Rep*. 2017;1:1-6.
14. Beatty SA, Gibbons NE. The measurement of spoilage in fish. *J Biol Board Can*. 1937;3(1):77-91.
15. Bick MA, Fogaça ADO, Storck CR. Cookies with different concentrations of quinoa flour in partial replacement of wheat flour. *Braz J Food Technol*. 2014;17:121-129.
16. Bosund I, Ganrot B. Lipid hydrolysis in frozen Baltic herring. *J Food Sci*. 1969;34(1):13-18.
17. Bureau of Indian Standards. Fish: dried and dry-salted—specification (IS 14950:2001). New Delhi; 2001.
18. Chaijan M, Benjakul S, Visessanguan W, Faustman C. Changes of lipids in sardine (*Sardinella gibbosa*) muscle during iced storage. *Food Chem*. 2006;99(1):83-91.

19. Chavan BR, Yakupitiyage A, Kumar S. Mathematical modeling of drying characteristics of Indian mackerel (*Rastrilliger kangurta*) in solar-biomass hybrid cabinet dryer. *Dry Technol.* 2008;26(12):1552-1562.
20. CMFRI. Annual report 2022-2023. Kochi; 2022.
21. Connell JJ. Intrinsic quality. In: *Control of fish quality*. Fishing News Books Ltd; 1995. p. 5-36.
22. Department of Fisheries. Handbook of fisheries statistics. Ministry of Fisheries, Animal Husbandry and Dairying; 2023.
23. Erkan N, Özden Ö. Gutted and un-gutted sea bass (*Dicentrarchus labrax*) stored in ice: influence on fish quality and shelf-life. *Int J Food Prop.* 2006;9(2):331-345.
24. FAO. The state of world fisheries and aquaculture: towards blue transformation. Rome; 2024.
25. Farid FB, Latifa GA, Chakraborty SC, Nahid MN, Begum M. Combine effect of *Curcuma longa* powder and dry-salt with sun-drying in quality changes of three freshwater fish species of Meghna River. *Eur J Biotechnol Biosci.* 2016;4(10):42-47.
26. Frank F, Xu Y, Jiang Q, Xia W. Protective effects of garlic (*Allium sativum*) and ginger (*Zingiber officinale*) on physicochemical and microbial attributes of liquid smoked silver carp (*Hypophthalmichthys molitrix*) wrapped in aluminium foil during chilled storage. *Afr J Food Sci.* 2014;8(1):1-8.
27. Fuentes A, Fernández-Segovia I, Serra JA, Barat JM. Influence of the presence of skin on the salting kinetics of European sea bass. *Food Sci Technol Int.* 2007;13(3):199-205.
28. Gallart-Jornet L, Barat JM, Rustad T, Erikson U, Escriche I, Fito P. A comparative study of brine salting of Atlantic cod (*Gadus morhua*) and Atlantic salmon (*Salmo salar*). *J Food Eng.* 2007;79(1):261-270.
29. Ghaly AE, Ramakrishnan VV, Brooks MS, Budge SM, Dave D. Fish processing wastes as a potential source of proteins, amino acids and oils: a critical review. *J Microb Biochem Technol.* 2013;5(4):107-129.
30. Gram L, Dalgaard P. Fish spoilage bacteria: problems and solutions. *Curr Opin Biotechnol.* 2002;13:262-266.
31. Hernández-Herrero MM, Roig-Sagués AX, López-Sabater EI, Rodríguez-Jerez JJ, Mora-Ventura MT. Total volatile basic nitrogen and other physico-chemical characteristics as related to ripening of salted anchovies. *J Food Sci.* 1999;64(2):344-347.
32. Holley RA, Patel D. Improvement in shelf-life and safety of perishable foods by plant essential oils and smoke antimicrobials. *Food Microbiol.* 2005;22(4):273-292.
33. Hosomi R, Yoshida M, Fukunaga K. Seafood consumption and components for health. *Glob J Health Sci.* 2012;4(3):70-72.
34. Hough G. Sensory shelf-life estimation of food products. CRC Press; 2010.
35. Huss HH. Quality and quality changes in fresh fish. FAO; 1995.
36. Hwang KT, Regenstein JM. Characteristics of mackerel mince lipid hydrolysis. *J Food Sci.* 1993;58(1):79-83.
37. Idris GL, Omojowo FS, Omojasola PF, Adetunji CO, Ngwu EO. Effect of different concentrations of ginger on the quality of smoked dried catfish. *Nature Sci.* 2010;8(4):59-63.
38. Iheagwara MC. Effect of ginger extract on stability and sensorial quality of smoked mackerel. *J Nutr Food Sci.* 2013;3(3):199-201.
39. Johnson D. Research on the social economy of dried fish in South and Southeast Asia. *J Inland Fish Soc India.* 2018;50(1):3-5.
40. Jora KM, Lende SR, Vala SR, Mevada J, Fofandi DC, Vagh SN, *et al.* Effect of different cooking methods on proximate composition of Indian mackerel. *J Entomol Zool Stud.* 2020;8(2):43-45.
41. Karimi S, Wawire M, Mathooko FM. Impact of frying practices and frying conditions on the quality and safety of frying oils. *J Food Compos Anal.* 2017;62:239-244.
42. Kindossi JM, Afé OHI, Dalodé GV, Boya OK, Akissoé NH, Anihouvi VB, *et al.* Effects of garlic extract and lemon juice on shelf life of fermented and dried fish fillets. *J Food Stab.* 2023;6(1):1-14.
43. Koizumi C, Ohshima T, Wada S. Accumulation of lyso-form phospholipids in fish flesh during storage. *Nippon Suisan Gakkaishi.* 1985;51:965.
44. Love RM. Biochemical dynamics and quality of fresh and frozen fish. In: *Fish processing technology*. Springer; 1997. p. 1-31.
45. Mah JH, Kim YJ, Hwang HJ. Inhibitory effects of garlic and other spices on biogenic amine production. *Food Control.* 2009;20:449-454.
46. Mailoa MN, Tapotubun AM, Matruttu TE. Analysis total plate count (TPC) on fresh steak tuna. *IOP Conf Ser Earth Environ Sci.* 2017;89:1-9.
47. McClements DJ. Analysis of ash and minerals. In: *Analysis of food products*. 2003. p. 1-57.
48. MOFPI. Annual report 2021-22. Ministry of Food Processing Industries; 2022.
49. Mohanty BP, Ganguly S, Mahanty A, Mitra T, Patra S, Karunakaran D, *et al.* Fish in human health and nutrition. Narendra Publishing House; 2019.
50. Mohanty BP, Mahanty A, Ganguly S, Mitra T, Karunakaran D, Anandan R. Nutritional composition of food fishes. *Food Chem.* 2019;293:561-570.
51. Murali S, Sathish Kumar K, Alfiya PV, Delfiya DA, Samuel MP. Drying kinetics and quality characteristics of Indian mackerel. *J Aquat Food Prod Technol.* 2019;28(5):541-554.
52. Nisa K, Asadullah K. Seasonal variation in chemical composition of Indian mackerel. *Iran J Fish Sci.* 2011;10(1):67-74.
53. Pacheco-Aguilar R, Lugo-Sánchez ME, Robles-Burgueño MR. Postmortem biochemical characteristics of sardine muscle. *J Food Sci.* 2000;65(1):40-47.
54. Pandey G, Raju CV, Jagpal. Effect of refrigerated storage on biochemical parameters of Indian mackerel. *J Entomol Zool Stud.* 2018;6(2):556-561.
55. Pigott GM, Tucker B. Seafood: effects of technology on nutrition. CRC Press; 2017.
56. Ranendra KM, Apurba S, Pradip KM, Amjad KB, Snehal S, Deepayan R. Effect of ginger extract on sausages. *Agric Res Technol J.* 2017;7(2):43-52.
57. Reddy KP, Setty TR. Intermediate moisture product from mackerel. *J Aquat Food Prod Technol.* 1996;5(2):65-82.
58. Ross CF, Smith DM. Use of volatiles as indicators of lipid oxidation. *Compr Rev Food Sci Food Saf.* 2006;5(1):18-25.

59. Ruiz-Capillas C, Moral A. Correlation between biochemical and sensory quality indices in hake. *Food Res Int.* 2001;34(5):441-447.
60. Schormüller J. Manual of food chemistry. Springer-Verlag; 1968.
61. Sharifian S, Zakipour E, Mortazavi MS, Arshadi A. Quality assessment of fish during ice storage. *Int J Food Prop.* 2011;14(2):309-318.
62. Shewfelt RL. Fish muscle lipolysis: a review. *J Food Biochem.* 1981;5(2):79-100.
63. Siddhnath, Ranjan A, Mohanty BP, Saklani P, Dora KC, Chowdhury S. Dry fish and its contribution to food security. *Food Rev Int.* 2022;38(4):508-536.
64. Simeonidou S, Govaris A, Vareltzis K. Quality assessment of Mediterranean fish species. *Food Res Int.* 1997;30(7):479-484.
65. Singini W, Kaunda E, Kasulo V, Wilson J. Wealth-based fisheries management of chambo fish stock. *Int J Fish Aquac.* 2013;5(11):270-277.
66. Sonavane AE, Koli JM, Patange SB, Naik SD, Mohite AS. Proximate composition and fatty acid profiling of Indian mackerel. *Int J Pure Appl Biosci.* 2017;5(4):920-924.
67. Sule SO, Ashley-Dejo SS, Oyetunji OT, Olaniyi SE, Adeyemi AY, Abdullahi UU. Effects of onion peel wastes on smoked fish. *J Aquat Sci.* 2023;38(2):253-261.
68. Sunil J, Shiva Shankar V, Satyakeerthy TR, Binoj KK, Nissy AH, Janey MM. Proximate composition analysis of fishes of Kerala. *IJBPA.* 2023;12(11):5055-5061.
69. Svanevik CS, Roiha IS, Levsen A, Lunestad BT. Microbiological assessment along fish production chain. *Food Microbiol.* 2015;51:144-153.
70. Tairu HM, Adedokun MA, Adelodun OB, Badmus BD. Microbial examination of preservatives on smoked tilapia. *Res Rev J Microbiol Biotechnol.* 2017;6(1):28-35.
71. Tsighe N, Wawire M, Bereket A, Karimi S, Wainaina I. Physicochemical and microbiological characteristics of fish. *J Food Compos Anal.* 2018;70:98-104.
72. Uchoi D, Lekshmi M, Ghag A, Thakur A, Kishore P, Nayak BB. Quality changes in Indian mackerel during preservation. *J Food Process Preserv.* 2022;46(10):4-7.