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Quality Characteristics of Yellowfin Tuna (*Thunnus albacares*) in the Fish Landing Centre at Cochin, India

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Abstract

Yellowfin tuna being one of the commercially important fish species, the quality characteristics were investigated. Yellowfin tuna muscle had 23.18% crude protein and 1.52% crude fat. Tuna protein was well balanced with amino acids and the percentage ratio of essential amino acids to total amino acids was 48.2. Tuna meat was rich in docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). Saturated fatty acid (SFA), monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) contents of raw tuna were 31.19, 8.23 and 58.79%, respectively. n-3/n-6 polyunsaturated fatty acid ratio was 6.78, showing that yellowfin tuna meat is rich in n-3 PUFA. The other quality parameters like total volatile base nitrogen (TVBN) and trimethyl amine (TMA) were well within acceptable limits. Primary and secondary lipid oxidation products were also studied. The surface colour parameters and texture of yellowfin tuna meat showed that the samples used in the present study were of good quality.

Keywords: Yellowfin tuna, fatty acid, amino acid, proximate composition, PUFA

Introduction

Tunas are commercially important fish belonging to the family Scombridae, found in tropical and temperate waters and is a highly traded fish commodity (FAO, 2016). Among tuna, yellowfin tuna is an important species in the global commercial tuna fishery (FOC, 2016) contributing about 26% of the catch of principal tunas in 2013 (FAO, 2016). Large quantities of yellowfin tunas are commercially used as canned, dry, salted products like cured tuna loin and sashimi, a delicious raw fish product famous in Japanese and Korean markets. Because of the highly perishable nature of fish, the success of seafood industry depends on delivery the product to the consumer in acceptable condition since the consumers prefer fresh fish (De Silva & DAM, 2011). The term quality refers to the sensory characteristics of the product including appearance, flavor, odour and texture. Quality also indicates the nutritional value and safety of the product which determines the purchasing behavior of consumer (Jones & Disney, 1996). Like any premium food product, fresh tuna is priced based on its quality. Considering the nutritional benefits and the importance of yellowfin tuna an attempt was made to characterize the quality of yellowfin tuna available at Cochin, India.

Materials and Methods

Yellowfin tuna were sourced from fish landing center at Cochin, Kerala, India. The average weight of fish used in the study was 7.5±1.4 kg with 71±3.8 cm length and 20±1.4 cm width. Three fish samples were purchased for the analysis and brought to the laboratory in iced condition. After reaching the laboratory, fish were washed in chilled potable water and kept in iced condition during dressing. Boneless meat used for the analysis were collected from the dorsal side of fish. The proximate composition of the samples was determined by AOAC (2000) method. Amino acid concentration (Ishida et al. 1981) tryptophan (Sastry & Tummuru, 1985) and fatty acid composition were estimated as described by AOCS (1989) method. Minerals like sodium, potassium, calcium and iron were analyzed according to APHA (1998) using flame photometer (BWB Technologies, United Kingdom). Cholesterol content was estimated by Zlatkis et al. (1953) method and expressed as mg 100 g^{-1} of tissue. pH

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was measured according to APHA (1998) using a digital pH meter (Cyberscan 510, Eutech instruments, Singapore). TVBN and TMA were estimated by the micro diffusion method (Conway, 1950). Thiobarbituric acid (TBA) value of the sample was estimated spectrophotometrically (Tarladgis et al., 1960) and expressed as mg malonaldehyde kg^{-1} of sample. Free fatty acid (FFA) was measured and expressed as mg% oleic acid (AOCS, 1989). Peroxide value (PV) was analysed and expressed as milli equivalent of O_2 kg^{-1} fat (AOCS, 1989). The colour of the sample was measured with Hunter colorimeter (Hunter Lab colorimeter, MiniScan XE Plus Hunter Associates Lab inc., Reston, Virginia, USA).

Texture profile analysis was measured with a Universal Testing Machine (Lloyd instruments LRX plus, UK) with a cylindrical probe of 50 mm diameter equipped with a sensor of 50 N. Samples were cut into uniform size of 2 cm^3 for the texture analysis. Hardness, cohesiveness, springiness, springiness index, gumminess, adhesive force, adhesiveness, stiffness, chewiness, and fracture forces were calculated as defined in the texture analyzer user manual. All analyses were carried out in triplicate. The results were expressed as mean values ± standard deviation.

Results and Discussion

Chemical composition is an important aspect of fish quality and it influences the quality of fish (Huss, 1988). In fish, the major constituents include water, protein, fat and ash. In the present study, proximate composition of yellowfin tuna showed 73.28% moisture, 1.52% crude fat, 23.18% crude protein and 1.52% ash (Table 1). Proximate composition of fish varies widely between species and within the species it varies depending on age, sex, environment and season. According to Venugopal (2006), the protein content of most raw fin fish flesh ranged between 17-22% and the protein content of most tuna species ranges between 15-30%. The protein content of yellowfin tuna in the present study was found to be higher than other species like *Pampus punctatissimus* (Zhao et al., 2010) and seer fish (Mohan, 2008). Peng et al., 2013 observed 23.52 and 23.72% crude protein in yellow fin tuna and bigeye tuna respectively. However Nakamura et al. (2007) observed 26% protein content in bluefin tuna.

Fat content of yellowfin tuna in the present study was 1.52%, which could be classified as semi fatty fish (Ozogul & Ozogul, 2007). The cholesterol content of fresh tuna was found to be 31.11 mg 100 g^{-1} (Table 1). The cholesterol content of yellowfin tuna was found to be within the range of 30-60 mg 100 g^{-1} as described by Robert & Marcus (1990) in marine fish samples. Seafood is considered as a rich source of mineral components. Mineral composition of marine fish is in the range of 0.6-1.5% wet weight (Sikorski et al., 1990). Table 1 shows the mineral composition of yellowfin tuna meat. The most abundant mineral was potassium followed by sodium. The average calcium and iron content in yellowfin tuna meat was 381.0 ppm and 101.86 ppm respectively. The concentration of minerals in fish muscle is influenced by the ability of fish muscle to absorb the inorganic elements from their diet and from the water bodies they live (Adewoye & Omotosho, 1997).

Amino acid composition of yellowfin tuna is given in Table 2. The most predominant essential amino acids were lysine and leucine, while tryptophan was the essential amino acid with the lowest concentration. Glutamic acid constituted the highest non-essential amino acid. Glutamic acid is known to contribute taste with degradation particles of nucleotides like inosine (Olafsdottir & Jonsdottir, 2010). The higher content of glutamic acid in the muscle makes it into more palatable during winter season (Venugopal, 2009). Lysine, a limiting amino acid in cereal based diets in developing countries was also found in significant amount in yellowfin tuna protein. Hence it can serve as a source of fortification of cereal weaning foods. 5.355 g 100 g^{-1} of arginine, an essential amino acid for children was observed in present study. The percentage ratio of total

Table 1. Proximate and mineral composition of yellowfin tuna

Parameter	Values
Moisture	73.28±0.51%
Fat	1.52±0.12%
Protein	23.18±0.23%
Ash	1.52±0.03%
Cholesterol (mg 100 g^{-1})	31.11±0.01
Sodium (ppm)	884.78±0.01
Potassium (ppm)	1500.23±0.02
Calcium (ppm)	381.80±0.01
Iron (ppm)	101.86±0.01

(All values are the means ±standard deviations of three replicates)

Table 2. Amino acid composition of yellowfin tuna

Name of amino acids	g amino acid 100 g^{-1} of protein
Essential amino acids	
Valine	4.7037±0.05
Leucine	6.9629±0.04
Threonine	3.1932±0.09
Lysine	9.589±0.06
Methionine	3.1980±0.06
Phenylalanine	3.1425±0.17
Arginine	5.355±0.12
Tyrosine	4.4862±0.54
Histidine	5.5187±0.10
Tryptophan	1.1041±0.09
Non-essential amino acids	
Glycine	3.3±0.05
Alanine	5.9424±0.02
Cysteine	1.1317±0.20
Serine	5.8163±0.54
Aspartic acid	8.127±0.12
Glutamic acid	22.1766±0.20
Proline	4.6235±0.09

(All values are the means ±standard deviations of three replicates)

Table 3. Concentrations of essential, non essential, acidic, basic, neutral, aliphatic, aromatic and sulphur containing amino acids (based on g amino acid 100 g^{-1} of protein)

Amino acids	Values
total amino acid (TAA)	98.37
total essential amino acid (TEAA)	47.25
total non-essential amino acid (TNEAA)	51.12
total acidic AA	30.3
total basic AA	20.46
total aliphatic AA	20.81
total aromatic AA	18.73
total neutral AA	14.62
total sulphur containing AA	4.32
percentage of TEAA	48.2
percentage of TNEAA	51.97
percentage of total acidic AA	30.63
percentage of basic AA	20.8
percentage of aliphatic AA	21.15
percentage of aromatic AA	19.04
percentage of neutral AA	14.86
percentage of cys in sulphur containing AA	26.13

essential amino acids to total amino acids was 48.2 (Table 3) which is well above the level (39%) considered to be the adequate for ideal protein food for infants, 26% for children and 11% for adults (FAO/WHO/UNU, 1985). Most of the animal protein contains less amount of cysteine compared to vegetable proteins. Cysteine is one of the sulphur containing amino acids having positive effects on mineral absorption, particularly zinc. In the present study, Cys/TSAA was 26.13%. Adeyeye (2009) observed 23.8, 28.4 and 30.1% Cys/TSAA in *C. anguillaris, O. niloticus* and *C. senegalensis* respectively. From the present study, it was observed that the protein in yellowfin tuna muscle was found to be well balanced with essential amino acid composition and of high quality.

Table 4 presents the fatty acid composition of raw yellowfin tuna meat. Fish lipids have gained more importance because of the presence of health beneficial omega-3 polyunsaturated fatty acids (ω-3 PUFA). PUFA especially eicosapentaenoic acid and docosahexaenoic acid play a crucial role in the prevention of atherosclerosis, heart attack, depression, stroke and are believed to improve the vision and memory (Chin & Dart, 1995). Recognizing the health benefits of ω-3-fatty acids and the serious consequences of their deficiency, the US National Institute recommended a daily intake of 650 mg of ω-3 fatty acids in the form of fish (Venugopal, 2006). In the present study, yellowfin tuna meat was rich in DHA and EPA (45.14 and 5.51% respectively). The DHA value was found to be higher than those reported for big eye tuna (Peng et al., 2013) and blue fin tuna (Nakamura et al., 2007). In the present study, saturated fatty acid (SFA), mono unsaturated fatty acid (MUFA) and PUFA contents of raw tuna were 31.19, 8.23 and 58.79% respectively, (Table 4). Arachidonic acid (C20:4) a precursor to prostaglandins and thromboxanes was also found in yellowfin tuna meat (5.35%). The major SFA were palmitic (C16:0) and stearic (C18:0) acids. The C16:0 has been reported as the major fatty acid in marine fish followed by C18:0 by Bhuiyan et al. (1986). The

Table 4. Fatty acid profile of yellowfin tuna

Fatty Acid	Raw tuna (% of fatty acid)
Mono Unsaturated Fatty Acid	
Eicosaenoic acid ($C_{20:1}$)	0.25±0.40
Palmitoleic acid ($C_{16:1}$)	2.27±0.14
Heptadecaenoic acid ($C_{17:1}$)	1.33±0.23
Oleic acid ($C_{18:1}$)	4.35±0.06
ΣMUFA	8.2±0.13
Poly Unsaturated Fatty Acid	
Decosahexaenoic acid ($C_{22:6}$) n3	45.14±0.2
Eicosapentaenoic acid ($C_{20:5}$) n3	5.51±0.37
Arachidonic acid ($C_{20:4}$) n6	5.35±0.03
Eicosadienoic acid($C_{20:2}$) n-6	0.45±0.01
Eicosatrienoic acid($C_{20:3}$) n3	0.28±0.01
Linolenic acid ($C_{18:3}$) n3	0.31±0.02
Linoleic acid ($C_{18:2}$) n6	1.75±0.01
ΣPUFA	58.79
Saturated Fatty Acid	
Myristic acid (C_{14})	1.81±0.02
Pentadecanoic acid (C_{15})	1.97±0.01
Heptadecanoic acid (C_{17})	1.03±0.01
Stearic acid (C_{18})	9.22±0.01
Tricosanoic acid (C_{23})	2.31±0.02
Palmitic acid (C_{16})	14.85±0.09
Σ SFA	31.19
Σ n-3	51.24
Σ n-6	7.55
n3/n6	6.78
n6/n3	0.147

(All values are the means ± standard deviations of three replicates)

major MUFA's were palmitoleic (C16:1) and oleic (C18:1) acids in raw tuna. Another major MUFA noticed in this study was heptadecaenoic acid. Presence of linolenic (C18:3) acid (0.31%) was also noticed.

The n-3 and n-6 PUFA is having positive effects on cardiovascular diseases and certain types of cancer (Peng et al., 2013). The n-3/n-6 ratio is an important indicator for comparing the relative nutritional values of fish oils. In the present study n-3/n-6 ratio was 6.78, which was greater than the values reported by Peng et al. (2013) for two tuna species. The ratio of n-6/n-3 in the present study was 0.14, which was lower than the maximum value recommended by the UK Department of Health (HMSO, 1994). Values higher than the maximum are harmful to health and may promote cardiovascular diseases. The PUFA/SFA ratio of yellowfin tuna was ranged between 1.82 revealing that yellowfin tuna meat is a good source of PUFA.

The autolytic spoilage is responsible for the early loss of quality in seafood and is widely used as a quality index for fish. In marine fish, trimethyl amine oxide (TMAO) is broken down by autolytic enzymes but mostly as a result of microbial action to trimethyl amine (TMA), dimethyl amine (DMA), ammonia, formaldehyde and other volatile amines (Huss, 1994). In the present study total volatile base nitrogen (TVBN) content of yellowfin tuna was 11.93 mg% (Table 5) which was lower than the highest limit permitted by EC (EC directive149, 1995) for raw fish (35 mg %). Similar result was obtained for red drum (Li et al., 2013). Among the chemical indices of spoilage, TMA is the one of the best spoilage indices produced by the bacterial breakdown of TMAO which is an osmolyte naturally found in marine fish. TMA is responsible for the fishy off flavor in spoiled seafood (Fu et al., 2007) and the rejection limit is usually from 5-10 mg% (El Marrakchi et al., 1990). TMA content of raw tuna meat is presented in Table 5. The results indicate that yellowfin tuna used in the study was of prime quality. A similar result was observed in Japanese sea bass (Cai et al., 2014).

One of the major reasons for the spoilage of fish is due to the oxidation of lipids. Oxidation of fat causes the formation of toxic compounds, changes in colour, taste, texture and nutritional value (Indergard et al., 2014). The auto oxidation of unsaturated lipids occurs by the action of oxygen. It leads to the formation of hydroperoxides, which further degrades to aldehydes and ketones causing strong rancid odour and flavor (Huss, 1994). The results of lipid oxidation parameters are shown in table 5. In the present study, primary oxidation of lipid was analyzed by measuring PV. The PV was not observed in the present study. A similar result was observed by Rodriguez-Turienzo et al. (2013). Lipid hydrolysis was determined by measuring the formation of FFA. In the present study the FFA observed for fresh yellowfin tuna meat was 2.24

mg% of oleic acid. The formation of FFA itself does not lead to nutritional losses, but its measurement is important to measure the rancidity development. The pro-oxidant effect of FFA on lipid mater has been explained by Aubourg (2001). FFA have also been shown to undergo faster oxidation than intact lipids affecting the sensory quality of aquatic food products and provide greater accessibility to oxygen and other pro oxidant molecules. The secondary oxidation products of lipid were measured by TBA. The presence of TBA reactive substances (TBARS) is on account of the second stage of auto oxidation during which peroxides are oxidized to aldehydes and ketones (Li et al., 2013). TBARS observed in the present study are presented in Table 5. The value did not exceed 1-2 mg malonaldehyde kg^{-1}, which is normally regarded as the limit of acceptability (Connel, 1995).

Table 5. Physicochemical quality parameters of raw yellowfin tuna

Parameter	Values
TVBN (mg%)	11.93±0.05
TMA (mg%)	1.3±0.04
TBA (mg malonaldehyde kg^{-1})	0.21±0.01
pH	6.5±0.8
FFA (mg% of oleic acid)	2.24±0.02
PV	Nil
hardness 1 (kg f)	26.788±0.4
hardness 2 (kg f)	23.210±0.21
Cohesiveness	0.365±0.03
Springiness (mm)	6.311±0.07
Springiness Index	0.529±0.01
Gumminess (kgf)	0.997±0
Chewiness (kgf.mm)	6.293±0.01
Fracture Force (kgf)	0.049±0
Adhesive Force (kgf)	0.039±0
Adhesiveness (kgf.mm)	0.036±0
Stiffness ($kgfmm^{-1}$)	0.519±0.01
l*	34.38±0.4
a*	5.67±0.2
b*	8.15±0.09

(All values are the means ± standard deviations of three replicates)

The pH of live fish muscle tissue is close to neutrality. pH of yellowfin tuna meat observed in the present study was 6.5 (Table 5). A similar result was also observed by Wei et al. (1990) for tuna meat. The colour of seafood is an important determinant of quality in seafood especially in tuna. The colour in seafood is influenced by muscle structure characteristics and pigment concentrations. In tuna, the colour changes from red/purple to cherry red to brownish red. This reflects the chemical oxidation state of myoglobin in the fish muscle (Anderson & Wu, 2005). In the CIE L*, a*, b* system, L* denotes lightness on a scale from 0 to 100 from black to pure white, a* denotes (+) red or (-) green, and b* denotes (+) yellow or (-) blue. The surface colour parameters of yellowfin tuna are shown in Table 5. L* value of yellowfin tuna meat was 34.38 and a* and b* values were 5.67 and 8.15 respectively. From the result it was observed that there was no dark discolouration in the tuna meat used for study.

Food texture is defined as all the rheological and structural attributes of the product perceptible by means of mechanical, tactile and where appropriate, visual and auditory receptors (Chen & Opara, 2013). Texture analysis results of the present study are shown in Table 5. Texture of fish muscle depends on numerous intrinsic biological factors like density of muscle fibers, fat and collagen content of fish muscle. Fish death triggers autolytic and microbial processes that make fish muscle softer and less elastic (Li et al., 2011). Hardness 1 of yellowfin tuna meat used for the study was 26.78. The springiness of sample was tested to simulate finger feel of raw sample. The sample showed a springiness value of 6.311 mm. Chewiness represents the work done. The yellowfin tuna showed a chewiness value of 6.293 kgf mm. The gumminess value and fracture force was 0.99 kgf and 0.049 kgf respectively.

In summary, yellowfin tuna is rich in crude protein with 23.18% and the percentage ratio of total essential amino acids to total amino acids was 48.2. Protein in yellowfin tuna muscle is well balanced with essential amino acids. The PUFA/SFA ratio of yellowfin tuna ranged between 1.82 revealing that yellowfin tuna meat is a good source of PUFA. The most abundant mineral was potassium followed by sodium. The average calcium and iron content in yellowfin tuna meat was 381.0 ppm and 101.86 ppm respectively. The other quality indices like TVBN, TMA, PV, FFA, exhibited very low values which indicates the quality of yellowfin tuna collected from the landing center at Cochin was good.

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