Red and White Meat of Tuna *(Euthynnus affinis)*: Their Biochemical Role and Nutritional Quality

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The biochemical and nutrient compositions of red and white meat of tuna are reported. Based on the data the biochemical role and nutritional quality of red and white meat are discussed. The results show that red meat is adapted for slow and continuous activity and white meat for quick but occasional activity. In spite of comparatively low lysine content the red meat is adjudged more nutritious than white meat.

Tuna is an important food fish. Out of the total world fish catch of 70 million tons, 1.5 million tons are composed of tuna, belonging to about 12 species (Anon, 1975). Substantial quantities of tuna are canned, a part is processed to conventional cured products like 'massmin' and the rest is consumed fresh. Generally tuna meat is considered highly nutritive owing to its content of essential amino acids, protein and fat (Chinnamma, 1975). Probably this is why tuna is nicknamed chicken of the sea.

Like majority of the fish, tuna too is composed of red and white meat, a characteristic trait of fish capable of continuous swimming, where the red muscle is supposed to play an important role in muscular activity (Anon, 1966). However, the proportion of red meat in tuna is very high forming about 11% (Chinnamma, 1975). In the case of certain species of tuna the red meat content is low while in some other species like mackerel tuna *(Euthynnus affinis)* it is still higher. In tuna canning, only the white meat is used discarding considerable quantities of red meat as waste, which is often converted to poultry and animal feeds.

The wastage of red meat, a valuable food has prompted a rethinking among food scientists as evidenced by the numerous studies on red and white meat of tuna and other fishes, though most of them are biochemical in nature rather than nutritional. Thus the distribution of histidine (Amano & Bito, 1951), cytochrome C and myoglobin (Matsura & Hashimoto, 1954), major chemical constituents and vitamins (Breakken, 1956), cholesterol and long chain polyenoic acids (Igarashi *et al.,* 1957) and biochemical constituents (Chinnamma, 1975) in red and white meat of different species of tuna were reported. Similar studies on red and white meat were conducted in mackerel *(Scomber scombrus)* (Breakken, 1959; Nagayama, 1961), mackerel *(Rastrelliger kanagurta)* (George, 1962) and sardine *(Sardinella longiceps)* (Watabe *et al.,* 1977). In spite of all their data, a critical study of the red and white meat from the nutritional point of view does not appear to have been made.

The present study reveals the difference between red and white meat of tuna with respect to their biochemical and nutritional character.

Materials and Methods

Fresh tuna weighing 4 to 5 kg each obtained from local market were gutted and kept in chilled storage before use. In any case the storage never exceeded 24 h. The red and white meat from the central region (between the two dorsal fins) were separated, minced and used. All chemicals employed were of pure or analar grade.

Moisture and ash were determined as described in AOAC (1970). Fat was estimated according to Bligh & Dyer (1959). The ash obtained above was dissolved in normal hydrochloric acid and was used for the determination of sodium, potassium and calcium (Vogel, 1960) and iron (Lawrence 1960). For protein estimation, about 100 mg dry muscle was digested with concentrated sulphuric acid and a pinch of digestion mixture and its nitrogen content estimated according to microkjeldahl method (Hawk, 1954). From the total nitrogen so obtained the non-protein nitrogen was deducted and the result multiplied by 6.25 to give the protein content.

Glycogen was estimated in the wet tissue using the method of Schwartz & Rall (1973). Trichloroacetic acid extracts of the tissue were prepared according to Umbriet *et al.* (1959) which were used for the estimation of reducing sugar (Folin & Malmros, 1929), inorganic phosphate (Fiske & Subbarow, 1925), non-protein nitrogen (Hawk, 1954) and lactic acid (Barker & Summerson, 1941).

Sarcoplasmic proteins were extracted according to Paul *et al.* (1966) using pH 7.5 borate buffer and electrophorised in polyacrylamide gel columns as described by Ornstein & Davis (1964).

Amino acid composition was determined by the standard microbiological assay (Kavanagh, 1963). All colourimetric measurements were done in Spectronic-20 (Bosh and Lomb) and the flame photometric measurements in a flame photometer (Systronics Instruments).

Results and Discussion

The percentage of fat, protein, carbohydrate, moisture and the computed calorific values for red and white meat of tuna along with that of hen's egg (whole) and fresh tuna liver tissues are shown in Table 1. The data show a clear difference between red and white meat in their carbohydrate and fat contents which are significantly more in red meat. The threefold occurrence of carbohydrate in red meat compared to white meat as also reported by Breakken (1959) and Chinnamma (1975) along with the higher percentage of fat shows the role of red muscle as a storage and regulatory organ like liver (White *et. al.*, 1973) in mammals. This view is further supported by the reports that red muscle contains more of the enzyme systems like arginase (Matsura *et al.*, 1953), cytochrome C (Matsura & Hashimoto, 1954), phosphatase and phosphorylase (Ogata & Mori, 1963). The only difference of liver from red meat, is its high carbohydrate content, the differences in protein contents among red meat, white meat and liver being negligible. However, egg displays a peculiar composition characterised by high fat and moisture contents and low protein value.

The calorific values computed also show that red meat has more food value than white meat. The reports on the higher concentrations of vitamins like pantothenic acid, riboflavin, thiamine and cyanocobalamine (Breakken, 1959) and vitamin A (Higashi, 1961) in red meat of tuna also show that it is more nutiitious than white meat. The only vitamin reported to occur in large quantities in white meat of tuna is niacin (Breakken, 1956; 1959). Thus from Table 1 it can be seen that red meat with a calorific value of 120 resembles liver more closely than white meat, which is rated lowest in the order egg, liver, red meat and white meat.

Table 1. *Proximate composition and calorific value of tuna meat*

Type of meat	Moisture g/100g	Fat g/100g	Protein g/100g	Carbohydrate g/100g	Calorific value kcal/100g
Tuna red meat	69.37	4.631	18.28	0.750	120
Tuna white meat	70.94	3.056	18.90	0.263	104
Liver tissue	70.90	4.200	19.80	3.600	133
* Egg whole	74.00	11.50	12.80	0.700	159

* Values taken from Harrow & Mazoor (1962)

Table 2. *Amino acid composition and FAO/WHO suggested pattern of essential amino acids*

	Amino acid composition g/100g (dry muscle)		Amino acid requirement g/day*		
	Red meat	White meat	Infant	Child	Adult
Isoleucine	5.00	5.53	3.5	3.7	1.8
Leucine	8.57	8.50	8.0	5.6	2.5
Lysine	4.17	9.48	5.2	7.5	2.2
Methionine + cystine	3.88	3.80	2.9	3.4	2.4
Phenyl alanine	4.31	4.64	6.3	3.4	2.5
Tyrosine	**	**			
Threonine	4.99	5.38	4.4	4.4	1.3
Valine	4.24	5.36	4.7	4.1	1.8
Histidine	2.38	5.36	1.4		
Glutamic acid	13.35	14.01			
Tryptophan	0.45	1.70			
Arginine	4.65	5.95			
Serine	3.83	4.59			
Proline + hydroxyproline	7.18	6.21			
Aspartic acid	7.46	7.92			
Glycine	3.93	2.86			

* FAO/WHO suggested pattern (1973) **Not determined

Listed in Table 2 are the amino acid compositions of red and white meat of tuna, along with the FAO/WHO (1973) suggested pattern of amino acid requirement for infant, child and adult per day. The data clearly shows that red and white meat are of comparable amino acid composition excepting lysine, histidine and tryptophan whose occurrences in white meat are more than twice that in red meat. But when the essential amino acid distribution is considered, the difference is confined only to lysine content.

However, from the FAO/WHO (1973) recommended pattern of amino acid requirement, it can be seen that 50 g of dry muscle of both red and white meat of tuna can easily meet the normal amino acid requirement of an adult human being, though in the case of infants and children it cannot provide the lysine required. Excepting for lysine, red meat is as rich a source of essential amino acids as white meat, especially in comparison with the amino acid composition of plant and cereal foods, in which lysine, threonine, isoleucine and methionine are reported to be limiting amino acids (Harden *et al.*, 1976).

Fig. 1 shows the graphic representation of electrophorogram of the aqueous extracts of white meat (W), red meat (R) and liver (L). The sarcoplasmic proteins of all the three samples differ clearly from each other, particularly in low molecular weight components. In the sarcoplasma of liver there are about 7 protein bands in the low molecular weight region (bands 7 to 13), while the sarcoplasma of red and white meat respectively have 5 and 3 bands only. In the slow moving high molecular weight group (bands 1 to 6) also the number of protein bands is less in white meat (four) whereas liver and red meat sarcoplasma have 5 and 6 bands respectively. From these results, it is clear that red meat electrophorogram with 11 sarcoplasmic protein bands is more similar to liver with 12 sarcoplasmic

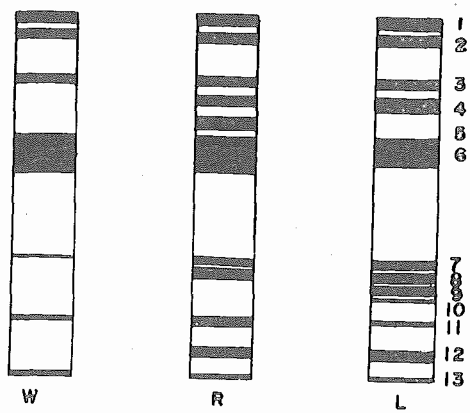

Fig. 1. Electrophorogram of the sarcoplasmic proteins of white muscle (W), red muscle (R) and liver tissue (L)

protein bands and superior to white meat with a sarcoplasmic protein pattern of 7 bands.

Table 3 summarises the ash, sodium, potassium, calcium and iron contents of tuna's red and white meat and tuna liver. It is seen that ash content of red meat is slightly less than that of white meat, but it is richer in sodium and iron, the latter occurring more than twice in quantity compared to white meat. On the other hand, white meat is characterised by the presence of potassium and calcium in higher amounts. The iron contents of liver and red meat show a clear similarity between the two, which perhaps is the reason for the similar pigmentation exhibited by them.

Vinogradov (1953), Parks & Rose (1933) also found red muscle to be generally rich in iron. Alexander (1955), Fujikawa & Naganuma (1936) reported similar observations in *Labeo rohita* and *Sardinella melanostica* respectively. In the case of potassium, Thurston & McMaster (1960) reported a lesser concentration in red meat of halibut *(Hippoglossus hippoglossus)*. Contrary to the present observations, Vinogradov (1953) found calcium content to be equal in red and white meat in general. However because of the major contribution of white muscle to muscular activity (Love, 1970) and the role of calcium in muscle contraction (Smellie, 1974) a higher concentration of calcium in white muscle seems more probable. The higher concentration of calcium in red meat over that of liver tissue can also be attributed to the association of the former in muscular activity with which the liver is not associated.

Further the high concentration of iron in red meat which is an indication of the presence of haemoglobin/myoglobin or other iron containing protiens/enzymes explains the higher amount of cellular oxidation going on in red muscle, a peculiar trait of liver tissue. The reported higher concentrations of cytochrome C, haemoglobin and myoglobin (Matsura & Hashimoto, 1954) and myoglobin and haemoglobin (Chinnamma, 1975) in the red meat of tuna endorses this view.

Striking differences are observed in the distribution of reducing sugar, lactic acid and inorganic phosphate in red and white meat of tuna. It is of interest to note that even though reducing sugar and glycogen are more in red meat, the end product of their catabolism namely lactic acid is present in larger quantities in white meat. Tsuchiya & Kunii (1960) have also made similar observations. Probably when once glycogen present in red muscle is degraded to simple sugar phosphates, a major part of them is transported to white muscle, where they are subjected to anaerobic glycolysis to give lactic acid. The occurrence of phosphorylase in larger quantities in red meat (Ogata & Mori, 1963) and higher amounts of L-glycerophosphate dehydrogenase and lactic dehydrogenase in white meat (Mellgren & Mathisen, 1966) lends support to this postulation.

The existence of comparatively larger quantities of inorganic phosphate (Table 4), an essential requirement for glycolysis in white

Table 3. *Mineral composition of tuna meat*

Type of meat	Ash g/100g	Na mg/100g	K mg/100g	Ca mg/100	Fe mg/100g
Tuna red meat	1.224	53.74	238.4	134.4	11.05
Tuna white meat	1.704	47.50	391.2	178.8	4.75
Liver tissue	—	—	—	8.0	12.10
* Egg whole	—	—	—	54.0	2.70

* Values taken from Harrow & Mazoor (1962)
–Values not determined

Table 4. *Composition of certain metabolites in tuna red and white muscles*

Type of muscle	Reducing sugar mg/100g	Latic acid mg/100g	Inorganic phosphate mg/100g
Red	110.0	23	120
White	10.6	44	240

meat and the extensive distribution of iron, the bio-oxygen receptor and hence an inhibitor of glycolysis, in red meat, fuither support the above view. The major role of white muscle in muscular activity especially in quick movement and the consequent instant energy requirements of white meat too, suggest the probability of a larger extent of glycolysis to occur in white meat in comparison with red meat.

From the foregoing results it is clear that red meat of tuna is in itself a specialised tissue resembling liver in many respects. Like livei, the red meat is a centre for biological oxidation and the aerobic metabolisms like citric acid cycle and β oxidation. It is also a store for the energy fuels like carbohydrate and fat. However the red meat is not as lethargic as liver in which respect it has similarities to heart tissue–a system adapted for continuous activity, deriving energy from aerobic metabolism.

This view is endorsed by Mellgren & Mathisen (1966), George (1962) and Bilinlski (1963) against that of Breakken (1959). In this regard it may be said that white muscle contributes to quick movements and red meat to slow but continuous movement depending respectively on anaerobic and aerobic metabolisms for energy. The increased distiibution of red muscle in continuously swimming fishes like tuna, mackerel and sardine and the absence or near absence of red meat in sluggish fishes substantiate this observation.

In the matter of food value too ied meat occupies a higher status with higher amounts of carbohydrate, fat, essential minerals like iron, phosphorous, sodium and vitamins. The amino acid composition also proves that the red meat is highly nutritious though lysine, histidine and tryptophan occur in smaller quantities than in white meat.

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