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# *'Shrimp as health food -Advisory fact sheet'*

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## Introduction

The worthiness of the food to the human being is to maintain a state of positive health and optimal performance by providing all essential nutrients in adequate quantities to prevent deficiency diseases and also prevent diet related chronic disorders. Consuming variety of foods in balanced proportions will ensure this objective of disease free healthy life. Seafood is an important constituent of the human diet. The consumers are looking at sea food as health food due to its fatty acid profile. Shrimp is one of the world's most popular shellfish and is part of almost every nation's traditional meal. The present review highlights hereunder brings out the following facts to establish that shrimp is a high nutritious food with many health advantages. Shrimp provides high quality proteins and essential amino acids, minerals and trace elements, fat soluble vitamins and essential fatty acids including long chain n-3 fatty acids for human body. Contrary to the popular perception, shrimp is a low-fat (low-calorie) source of protein. Shrimp lipid contains mostly polyunsaturated fatty acids (essential fatty acids), which includes linoleic acid and alpha-linolenic acid that are parent compounds of omega-6 and omega-3 acid series, respectively, which provide various health benefits to humans.

### *Food energy of shrimp*

The energy content of shrimp was calculated based on its nutrient contents. One serving (100g) of shrimp provides around 90 calories of energy (Table 1). The energy from carbohydrates is very negligible indicating its low glycaemic index qualifying it as a choice food for diabetic patients. The nutritional guidelines stipulate that the energy contribution from fats should not be more than 20%. The fat contributes around the 10% of the total energy indicating it can be a preferred food item for inclusion in calorie restricted diets recommended for weight loss.

Table 1: Food Energy (K k cal/100g) of two popular shrimp species

| | *Black tiger shrimp* | *Indian white shrimp* |
|---|---|---|
| Calories contributed by | 92 | 88 |
| Carbohydrates | 2 | 2 |
| Fat | 10.8 | 9.9 |
| Proteins | 78.8 | 76.4 |

***Shrimp proteins***

Shrimp contains about 19% protein and more than 90% of dry matter. Human body cannot synthesis certain amino acids and they must be obtained through diet, and they are called essential amino acids. Shrimp proteins are made of α-amino acids and all the 20 naturally occurring amino acids are found in varying proportions with all essential amino acids as per needs of the human being. The results presented are based on studies carried out by CIBA on the tiger shrimp *Penaeus monodon* and Indian white shrimp *Fenneropenaeus indicus*. The amino acid profile clearly indicate that shrimp is -a highly nutritious item for man. One portion of 100g shrimp will provide one third to one half of one's daily protein requirement. Shrimp is also characterized by easy digestibility (85%) and has got high biological value compared to proteins from many other sources. The Essential Amino Acid Score (EAAS) and Essential Amino Acid Index (EAAI) were calculated based on WHO Ideal Protein. The Protein Digestibility Corrected Amino Acid Score (PDCAAS) is based on shrimp protein's amino acid content, true digestibility, and its ability to supply the essential amino acids as per requirement. The PDCAAS of shrimp is 1 indicating its superior protein quality. It is now established that these protein behaves as a hypo-cholesteraemic agent, a strong cardio protective agent and protects the antioxidant system due to its amino acid ratios and unique nutritional characteristics. All these factors make shrimp an ideal source of protein.

***Shrimp fat***

Shrimp has one of the lowest fat content among non-vegetarian food items. The average lipid content in the edible portions of shrimp is ~1%. The lipid class composition in shrimp is 65-70% phospholipids, 15-20% cholesterol and 10-20% total acyl glycerols in our study.

**Table 2: Summary of Lipids of shrimp and other Non-vegetarian food items***

| Nutrient | Shrimp | Other NV items | Dietary Guidelines | Nutritional significance of shrimp |
|---|---|---|---|---|
| Fat % | 0.4-2 (1) | Egg 11<br>Chicken 18<br>Mutton 13<br>Beef 16<br>Pork 35 | Fat should not be more than 20-30% of total calorific intake. | Shrimp is lowest fat NV item along with other crustaceans. |
| Saturated fatty acids (SFA) | 0.2-0.3 (g) | Egg 4<br>Chicken 6<br>Mutton 7<br>Beef 8<br>Pork 13 | Higher SFA stimulates the *de nova* synthesis of Cholesterol in the body. | Lowest SFA content in the shrimp and it is good for the body. |
| PUFA : SFA (P:S) | 1.2 | Egg 0.4<br>Chicken 0.7<br>Mutton 0.13<br>Beef 0.12<br>Pork 0.53 | P:S should be above 0.45 | Favourable ratio of Shrimp lipids for cardiac protection. |
| ω-3/ω-6 PUFA | 1.5 | Egg 0.2<br>Chicken 0.06<br>Mutton 0.73<br>Beef 0.53<br>Pork 0.13 | Primitive man food contains ω-3/ω-6 PUFA ratio of 1. The ratio of > 0.2 is recommended. | Favourable ratio of Shrimp lipids for cardiac protection, plays anti-inflammatory role, cognitive development. |
| Cholesterol (mg/100g food) | 150-200 mg% | Egg 400<br>Chicken 100<br>Mutton 65<br>Beef 70<br>Pork 90<br>Brain 2000<br>Liver 300 | Dietary intake of cholesterol should not be more than 200 mg. | Shrimp is having moderate amount of cholesterol but it is not harmful due to favourable P:S and ω-3/ω-6 PUFA ratio. |
| Atherogenic Index | 0.24-0.30 | Egg 0.4<br>Chicken 0.5<br>Mutton 1.0<br>Beef 0.7<br>Pork 0.67 | Lower the ratio good for the health. | This index is a overall effect of dietary fat on vascular atherosclerosis. Lower the value, better for health. |

*Source from Dayal et al., (2011a)

The predominance of phospholipids in shrimp lipid indicates it's rich nutritional quality. Phospholipids are transport lipids present in plasma in combination with proteins as lipoproteins which plays major role in transport of fat and cholesterol. They are also involved in certain metabolic enzymes such as cytochrome oxidase and succinate oxidase. Mitochondria contain large amounts of phospholipids which are essential for the organization and function of the electron transport chain which is essentially required for cellular energy production. They are also important constituent of all cell membranes and influence the membrane permeability to various substances. They are concerned in the selective cation transport across the erythrocyte membrane. They are also essential components of thromboplastin, a blood coagulating factor. They are also present in large amounts in the nervous tissues and essential for its function. Grey matter of human brain contains 60-70% and white matter 40% of phospholipids, within the total lipid fraction. They are significant structural components of the phospholipid membranes of tissues throughout the body and are especially rich in the retina, brain, and spermatozoa, in which docosahexanoic acid (DHA; 22:6 ω-3) constitutes $\leq$36.4% of total fatty acids. The phospholipids are said to reverse the symptoms of dementia and to increase the sporting performance of individuals.

Shrimp lipids differ greatly from mammalian lipids in that they include up to 40% of long-chain fatty acids (C14-C22) that are highly unsaturated and contain 5 or 6 double bonds (Table 2). Intake of unsaturated fatty acids is better than saturated fatty acids as the later fatty acids stimulate body to synthesize more low density lipoproteins which is 'un health cholesterol'. Fatty acids found in shrimp lipids are recognized by high degree of un-saturation (high proportions of long chain polyunsaturated fatty acids, PUFA), found in proportions of about 35-55 % in shrimp body lipids. Also, the PUFA belong to the n-3 or ω-3 groups. The fatty acid content of shrimp lipids is 25-30% saturated fatty acids (SFA), 20-25% monounsaturated fatty acids (MUFA). Within PUFA, ω-3 fatty acids are predominant and ω6/ω3 PUFA ratio is 0.6-0.80 indicative of its rich health benefits to human being. The studies have clearly indicated that dietary ω-3 PUFA will augment the ω-3 PUFA level of cell membranes. ω-3 PUFAs effectively act on the properties and functioning of cell membranes including transport of materials across the cell membrane, an integral part of normal metabolic processes. Unsaturated fatty acids play an important role in maintaining the fluidity and functionality of cell membranes. A healthy diet should have a PUFA/SFA ratio at least 0.54 and above. The shrimps assessed in our study had values (>1.9) higher than these recommendations and are definitely a worthy source of PUFA for man's plate.

Higher ω-3 PUFA levels in cell membrane favourably alter the cardiac ion channel function and this in turn reduces myocardial vulnerability to myocardial fibrillation. The presence of high levels of the long-chained ω-3 fatty acids, EPA and DHA, is identified as one of the major benefits of ingesting fish and shellfish derived lipids. EPA is a substrate for eicosanoid synthesis. DHA, however, is the most abundant ω-3 fatty acid present in tissues. Its multiple and unique metabolic functions which are not replicated by other fatty acids indicates its essentiality in human diet.

EPA is believed to play important roles in maintaining the health of heart and circulatory system, where as DHA are involved in the functioning of brain, nerves, etc. Various studies have clearly

brought out the role of ω-3 PUFA's influence on various metabolic processes, such as in eicosanoids metabolism and lipid protein interactions controlling membrane functions. They are also involved in production of cytokines, which are involved in inflammatory processes and immune systems and in expression of genes associated with enzymes of lipid metabolism. This clearly shows that ω-3 PUFA influence wide spectrum of basic metabolic processes and plays a crucial role in maintaining healthy functioning of the system. In order to measure the propensity of shrimp eating to influence the incidence of coronary heart disease, the atherogenic and thrombogenic indices were calculated. Shrimp is having 0.36-0.28, respectively. These indices are much lower in shrimp compared to other non-vegetarian foods indicative of its cardio-protective nature of shrimp.

**Mechanism of action of EPA as cardio protective agent**

Eicosanoids are a group of compounds derived from 20 carbon PUFA's and optimum eicosanoid levels are required for regulating the functions of cardiovascular system, reproductive system, kidney function and overall functionality of the body. Changing the normal patterns of eicosanoid production can be useful in ameliorating certain forms of cardiovascular disease, osteoporosis and arthritis. These are highly active compounds present in very small concentration. Many of these eicosanoids are synthesized in the body depending upon the site of production, enzymes involved and degree of free unsaturation of precursors of fatty acids (Figure 1). Prostaglandins, prostacyclins, thromboxanes etc, belongs to this group. The effects of eicosanoids are highly diverse and action of different eicosanoids often opposes each other.

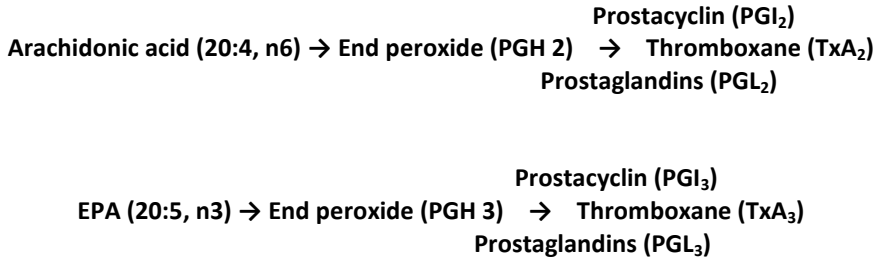


Figure 1. Formation of eicosanoids from arachidonic acid and EPA

Unlike hormones, eicosanoids are not produced in a central location and then transported to the target organ. They act locally in the cells in which they are created and disappear quickly due to their rapid inactivation and extremely short half-lives. In general, eicosanoids bind to receptors on target cell plasma membranes in various tissues and stimulate or inhibit the synthesis of other messengers - like cyclic AMP. Eicosanoids from arachidonic acid belong to 2 series, whereas those from eicosapentanoic acid (EPA) belong to the 3 series. Prostaglandins have both positive and negative effects on reproduction. Thromboxane ($TxA_2$) promotes platelet aggregation and smooth muscle contraction. On the other hand end products of EPA eicosanoids ($PGH_3$) act as platelet antiaggregatory and vasodilating agent.

**Mechanism of action of Omega-3 Fatty Acids as cardio protective agent**

**The potential mechanisms by which Omega-3 Fatty Acids may reduce risk for cardiovascular disease identified by** Canor, 2000 is given below:

- Reduce susceptibility of the heart to ventricular arrhythmia
- Antithrombogenic
- Hypotriglyceridemic (fasting and postprandial)
- Retard growth of atherosclerotic plaque
- Reduce adhesion molecule expression
- Reduce platelet-derived growth factor
- Antiinflammatory
- Promote nitric oxide-induced endothelial relaxation
- Mildly hypotensive

The proper balance of diet, in terms of availability of PUFA and the precursors for the eicosanoids are the key factors for eicosanoid-optimum functions. Among the animal protein foods, only fish and shrimp can be termed as balanced diet leading to production of eicosanoids in balanced proportions. Diets with disproportionately high arachidonic acid will lead to increased concentrations of pro-platelet aggregatory and pro-thrombatic eicosanoids beyond desirable levels and will affect the balance of 3 series eicosanoids. This situation, combined with other factors will lead to coronary heart diseases. In the case of diet containing adequate level of EPA will be available in the membrane lipids to promote synthesis of platelet antiaggregatory and vasodilating eicosanoids. The production of platelet thromboxane $A_3$ and prostaglandin $I_3$ made in vessel walls in the presence of EPA competitively inhibit the production of pro-platelet aggregating eicosanoids.

Based on these beneficial effects of EPA and DHA, the Nutritional Dietary Guidelines recommends that individuals at both higher and average coronary vascular disease risk should consume an average of at least 250 mg/day EPA+DHA (1,750 mg/week). Eating 100 g edible portion of shrimp in a day will provide >180 mg of EPA+DHA providing at least 70% of the daily needs and thereby reduces the CVD risk.

***Vitamin, mineral and carotenoid contents in shrimp***

Shrimp are a rich source of calcium, iron, zinc, iodine, phosphorus and selenium and these minerals are highly bioavailable. 100g shrimp eating provides 100 mg of calcium and 300 mg of phosphorous meeting one third of the requirements of adult human being. They are also rich source of vitamins, particularly, vitamins A, D, E and as well as thiamin, riboflavin and niacin (vitamin B1, B2 and B3). Shrimp contains 0.02, 0.015, 1.78, 0.16 and 0.31 and 0.16 mg of thiamin, riboflavin, niacin, B6 and B-complex vitamins, respectively in 100g. Shrimp is a rich source of fat soluble vitamins of 180 IU, 2 IU and 1.32 µg of A, D and E, respectively in 100 g (USDA 2010). In addition, shrimp also contains 2 mg % of carotenoids a fat soluble pigment known to play an important potential role in human health by acting as biological antioxidants, protecting cells and tissues from the damaging effects of free radicals and singlet oxygen. Other health benefits of carotenoids that may be related to their anti-oxidative potential include

enhancement of immune system function, protection from sun burn and inhibition of the development of certain types of cancers. Lipid oxidation is a serious problem particularly during dry cooking and frying of meaty foods containing considerable amount of unsaturated fatty acids and cholesterol. Antioxidants are chemical molecules which inhibits the oxidation of other molecules, here the fatty acids. Astaxanthin has been found to be potent natural antioxidant, exceeding 10 times the antioxidant activity of β -carotene and 500 times of α-tocopherol. Astaxanthin level of wild shrimps has been reported to vary between 740 and 1400 µg/100 g in edible meat portions which again supports the argument to include shrimps as part of regular diet.

**Consumer concerns regarding shrimp consumption**

In spite of very low fat content in shrimp, the cardiologists suggest to avoid shrimp eating due to its moderately high cholesterol content (200 mg/100 g shrimp). But the cholesterol content in shrimp is much lower than hen egg (500 mg%), liver (300-600 mg%), brain (2000 mg%) and butter and ghee (300 mg%).

To know the effect of eating shrimp on lipid profile,systematic clinical trials have been carried out. In a randomized study, a diet containing 300 g shrimp/day increased low-density-lipoprotein (LDL) cholesterol by 7.1% and high-density-lipoprotein (HDL) cholesterol by 12.1 % when compared with a baseline diet matched for fat content but containing only 107 mg cholesterol/d. At the same time, the shrimp diet did not worsen the ratio of total cholesterol to HDL cholesterol or the ratio of LDL to HDL cholesterol. Moreover, shrimp consumption decreased triacylglycerol (triglyceride) concentrations by 13%. The study showed that moderate shrimp consumption in normolipidemic subjects will not adversely affect the overall lipoprotein profile and can be included in 'heart healthy' nutritional guidelines. This supports the notion that the type of dietary fatty acid, rather than the level of dietary cholesterol, is the most potent regulator of serum cholesterol levels. Dietary cholesterol is also said to have an inverse effect in endogenous cholesterol synthesis and lower saturated fatty acids intake would have increased LDL-receptor – mediated catabolism. The reduction in triglyceride levels may be due to shrimps' ω-3 Fatty acid content, that are shown to decrease VLDL production, probably by increasing the intracellular degradation of hepatic apolipoprotein B. Similarly, the atherogenic index in shrimp (0.24-0.36) is much lower than other animal foods such as lamb (1.00), beef (0.72), pork (0.69), chicken (0.5) and similar to those fin fish foods (mackerel, 0.28).

The other concern is that contamination by toxic compounds like heavy metals in seafood. The risks associated with the body burden of methyl mercury and dioxins along with fish consumption on neurological/neuro- developmental outcomes in infants, immunological and reproductive dysfunctions and cancers have to be kept in mind. Eating a variety of fish should minimize this risk. Also heavy metals is accumulated by wild caught fishes like tuna and by adopting better manamgnet practices their presence in cultured shrimp can be avoided. The issues of allergens associated with crustaceans are of concern too. There has been concern about an increased risk of bleeding, especially after consumption of large doses of fish oil concentrates, but there is little clinical evidence in support of this even in patients treated with aspirin or anticoagulants. Taking all these into consideration, the US FDA advisory (2006) and joint

FAO/WHO expert consultation (2010) on the risks and benefits of fish (includes shrimp) consumption, based on the strength of scientific evidences concluded that there is *convincing* evidence of beneficial health outcomes from fish consumption as indicated by reduction of cardiac deaths and improved cognitive developments in children. In addition, eating of fish has probable benefits in preventing ischemic stroke and possible benefits in reducing depression. The health benefits of eating shrimp is beyond ω-3 fatty acids and other individual nutrients. It is the complimentary effect of the combined nutrients present in shrimp including proteins, trace minerals and beyond those other non-nutrient factors like carotenoids.

## Conclusion

At present aquaculture is regarded worldwide as one of the fastest growing food-producing sub-sectors compared to cereal and livestock production. This provides a more stable, sustainable and predictable food supply to the growing population to meet the nutritional needs. Shrimp is the richest source of protein with the lowest amount of fat. Presence of high proportions of phospholipids and long chain fatty acids like eicosapentanoic acids and docosahexanoic acids give additional health benefits to human beings. The scoring of daily value chart of nutrients for are shrimps are: outstanding (daily value (DV%) > 70) – selenium, methionine, tryptophan, threonine, EPA+DHA and lysine; excellent (DV% 50 to 70) – copper, isoleucine, cystine, histidine, leucine, valine and phosphorus; very good (DV% 25 to 50) – protein and phenylalanine; good (DV% 10 to 25) – calcium, magnesium, iron and zinc; poor (DV% <10) sodium, potassium, energy, lipid and manganese. The overall benefits of eating shrimp are overwhelmingly high and this is emerging as a functional food mainly due to its cardio protective character. That is the reason US FDA Advisory (2006) clearly advocates eating two meals of shellfish (shrimp) per week.

**Further Reading**


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This Advisory Fact Sheet on 'Shrimp as Health Food' is brought out as an **e-publication** to bring awareness among public and scientific communities regarding the health benefits of consuming shrimp and to dispel some misconceptions. The information provided and interpretations given are based on our own research work and review of literature.