

Shrimps – a nutritional perspective

J. Syama Dayal*, A. G. Ponniah, H. Imran Khan, E. P. Madhu Babu, K. Ambasankar and K. P. Kumarguru Vasagam

This article presents the nutritional value of shrimp on the strength of its nutrient composition and daily value (DV%). With its relatively lower lipid content (~1%), the DV (%) of 100 g shrimp for an adult human is 75%, 70% and 35% for eicosapentanoic acid + docosahexanoic acid, essential amino acids (methionine, tryptophan and lysine) and protein respectively. The lower atherogenic (0.36) and thrombogenic (0.29) indices of shrimp show its cardio-protective nature. The controversy relating to shrimp cholesterol and the overall health benefits of eating shrimp are discussed to indicate that shrimp should be a regular item in the diet of normolipidemic peoples.

Keywords: Daily value, dietary cholesterol, nutritional composition, shrimp.

FOOD helps human beings maintain good health by providing all essential nutrients. Consuming a variety of foods in balanced proportions will prevent deficiency diseases and chronic diet-related disorders. Shrimp is one of the most delicious seafoods and is part of almost every nation's traditional meal. Its popularity has created a demand for its produce around the world. Considering the limit in the supply from wild catch, farming of shrimp was started in many countries to meet the demand, and is growing rapidly. One can gauge its growth from the past production figures which rose from 1 million tonnes (mt) in 2001 to 4.02 mt in 2010, including the Indian contribution of about 0.1 mt (ref. 1). The potential for growth of Indian shrimp is exhibited by increase in its exports by 24% in quantity and 42% by value in 2012 compared to 2011 (ref. 2). Shrimp production is expected to grow more than 50% globally during 2010–2030, indicating its vibrant production potential³.

Fresh and clean shrimps can be served either cooked or uncooked with sauce. From a nutritional standpoint, shrimps are high in protein, low in saturated fat⁴ and calories, and have a neutral flavour. Due to these characteristics, shrimps form a natural additive in salads, pastas, curry, soups and stir-fried dishes. Shrimps have also been identified as a rich source of vitamin B₁₂, selenium, ω -3 highly unsaturated fatty acids (HUFA) and astaxanthin, a potent natural antioxidant⁵. Despite the several nutritional parameters of shrimp based on which it can be considered as a healthy food, there is reluctance among dieticians and health professionals as well as consumers because of its relatively higher cholesterol^{6–8}. A clinical study showed that moderate shrimp consumption in normolipidemic subjects will not adversely affect the overall lipo-

protein profile and can be included in 'heart healthy' nutritional guidelines⁹. Lack of scientific studies directly linking shrimp consumption to cardiovascular disease (CVD) has left the dieticians and doctors in a predicament. Egg from poultry has been identified as a high-cholesterol food item for human and its consumption has been a matter of debate for cardiovascular health. Unlike shrimps, many studies have been carried out on the effect of egg consumption on serum lipid profile in relevance to CVD and other metabolic disorders in humans. However, the argument on cholesterol-rich egg consumption and its relation on CVD risk has not yet been conclusively settled. A review by a medical doctor and co-workers criticized the indiscriminate consumption of eggs by adults¹⁰. Another recent review argues that dietary cholesterol does not increase the risk of heart disease in healthy populations, and therefore suggests the withdrawal of recommended dietary intake (RDI) of less than 300 mg/day (in USA)¹¹. Several studies agree that cholesterol in egg does not contribute much to blood cholesterol, and support the idea of eating an egg each day.

An attempt has been made in this article to evaluate the nutritional value of shrimp in man's platter, mainly focusing on its nutritional composition, daily value of major nutrients and dietary cholesterol. This may put to rest the negative perceptions and controversies on shrimp cholesterol and might pave the way for accepting it as a nutritional food for healthy human beings^{6,7,9,12}. The shrimps (*Penaeus monodon* and *Fenneropenaeus indicus*) used for analysis in our laboratory were in the size range 10–25 g collected from both wild caught and cultured.

Protein and other vital nutrients of human importance in shrimp

Similar to any animal meat, shrimp is an excellent source of dietary protein. The analysed nutrients in the eatable

The authors are in the Central Institute of Brackishwater Aquaculture, No. 75, Santhome High Road, R.A. Puram, Chennai 600 028, India.

*For correspondence. (e-mail: syamdayal@ciba.res.in)

muscle of shrimp are presented in Table 1. Three-fourths of the edible portion of shrimp are water. Nearly 80% of the remaining portion (dry matter) comprises of protein. The average protein content of fresh shrimp is 19.4 g/100 g and it contributes 87% of the total energy. Our body cannot synthesize certain amino acids and they must be obtained through diet; these are called essential amino acids. The protein digestibility corrected amino acid score (PDCAAS) is based on the amino acid content of food protein, true digestibility, and its ability to supply the essential amino acids according to requirement. The PDCAAS of shrimp is 1, indicating its superior protein

Table 1. Average analysed nutrient profile of 100 g edible shrimp meat*

Nutrient	
Protein (g)	19.4 ± 0.56
Lipid (g)	1.15 ± 0.19
Water (g)	76.3 ± 0.57
Energy (kcal)	89.0 ± 1.12
Essential amino acids (mg)	
Isoleucine	930.7 ± 8.10
Leucine	1463.9 ± 22.30
Lysine	1480.1 ± 27.57
Methionine + cysteine	668.1 ± 16.57
Phenylalanine + tyrosine	1389.2 ± 19.27
Threonine	756.0 ± 8.89
Tryptophan	223.3 ± 2.90
Valine	935.7 ± 5.89
Lipid composition	
∑SFA (mg)	257.5 ± 3.71
∑MUFA (mg)	163.5 ± 7.90
∑PUFA (mg)	321.0 ± 5.23
Eicosapentaenoic (mg)	112.0 ± 3.02
Docosahexaenoic (mg)	75.5 ± 1.43
∑n - 3 PUFA (mg)	204.5 ± 2.23
∑n - 6 PUFA (mg)	106.0 ± 2.31
n - 6/n - 3 PUFA	0.5 ± 0.01
PUFA/SFA	1.3 ± 0.05
Cholesterol (mg)	173 ± 6.93
Macro minerals (mg)	
Calcium	107.3 ± 1.96
Magnesium	58.5 ± 1.38
Phosphorus	303.4 ± 3.22
Potassium	259.6 ± 3.25
Sodium	176.1 ± 3.04
Micro minerals (µg)	
Copper	918 ± 4.62
Iron	2196.5 ± 16.61
Manganese	50.5 ± 1.64
Selenium	44 ± 1.06
Zinc	1403.5 ± 5.43

*These are the average values ($n = 60$) with SEM of nutrients from the data obtained for tiger shrimp (*Penaeus monodon*) and Indian white shrimp (*Fenneropenaeus indicus*) from both wild caught (10–20 g) and cultured (20–25 g). The average proximate composition (%) of feeds used is 9.55, 38.32, 6.30, 3.93, 12.51 and 29.39 for moisture, crude protein, ether extract, crude fibre, total ash and nitrogen-free extract respectively.

quality. The fullness factor is 3.3 on a 0–5 scale, indicating that it provides more essential nutrients per calorie and can be considered a healthy food choice like fish¹³. Another advantage of eating shrimp is its significant lower lipid content. Analysed lipid levels in shrimp were around 1.15 g/100 g. No other meaty food can claim such a low lipid level as fresh shrimp. The lipid class composition of shrimp comprises of 65–70% phospholipids, 15–20% cholesterol and 10–20% total acyl glycerols. The predominance of phospholipids in shrimp lipid indicates its rich nutritional quality, which is an integral part of cell membrane and transport lipoproteins. Furthermore, 32% of shrimp lipid is composed of poly unsaturated fatty acids (PUFA), a term usually associated with high-quality seafood. Within this, about 64% is contributed by ω -3 PUFA and the remaining 33% by ω -6 PUFA, making a ω -6/ ω -3 PUFA ratio around 1.9, indicating high health benefits. The ω -6/ ω -3 PUFA ratio is a critical dietary factor due to its decisive role in balancing the eicosanoid synthesis¹⁴. A healthy diet should have a PUFA/SFA ratio of at least 0.54 and above¹⁵. The shrimps assessed in our study had higher values (> 1.9) than the recommend ratio and are definitely a valuable source of PUFA. Shrimp is also beneficial due to its mild anti-inflammatory nature because of its high selenium, docosahexanoic acid and low saturated fatty acids¹³.

Epidemiological studies revealed that consumption of seafood, including shrimp rich in ω -3 PUFA is associated with a reduced risk of coronary heart diseases^{16,17} and cancer¹⁸. The US Dietary Guidelines recommend that individuals at both higher and average CVD risk consume an average of at least 250 mg/day EPA + DHA (1750 mg/week)¹⁹. Eating 100 g edible portion of shrimp in a day will provide > 180 mg of EPA + DHA. In order to measure the propensity of shrimp-eating in reducing the risks of coronary heart disease, the atherogenic and thrombogenic indices were calculated²⁰. Shrimp exhibited values of 0.36 and 0.29 for atherogenic and thrombogenic indices respectively, which are lower than other non-vegetarian foods, indicating its cardio-protective nature.

Shrimps were also found to be a rich source of astaxanthin, a lipid soluble carotenoid formed from ingested β -carotene or zeaxanthin through oxidative transformation^{5,21}. Astaxanthin has been found to be a potent natural antioxidant, exceeding ten times the antioxidant activity of β -carotene and 500 times that of α -tocopherol⁵. The astaxanthin level of wild shrimps has been reported to vary between 740 and 1400 μ g/100 g in edible meat portions²¹, which again supports the argument for including them as part of the daily diet.

Human diet requires minerals such as calcium, phosphorus, magnesium, potassium and sodium in large amounts and hence these are referred to as macro minerals. A 100 g serving of shrimp provides > 100 mg of calcium, > 300 mg of phosphorus and > 40 μ g of selenium. Among their numerous functions, minerals help regulate the fluid balance,

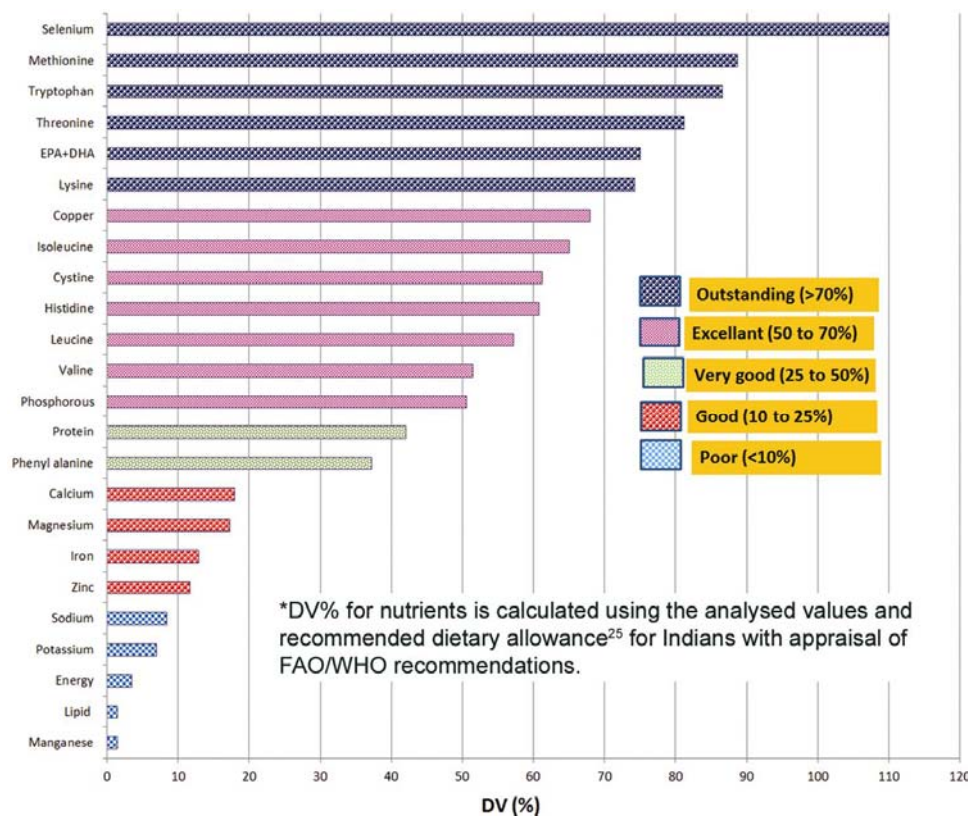


Figure 1. Daily value (DV%)* of one serving (100 g) of shrimp for important nutrients.

enzyme production and bone health. Eating shrimp (100 g/day) would provide approximately ten vitamins and ten minerals. Shrimp contains important vitamins like vitamin A (180 IU), vitamin D (2 IU) and vitamin E (1.32 µg), vitamin B₁₂ (1.11 µg) and vitamin B₃ (1.77 mg)²². All these nutrients are known to exhibit considerable level of variation in relation to molting stage of shrimp²³. Hence the shrimps used for analysis in our laboratory were in post-molt stage. Within the marketable size range, much variation is not observed in macro and micro nutrients. The cultured tiger shrimps were sampled from commercial ponds with standard management culture practices without any disease outbreaks and natural calamities.

Shrimp consumption in relation to RDA of nutrients

The recommended daily allowance (RDA) projects the quantitative recommendation of nutrients for people in general to stay healthy. This may be different for different categories like children, adult males and females. The Indian Council for Medical Research (ICMR) favours the FAO/WHO/UNU guidelines for framing the RDA guidelines, with slight modifications. The RDA for a nutrient will be in a standard unit which helps the common man to

easily calculate his own requirements based on the body weight and/or basal metabolic rate. The RDA can be used to calculate the daily value of foods (DV%). Hundred grams of shrimp has been taken to calculate the DV% that was recommended as serving size of meat²⁴. For example, the RDA of protein is measured as intake/kg body weight, as 0.8 g/kg of individual body weight²⁵. It means that an individual weighing 70 kg would need to take 56 g (0.8 × 70) of protein daily. Considering this RDA, consumption of 100 g shrimp containing 19.4 g protein by an individual weighing 70 kg would fulfil 35% of the daily protein requirement. This is the DV% of 100 g shrimp with respect to protein. Similarly, one can compute the DV% for the nutrients considering the requirement and content of a particular nutrient in the selected food item. Figure 1 shows the calculated DV% for important nutrients in 100 g shrimp for a 70 kg adult man. Using this chart one can obtain a quick assessment for selecting shrimp for his/her meal in a day. When shrimps are scored in the DV% chart of nutrients, the following is observed: DV% > 70 is rated outstanding – selenium, methionine, tryptophan, threonine, EPA + DHA and lysine; DV% 50–70 (excellent) – copper, isoleucine, cystine, histidine, leucine, valine and phosphorous; DV% 25–50 (very good) – protein and phenylalanine; DV% 10–25 (good) – calcium, magnesium, iron and zinc; DV% < 10 (poor) – sodium, potassium, energy, lipid and manganese.

Table 2. Comparison of shrimp, egg and meat* on their cholesterol, saturated fatty acids and atherogenic index

Non-vegetarian food	SFA [@] (g/100 g)	Cholesterol [#] (mg/100 g)	Atherogenic index [§]
Shrimp	0.25	173	0.36
Egg	4.0	400	0.40
Chicken	6.0	100	0.50
Mutton	7.0	65	1.00
Beef	8.0	70	0.70
Pork	13.0	90	0.67
Health significance	Lowest in shrimp; good for health	Moderate in shrimp; but not harmful due to low SFA	Lowest in shrimp; good for health

*Dietary guidelines^{24,25,30}. @Higher saturated fatty acids consumption increases blood cholesterol.

[#]Cholesterol consumption should not be more than 300 mg (USA) per day. [§]Lower atherogenic index is good for a healthy heart.

Dietary cholesterol controversies and shrimp consumption

Cholesterol is an important sterol that plays a prominent role in membrane structure and is also a precursor for the synthesis of steroid hormones and bile acids in man. A relatively constant level of cholesterol in the blood (150–200 mg/dl) is maintained primarily by controlling the level of *de novo* synthesis. The synthesis and utilization of cholesterol must be tightly regulated in order to prevent CVD. Reduction in circulating cholesterol levels can have a profound positive impact on CVD. It is long been presumed that control of dietary intake is one of the easiest means to reduce cholesterol. The cholesterol, SFA and atherogenic indices of shrimp, egg and other non-vegetarian meats are given in Table 2 in relation to the ICMR dietary guidelines²⁵. Though shrimps are adequate in many essential nutrients, their higher cholesterol level and with the consumers' perception of the link between dietary cholesterol and CVD, medical practitioners and dieticians have placed shrimp in avoidable food item ignoring its overall lipid and fatty acid profiles^{6,7}. Moreover, there is no sound scientific evidence to support this assumption, in particular, the relation between shrimp cholesterol level and occurrence of CVD. A clinical trial comparing the serum lipid profile of volunteers who ate shrimp and eggs, concluded that shrimp consumption in normolipidemic people would not adversely affect the overall lipoprotein profile and shrimp can be included in 'heart healthy' nutritional guidelines⁹. A recent review based on epidemiological and clinical studies from the past 20 years, claims that dietary cholesterol does not increase the risk for heart disease in healthy populations¹¹. Studies in support of a direct relationship between dietary cholesterol and increased risk for heart disease are limited, and they mostly demonstrate that diabetic individuals are at risk. Citing this as evidence, withdrawal of RDI of less than 300 mg/day (in USA) of dietary cholesterol was suggested, since this is restricting the consumption of eggs, otherwise a good source of quality protein, carote-

noids and choline. Further evidence was provided by a challenge trial in which adults were allowed to consume 640 mg of daily cholesterol for four weeks. This study identified that in 75% of individuals there was limited or no increase in plasma cholesterol level. However, in 25% of the individuals, there was blood cholesterol elevation consequent to high cholesterol intake. Surprisingly, the increase was observed for both LDL and HDL cholesterol with no changes in the LDL/HDL cholesterol ratio, a key marker of CVD risk¹¹. Consumption of a high-cholesterol diet with high saturated fat results in the increase of LDL level rather than diets with high PUFA²⁶. This indicates the necessity to look at the overall dietary lipid influence on serum lipids rather than cholesterol alone. In another clinical study with type-2 diabetic patients, low-cholesterol beef was replaced with cholesterol-rich poultry meat; 18% reduction in serum total cholesterol was observed. This study also concluded that significant reduction in cholesterol may be due to the higher PUFA and lower SFA proportions in poultry meat compared to beef²⁷. 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 levels²⁸. Another reason to encourage shrimp consumption is the potential association between hypotriglyceridemic ω -3 PUFA and CVD¹⁷, shrimp being an excellent source of EPA + DHA (DV > 70%). It was concluded in a human clinical trial that shrimp when consumed in moderation can play a role in a heart-healthy diet, because it does not markedly affect the ratio of 'good' HDL to 'bad' LDL cholesterol⁹. Therefore, consuming 100 g of shrimp even on a daily basis would only supply less than the RDA (<300 mg/day) of cholesterol. Furthermore, an experiment with hypercholesterolemic rat models documented the cholesterol-lowering effect of the extract of salted and fermented shrimp¹². Another study with a rat model reported the serum lipid-lowering effects of Antarctic krill oil on dietary intake²⁹. Antarctic krill is a small swimming crustacean, which is considered to be the ancestor of shrimp and prawn.

Shrimps have low fat, less cholesterol and high PUFA content compared to eggs, and the current understanding on dietary cholesterol linked with egg consumption clearly confirms the nutritional value of shrimps. Based on the above-mentioned evidences on health-related outcomes, the nutrient profiles analysed in this study and a detailed appraisal of the RDA of national and international agencies, it can be concluded that shrimp can be considered as healthy food for humans. The health benefits of eating shrimp go beyond ω -3 fatty acids and other individual nutrients; it is the effect of the combined nutrients present in shrimp, including proteins, trace minerals and carotenoids. Therefore, to benefit from vital nutrients like ω -3 HUFA, astaxanthin, protein, essential amino acids, vitamins and minerals, a moderate quantity of shrimp should be consumed by people. Only those who are at a clear risk of CVD and diabetics may avoid this, until the dietary cholesterol controversy is settled.

- Food and Agricultural Organization, The State of World Fisheries and Aquaculture, Bi-Annual Report, FAO, Rome, 2012, p. 209.
- The Marine Products Export Development Authority, Marine products exports crossed 3.5 billion mark in 2011–12. Ministry of Commerce, Government of India, Cochin, 2012; <http://www.mpeda.com/press1.pdf>
- Larkin, T., Aquaculture global outlook and sustainability. In 24th Annual North Carolina Aquaculture Development Conference, Raleigh, NC, USA, 2012.
- Dayal, J. S., Ponniah, A. G. and Ambasankar, K., Food value of shrimp. In 9th Indian Fisheries Forum – Renaissance in Fisheries: Outlook and Strategies Souvenir (eds Ramachandran, C. *et al.*), Organized by Asian Fisheries Society (Indian Branch) hosted by Central Marine Fisheries Institute, Chennai, 19–23 December 2011, pp. 1–72.
- Venugopal, V. (ed.), In *Marine Products for Healthcare: Functional and Bioactive Nutraceutical Compounds from the Ocean*, CRC Press, London, 2009, pp. 221–239.
- Robinson, C. H., The low cholesterol, low fat diet. *Am. J. Clin. Nutr.*, 1954, **2**, 353–355.
- Assmann, G. *et al.*, Coronary heart disease: reducing the risk: a worldwide view. *Circulation*, 1999, **100**, 1930–1938; doi: 10.1161/01.CIR.100.18.1930.
- Carney, C., Is shrimp high in cholesterol; http://www.chow.com/facts_5474631_shrimp-high-cholesterol.html
- De Oliveira e Silva, E. R., Seidman, C. E., Tian, J. J., Hudgins, L. C., Sacks, F. M. and Breslow, J. L., Effects of shrimp consumption on plasma lipoproteins. *Am. J. Clin. Nutr.*, 1996, **64**, 712–717.
- Spence, J. D., Jenkins, D. J. A. and Davignon, J., Dietary cholesterol and egg yolks: not for patients at risk of vascular disease. *Can. J. Cardiol.*, 2010, **26**, 336–339.
- Fernandez, M. L., Rethinking dietary cholesterol. *Curr. Opin. Clin. Nutr. Metab. Care*, 2012, **15**, 117–121.
- Seok, S. H., Park, J. H., Cho, S. A., Choi, S. A. and Park, J. H., Cholesterol lowering effect of SG-GN3, the extract of salted and fermented small shrimps, *Acetes japonicus*, in Triton WR-1339 or high cholesterol-diet induced hypercholesterolemic rats. *J. Ethnopharmacol.*, 2004, **91**, 231–235.
- Nutrition Data, Nutrition facts, crustaceans, shrimp, mixed species, cooked, moist heat. <http://nutritiondata.self.com/facts/finfish-and-shellfish-products/4174/2>
- Simopoulos, A. P., The importance of the omega-6/omega-3 fatty acids ratio in cardiovascular disease and other chronic diseases. *Exp. Biol. Med.*, 2008, **233**, 674–688.
- Health Education Authority, Nutritional Aspects of Cardiovascular Disease, Hamilton House, London, 1996, pp. 13–17.
- Kris-Etherton, P. M., Harris, W. S. and Appel, L. J., Fish consumption, fish oil, omega-3 fatty acids and cardiovascular disease. *Circulation*, 2002, **106**, 2747–2757.
- Mozaffarian, D. and Wu, J. H., Omega-3 fatty acids and cardiovascular disease: effects on risk factors, molecular pathways and clinical events. *J. Am. Coll. Cardiol.*, 2011, **58**, 2047–2067.
- Murphy, R. A., Mourtzakis, M. and Mazurak, V. C., $n-3$ Polyunsaturated fatty acids: the potential role for supplementation in cancer. *Curr. Opin. Clin. Nutr. Metab. Care*, 2012, **15**, 246–251.
- US Department of Agriculture and US Department of Health and Human Services. *Dietary Guidelines for Americans*, US Government Printing Office, Washington, DC, December 2010, 7th edn.
- Ulbricht, T. L. and Southgate, D. A. T., Coronary heart diseases: seven dietary factors. *Lancet*, 1991, **338**, 985–992.
- Sachindra, N. M., Bhaskar, N. and Mahendrakar, N. S., Carotenoids in different body components of Indian shrimps. *J. Sci. Food Agric.*, 2005, **85**, 167–172.
- USDA, National Nutrient Database for Standard Reference Release 24. Nutrient Data Laboratory, Beltsville, MD, 2012; http://www.ars.usda.gov/main/site_main.htm?modecode=12-35-45-00
- Chang, E. S., Physiological and biochemical changes during the molt cycle in decapod crustaceans: an overview. *J. Exp. Mar. Biol. Ecol.*, 1995, **193**, 1–14.
- Enser, M., Hallet, K., Hewitt, B., Fursey, G. A. J. and Wood, J. D., Fatty acid content and composition of English beef, lamb and pork at retail. *Food Chem.*, 1996, **42**, 443–456.
- Indian Council of Medical Research, Nutrient requirements and recommended dietary allowances for Indians. ICMR, New Delhi, 2009, p. 334.
- Fielding, C. J., Havel, R. J. and Todd, K. M., Effects of dietary cholesterol and fat saturation on plasma lipoproteins in an ethnically diverse population of healthy young men. *J. Clin. Invest.*, 1995, **95**, 611–618.
- Gross, J. L. *et al.*, Effect of a chicken based diet on renal function and lipid profile in patients with type 2 diabetes. *Diabetes Care*, 2002, **25**, 645–651.
- Schaefer, E. J., Lipoproteins, nutrition, and heart disease. *Am. J. Clin. Nutr.*, 2002, **75**, 191–212.
- Zhu, J. J., Shi, J. H., Qian, W. B., Cai, Z. Z. and Li, D., Effects of Krill Oil on serum lipids of hyperlipidemic rats and human SW480 cells. *Lipids Health Disease*, 2008, **7**, 30.
- Ghafoorunissa and Kamala, K., Diet and Heart Disease. National Institute of Nutrition, Hyderabad, 2007, p. 74.

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