Korean J. Food Sci. An. Vol. 36, No. 5, pp. 577~582 (2016)

DOI http://dx.doi.org/10.5851/kosfa.2016.36.5.577
ISSN 1225-8563 eISSN 2234-246X

REVIEW

Health Implications of Beef Intramuscular Fat Consumption

Declan J. Troy*, Brijesh K. Tiwari, and Seon-Tea Joo[1]
Teagasc Food Research Centre, Ashtown, Dublin 15, Ireland
[1]*Division of Applied Life Science (BK21 Program), Gyeongsang National University, Jinju 52852, Korea*

Abstract

Despite several issues in relation to human health, beef is still a most popular meat product among large section of society due to the presence of high quality protein and other nutrients. The current paper reviews numerous studies that provide nutritional profiles and health implications of high marbled beef consumption. In relation to lipid content of beef, intramuscular fat contains high level of PUFA and MUFA compared to other beef fat. Level and composition of intramuscular fat varies depending on breed and feeding regime. Literature suggests that the marbling is more complex than the development of subcutaneous fat and marbling not only provides good fatty acids but also contributes to the higher eating quality of beef. Finally, the current work emphasize that meat plays a pivotal role in nutritious diets, high quality marbled beef is not only of excellent eating quality but also contain more beneficial fatty acids.

Keywords: beef, Intramuscular fat, Marbling, Fatty acid composition

Received September 6, 2016; Revised September 19, 2016; Accepted September 19, 2016

Introduction

Meat plays an ever increasingly important role in the diets of the world's population. Consumption is growing generally around the globe as major populations become more affluent. A significant increase in consumption of beef has been observed in countries like Korea, Japan, Malaysia, Kuwait, Saudi Arabia, Mexico, Taiwan and Brazil. In general, consumption of beef is heavily and disproportionately concentrated in the industrial countries with an average annual per capita consumption in the range of 6.5-6.7 kg per capita. Argentina is the largest consumer of beef accounting for 40 kg per capita followed by Brazil (25.4 kg per capita) and USA (23 kg per capita) whereas in the EU (28 countries) consumption of beef and calve meat is 10.9 kg per capita based on kilograms of retail weight per capita per annum (Ojha *et al*., 2016). Unlike poultry, cultural and religious factors have implications on consumption trends in some countries. Apart from social factors meat have negative perception in terms of food safety, environmental and health implications. Despite several issues, beef is still a most popular meat product among large section of society.

Like any other meat, beef is an excellent source of high quality protein and contains all essential amino acids. Dietary protein is required for growth, maintenance and repair of the body and can also provide energy. Human requirements for protein have been thoroughly investigated over the years and are currently estimated to be 55 g per day for adult man and 45 g for woman. Average servings of lean beef adequately meet these requirements. It also contains a rich source of many minerals including zinc, iron, selenium, phosphorus, magnesium, potassium and copper. Minerals present in beef are more bioavailable compared to plant sources. Apart from proteins beef also contains high level of lipids. These lipids provide dietary energy and essential nutrients including essential fatty acids. Consumer's concern and awareness centred on consumption of high fat foods including red meat has some effects on the meat consumption pattern. Nutritional value of meat and beef has been reviewed extensively (Cabrera and Saadoun, 2014). Overall, beef is a rich source of proteins with high biological values and other micronutrients. From this perspective, the current paper reviews the scientific literature in health implications of beef intramuscular fat consumption.

*Corresponding author: Declan J. Troy, Teagasc Food Research Centre, Ashtown, Dublin 15, Ireland. Tel: +353-59-917-0200, Fax: +353-59-918-2-97, E-mail: Declan.troy@teagasc.ie

Nutritional Profile of Beef

In October, 2015, 22 scientists from ten countries evaluated the carcinogenicity of the consumption of red meat (unprocessed) and processed meat at the International Agency for Research on Cancer (IARC) (Bouvard *et al.*, 2015) based on 800 epidemiological studies. Epidemiological studies were selected based on the association of cancer with consumption of red meat or processed meat in various countries around the world. The report concluded that the consumption of red meat is probably carcinogenic to humans with strong positive association with pancreatic and prostate cancer. However, the association of meat consumption with cancer was based on epidemiological studies. The IARC report did not include the role of environmental pollutants and processing induced chemical (e.g., N-nitroso-compounds, polycyclic aromatic hydrocarbons and heterocyclic aromatic amines) which are formed as a result of processing (e.g., curing and smoking) at high temperatures or present in raw meat (Domingo and Nadal, 2016). Furthermore, Kurtfield (2015) has recognised there are many limitations of such studies including inability to accurately estimate intake, lack of pre-specified hypotheses, multiple comparisons, and confounding factors – including body weight, fruit/vegetable intake, physical activity, smoking, and alcohol – that correlate significantly either positively or negatively with meat intake and limit the reliability of conclusions from these studies. Nonetheless, despite global attention red meat remains a popular source of protein and has several nutritional benefits.

In addition to the traditional essential nutrients of proteins and lipids, beef meat is a potential source of a number of bioactive substances that have been studied for their potential beneficial effects. These meat-based bioactives include taurine, creatine, conjugated linoleic acid (CLA), carnitine, and several endogenous compounds (Arihara, 2006). Imidazole dipeptides such as anserine and carnosine are antioxidants naturally present in beef and have a role as a metal chelator and free-radical scavenger (Kohen *et al.*, 1988). Although the beef contains low levels of antioxidants and associated antioxidant activity compared to plant foods, presence of certain antioxidants along with high quality proteins is certainly advantageous for health conscious beef consumers. Beef is also rich in many vitamins (e.g., vitamin B12, B6, riboflavin, thiamine and pantothenic acid) and mineral (e.g., zinc, iron, selenium, phosphorus, magnesium, potassium and copper) (Williams, 2007).

Role of nutrients for various health benefits are reported extensively. The nutritional value of macronutrients such as protein, fat, and minerals and its role to integrate as a part of a healthy diet depends on several factors including, the level, composition and their bioavailability. For example, the minerals found in beef are more bioavailable compared to vegetable sources (Hunt, 2003). Half of the iron in meat is present as haem iron (in haemoglobin). This is well absorbed, about 15-35%, a figure that can be contrasted with other forms of iron, such as that from plant foods, at 1-10%. Not only is the iron of meat well absorbed but it enhances the absorption of iron from other sources - e.g., the addition of meat to a legume/cereal diet can double the amount of iron absorbed and so contribute significantly to the prevention of anaemia, which is so widespread in developing countries. The chemical composition of beef is varies not only based on genotype but also on the type of cut (Jung *et al.*, 2015; Jung *et al.*, 2016; Kim *et al.*, 2002). For example, Oh *et al.* (2016) reported the chemical composition of high-preference and low preference cuts of Hanwoo beef (Table 1). Table 1 shows significant variations in chemical compositions of various cuts on dry basis. In general, moisture, protein, lipid, and ash content of various retail cuts of beef varies from 58.5% to 71.3%, 18.8% to 21.8%, 4.9% to 19.4%, and ash 2.3% to 3.1% respectively based on fresh weight basis (Jung *et al.*, 2015).

Nutritional compositions of various cuts and popular beef breeds allow consumer to make choice and may satisfy their health consciousness. However, a judicious balance between the cost of various cuts and nutritious profile is a challenge to promote consumption of beef for profit margins.

Table 1. Chemical composition contents by cut of Hanwoo beef (Oh *et al.*, 2016)

Composition (%)	High preference cut			Low preference cut		
	Loin	Tenderloin	Rib	Brisket	Topside	Shank
Dry matter	36.28 ± 1.42^{b}	41.18 ± 2.51^{a}	35.97 ± 1.51^{b}	30.00 ± 1.01^{c}	29.85 ± 1.77^{c}	29.00 ± 1.36^{d}
Crude protein[1)]	53.20 ± 3.26^{c}	40.01 ± 3.25^{e}	46.94 ± 1.52^{d}	64.68 ± 3.19^{b}	67.27 ± 2.92^{a}	65.09 ± 2.10^{b}
Crude fat[1)]	41.58 ± 3.40^{c}	55.66 ± 4.47^{a}	47.73 ± 2.95^{b}	30.75 ± 3.25^{d}	26.22 ± 3.99^{e}	29.85 ± 1.29^{d}
Crude ash[1)]	4.31 ± 0.76^{b}	3.21 ± 0.55^{b}	2.98 ± 0.38^{b}	6.31 ± 0.89^{a}	6.83 ± 0.91^{a}	6.93 ± 0.99^{a}

[a-e]Values followed by same alphabets are not significantly different. [1)]Dry matter basis.

Lipid Profile of Beef

Presence of high level of lipids in beef has been a topic of discussion for beef consumers because of their associated health implications. In general lipid fraction in beef varies from 4-15% on fresh basis depending on several factors including genotype, feeding regime and meat cut. In recent years, strategies for increasing the level of beneficial fatty acid while reducing saturated fatty acids in beef with particular focus on intramuscular fat has been investigated (Scollan *et al*., 2006).

The relationships between dietary fat irrespective of the food source and their relationship with various incidence of lifestyle diseases including cardiovascular diseases is well established and several health agencies have specific guidelines. According to World Health Organisation (2003) recommendations various dietary fat fractions showed contribute <15-30%, <10%, <5-8%, <1-2% and <1% of total energy intake from total fat, saturated fatty acids, n(6)-polyunsaturated fatty acids, n(3)-polyunsaturated fatty acids and trans fatty acids respectively. In general fatty acid in beef varies depending on the genotype, muscle type and feeding regime (Mapiye *et al*., 2013). Pavan and Duckett (2013) studied fatty acid profile of eight retail cuts (eye of round, ribeye, top round, striploin, tenderloin, top-sirloin, underblade, ground beef) from grass-fed steers. They reported that the total fatty acids on fresh basis ranges from 1.31-11.08 mg/100 g in retail cuts studied with saturated fatty acids, mono unsaturated fatty acids and poly unsaturated fatty acids ranging from 41.49 to 48.95%, 33.92 to 35.86% and 1.99 to 6.87%, respectively. Presence of these long chain n-3 and n-6 poly unsaturated fatty acids in beef samples has been reported for various health benefits and improve maternal and offspring health, growth and development, cognitive function and psychological status in humans (Mapiye *et al*., 2015; Pelliccia *et al*., 2013).

Various nutritional fractions based on beef fats namely total SFA, PUFA, PUFA (n3), PUFA (n6), ratio of PUFA: SFA, PUFA (n3): PUFA (n6) and Atherogenic Index (AI) are becoming increasingly popular to evaluate the nutritional quality of beef fat in regard to the prevention of coronary heart diseases and anticarcinogenic activity (Vannice and Rasmussen, 2014). AI assesses the risk of atherosclerosis and considered as an indicator of impact of fat on the cholesterol concentration. AI is based on those fatty acids (C12:0, C14:0 and C16:0) which can increase or decrease the level of cholesterol. Mathematically, it can be defined as the relationship between key SFA and the total unsaturated fatty acids (Eq. 1) (Nantapo *et al*., 2014; Ulbricht and Southgate, 1991).

$$Atherogenic\ Index\ (AI) = \frac{[C12{:}0 + 4 \times (C14{:}0) + C16{:}0]}{[\Sigma MUFA + \Sigma PUFA]}$$

It is believed that all saturated fatty acids have negative effect on human health due to their hypercholesterolic effect. Research has shown that certain saturated fatty acids (e.g., steric acid, C18:0) have no effect on plasma cholesterol level (Ulbricht and Southgate, 1991). Similarly, some fatty acids trans-11 vaccenic acid (C18:1 trans-11) and their isomers i.e., cis-9, trans-11 of conjugated linoleic acid (CLA cis-9, trans-11) found in beef at varying level are known to have anti-carcinogenic and anti-atherogenic effects (Tricon *et al*., 2005; Turpeinen *et al*., 2002).

Factors Effecting Intramuscular Fat Content in Beef

The total lipid content of muscle is often termed as marbling fat or intramuscular fat. Marbling fat is the speckles of fatty tissues composed mainly of neutral lipids. It consists of clusters of individual cells (adipocytes). Intramuscular adipocytes increase both in number and size in cattle as beef progresses from being “almost absent” to higher marbling scores. Marbling of muscles has a role in eating quality of beef in terms of tenderness and juiciness of cooked meat. Presence of intramuscular fat is one of the important factors associated with the consumer perception of beef eating quality influencing flavour and sensory attribute (Hunt *et al*., 2016). The interaction of muscle with the level of intramuscular fat have shown the effect on consumer ranking of beef flavour (Legako *et al*., 2015). Studies have shown that the composition of intramuscular fat is strongly influenced by both the genotype and production system, including slaughter weight (De la Fuente *et al*., 2009). A plethora of literature is available, demonstrating that grass-fed cattle have higher levels of n(3), MUFA compared to concentrate fed animals (French *et al*., 2000; Nuernberg *et al*., 2005; Realini *et al*., 2004). However, the composition of intramuscular fat is largely influenced by genetic factors compared to dietary factors. Meat fatty acid composition is influenced by genetic factors, although to a lower extent than dietary factors (De Smet *et al*., 2004). Increase in fatness of a given species also has an effect on the fatty acid composition influencing the PUFA/SFA ratio. In the case of beef, as fat content increases the level of SFA and MUFA increases at a much faster rate compared to PUFA (De Smet *et al*., 2004).

Literature reveals that the lipid composition and fatty acid profile of intramuscular fat in beef can be manipulated based on three factors namely (i) genotype, (ii) time on feed and (iii) finishing diet (Wood *et al*., 2008). For example, in a study by Cho *et al*. (2005), fatty acid profiles of 3 muscles (*Longissimus dorsi, Triceps brachii* and *Semimembranosus*) were compared from 24 mon old Korean Hanwoo and Australian Angus beef on different feeding regime. They reported that the Hanwoo beef from cattle raised on concentrate feeding had higher unsaturated fatty acids (C16:1n7, C18:1n7, C18:2n6 and C20:1n9) compared to Angus beef. However, Australian Angus beef had significantly higher n-3 PUFA, whereas Korean Hanwoo beef contained higher n-6 PUFA for the three muscles being studied. To improve the marbling of the Korean beef breed, a grain based feeding system is performed however, this can also cause an increase in the level of subcutaneous and visceral fat, which may lead to inefficient meat production (Lee *et al*., 2008). Hence, recent focus on the identification of genes responsible for the marbling effect in beef is important to enhance beneficial fatty acids while reducing subcutaneous and visceral fat which is mainly saturated fatty acid. Pethick *et al*. (2004) reported that intramuscular fat development within muscle is not late maturing and that the expression of marbling is due to maintained fat synthesis due to energy availability in combination with declining muscle growth as animals get older.

Fatty Acid Profile of Intramuscular Fat

Generally, oleic acid (C18:1) is the most abundant fatty acid in beef followed by palmitic (C16:0) and steric acid (C18:0). Varying the level of α-linoleic acid (C18:3n-3) and conjugated linoleic acid (C18:2cis-9, trans-11) has been reported (Smith *et al*., 2004). Literature review highlights that the intramuscular fat contains high level of PUFA and MUFA compared to other fats in beef. Insausti *et al*. (2004) studied the fatty acid composition of five Spanish cattle breeds (Asturiana de los Valles, Morucha, Parda Alpina, Pirenaica, and Retinta). They observed that the intramuscular fat contains higher PUFA/SFA ratio and demonstrated the presence of long chain fatty acids with an increase in intramuscular fat. It can be concluded that an increase in intramuscular fat showed an increase in the level of long chain PUFA (e.g., C22:6n-3 and C20:5n-3) may not always involve higher SFA. Marbling fat contains more oleic acid and less stearic acid than subcutaneous adipose which effects not only the palatability of beef but also has a positive health aspect.

Health Implications of Beef Consumption with High Degree of Marbling

Beef remains a highly valued, nutritious food and associated with good health and prosperity. It contains valuable nutritious components discussed above. Health professionals' recommendation to reduce the overall consumption of fats and the diet-heart (lipid) hypothesis focussed attention on the saturated fat contributed from meat. A number of epidemiological studies have proposed an association of red meat consumption with development of cardiovascular disease (CVD) and colon cancer. However cause and effect with regard to a direct relationship to many of these studies remains unproven.

Factors such as the inability to accurately measure intake, identification of the proposed causative agents, lifestyle of the subjects greatly limits the reliability of the conclusions of these studies. However different strategies are being developed by producers and processors, aiming to reduce fat level in beef. These approaches include selective breeding and feeding practices designed to increase the carcass lean to fat ratio; improved official carcass classification systems designed to favour leaner production; and modern butchery techniques (seaming out whole muscles, and trimming away all intermuscular fat). Research over past few decades suggests that grass-only diets can significantly alter the fatty acid composition and improve the overall antioxidant content of beef. Grass feeding improves the quality of beef, and makes the beef richer in omega-3 fats, vitamin E, beta-carotene, and CLA. There is tremendous potential to enhance health benefits of beef by the production of high-quality beef from better-bred animals with superior genetics and improved nutritional profile via better feed management.

In the US, Smith and Johnson (2014) produced a "white paper" citing that as the concentration of intermuscular fats in beef loins increased the amount of MUFAs increased also. In particular, an increase in the healthier oleic acid was observed at the expense of SFAs in USDA Select beef (less marbled) and the MUFA / SFA ratio was 0.75 compared with 1.33 in the USDA Prime beef (more marbled). The conclusion being that a more marbled beef cut (especially the brisket) is healthier. The results of this study are very positive for producers and consumers of high marbled beef animals but the authors observe that further studies especially across different breeds is required to substantiate this hypothesis.

Conclusions

Despite several issues centred around safety of raw and processed beef, enjoys popularity among various segments due to the presence of high quality protein and other nutrients. In relation to lipid content of beef, intramuscular fat contains high level of PUFA and MUFA compared to other beef fat. Level and composition of intramuscular fat varies depending on breed and feeding regime. Literature suggests that the marbling is more complex than the development of subcutaneous fat and marbling not only provides good fatty acids but also contributes to the higher eating quality of beef. Most studies conclude that meat plays a pivotal role in nutritious diets, high quality marbled beef is not only of excellent eating quality but may also contain more beneficial fatty acids. In any case a healthy lifestyle will include a well-balanced diet including meat and regular exercise.

References

1. Arihara, K. (2006) Strategies for designing novel functional meat products. *Meat Sci.* **74**, 219-229.
2. Bouvard, V., Loomis, D., Guyton, K. Z., Grosse, Y., Ghissassi, F. E., Benbrahim-Tallaa, L., Guha, N., Mattock, H., and Straif, K. (2015) Carcinogenicity of consumption of red and processed meat. *Lancet Oncol.* **16**, 1599-1600.
3. Cabrera, M. C. and Saadoun, A. (2014) An overview of the nutritional value of beef and lamb meat from South America. *Meat Sci.* **98**, 435-444.
4. Cho, S., Park, B., Kim, J., Hwang, I., Kim, J., and Lee, J. (2005) Fatty acid profiles and sensory properties of Longissimus dorsi, Triceps brachii, and Semimembranosus muscles from Korean Hanwoo and Australian Angus beef. *Asian Australas. J. Anim. Sci.* **18**, 1786-1793.
5. De la Fuente, J., Díaz, M. T., Álvarez, I., Oliver, M. A., Font i Furnols, M., Sañudo, C., Campo, M. M., Montossi, F., Nute, G. R., and Cañeque, V. (2009) Fatty acid and vitamin E composition of intramuscular fat in cattle reared in different production systems. *Meat Sci.* **82**, 331-337.
6. De Smet, S., Raes, K., and Demeyer, D. (2004) Meat fatty acid composition as affected by fatness and genetic factors: A review. *Anim. Res.* **53**, 81-98.
7. Domingo, J. L. and Nadal, M. (2006) Carcinogenicity of consumption of red and processed meat: What about environmental contaminants? *Environ. Res*. **145**, 109-115.
8. French, P., Stanton, C., Lawless, F., O'riordan, E., Monahan, F., Caffrey, P., and Moloney, A. (2000) Fatty acid composition, including conjugated linoleic acid, of intramuscular fat from steers offered grazed grass, grass silage, or concentrate-based diets. *J. Anim. Sci.* **78**, 2849-2855.
9. Hunt, J. R. (2003) Bioavailability of iron, zinc, and other trace minerals from vegetarian diets. *Am. J. Clin. Nutr.* **78**, 633S-639S.
10. Hunt, M. R., Legako, J. F., Dinh, T. T. N., Garmyn, A. J., O'Quinn, T. G., Corbin, C. H., Rathmann, R. J., Brooks, J. C., and Miller, M. F. (2016) Assessment of volatile compounds, neutral and polar lipid fatty acids of four beef muscles from USDA Choice and Select graded carcasses and their relationships with consumer palatability scores and intramuscular fat content. *Meat Sci.* **116**, 91-101.
11. Insausti, K., Beriain, M., Alzueta, M., Carr, T., and Purroy, A. (2004) Lipid composition of the intramuscular fat of beef from Spanish cattle breeds stored under modified atmosphere. *Meat Sci.* **66**, 639-646.
12. Jung, E. Y., Hwang, Y. H., and Joo, S. T. (2015) Chemical components and meat quality traits related to palatability of ten primal cuts from Hanwoo carcasses. *Korean J. Food Sci. An*. **35**, 859-866.
13. Jung, E. Y., Hwang, Y. H., and Joo, S. T. (2016) Muscle profiling to improve the value of retail meat cuts. *Meat Sci.* **120**, 47-53.
14. Kim, J., Cheon, Y., Jang, A., Min, J., Lee, S., and Lee, M. (2002) Determination of physico-chemical properties and quality attributes of Hanwoo beef with grade and sex. *J. Anim. Sci. Tech. 44*, 599-606.
15. Kohen, R., Yamamoto, Y., Cundy, K. C., and Ames, B. N. (1988) Antioxidant activity of carnosine, homocarnosine, and anserine present in muscle and brain. *Proc. Natl. Acad. Sci.* **85**, 3175-3179.
16. Kurtfield, D. M. (2015) Research gaps in evaluating the relationship of meat and health. *Meat Sci.* **109**, 86-95.
17. Lee, S.-H., Cho, Y.-M., Lee, S.-H., Kim, B.-S., Kim, N.-K., Choy, Y.-H., Kim, K.-H., Yoon, D., Im, S.-K., and Oh, S.-J. (2008) Identification of marbling-related candidate genes in *M. longissimus dorsi* of high- and low-marbled Hanwoo (Korean native cattle) steers. *BMB Reports* **41**, 846-851.
18. Legako, J., Brooks, J., O'Quinn, T. G., Hagan, T., Polkinghorne, R., Farmer, L., and Miller, M. (2015) Consumer palatability scores and volatile beef flavor compounds of five USDA quality grades and four muscles. *Meat Sci.* **100**, 291-300.
19. Mapiye, C., Aalhus, J. L., Turner, T. D., Rolland, D. C., Basarab, J. A., Baron, V. S., McAllister, T. A., Block, H. C., Uttaro, B., Lopez-Campos, O., Proctor, S. D., and Dugan, M. E. R. (2013) Effects of feeding flaxseed or sunflower-seed in high-forage diets on beef production, quality and fatty acid composition. *Meat Sci.* **95**, 98-109.
20. Mapiye, C., Vahmani, P., Mlambo, V., Muchenje, V., Dzama, K., Hoffman, L., and Dugan, M. (2015) The trans-octadecenoic fatty acid profile of beef: Implications for global food and nutrition security. *Food Res. Int.* **76**, 992-1000.
21. Nantapo, C. T. W., Muchenje, V., and Hugo, A. (2014) Atherogenicity index and health-related fatty acids in different stages of lactation from Friesian, Jersey and Friesian × Jersey cross cow milk under a pasture-based dairy system. *Food Chem.* **146**, 127-133.
22. Nuernberg, K., Dannenberger, D., Nuernberg, G., Ender, K., Voigt, J., Scollan, N., Wood, J., Nute, G., and Richardson, R. (2005) Effect of a grass-based and a concentrate feeding sys-

tem on meat quality characteristics and fatty acid composition of longissimus muscle in different cattle breeds. *Livest. Prod. Sci.* **94**, 137-147.

23. Oh, M., Kim, E.-K., Jeon, B.-T., Tang, Y., Kim, M. S., Seong, H.-J., and Moon, S.-H. (2016) Chemical compositions, free amino acid contents and antioxidant activities of Hanwoo (Bos taurus coreanae) beef by cut. *Meat Sci.* **119**, 16-21.
24. Ojha, K. S., Tiwari, B. K., Kerry, J. P., and Troy, D. (2016) Beef. In: *Encyclopedia of Food and Health.* Academic Press, Oxford, pp. 332-338.
25. Pavan, E. and Duckett, S. K. (2013) Fatty acid composition and interrelationships among eight retail cuts of grass-feed beef. *Meat Sci.* **93**, 371-377.
26. Pelliccia, F., Marazzi, G., Greco, C., Franzoni, F., Speziale, G., and Gaudio, C. (2013) Current evidence and future perspectives on n-3 PUFAs. *Int. J. Cardiol.* **170**, S3-S7.
27. Pethick, D. W., Harper, G. S., and Oddy, V. H. (2004) Growth, development and nutritional manipulation of marbling in cattle: A review. *Aust. J. Exp. Agr*. **44***,* 705-715.
28. Realini, C., Duckett, S., Brito, G., Dalla Rizza, M., and De Mattos, D. (2004) Effect of pasture vs. concentrate feeding with or without antioxidants on carcass characteristics, fatty acid composition, and quality of Uruguayan beef. *Meat Sci.* **66**, 567-577.
29. Scollan, N., Hocquette, J.-F., Nuernberg, K., Dannenberger, D., Richardson, I., and Moloney, A. (2006) Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. *Meat Sci.* **74**, 17-33.
30. Smith, S., Smith, D., and Lunt, D. (2004) Chemical and physical characteristics of meat: Adipose tissue. *Encyclopedia Meat Sci.* 225-238.
31. Smith, S. S. and Johnson, B. J. (2014) Marbling: Management of cattle to maximize the deposition of intramuscular adipose tissue. White Paper: Product quality. Publ.: Cattleman's Beef Board and National Cattlemen's Association, US.
32. Tricon, S., Burdge, G. C., Williams, C. M., Calder, P. C., and Yaqoob, P. (2005) The effects of conjugated linoleic acid on human health-related outcomes. Proceed. 64^{th} Nutrition Society, pp. 171-182.
33. Turpeinen, A. M., Mutanen, M., Aro, A., Salminen, I., Basu, S., Palmquist, D. L., and Griinari, J. M. (2002) Bioconversion of vaccenic acid to conjugated linoleic acid in humans. *Am. J. Clin. Nutr.* **76**, 504-510.
34. Ulbricht, T. L. V. and Southgate, D. A. T. (1991) Coronary heart disease: Seven dietary factors. *Lancet* **338**, 985-992.
35. Vannice, G. and Rasmussen, H. (2014) Position of the academy of nutrition and dietetics: Dietary fatty acids for healthy adults. *J. Am. Nutr. Diet.* **114**, 136-153.
36. Williams, P. (2007) Nutritional composition of red meat. *Nutr. Diet.* **64**, S113-S119.
37. Wood, J., Enser, M., Fisher, A., Nute, G., Sheard, P., Richardson, R., Hughes, S., and Whittington, F. (2008) Fat deposition, fatty acid composition and meat quality: A review. *Meat Sci.* **78**, 343-358.