Strategies for Optimising the Fatty Acid Composition of Beef

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Fat in meat provides essential fatty acids and vitamins to the consumer and plays a critical role in the sensory perception of juiciness, flavour and texture. However, there is a perception among consumers that red meat, in particular beef, is a food with a high fat content and is considered to contribute towards certain human diseases because of the belief that it has a high proportion of saturated fatty acids. The Department of Health has recommended a reduction in the intake of saturated fats and an increase in the intake of unsaturated fatty acids, and in particular the omega-3 polyunsaturated fatty acids (n-3 PUFA), because they are known to be beneficial to human health. These factors have provided an impetus to develop strategies to alter the total fat concentration of beef and the fatty acid composition of the fat to be more compatible with consumer requirements.

Fat content of beef

The fat content of beef varies with the choice of cut or beef product, the animal (genetic) and the production system. The fat may be present as intermuscular fat (between the muscles), intramuscular fat (marbling, i.e. within the muscles) and subcutaneous fat (under the skin). Most of the fat is present as triglycerides, but phospholipids, cholesterol and fatty acid esters are also present. The beef industry has made excellent progress in reducing the fat content of beef as a result of changes in breeding and feeding practices and modern butchery techniques. Beef produced during recent research at IGER had a marbling fat concentration ranging from 20-50 g/kg (Figure 7.1). This lean beef could be considered as a low fat food.

Fatty acid composition of beef

Intramuscular fat typically consists of saturated fatty acids (SFA, approximately 47%), monounsaturated fatty acids (MUFA, 42%) and PUFA (4% of total fatty acids). Of the total SFA, 30% is represented by stearic acid (C18:0) which is considered to be neutral in its effect on plasma cholesterol in humans. The PUFA within beef contains considerable amounts of n-3 PUFA, particularly α-linolenic (C18:3n-3) and the longer chain PUFA, eicosapentaenoic acid (EPA; C20:5n-3) and, docosahexaenoic acid (DHA; C22:6n-3). Beef contributes significantly to man’s intake of the important fatty acids EPA and DHA, of which there are few rich sources apart from oily fish. These fatty acids are not incorporated into triacylglycerols (storage fat) to any significant extent in ruminants. Our studies have shown that they are mainly found in membrane phospholipids and hence predominantly in muscle. This is important since it provides the opportunity to alter intramuscular fatty acid composition of beef without altering total fat content.

Figure 7.1. Intramuscular fat concentration of beef (Belgian Blue data courtesy of the University of Ghent. DM = double-muscled)
Two important nutritional indices are frequently used to describe the fatty acid composition of foods. The first is the ratio of PUFA : SFA (P:S), where values of 0.4 are considered optimum. The P:S ratio for beef is typically low at around 0.1, except for double-muscled animals which are very lean (<1% intramuscular fat) where P:S ratios are typically 0.5-0.7. Our recent studies have demonstrated a strong relationship between total intramuscular fat content and P:S ratio (Figure 7.2). The second index is the ratio of the n-6:n-3 fatty acids (usually expressed as the ratio of essential fatty acids C18:2n-6 (linoleic acid) : C18:3n-3 (linolenic acid), where values of less than 4 are considered optimum. The n-6:n-3 ratio for beef is beneficially low, typically less than 3. In our studies we have been specifically interested in methods of increasing the P:S ratio and lowering the n-6:n-3 ratio by increasing the content of beneficial n-3 PUFA.

**Important sources of dietary fatty acids**

The most important method of manipulating the fatty acid composition of beef is by changing dietary ingredients which are known sources of long chain PUFA. These include forages and a range of oils and oil seeds. Grass is an important feed source for beef animals across the UK and it is beneficial that the main fatty acid in grass is $\alpha$-linolenic acid (approximately 60%, Figure 7.3). Oilseeds differ widely in the fatty acid composition of their lipid but usually one fatty acid is predominant. Rapeseed, soybean and linseed are rich in oleic, linoleic and linolenic acids, respectively, and feeding animals on these products generally results in increases in the corresponding fatty acid in beef. Fish oils are rich in the long chain PUFA, EPA and DHA. However, the way in which the lipid is offered to the animal (for example, as the oil or whole oilseed) can have a major effect on the degree of response.

**Feed effects on fatty acids in beef**

In feeding trials with beef animals, providing a grass diet, in comparison with concentrates (based on barley, molasses, soya), increased the proportions of n-3 PUFA (C18:3n-3, C20:5n-3, C22:5n-3 and C22:6n-3) in the intramuscular lipid of longissimus.
dorsi muscle (Figure 7.4) and also reduced the proportion of saturated C16:0. It is particularly noteworthy that feeding a diet rich in the “building block” for the n-3 series, C18:3n-3, not only increased C18:3n-3 in beef muscle but also the longer chain EPA and DHA. Studies in an IGER co-ordinated, EU-funded project have demonstrated that the response to grass feeding is time dependent. Typical P:S and n-6:n-3 ratios for grass-fed beef are 0.1 and 1.5, respectively.

Linseed is also a rich source of $\alpha$-linolenic acid and when included as part of a concentrate feed also results in beneficial improvements in the content of n-3 PUFA in beef muscle and reduces the n-6:n-3 ratio. However, in most studies to date it has proved difficult to significantly increase the P:S ratio.

Rumen metabolism and use of ruminally protected lipids

Our research has confirmed the extensive degree of lipolysis (fat breakdown) and biohydrogenation (conversion of unsaturated to saturated) of dietary lipids in the rumen. Biohydrogenation of dietary C18:2n-6 and C18:3n-3 is high, typically 80-92%, and so the beneficial changes noted when feeding grass or linseed result from only small amounts of these fatty acids appearing at the muscle. This process of biohydrogenation is the main reason why it is difficult to have major positive shifts in the P:S ratio. However, the use of ruminally protected lipids (PLS), which allow unsaturated fats to bypass the rumen, has a very beneficial effect on P:S ratio (Figures 7.5 and 7.6). This highlights the role of the rumen in modifying dietary fatty acids and emphasises the importance to our current research programme of understanding the mechanisms of lipolysis and biohydrogenation.

Breed effects on fatty acids in beef

Breeds may also differ in the fat composition of beef. We have compared Holstein-Friesian (dairy) v. Welsh Blacks (traditional beef animals) and found that total muscle fatty acids were higher in Holstein-Friesians than Welsh Blacks. The content of the beneficial PUFA, EPA, was 20% higher in Welsh Blacks. When expressed as a proportion of the total fatty acids, n-3 linolenic acid as well as EPA was higher in the Welsh Black, resulting in improved P:S and n-6:n-3 ratios.

Effects on meat appearance and flavour

Altering the fatty acid composition of beef can alter meat quality by providing a different mix of reactive ingredients in the beef, which affect oxidative stability (shelf life), colour and flavour. Increasing the levels of PUFA in meat may sometimes lead to accelerated colour changes from red to brown, due to oxidative changes. Grass feeding, in comparison to concentrate feeding, enhanced not only n-3 PUFA in the meat but reduced the oxidative changes during retail display and slowed colour deterioration. This was related to the delivery of beneficial $\alpha$-tocopherol (vitamin E) from the grass diet through to the meat.

We know that the fatty acid composition of muscle lipids has important consequences for meat flavour, because lipid degradation products, such as aldehydes, participate in the flavour forming reactions which occur during cooking. For example, we have shown that fish oil not only increased the content of n-3 PUFA EPA and DHA but also...
produced the greatest oxidative lipid changes in meat, and this coincided with generally negative comments on odour and flavour from a taste panel. However, in comparison, taste and appearance were good in meat derived from animals fed on concentrates containing linseed, with a high concentration of $\alpha$-linolenic acid and medium levels of EPA and DHA.

**Conclusions**

Beef can be produced that is low in fat, has a lower concentration of SFA (which can lead to fatty degeneration of the arteries), higher MUFA and PUFA concentrations, higher P:S ratio and lower n-6:n-3 PUFA ratio than was possible previously. Our current and future research seeks to further enhance the beneficial fatty acid profile of beef. An important part of this research also involves communication with consumers and health professionals in the important role that meat has to play as part of a healthy balanced diet.

These studies are conducted in conjunction with the University of Bristol.

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*Figure 7.6  Effect of feeding a ruminally protected lipid supplement (PLS)*