MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

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Fat composition of beef & sheepmeat: opportunities for manipulation

- **The fatty acid composition of fat from cattle and sheep varies considerably.**
- **Beef is known to have contents of mono-unsaturated and polyunsaturated fatty acids that are beneficial to human nutrition.**
- **Various factors such as species, breed, diet and age are known to have influence on composition; however, some are inadequately understood.**
- **There are opportunities for differentiating meat and tallow for marketing—based on the superior properties of the fat they contain, if gaps in current knowledge are clarified.**

The fat in the muscle and adipose tissue of beef and sheep meat contains combinations of saturated (SFA), mono-unsaturated (MUFA) and polyunsaturated (PUFA) fatty acids. In beef, SFA range from 30 to 50%, MUFA 35 to 60% and PUFA 1.5 to 4%. In lamb and mutton the ranges of SFA, MUFA and PUFA are, respectively, 40 to 55%, 35 to 45% and 1.5 to 7%.

The respective proportions of the three classes influence the physical and nutritional properties of the fat. The most notable physical effect is on fat hardness: fat is harder when the proportions of unsaturated fatty acids—MUFA and PUFA—relative to SFA are lower. Marbling fat that contains higher levels of saturated fat with an elevated solidification point will be more evident at chiller temperature than fat with a lower solidification point.

Various ratios have been used to express the profiles of fat including PUFA/SFA, MUFA/PUFA/SFA, and MUFA/SFA. The most widely quoted ratios are PUFA/SFA and MUFA/PUFA/SFA. Human foods containing significant quantities of PUFA are widely considered to be beneficial to health, particularly in reducing the risk of cardiovascular disease; however, as is discussed later in this article, oleic acid—the major MUFA in beef and sheep meat—is becoming more widely recognised as a dietary influence on metabolic disease in humans. As a consequence, other ratios are increasingly being used in scientific literature.

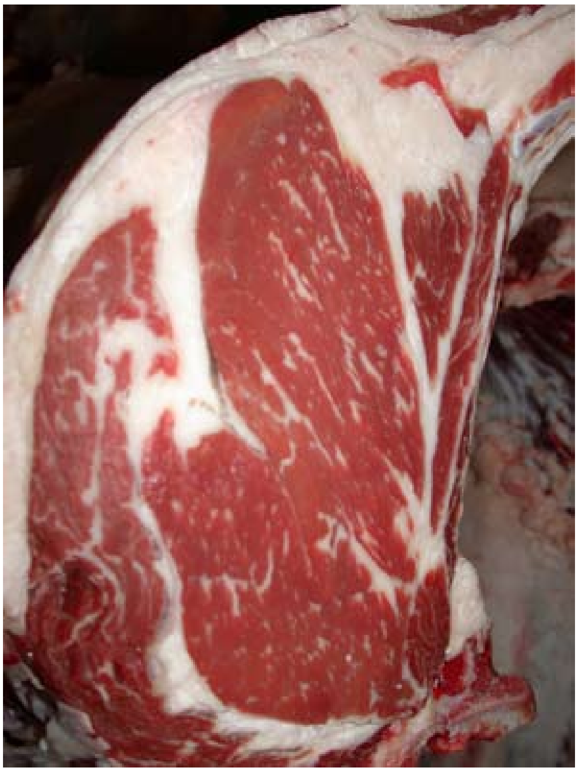

Figure 1. Composition of fat influences its physical and nutritional properties

Fat composition

Fat tissue is made up of fat cells embedded in a matrix of connective tissue. Triglycerides within fat cells make up about 85% of the fat tissue. Each triglyceride is made up of three fatty acids; the three can be any of many combinations of saturated, mono-unsaturated and polyunsaturated acids. Connective tissue and other protein makes up around 3% of the fat tissue, with water the remainder—around 12%.

Six different fatty acids predominate in the fat of cattle and sheep (See Table 1—page 2).

Meat processors are well aware that fat from deep body tissues, such as kidney fat, are generally much harder at

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specific chiller temperatures than subcutaneous fat. As will be discussed below, the composition of fat varies between depots.

Table 1. Predominant fatty acids in cattle and sheep

Fatty acid	SFA/MUFA/ PUFA	Percentage Beef	Percentage Sheep	Melting Point (°C)
Myristic (C14:0)	SFA	2–4	2.5–4	53
Palmitic (C16:0)	SFA	22–28	22–27	63
Palmitoleic (C16:1)	MUFA	1–12	1–2	0
Stearic (C18:0)	SFA	4–30	17–30	70
Trans-vaccenic (C18:1)	MUFA	1–12	0.3–4	45
Oleic (C18:1)	MUFA	35–50	19–31	16
Linoleic (C18:2)	PUFA	1–2	2–4	-9

In adipose tissue, by far the predominant class of lipid or fat is triglyceride, sometimes referred to as triacyl-glycerol or neutral lipid. In muscle, on the other hand, a significant proportion is phospholipid which, in order to function as a constituent of cellular membranes, has a higher PUFA content than does adipose tissue.

Fatty acid composition and fat hardness

Grain feeding has become widespread because it improves fat colour and leads to greater product uniformity. It also sometimes results, though, in an increase in hardness of the fat—in Australia at least. Lot-fed cattle, particularly those destined for the Japanese market, produce carcases of 300 to 400 kg. Because of their size and the feeding regime the cattle have been on, the carcases can have fat that is thick and hard.

One measure of the hardness of fat is by a slip-point test where melted fat is run into a blood haematocrit tube by capillary action, then held at about 3°C overnight. For measurement of slip-points, the tubes are immersed in a water bath and the temperature is raised at about 1°C per minute until slipping occurs. Test results on fat samples collected in Japan and Australia illustrate the variation that is observed.

	Average slip-point (°C)
Wagyu (Japan)	22.3
Dairy (Japan)	28.7
Murray Grey (Japan)	28.4
Murray Grey (Aust.)	38.2
Long-term cotton seed fed (Aust.)	45.1

Several studies have demonstrated a clear direct relationship between the content of stearic acid in the fat and fat hardness: as the content of stearic acid increases, so does the fat hardness. Japanese black cattle have been reported to have adipose tissue with as little as 8% stearic acid whereas samples from long-fed Australian cattle have had up to 30%. Angus and other British-breed cattle raised in feedlots in North America consistently produce carcases with softer fat than similar cattle in Australia. A difference in diet is thought to be the main reason.

Certain *trans* fatty acids, notably vaccenic acid, are sometimes found in significant amounts in beef fat. Although mono-unsaturated—like oleic acid (*cis* form)—the melting point of vaccenic acid is almost 30°C higher than oleic acid. *Trans* fatty acids are formed in the rumen by the partial hydrogenation of polyunsaturated acids by certain microflora. While more recent studies have identified these trans acids separately from oleic, older studies did not. These fatty acids (vaccenic particularly) should be distinguished from those *trans* fatty acids that are formed by chemical hydrogenation of plant oils and which have been identified as posing some risk to health.

Rumen micro-organisms are also thought to influence whether there is an increase in the proportion of saturated acids when whole cotton seed is included in cattle feed. Inclusion of cotton seed, which contains significant quantities of cyclopropenoid fatty acids, is thought to sometimes lead to very hard fat due to the inhibition of an enzyme, fatty acyl desaturase, that converts some saturated fatty acids to unsaturated ones (e.g. stearic to oleic).

Fatty acid composition and marbling

Generally the composition of marbling fat is similar to subcutaneous fat from the same animal, but the marbling fat always contains a higher percentage of stearic acid. More than 90% of marbling fat cells are comprised of triglyceride lipids. In the live animal, or in warm meat, they are in a melted state and the fat cells are not clearly visible. With carcase chilling, the fat crystallises and becomes opaque and visible against the red lean tissue. As the content of stearic acid increases towards 30%, the amount of high melting point lipid increases dramatically.

For meat from different carcases having identical fat contents, there may be large differences in the visual appearance of marbling. If the marbling scores of carcases are determined before the marbling fat has fully solidified, there will be an underestimation of the extent of marbling. Carcases in which the marbling lipids have a lower melting point and, therefore, need to cool more for marbling to be fully visible, will be assessed as having a lower marbling score than other carcases if they are assessed before they have fully cooled—as may well be the case after overnight chilling of carcases. Such carcases will benefit from being chilled for two days, the common practice in the USA.

Fatty acid composition and human nutrition

The benefits of polyunsaturated fatty acids in human diets have been much talked and written about. Omega-3 fatty acids are essential to healthy growth and development. Omega-3 fatty acids (e.g. alpha-linolenic acid or ALA) come from plant sources. Long-chain omega-3 fats (e.g. eicopentaenoic acid or EPA, and docosahexanoic acid or DHA) from fish can reduce sudden death from heart attack by about 45%. Fish is the best source. After fish, the second largest source of long-chain omega-3 fatty acids is red meat. The omega-6 fatty acid, linoleic acid, is also essential. While various vegetable oils are good sources, linoleic acid is present in fat from cattle and sheep as can be seen from the table.

While various researchers have concluded that dietary saturated fatty acids elevate serum cholesterol concentrations, not all saturated fatty acids have the same effect. Stearic acid, one of two major saturated fatty acids in beef, has been found to have a neutral effect on serum cholesterol.

There is a growing body of information to indicate that increasing the intake of oleic acid, the major mono-unsaturated fatty acid in beef, also reduces risk factors for metabolic disease in humans; for this reason the ratio of mono-unsaturated fatty acid to saturated fatty acid (MUFA/SFA) is being used increasingly. It is the overall ratio of the meat (lean tissue plus adipose tissue) that is important. Oleic acid is also the predominant fatty acid in unprocessed olive and canola oils.

Purified oleic acid, olive oil, and canola oil have been shown to lower LDL-cholesterol in humans without affecting the beneficial HDL-cholesterol, the effect being most pronounced in studies in which olive oil was used to supplement diets with oleic acid.

In the US, domestic ground beef that contains 30% fat normally has a ratio MUFA:SFA ranging from 0.8 to around 0.95; however, studies undertaken by Texas A & M University scientists show the ratio can be around 1.30 or higher in other ground beef, e.g. that from Wagyu or from British breeds fed specific rations. Their studies show that increasing MUFA in ground beef leads to a significant increase in the beneficial HDL cholesterol in men. They also show that consumption of such ground beef leads to an increase in particle size of LDL cholesterol which has been reported previously to reduce its harm. The effect is more pronounced in men consuming high-oleic beef. The researchers have concluded from their ongoing study that consumption of high MUFA beef increases HDL cholesterol and LDL particle diameter—both beneficial influences. The outcomes of further studies in this area will be of great interest to both meat industry people and human nutritionists.

Why does fatty acid composition vary?

Factors that influence fatty acid composition of beef fat

Location in carcase

Fat in peripheral parts of the carcase, e.g. legs, is softer. The proportion of MUFA is consistently higher in subcutaneous fat tissue than in either intramuscular fat or deep body intermuscular depots. This is reflected in subcutaneous fat being softer at any particular temperature than at other locations. The MUFA:SFA ratio in intramuscular fat is lower than in subcutaneous fat. Internal body fat, e.g. kidney fat, is harder than intermuscular and subcutaneous fat.

Importantly, any production practice that increases the MUFA:SFA ratio in intramuscular fat results in an increase in marbling. As mentioned earlier; however, if they are scored for marbling after minimal chilling, carcases in which the marbling fat has a lower solidification point will be given lower scores.

Species, breed

In ruminants, the PUFA linoleic acid which is at high levels in many concentrate feeds (grains and oilseeds) is converted in the rumen to, mainly, mono-unsaturated and saturated fatty acids. Normally, only about 10% of dietary linoleic acid is available for incorporation into tissue lipids. By contrast, in pigs linoleic acid does not undergo significant conversion and, therefore, they have rather higher proportions of linoleic acid in both muscle and subcutaneous tissue than do cattle and sheep.

The difference between Japanese Wagyu and other breeds is well documented. The fat of Wagyu frequently has stearic acid at less than 10% and the MUFA:SFA ratio has been reported to be as high as 1.7. Within European breeds there are differences (e.g. Murray Grey steers seem to have harder fat), reasons for which are poorly understood. There are also differences between cross-breeds of Bos Indicus and Bos Taurus cattle; these are also poorly understood. The differences may be due to differences in activity of the enzyme $\Delta 9$ desaturase which converts saturated fatty acids to mono-unsaturated fatty acids.

There are also differences between sheep breeds. For instance, in common with other species, those sheep breeds with leaner carcases have low concentrations of total lipid in muscle. The phospholipid in those carcases is a higher proportion of the total lipid, meaning that lean carcases have higher proportions of PUFA than those breeds with fatter carcases.

Animal age, gender, geographical source

The fat content of an animal and the meat increases with age. $\Delta 9$ desaturase activity and MUFA appear to increase with age. In a trial in which British cattle were fed a concentrate ration between 14 and 24 months of age, the carcase fat greatly increased, the proportion of oleic acid in subcutaneous adipose tissue increased and the proportion of stearic acid decreased. Cows have higher MUFA:SFA ratios than steers; this may be a combined gender and age effect.

Subcutaneous fat in cattle of a particular breed that are sourced from cooler climates is likely to be softer than the fat in cattle from warmer areas, reflecting elevated proportions of MUFA and PUFA. In British work, lamb subcutaneous fat sampled during the year displayed a seasonal variation for slip-point from 30°C to 49°C, being lowest in spring and summer.

Diet, feeding practices

Despite the conversion of unsaturated fatty acids in the rumen mentioned earlier, diet can influence the levels of MUFA and PUFA in adipose tissue and muscle. Scientific trials in the US have shown that corn-fed Angus cattle have higher MUFA and PUFA than hay-fed Angus. Corn-fed Angus can have higher MUFA than hay-fed Wagyu.

The $\Delta 9$ desaturase activity appears to increase with time on feed—the more so on some rations than others. Fatty acids typically become less saturated between weaning and slaughter in cattle on corn-fed diets, but not on hay-fed diets, and not necessarily on Australian grain diets.

Several studies have shown that PUFA can be incorporated into muscle of cattle and sheep despite the rumen biohydrogenation of fatty acids in feeds. For instance, a British study showed that linoleic acid was higher in the phospholipid of *longissimus* muscle when a concentrate ration was fed to two breeds of steers—Aberdeen-Angus cross and Holstein-Friesian—than if grass silage was fed. When the diets were fed from 6 months of age, the proportion of linoleic acid in the lipid was highest when the steers were aged 14 months, when the proportion of phopholipid in total lipid was 30%. As the steers aged to 24 months, the total lipid in the muscle increased and the proportions of phospholipid and linoleic acid decreased.

Level of fatness (fat depth) at slaughter at a given age seems to have little effect on the degree of unsaturation of subcutaneous fat.

Diets containing PUFA and MUFA lipids that are protected from degradation in the rumen lead to higher amounts of these in beef and sheep fat. Thirty years ago CSIRO research led to feeds in which PUFA lipids were protected. The elevated levels of PUFA led to faster development of rancid flavours. More recently, the procedure was shown to protect MUFA lipids in rations formulated using certain oil seeds.

The reason cattle fed on diets containing whole cottonseed may have lower MUFA than cattle fed other diets because of inhibition of $\Delta 9$ desaturase activity by cyclopropenoic acids in cottonseed.

What can we make of all this information?

Oleic acid and MUFA

Oleic acid is the most abundant fatty acid in beef fat tissue. It is also the most variable. As indicated earlier, breed clearly has a significant influence. The Japanese Wagyu and Korean Hanwoo breeds share a common ancestry. They both exhibit high MUFA:SFA ratios in both their muscle and subcutaneous tissues.

With additional knowledge of some influences of fatty acid composition, there appear to be opportunities to differentiate and market beef based on superior properties of its fat content. As well as the obvious one related to long-fed premium grain-fed beef for restaurants and export, other opportunities include:

- short-fed grain-fed beef for the domestic market;
- budget (cow) beef for the domestic market;
- beef trimmings for patties and other manufactured beef products for the domestic, US and Japanese markets;
- edible tallow.

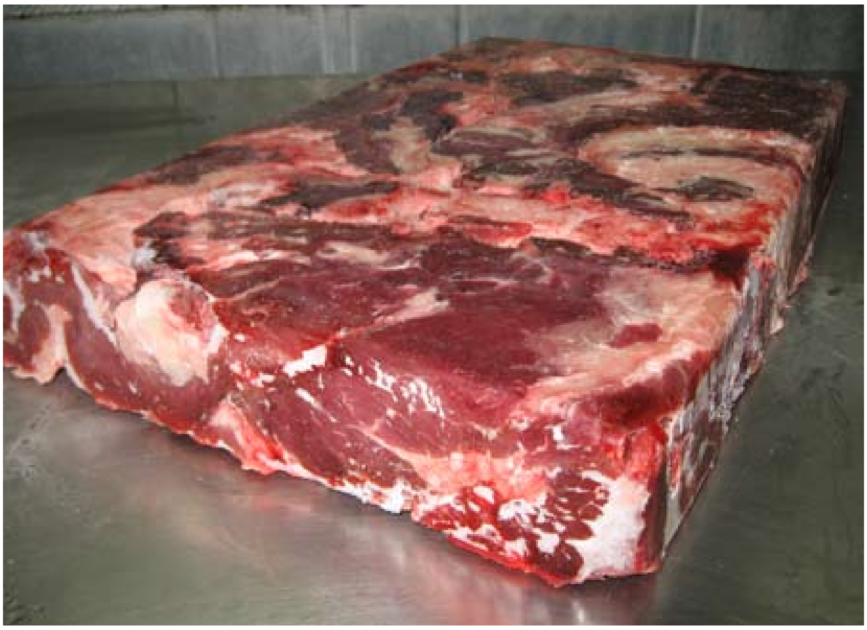

Figure 2. Fat in meat can contain over 50% MUFA and PUFA.

What do we need to know?

We need more comprehensive information about the breed and feeding influences on fatty acid composition, in particular, how the fatty acid composition of long-fed and short-fed beef can be managed and promoted, and information to allow us to determine whether there is an opportunity to emphasise the health benefits of fat in other categories—budget cow beef for instance.

Currently, about the only selection that occurs for beef trimmings is that the trimmings that are 65 CL or fatter usually come from cattle that are grain-fed for export. More information may reveal an opportunity to select beef trimmings in order to capitalise on any enhanced MUFA:SFA ratio.

There may be an opportunity to select and market tallows based on their MUFA:SFA ratio or on other properties. For example, can tallow with a very high melting point from some categories of beef be used as a highly functional replacement for hydrogenated fats?

Further reading

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Contact us for additional information

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