Fatty Acids and Wagyu Beef

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Summary

All life on this planet vitally depends on fatty acids. Of the thousands of fatty acids that exist we concentrate on a few that really make a difference in human health. These fatty acids are derived from two parent compounds that go by the names linoleic acid and alpha-linolenic acid. Some of their metabolites are arachidonic acid (AA), eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and conjugated linoleic acid (CLA). Wagyu beef is an excellent source of these essential fatty acids and we describe how this is made possible by an interrelated combination of genetics and diet. As such, when consumers shout, "Where's the beef?" they may mean Wagyu beef.

Introduction

Everyone nowadays seems to be concerned about the fat they eat. Many of you have heard of 'good' and 'bad' fats, cholesterol, CLA, DHA, EPA, omega-3, omega-6 and trans fatty acids. These are just a few of the exotic words and abbreviations used in newspapers, magazines and television to describe certain aspects of the fat you eat. In this paper we present an overview of fats, including some health implications, and how fatty acids relate, in particular, to the Wagyu beef product.

Overview of fatty acids

Fatty acids are members of a larger group of compounds called lipids. Lipids are defined as a wide variety of natural products including fatty acids and their derivatives, steroids, terpenes, carotenoids, and bile acids, which are readily soluble in organic solvents such as ether, hexane, benzene, chloroform, or methanol. In short, lipids are those substances that are insoluble in water, but are soluble in organic solvents. Though both are classified as lipids, steroids and fatty acids are chemically very different and thus not really related. The term fat is more familiar to laymen than lipid and brings to mind substances that are clearly fatty in nature, greasy in texture and insoluble in water. Familiar examples are butter and the fatty parts of meats.

The fatty acids we are interested in are long chain carbon structures known as unsaturated fatty acids if they contain double bonds and saturated fatty acids if they do not. Acids from 2 carbons to longer than 30 carbons have been reported but the most common lie in the range 12-22 carbons. More than one thousand different fatty acids can be found in cell membranes; the cell structure separating the inside environment from the outside.

There are several different naming systems for fatty acids and they are somewhat complicated. For example, oleic acid, which accounts for 41% of the fatty acids in a Wagyu ribeye steak, is also known in shorthand as C18:1ω9 (ω, or omega, is the last letter of the Greek alphabet) as it contains 18 carbons and 1 double bond in the omega-9 position (which means the double bond is 9 carbons from the methyl end of the molecule; the other end contains the carboxyl group that makes these molecules acids). Fatty acids with a single double bond are called monounsaturated fatty acids (MUFA). Linoleic acid, C18:2ω6, contains two double bonds, is a polyunsaturated fatty acid (PUFA) and its first double bond is located 6 carbons from the methyl end, so it is known as an omega-6 fatty acid. Linolenic acid, C18:3ω3, also has 18 carbons, but with 3 double bonds. It is also a PUFA, and is designated an omega-3 fatty acid as its first double bond is located 3 carbons from the methyl end. Table 1 presents the structures of these fatty acids.

Table 1. Structures of selected fatty acids

1) Oleic acid (18:1 ω9)

```
COOH-CH2-CH2-CH2-CH2-CH2-CH2-CH2-CH=CH-CH2-CH2-CH2-CH2-CH2-CH2-CH2-CH3
1     2    3    4    5    6    7    8    9   10  11   12   13   14   15   16   17   18
↑                                            ↑                                      ↑
```

Carboxyl (COOH; Alpha) end — Double bond is 9 carbons from the omega end — Methyl (CH3; Omega) end

2) Linoleic acid (18:2 ω6)

```
COOH-CH2-CH2-CH2-CH2-CH2-CH2-CH2-CH=CH-CH2-CH=CH-CH2-CH2-CH2-CH2-CH3
1     2    3   4    5    6    7    8    9   10  11   12   13  14   15   16   17   18
                                                         ↑
```

In linoleic acid the first of two double bonds is 6 carbons from the omega end

3) Linolenic acid (18:3 ω3)

```
COOH-CH2-CH2-CH2-CH2-CH2-CH2-CH2-CH=CH-CH2-CH=CH-CH2-CH=CH-CH2-CH3
1     2    3    4    5    6    7    8    9   10  11   12   13  14   15   16  17   18
                                                                     ↑
```

In linolenic acid the first of three double bonds is 3 carbons from the omega end

4) Conjugated linoleic acid (18:2 c9t11)

```
COOH-CH2-CH2-CH2-CH2-CH2-CH2-CH2-CH=CH-CH=CH-CH2-CH2-CH2-CH2-CH2-CH3
1     2    3    4    5    6    7    8    9   10  11   12  13   14   15   16   17   18
                                          ↑         ↑
```

In conjugated linoleic acid the two double bonds are close to each other

Omega-3 and omega-6 fatty acids belong to separate metabolic families that lead to a series of very important fatty acid derivatives controlling many biochemical pathways and physiological processes in animals and humans. Table 2 lists 15 important fatty acids found in Wagyu beef.

The number of carbons and the number, type and location of the double bonds affects the way fatty acids function in food. The greater the number of carbons, the higher the melting point and the more double bonds the lower the melting point. For example, stearic acid, C18:0, is 18 carbons in length, does not contain any double bonds, and so is a saturated fatty acid. Stearic acid melts at 158 °F and thus is a solid at room temperature. But, add just one double bond and you get oleic acid, C18:1, which melts at 61 °F and so is an oil at room temperature. Saturated fatty acids are very stable, but unsaturated acids are susceptible to oxidative rancidity and the more double bonds the greater the susceptibility. Oxidation of these unsaturated fatty acids is responsible for the rancidity we often detect in food products. To stabilize or solidify food products, processors often use a process called hydrogenation to convert unsaturated fatty acids into saturated fatty acids. The drawback of this process is that it also generates unnatural fatty acids, called trans fatty acids. Not only is the body unable to use these trans fatty acids but, they compete and block the functions of the natural essential fatty acids.

Table 2. Fifteen important fatty acids in Wagyu ribeye steak

Number of carbons: Double bonds	Common name	Class	Fatty acid composition(%)
C14:0	Myristic acid	Saturated	4.1
C14:1	Myristoleic acid	MUFA	1.3
C16:0	Palmitic acid	Saturated	29.8
C16:1	Palmitoleic acid	MUFA	5.1
C18:0	Stearic acid	Saturated	9.2
C18:1□9	Oleic acid	MUFA	41.1
C18:2□6	Linoleic acid	Omega-6	1.1
C18:2 9c11t	Conjugated linoleic acid (CLA)	Conjugated	0.3
C18:3□3	□-Linolenic acid	Omega-3	0.1
C20:3□6	Eicosatrienoic acid	Omega-6	0.8
C20:4□6	Arachidonic acid (AA)	Omega-6	4.0
C20:5□3	Eicosapentaenoic acid (EPA)	Omega-3	0.2
C22:4□6	Adrenic acid	Omega-6	0.5
C22:5□3	Docosapentaenoic acid (DPA)	Omega-3	0.7
C22:6□3	Docosahexaenoic acid (DHA)	Omega-3	0.5

Fatty acids and human health

When most people think of fat, they think of the blubber deposited around the waist or thighs. In many ways it can be tempting to spell it “fatt” – making it an unspeakable, four letter word. But fat serves critical functions in the body. First of all, fat is one way the body stores energy for long periods of time. Furthermore, fat serves vital functions in each cell. The membranes of our cells contain a wide variety of fatty acids. Many cellular functions act upon or through this fat barrier: hormones signal through fat, energy passes through fat, life proceeds because of fat. Fat, then, is not a dirty word. It is vital to life.

Obesity. Most people are aware that fats are often implicated in human health problems, such as obesity and heart disease, but these relationships are not as simple as they are often presented. The concept that “all fat is bad” is being replaced by concepts that type, rather than amount of fat, may be more important, and carbohydrates, especially simple sugars, may have harmful effects. For example, there is no evidence that the increased prevalence of obesity is caused by increased fat intake. The body has ways to regulate energy balance and lipid metabolism, and a diet containing 30-35% energy from fat can promote weight loss. The best option for preventing obesity and cardiovascular disease may be a modest reduction in fat intake to 30-35% of energy, with the bulk of carbohydrates coming from unrefined complex carbohydrates.

Heart Disease. There are also many misconceptions regarding the relationship of lipids to heart disease. For example, there is no “good” and “bad” cholesterol in food products. Physicians and scientists refer to the cholesterol in our blood associated with the low density lipoprotein (LDL) fraction as “bad” and the cholesterol associated with the high density lipoprotein (HDL) fraction as “good” because a high LDL to HDL cholesterol ratio has been associated with increased risk of heart disease. Also for most people, the amount of cholesterol we consume does not affect LDL and HDL cholesterol levels as much as the amount and type of fat. In general, saturated fatty acids raise LDL cholesterol levels, PUFA’s lower both LDL and HDL cholesterol, and

MUFA's lower LDL, but not HDL cholesterol. Some people simplistically say you should eat more unsaturated fatty acids and less saturated fatty acids, because the solid saturated fatty acids tend to clog your blood vessels, but melting point has little or nothing to do with "artery clogging". For example, stearic acid (18:0) melts at a higher temperature than myristic acid (14:0) and palmitic acid (16:0), but is less "artery clogging". The LDL receptor in the liver controls the amount of LDL cholesterol removed from the body. Saturated fatty acids down regulate the LDL receptor thus increasing the amount of LDL cholesterol remaining in the blood. Stearic acid does not have this effect because much of it is converted to the MUFA, oleic acid after it is absorbed.

Essential Fatty Acids. The body can produce most of the specific fatty acids it requires, but there are a few it cannot produce in sufficient quantities. Similar to the way certain vitamins like vitamin C are essential to good health and not produced in sufficient quantities, or at all, by the human body, these fatty acids, dubbed essential fatty acids, need to be supplied in the diet. Of these fatty acids, we will discuss how linoleic acid, alpha-linolenic acid, EPA, DHA, and CLA relate to human health and to Wagyu beef.

Linoleic acid and alpha-linolenic acid are the parent compounds for two distinct fatty acid families. These families, which are not inter-convertible, but which compete metabolically with each other, lead to distinct fatty acids and derivatives that control or influence human health. Table 3 presents the pathways that convert these parent fatty acids into more biologically active compounds that are of special interest to human nutrition. The parent compounds undergo a series of repeated steps. In a desaturation step a double bond is introduced into the fatty acid making it more unsaturated and often more biologically important. In an elongation step two carbons are added to the fatty acid chain making the fatty acid longer and, once again, generally more biologically important.

Table 3. Pathways for formation of omega-6 and omega-3 fatty acids

Omega-6 family		Omega-3 family
Linoleic acid 18:2 ω6	← Parent EFAs →	Alpha-linolenic acid 18:3 ω3
↓	desaturation	↓
Gamma-linolenic acid 18:3 ω6		Steridonic acid 18:4 ω3
↓	elongation	↓
20:3 ω6		20:4 ω3
↓	desaturation	↓
Arachidonic acid 20:4 ω6 (AA)		Eicosapentaenoic acid 20:5 ω3 (EPA)
↓	elongation	↓
22:4 ω6		22:5 ω3
↓	desaturation	↓
Docosapentaenoic acid 22:5 ω6 (DPA)		Docosahexaenoic acid 22:6 ω3 (DHA)

A ratio of omega-6 to omega-3 fatty acids of 4:1 to 8:1 may be optimal for human diets. This ratio may be as high as 50:1 in some industrial populations, and this may contribute to a high rate of cardiovascular diseases. The clotting ability of blood also depends largely on the balance of the clotting agent arachidonic acid (C20:4 ω6) and the anticlotting agents dihomo-gamma-linolenic acid (C20:3 ω6) and eicosapentaenoic acid (EPA) (C20:5 ω3). A number of symptoms can occur when there is a deficiency of linoleic or linolenic acid (Table 4).

Table 4. Symptoms resulting from a deficiency in linoleic or linolenic acids

Linoleic deficiency symptoms	Linolenic deficiency symptoms
Skin eruptions – eczema	Mental retardation
Hair loss alpha-linolenic acid:	Weakness
Liver degeneration	Impaired vision and learning ability
Behavioral disturbances	Motor incoordination
Kidney degeneration	Neuropathy (tingling/numbing in feet, hands, arms, legs)
Excessive water loss through the skin accompanied by thirst	Behavioral changes
Drying up of glands	Elevated triglycerides
Susceptibility to infections	High blood pressure
Failure of wound healing	Sticky platelets
Sterility in males	Tissue inflammation
Miscarriage in females	Edema
Arthritis-like conditions	Dry skin
Heart and circulatory problems	Low metabolic rate
Growth retardation	Immune dysfunction

Increasing the fatty acid that is deficient can reverse all of the deficiency symptoms listed above. In addition to what seems like a Who's Who of symptoms, the ratio of omega 6 to omega 3 fatty acids may also affect disorders such as attention-deficit hyperactive disorder (ADHD), alcohol addiction and other behavioral disorders, depression, schizophrenia, Alzheimer's disease, inflammatory disorders, coronary artery disease, and diabetes. In short, the families of linoleic acid and linolenic acid affect the health of much of the human body

CLA. Conjugated linoleic acid (CLA) is an isomer of linoleic acid that contains two double bonds adjacent to one another. As such, it has properties different from that of linoleic acid that make it biologically special. In animal studies, CLA was shown to inhibit skin cancer induced by certain chemicals. CLA did this at various cancer stages, from initiation to metastasis. In animal experiments, CLA protected against many kinds of cancers including skin, colon, stomach, breast and prostate. Few anticarcinogens, and certainly no other known fatty acids, are as effective as CLA in inhibiting carcinogenesis in animal models.

One million Americans, an average of two per minute, die each year as a direct or indirect result of heart disease. Researchers have shown that two dangerous compounds, LDL cholesterol and triglycerides, were markedly lower in rabbits supplemented with CLA. Furthermore, the aortas of these animals – the largest artery leading from the heart – had a lot less blockage than those that were not given CLA. Thus in rabbits, CLA seems to reduce cholesterol and makes it so that arteries will not clog as easily. In hamsters, although it did not cut the amount of blood cholesterol, it did cut the amount of fatty build-up in the aorta.

In other experiments, using chickens and rats, CLA reduced muscle wasting during a bacterial infection and improved the immune system. If true in humans, it would greatly benefit patients suffering from long-term illnesses – including those illnesses that affect the immune system – who grow weak from a loss of muscle tone and from a loss of weight. For the animal industry, this nutrient may mean better production methods and healthier animals, as demonstrated in chickens. Animals ate up to 30 percent less while gaining weight. Cutting the amount of feed necessary to produce the same number of animals would be economically important and could reduce world starvation.

Two in three Americans could be termed overweight. CLA may be a nutrient that can change our body shape and does not require a great amount of self-control. Rats fed CLA for a month had 58 percent less body fat (4.3 % versus 10.1 %) and slightly more muscle mass than controls.

Favorable results for CLA in humans; however, have been harder to come by than in animals. Possible reasons include dosage requirements to obtain the same effects, inherent species differences, and not all animal experiments can be performed on people other than lawyers. Obviously, as with the naming of fatty acids, the function of essential fatty acids in the body is very complicated, but their importance is not in dispute.

Fatty acids and the Wagyu beef product

The MUFA, oleic acid, is the predominant fatty acid in beef followed by palmitic acid, a saturated fatty acid (Table 2). Interestingly, the omega-3 and omega-6 fatty acids make up only about 8% of the total fatty acids. Thus certain fatty acids, representing small percentages of the total available, can be the most biologically important.

How does the fatty acid composition of Wagyu beef compare to fat from other breeds? In studies conducted at Washington State University, differences in fatty acid composition between Wagyu cattle and domestic breeds of cattle for MUFA:SFA ratio have been small. We have identified some differences between Wagyu sires indicating that selection for higher MUFA percentage may be possible. Wagyu fat is often observed to be softer than some other breeds like Angus or Hereford, implying more unsaturated fat in Wagyu animals (the more unsaturated, the lower the melting point and the softer the fat). But, this may have more to do with extended time on feed than with genetics. Beef and milk products are the best natural sources of CLA; as most plants contain little CLA. Little is known about the effect of breed on CLA and Omega-3 fatty acid composition. It is likely that Wagyu cattle will have a greater amount, but not greater percentage of these because of the higher fat content of Wagyu beef.

A second important question is how can we improve the concentrations of the fatty acids we desire in Wagyu beef. In general, a higher ratio of unsaturated fat to saturated fat is preferred, as is a higher ratio of omega-3 to omega-6 fatty acids and perhaps an increase in CLA would also be desirable. The body fat of Wagyu is partly synthesized from dietary carbohydrates, partly from dietary fatty acids. In monogastric animals (people included) and poultry, PUFAs are readily absorbed and incorporated into meat and egg yolk lipids. In ruminants, however, PUFAs are hydrogenated to mainly saturated fats by rumen microorganisms with some formation of MUFAs, trans, odd, branched chain, and conjugated fatty acids. Those fatty acids are incorporated into meat unless dietary fatty acids are protected against biohydrogenation. The statement: "You are what you eat", is thus true for pork, poultry, and people, but not for beef. Animal scientists have developed methods to protect fats in the diet from biohydrogenation, but they are rarely used in common practice. Biohydrogenation also leads to formation of CLA by the rumen bacterium *Butyrivibrio fibrisolvens,* an outcome we definitely want. Thus, supplementing the diet with fats high in linoleic acid can also enhance the CLA content of beef.

Also, in ruminants given a rumen-inert fish oil preparation, the omega-6 to omega-3 ratio decreased from 5 to 1.9. Dietary linseed oil increases 20:5 □3 in intramuscular total lipids and phospholipids.

Another way to modify the fatty acid content of Wagyu beef, actually simpler than oil supplementation, is grass-feeding animals. Such an implementation may go a long way toward optimizing Wagyu beef fatty acid composition. The omega-6 to omega-3 ratio for PUFA in muscular lipids is 8.3 to 1.2 for concentrate versus grass-fed cattle. Simply putting Wagyu animals out to pasture may be an easy way to obtain the optimal fatty acid ratio. Grass-fed animals also produce much more CLA than grain-fed animals.

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