The Production of High-Quality Beef with Wagyu Cattle

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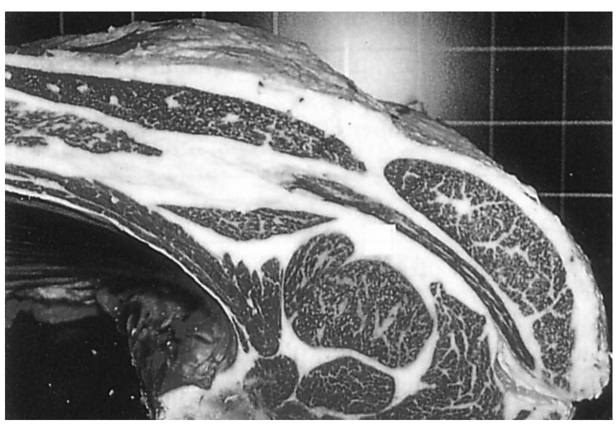

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Introduction

Although beef is consumed by virtually all cultures in the U.S., many Asian cultures prohibit beef consumption for religious reasons. Cattle have been important to agriculture in Japan for centuries as draft animals, but only since the Meiji Restoration (1868 – 1912) has consumption of beef been sanctioned. The production of cattle specifically for consumption now represents a thriving, modern industry in Japan. As in the U.S., beef producers in Japan represent only a small proportion of the populace, and cattle farms are considered a novelty (**Figure 1**). However, Japanese farmers utilize the latest technologies in producing cattle and feedstuffs (**Figure 2**) as beef consumption increases in Japan and other parts of Asia.

Due to its unique culture and geography, beef cattle production in Japan is quite different from that in the U.S., where grazing land is abundant and beef breeds, although numerous, vary widely from those in Japan. Although very little has been published about the feeding and handling of beef cattle in Japan, this review will describe the available information regarding high quality beef production from Wagyu cattle.

Figure 1. Japanese school children at an outing to a Japanese farm. Farms like this are located only on Kyushu and Hokkaido, where grazing land in more abundant. (Japan Livestock Technology Association, 1997)

Figure 2. A Japanese farmer bailing hay. (Japan Livestock Technology Association, 1997)

History of Beef Cattle Production

Definition of Wagyu cattle. Wagyu cattle (和牛; literally, Japanese style cattle) are classified into four breeds, Japanese Black, Japanese Brown, Japanese Shorthorn, and Japanese polled. The most famous Wagyu type is the Japanese Black (**Figure 3**), which accounts for over 90% of total Wagyu and is distributed widely around Japan. Depending on the prefecture (similar to states in the U.S.) in which they are raised, modern Japanese Black cattle were produced by crossing the original Japanese cattle with Holstein, Simmental, Shorthorn, or Angus. The Japanese Brown breed was produced by mating Simmental cattle with Korean cattle in the Kumamoto and Kochi prefectures. This breed type is found primarily in Kumamoto, Kochi, Nagasaki, and Akita prefectures. The Japanese Shorthorn was produced by mating Shorthorn cattle with a strain of Korean cattle native to the Iwate prefecture, and is raised primarily in Iwate, Aomori, Akita, and Hokkaido prefectures. The Japanese Polled breed type was produced by mating a Wagyu strain native to Yamaguchi prefecture with Angus cattle. This polled breed type is found only in the Yamaguchi prefecture. In this review, the term "Wagyu" will refer specifically to Japanese Black cattle produced in the U.S.

Figure 3. Purebred Japanese Black steer from the Hyogo prefecture of Japan. In most parts of Japan, steers are raised in confinement, with very little access to pasture. Because they have little opportunity for exercise, farmers sometimes feed them beer to stimulate their appetites. (Photo by S.B. Smith.)

Origin of Japanese cattle. Cattle were introduced into Japan via the Korean peninsula (South Korea) during the second century to serve as draft animals. The breed type that was imported was the Hanwoo (pronounced "Han-oo), which means "original style cattle". As in other parts of fareast Asia, these cattle served as draft animals for plowing or turning grist mills (**Figure 4**). Hanwoo cattle first were imported into the Shikoku region, and remained isolated there due to the mountainous terrain and lack of passable roads. To this day, Japanese cattle from the various prefectures remain genetically distinct. There are four old inbred lines of Japanese Black cattle, the Takenotani-zuru, Bokura-zuru, Iwakura-zuru, and Shusuke-zuru (Mitsumoto et al., 1989). The Bokura-zuru is a branch line of the Takenotani-zuru. Each line developed in separate, though adjacent regions in the southwest corner of Honshu (the main Japanese island) just prior to the Meiji Restoration.

Figure 4. Hanwoo cow at the Traditional Korean Folk Village, Suwon, Korea. These cattle were used to pull the grist mills (left of picture) or as draft animals. (Photo by S.B. Smith.)

Three of these Tsuru-ushi (also pronounced Zuru-ushi, literally "inbred lines of cattle") most commonly produced in the U.S. are Tottori, Shimane, and Hyogo cattle. These were established in the Takenotani-zuru, Bokura-zuru, and Shusuke-zuru regions, respectively. The origin of the

Takenotani-zuru (Tottori) line is well documented (Namikawa, 1984), and illustrates how the separate lines were established. Cattle of the Takenotani-zuru region originated from one cow, which produced 19 calves. Two of her best quality daughters were backcrossed to one of their sons to fix the traits of body size and dairy character, and these formed two sub-lines. Cows of the two lines were bred to two selected offspring bulls in successive generations. Cattle in the different prefectures were selected for varying carcass and body conformation traits. Hyogo cattle were selected for carcass quality, which is reflected in their greater amounts of intramuscular lipid (i.e., marbling) at the 6^{th} and 12^{th} ribs. Tottori cattle were selected for large size and a strong back line, which apparently selected against carcass quality. Shimane cattle were selected for traits similar to the Tottori cattle (being a sub-line of the Takenotani-zuru line); however, Shimane cattle apparently retained greater carcass quality than Tottori cattle.

Nomura et al. (2001) documented a reduction in the effective population size in Japanese Black cattle subsequent to the liberalization of beef import restrictions in 1991. This was caused primarily by the intensive use of a few popular sires during this time. As a direct consequence of using a small number of sires, genetic differences among prefectures have "essentially disappeared" (Nomura et al., 2001). Thus, the diversity in carcass composition across production regions soon may be lost.

Beef was consumed sparingly in Japan for 1,200 years due to religious beliefs associated with Buddism and Shintoism (Lunt, 1991; Japan Livestsock Technology Association, 1997). Cattle and horses were raised as draft animals, but not for food. The Meiji Restoration, which began around the time of our Civil War, relaxed dietary restrictions and the prohibition against eating beef was lifted. Livestock breeding and production were encouraged as a means of increasing agricultural products. Additionally, Japanese military leaders fed their troops beef to strengthen them for battle. When these soldiers returned to their homes in Japan, they retained their appetite for beef. Cooking beef inside the home still was considered a sacrilege by their parents, so the men cooked their beef outside. For stoves, they heated their plowshares over hot coals, and cooked the beef directly on the plowshares. When people order sukiyaki, they literally are ordering "plow-cooked" food (すき = suki = plow and 焼 = yaki = burn, roast, broil, or bake).

Wagyu Beef Quality

Japanese beef grading system. Beef cattle raised in Japan exhibit an unusual ability to accumulate marbling, and their system for grading cattle is quite different from the USDA quality grade system. Carcasses receive a Beef Marbling Score (BMS) based on the amount of visible marbling in the loin muscle at the 6^{th}-7^{th} thoracic rib interface (**Figure 5**; JMGA, 1988). In contrast, carcasses in the U.S. are graded at the 12^{th}-13^{th} rib interface.

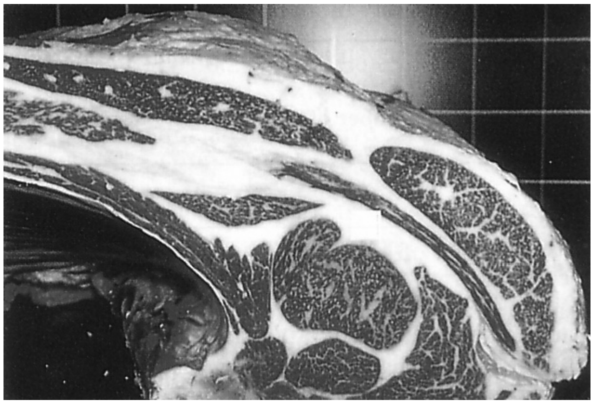

Figure 5. High quality Wagyu beef produced in Japan. In Japan, carcasses are graded at the 6th – 12th rib thoracic rib. This site has a higher abundance of marbling than the 12th – 13th rib interface, where U.S. carcasses are graded. (Japan Livestock Technology Association, 1997)

Another major difference between the Japanese and U.S grading systems in the overall scale. The U.S. marbling score covers the range of Practically Devoid to Abundant, or approximately 1% to 12% intramuscular lipid. The Japanese BMS values range from a score of 1 to 12, or 1% to 35% extractable intramuscular lipid (**Figure 6**; Cameron et al., 1994; Smith et al., 2004). USDA Choice cattle occupy the very lowest portion of this curve, whereas the highest grading Japanese Black cattle (with A5 carcasses) occupy the upper portion. This has been achieved by only a few Wagyu producers in the U.S.

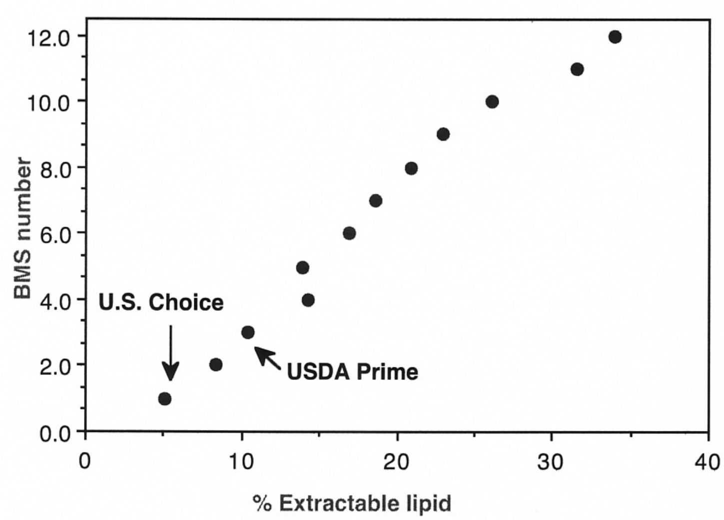

Figure 6. The Beef Marbling Score (BMS) is directly related to the percentage extractable lipid. Cattle typically produced in the U.S. grade USDA Choice, and occupy the lowest portion of the curve. Only Japanese Black cattle produced under strict Japanese production conditions achieve BMS scores of 12. (Cameron et al., 1994; Smith et al., 2004)

Marbling of beef. The enormous capacity of Wagyu cattle to accumulate marbling is based on their unique distribution of marbling adipocytes within their muscles (**Figure 7**). Whereas marbling adipocytes are rarely observed in microscopy samples of muscle from North American breed types, it is virtually impossible to obtain a field devoid of adipocytes in sections of ribeye muscle from Japanese Black cattle. Wagyu marbling adipocytes cluster in large group, much like bunches of grapes, whereas marbling adipocytes are arranged like strings of pearls in other breed types.

Figure 7. Microscopy sample of Wagyu ribeye muscle. Muscle fasciculi (dark polygons) are completely surrounded by clusters of small adipocytes. The cell borders of the adipocytes are barely visible. Each of the larger white areas contains 20 to 30 adipocytes. (Photo by S.B. Smith.)

Fatty Acid Composition

Fat quality. Fat firmness is another important characteristic of the Japanese beef grading system (JMGA, 1988), and reflects the fatty acid composition of the adipose tissue. *The most abundant fatty acid in beef is oleic acid* (18:1, a monounsaturated fatty acid) (**Figure 8**). The saturated fatty acids, palmitic (16:0) and stearic (18:0) contribute substantially to the overall fatty acid composition of beef and beef fat. Linoleic acid (18:2) contributes very little to beef fat.

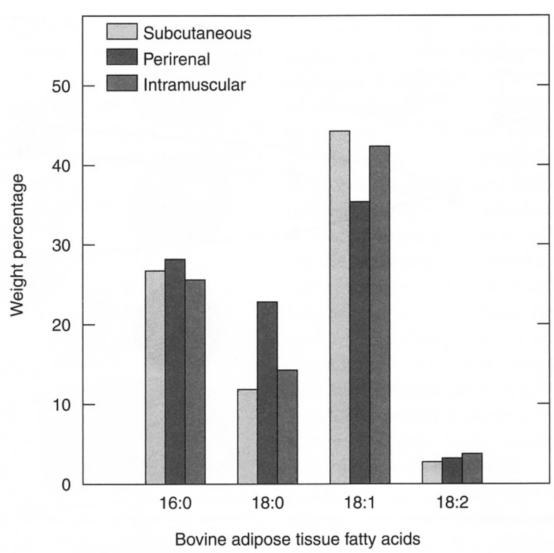

Figure 8. Fatty acid composition of beef fat. The most abundant saturated fatty acids in beef fat are palmitic acid (16:0) and stearic acid (18:0). However, the most abundant fatty acid overall is the monounsaturated fatty acid, oleic acid (18:1). Rule et al., 1995.

Fat softness. The melting point of beef fat is determined by the ratio of monounsaturated fatty acids (**MUFA**) to saturated fatty acids (**SFA**). Saturated fatty acids have melting points around 70°C (about 160°F), whereas MUFA have melting points below room temperature (around 20°C, 70°F). Linoleic acid (a polyunsaturated fatty acid that is common in corn oil) has a very low melting point, -20°C (-4°F), but there is very little linoleic acid in beef. Monounsaturated fatty acids have low melting points because of their chemical structure, which contains a single double bond located approximately in the middle of the molecule (**Figure 9**). The double bond causes a kink in the molecule, and this hinders the formation of the crystalline structure of solidified fat. Therefore, the more double bonds present in a fat, the lower the melting point.

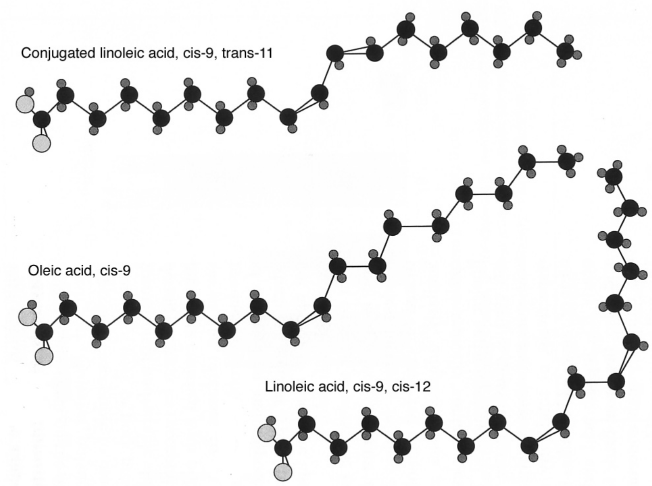

Figure 9. Structures of conjugated linoleic acid, oleic acid, and linoleic acid. Large filled circles are carbon, large shaded circles are oxygen, and small shaded circles are hydrogen. Linoleic acid has two major kinks in its structure, so it has a lower melting point than conjugated linloleic acid or oleic acid. (Smith et al., 2004)

The MUFA:SFA ratio. Scientists who are interested in the fatty acid composition of lean and fat trim frequently use the MUFA:SFA to classify fat into acceptable and unacceptable categories. The MUFA:SFA ratio is calculated by summing all of the MUFA (all of which have melting points below 20°C) and SFA (all of which have melting points around 70°C). The sum of the MUFA is then divided by the sum of the SFA.

The MUFA:SFA ratio gives us a very good approximation of the melting points of lipids in lean and fat trim. This is best demonstrated in comparisons across species or dietary treatments (**Figure 10**). The melting point of lipids from pigs fed standard finishing diets is approximately 30°C (86°F), but is less than 25°C (77°F) in pigs fed canola oil (which is rich in oleic acid). Feeding canola oil increases the MUFA:SFA ratio by about 50% in pig backfat, and this reduces the melting point of the fat. Sheep fat contains over 30% stearic acid and only about 30% oleic acid, and for this reason has a melting point of approximately 40°C (104°F).

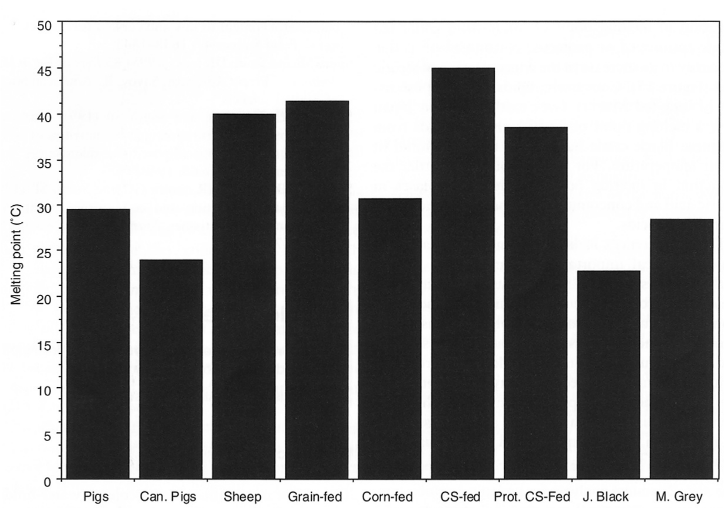

Figure 10. Melting points of lipids extracted from backfat of various species. Fat samples were obtained from pigs or pigs fed canola oil (Can. Pigs); from grass-fed sheep; from grain-fed cattle; from corn-fed cattle; from cattle fed whole cottonseed (CS-fed) or protected CS (Prot. CS-fed), Japanese Black cattle, or Murray Grey cattle. The J. Black and M. Grey cattle were raised in Japan by traditional practices, and the other animals were raised in Australia. Adapted from Smith et al., 1998.

Cattle fed a standard, corn-based finishing diet in the U.S. produce backfat and marbling fat that has consistently low melting points. This is discussed in detail later in this review. The situation is different in Australia, where grains such as barley or wheat are fed in place of corn. When these grains are fed in combination with whole cottonseed or rumen-protected cottonseed oil, the melting point of the fat can exceed 45°C (113°C). This fat is very hard because it is very high in SFA and, therefore, has a low MUFA:SFA ratio. When Australian cattle are fed a corn-based diet, the melting point of the fat is reasonably low, and resembles the backfat of feedlot cattle produced in the U.S.

Lipids extracted from the fat of Japanese Black cattle or Murray Grey cattle raised in Japan have melting points as low as 24°C (75°F; **Figure 10**), which is very soft because of its high MUFA:SFA ratio. Fat from Japanese Black cattle has the lowest melting point, indicating that genetics as well as production contribute to a high MUFA:SFA ratio.

Fat depots of cattle fed grain-based finishing diets typically display a general decrease with age in SFA and a concomitant increase in MUFA (Mitsuhashi et al., 1988a,b; Huerta-Leidenz et al., 1996; **Figure 11**). Thus, unlike the situation observed in Australian cattle, fat in U.S. cattle becomes softer the longer the cattle are on feed.

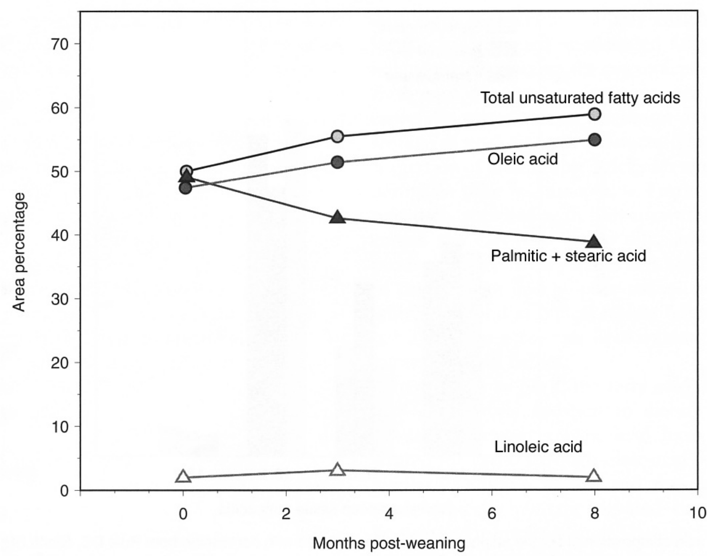

Figure 11. Changes in fatty acid composition of backfat from postweaning calves. Total unsaturated fatty acids increase gradually over time, caused by the increase in oleic acid. Conversely, the combination of palmitic and stearic acid decreases with time. There were only small changes in linoleic acid. Fat softness also increases with age in U.S. cattle, and this is caused by the gradual increase in oleic acid. Smith, 1995.

Cattle in Japan are fed for unusually long periods of time before slaughter (around 19 months past weaning), and this may contribute to the high MUFA:SFA ratio seen in Japanese Black cattle relative to Japanese Shorthorn and Holstein cattle (Tanaka, 1985). The MUFA:SFA ratio of backfat from Japanese Black cattle raised in Japan usually is around 2.0, but can exceed 2.5 (Sturdivant et al., 1992; Smith et al., 1998; **Figure 12**). The highest MUFA:SFA ratios typically are observed in fat and lean from those Japanese Black cattle that achieve the highest BMS scores, suggesting a genetic relationship between fatty acid composition and marbling. This was confirmed by a study conducted at Texas A&M University, in which Wagyu and Angus steers were fed high-roughage diets for 550 days. The steers weighed about 1,400 pounds at slaughter, but fat from the Wagyu steers had a higher MUFA:SFA ratio than fat from the Angus steers (Lunt et al., 1993; May et al., 1993). Both long-fed groups of steers had MUFA:SFA ratios greater than typical Angus x Hereford crossbred steers, but their ratios were far below those of Japanese cattle produced in Japan (**Figure 12**).

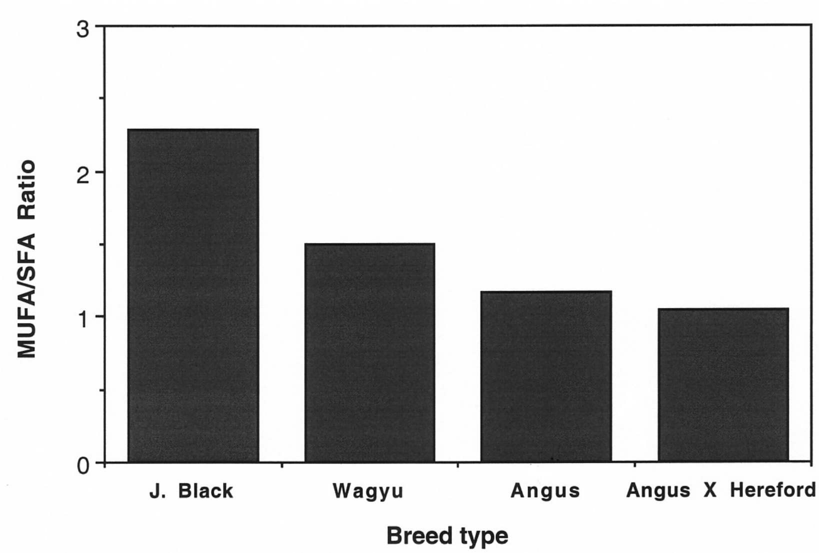

Figure 12. MUFA:SFA ratios of fat from Japanese Black cattle raised in the Hyogo prefecture of Japan; from Wagyu steers fed high-roughage diets for 550 days in Texas; from Angus steers fed high-roughage diets for 550 d in Texas; and from Angus x Hereford crossbred steers fed a standard finishing diet for 150 days. Japanese Black cattle have the softest fat, whereas the Angus x Hereford crossbred cattle have the hardest fat.

Differences in fatty acid composition between Wagyu cattle and other breed types are most apparent in their fat depots, because these depots consist of as much as 90% lipid. Muscle contains only about 2% lipid once the marbling has been removed. Most of the lipid in muscle is found in the membranes that surround the muscle structure and is necessary for proper function of the muscle in the living animal. In spite of the low fat content of muscle, its fatty acid composition is virtually identical to that of the marbling contained within it (**Figures 13 and 14**). Therefore, even lean beef that has had all of its marbling physically removed is high in MUFA if it comes from Wagyu cattle.

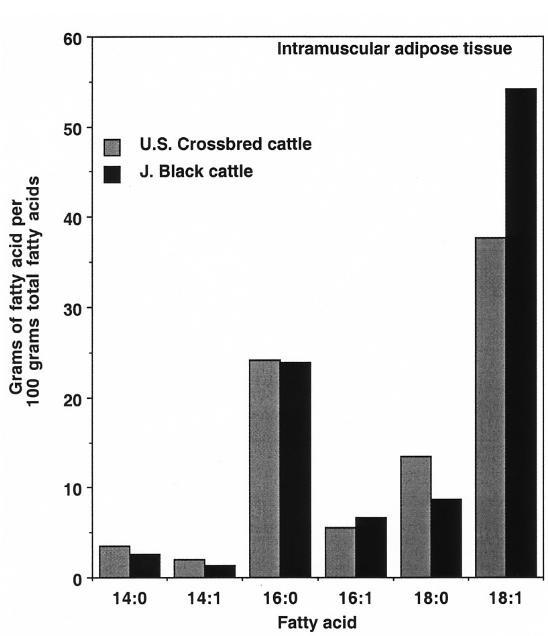

Figure 13. Fatty acid composition of intramuscular adipose tissue (marbling) dissected from the longissimus (loin) muscle of U.S. crossbred cattle or Japanese Black cattle raised in Japan. **(Adapted from Sturdivant et al., 1992.)**

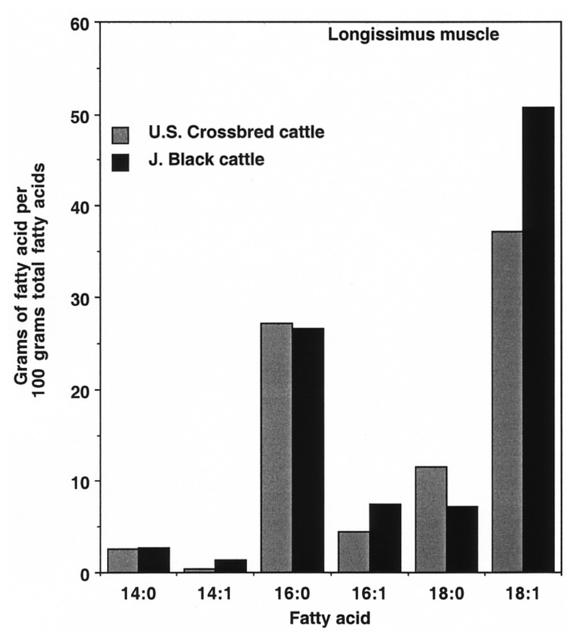

Figure 14. Fatty acid composition of longissimus (loin) muscle of U.S. crossbred cattle or Japanese Black cattle raised in Japan. **(Adapted from Sturdivant et al., 1992.)**

Why is Wagyu Beef Better?

Fatty acids and flavor. Monounsaturated fatty acids in meat have been shown to influence beef palatability (Dryden and Marchello, 1970; Westerling and Hedrick, 1979). These early studies demonstrated that the more oleic acid in beef, the greater the overall palatability of the beef. Some portion of the effect of oleic acid on increasing palatability of beef may be due to the fat softness associated with this fatty acid (Perry et al., 1998; Smith et al., 1998). This provides a more fluid mouthfeel, which most perceive as more desirable.

We conducted a consumer triangle test between Angus and Wagyu beef from the cattle that had been fed to the Japanese endpoint. Out of 180 responses, 98 indicated a difference between the Wagyu and Angus beef. This means that, at a 99.5% confidence interval, 47.5% of consumers would be able to distinguish between Wagyu and Angus beef (**Figure 14**), even when both were fed to the Japanese endpoint. The consumer panel indicated that the degree of difference was primarily "slight" to "moderate".

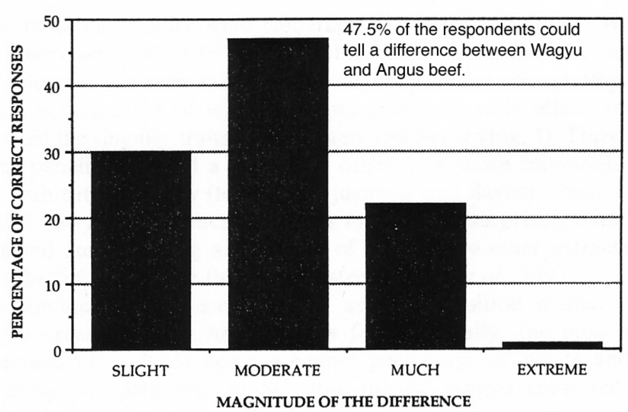

Figure 14. Magnitude of the difference between Wagyu and Angus beef, as scored by a consumer taste panel. Out of 180 responses, 98 indicated a difference between the Wagyu and Angus beef. (May et al., 1993)

The major qualitative traits used to describe differences in eating quality were tenderness, juiciness, and flavor (**Figure 15**). When the consumers were asked to indicate which traits they used to determine the difference between Wagyu and Angus samples, the majority of the respondents used a combination of tenderness and juiciness, while other consumers indicated the singular traits of flavor and tenderness. Certainly, juiciness and flavor differences are largely due to differences in fatty acid composition between Wagyu and Angus beef.

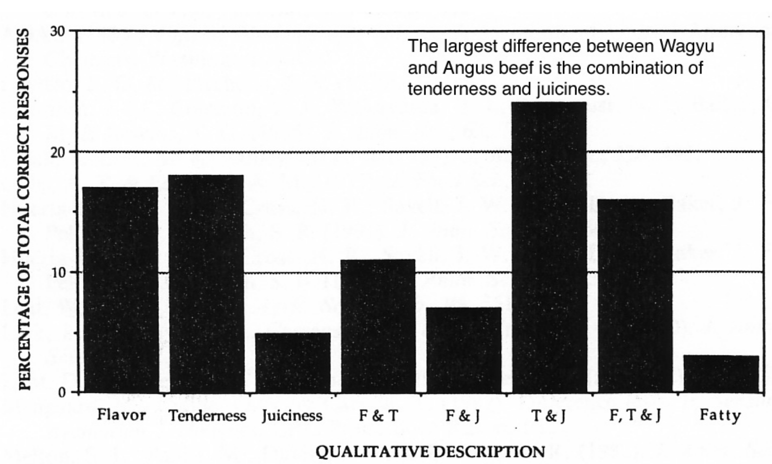

Figure 15. Qualitative descriptors as assessed by the consumers who correctly identified a difference between Wagyu and Angus beef. (May et al., 1993)

Fatty acids and cardiovascular disease. Cardiovascular disease (**CVD**) is the leading cause of death within the U.S. Risk factors include total and LDL-cholesterol, and can be favorably influenced by diet; the exact nature of what constitutes favorable dietary change is contentious. In 2000, the Nutrition Committee of the American Heart Association moved away from its former insistence on low fat diets and concluded that diets providing up to 40% of dietary energy as primarily unsaturated fat (20% MUFA, <10% SFA, 10% polyunsaturated fatty acids [**PUFA**]) were as heart-healthy as low fat diets (Krauss et al., 2000). An outcome of this official opinion has been the re-evaluation of the nutritional properties of a number of higher fat foods such as dairy, nuts, avocados, and dietary oils such as olive oil rich in the MUFA, oleic acid.

Reports linking dietary fat to serum lipid levels have often been interpreted to mean that the general public, especially those at risk for coronary heart disease, should consume diets containing little or no red meat. Researchers previously concluded that dietary SFA such as palmitic acid elevate serum cholesterol concentrations, whereas PUFA such as linoleic acid reduce serum cholesterol concentrations and MUFA have little or no effect (Hegsted et al., 1965; Keys et al., 1965). The major MUFA in beef, oleic acid, since has been studied in more detail and found to lower LDL-cholesterol without affecting the beneficial HDL-cholesterol (Grundy et al., 1988). By lowering LDL-cholesterol and increasing HDL-cholesterol, MUFA have little if any effect on total cholesterol, however are a heart-healthy option for dietary fat.

This effect is most convincing in studies in which natural foods were used to supplement diets with oleic acid. In addition, SFA have been found to have different effects. One of the major SFA in beef, stearic acid, has been found to have no effect or even to lower serum cholesterol (Bononome and Grundy, 1988). Monounsaturated fatty acids constitute 35 to 45% of the total fatty acids in beef produced in the United States (St. John et al., 1987; **Figure 8**). Perhaps because of the prevalence of oleic acid, some beef products have been shown to decrease or have no effect on serum cholesterol in free-living individuals (Smith et al., 2002).

Wagyu beef and plasma cholesterol. We conducted a pilot project to compare the effects of domestic ground beef and beef enriched with MUFA on cholesterol metabolism in human subjects (**Table 1**). These preliminary data provide convincing evidence that the concentration of oleic acid has a direct impact on the concentration of LDL-cholesterol in free-living subjects. The results suggest that ground beef products can be formulated to deliver nutritionally beneficial amounts of MUFA such as oleic acid.

Table 1. Fatty acid composition of ground beef containing fat trim from hay-fed steers, corn-fed steers, and Wagyu steers

Fatty acid	Hay-fed ground beef	Corn-fed ground beef	Wagyu/s.c.[x] ground beef
16:0, palmitic acid	25.4	24.4	23.1
16:1, palmitoleic acid	2.50	4.45	3.94
18:0, stearic acid	19.3	10.1	8.1
18:1, oleic acid	34.3	41.7	42.9
18:2, linoleic acid	1.93	1.81	2.41
MUFA:SFA ratio[y]	0.82	1.34	1.38

[x]Ground beef produced with Wagyu subcutaneous (s.c.) fat trim.
[y]Monounsaturated:saturated fatty acid ratio = (16:1+18:1)/(16:0+18:0). (Adams et al., 2010)

A group of 10 men consumed ground beef formulated with domestic fat trim or ground beef formulated with Wagyu fat trim. The domestic ground beef was obtained from the carcasses of Angus steers that had been fed a bermuda hay-based diet for 12 months (to 20 months of age), and from an Angus cross bred steer that had been fed a corn-based, finishing diet to 18 months of age. The Wagyu fat trim was from purebred steers fed to a final live weight of 1,400 pounds. The MUFA:SFA ratios of the three test beefs were 0.82, 1.34, and 1.38 for the hay-fed, corn-fed, and Wagyu ground beef, respectively (**Table 1**). The participants consumed five, 1/4-pound patties per week.

The lipoprotein cholesterol fractions changed in a manner that was consistent with the fatty acid composition of the types of ground beef (**Table 2**). The ground beef from the hay-fed steer (ratio = 0.82) increased LDL-cholesterol, and the LDL:HDL ratio was markedly increased by the hay-fed ground beef. The ground beef from the corn-fed steer (ratio = 1.34) and the Wagyu ground beef (ratio = 1.38) increased HDL-cholesterol and therefore decreased the LDL:HDL ratio, relative to the baseline values. Thus, the ground beef from corn-fed steers actually was more nutritious than the ground beef from the hay-fed steers.

Table 2. Plasma values of mildly hypercholesterolemic men fed ground beef from hay-fed steers, ground beef from corn-fed steers, or ground beef containing Wagyu fat trim

Item	Baseline	Hay-fed ground beef	Corn-fed ground beef	Wagyu/s.c.[x] ground beef
HDL-cholesterol	40.5	36.4	44.3	44.9
LDL-cholesterol	156.6	154.6	144.1	155.8
LDL:HDL ratio	3.92	4.25	3.25	3.44
Plasma oleic:stearic acid ratio	2.62	1.78	3.10	2.94

[x]Ground beef produced with Wagyu subcutaneous (s.c.) fat trim.
[ab]Means within a row with different superscripts differ ($P < 0.05$). (Adams et al., 2010)

There were only small differences in the concentration of palmitic acid among the ground beef preparations, and stearic acid was substantially higher in the hay-fed ground beef (19%) than in either the corn-fed ground beef (10%) or the Wagyu ground beef (8%) (**Table 2**). Dietary stearic acid, like oleic acid, can reduce LDL-cholesterol in human subjects, so the greater concentration of stearic acid should not have been responsible for the elevated LDL:HDL cholesterol ratio observed in the men consuming the ground beef from the hay-fed steers. Rather, we conclude that the lesser amount of oleic acid in ground beef from the hay-fed steers caused the increase in the LDL:HDL ratio. Similarly, the plasma oleic:stearic acid ratio strongly reflected the differences in composition of the test ground beefs.

The effect of the ground beef from hay-fed cattle on the LDL:HDL ratio is more apparent when viewed over time (**Figure 16**). It is clear that the ground beef from the hay-fed steers caused an increase in the LDL:HDL ratio that persisted over time. An LDL:HDL ratio over 3.6 is considered unhealthy, and the participants of this study were right at this level (on average). The information in Table 2 indicates two important results: 1) ground beef low in MUFA increases LDL-cholesterol, which is an independent risk factor for CVD; and 2) ground beef high in MUFA *increases* HDL-cholesterol, which is protective against CVD.

It was very unusual to locate domestic ground beef with a MUFA:SFA ratio as high as 1.34, and indicates that the fat and lean trim from this group was obtained from overly-fattened steers. It also was unusual to locate Wagyu fat trim with a MUFA:SFA ratio of only 1.38. If the Wagyu steers were of good genetics, then they had not been fed by the traditional Japanese method (see below).

What is apparent from these trials is that increasing the MUFA:SFA ratio in beef truly will lower the LDL:HDL ratio in free-living individuals. It also is very likely that beef from high-quality Wagyu cattle, raised under a Japanese production system, would provide even greater health benefits.

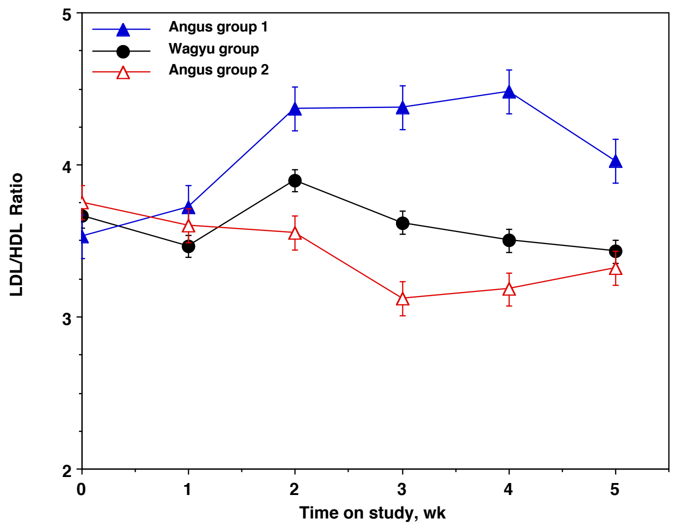

Figure 16. Plasma LDL/HDL ratio in mildly hypercholesterolemic men fed ground beef formulated with fat trim from a hay-fed steer (Angus group 1, MUFA:SFA ratio = 0.82), fat trim from a corn-fed steer (Angus group 2, ratio = 1.34) or with fat trim from Wagyu steers (MUFA:SFA ratio = 1.38). Adams et al. (2010)

Production of Wagyu Cattle

Conventional wisdom in Japan is that marbling in Wagyu steers is "60% genetics and 40% production". Culture, geography, and isolation all have contributed to the Japanese system of beef cattle production. Land mass in Japan is precious, and level land is restricted to the production of table vegetables and rice (**Figure 17**). Virtually no grains intended for animal production are grown in Japan, and livestock production itself is restricted to the foothills (**Figure 18**).

Figure 17. Left: A residential/ farming district in the Kyoto prefecture. Houses are built along the lower steps of foothills, and all flatland is cultivated for row crops or rice. The smaller barns in the distance house one or two Wagyu cows. . (Photo by S.B. Smith.) Right: A small pasture carved out of forest in the foothills. (Japan Livestock Technology Association, 1997)

As of 1985, the average Wagyu producer had only three cows, and 65% of the farmers had only one or two cows. Wagyu calves typically are raised in small barns or sheds (see **Figure 1**), and usually there is no grazing land available. Wagyu cows are fed only on roughage consisting of corn silage with added grasses. Italian rye grass is commonly reported in the Japanese scientific literature (Zembayashi, 1994), and it is assumed that this represents actual usage by Japanese beef cattle producers. Roughage typically is supplemented by cutting wild grass and making it into dried grass or haylage, which requires a great deal of labor. Cattle are fed in small concrete bunkers, and only the larger operations use machinery to feed the cattle.

Natural service of cows is virtually unheard of in Japan, because land is too valuable to commit to maintaining a bull. This is true due to the very small number of cows owned by the typical Japanese farmer. Instead, cows are impregnated by artificial insemination, which is seen in small farms, larger industrial farms, and university research centers in Japan (**Figure 18**).

Figure 18. The high-capacity steer production system at the Kyoto University Livestock Research Farm in Tanba-cho. Fifty to sixty cows are maintained at this research center, which also produces its own grains and some forage. In Japan, most cows are bred by artificial insemination because the cost and labor involved in maintaining bulls is prohibitive. (Photo by S.B. Smith.)

Comparison of U.S., Japanese, and Korean beef cattle production. Texas A&M University has been active in comparing Wagyu steers to U.S. breed types. The driving force for these studies was the assumption of beef trade with Japan. Since 1982, Japan has had a trade surplus with the U.S., which provided the impetus for trade negotiations. As a result, beef traded between the U.S. and Japan was liberalized in 1991. At this time, Dr. David Lunt of the Department of Animal Science at Texas A&M University traveled to Japan to learn about beef cattle production and carcass evaluation. Dr. Lunt's observations while in Japan provided the basis for ongoing studies of beef quality in Wagyu cattle at Texas A&M University. We felt there must be a strong genetic component to the high amounts of marbling and very soft fat in Wagyu carcasses. We also have conducted studies with the Korean Hanwoo, the national beef breed of Korea (**Figure 19**). As described above, the Korean Hanwoo provided the genetic base for the ultimate development of the Japanese Black and Japanese Brown breed types, and in fact resembles the Japanese Brown. A primary difference is that Koreans selected cattle with larger hindquarters, whereas the Japanese producers selected for cattle that were fine-boned, with large forequarters. The difference is especially pronounced between the Japanese Black cattle of the Hyogo prefecture and the Korean Hanwoo. Hyogo Japanese Black cattle have been highly selected for carcass quality, and lack the stature of the other strains of Japanese Black or the Korean Hanwoo.

The production of Korean cattle is of particular interest because of its strong similarity to beef cattle production in Japan, and optimal Wagyu production in the U.S. Japanese and Korean production systems both depend largely on rice straw and native grasses, and the cattle are well adapted to extensive feeding periods postweaning.

Figure 19. Purebred Hanwoo bull at the National Hanwoo Improvement Research Center, South Korea. As in Japan, Hanwoo steers are raised in confinement, with very little access to pasture.

As in Japan, animal production in Korea is limited to the foothills and margins of the flatlands (**Figure 20**), but the cattle produce highly marbled beef with a minimum of external fat trim.

Figure 20. Beef cattle farm (left) and dairy farm (right) in South Korea. The beef cattle farm had about 60 Hanwoo steers, and the dairy farm had a similar number of Hostein cows. As in Japan, Holstein steers are fed for long periods of time in a manner similar to that for beef cattle, but the meat produced from dairy steers is much cheaper than that of the Hanwoo steers. (Photos by S.B. Smith.)

This system of feeding even works well for cull dairy steers, primarily represented by the Holstein breed in both countries. Those individuals who are not familiar with Wagyu or Hanwoo beef would easily mistake it for high quality beef produced from Holstein steers. The meat is highly marbled and the fat is very soft. It is possible to consume grilled steaks from long-fed Wagyu, Hanwoo, or Holstein steers with chopsticks; the meat is so tender, no knife is necessary.

Production of Angus and Wagyu steers by the Japanese system. The first study conducted in the U.S. with Wagyu cattle compared Angus and American Wagyu cattle (derived from Japanese Black and Red bulls crossed to Angus cows) raised under an approximation of Japanese production conditions (**Figure 21**; Lunt et al., 1993). The study was conducted by the Department of Animal Science, Texas A&M University, and the steers were raised at the Texas A&M University Research Center at McGregor, Texas. The steers were provided by Fred Hildebrand of the Rosebud Ranch in central Texas, and were offspring of the first Japanese Black and Japanese Bulls imported into the U.S. Cattle were fed a high roughage diet intended to mimic feedstuffs (typical of finishing diets in Japan). The diet was designed to provide 0.9 kilogram per day (2 pound per day) average daily gain. The cattle were fed a total of 550 days, and both the Angus and American Wagyu steers, exceeding 1,400 pounds at slaughter.

We selected steers from some of the best Angus sires available to make certain the breed type was well represented. For this reason, the Angus cattle performed well, grading USDA Prime with 14.5% extractable lipid in their ribeye muscle (Lunt et al., 1993). However, carcasses from the American Wagyu cattle contained 19% lipid in the ribeye. Based on the Japanese grading system, the Angus cattle achieved a BMS value of 4.5, whereas the Wagyu cattle achieved a BMS of 7.30 (Lunt et al., 1993). The U.S. and Japanese carcass grading was performed by Dr. David Lunt, who was trained in the Japanese grading system. Dr. Lunt's assessment of BMS values was confirmed by visiting Japanese scientists who were experts in carcass grading.

We were surprised that the American Wagyu steers performed as well as they did, as they were at most 7/8 Wagyu, and were derived from a mixture of Japanese Black and Japanese Brown steers. Japanese Brown steers do achieve the same level of marbling as Japanese Black steers, and this depressed the average carcass quality of the American Wagyu steers. In spite of the modest genetic potential of the American Wagyu steers, they produced higher quality carcasses than our best Angus steers. We later confirmed the Angus cattle simply cannot achieve BMS greater than 5 in a second investigation (Cameron et al., 1993).

Figure 21. Angus and Wagyu crossbred cattle used in an early comparison of these breed types. The Wagyu steers were produced from Japanese Black and Japanese Brown bulls crossed on Angus cows, and were 3/4 to 7/8 Wagyu. The Angus steers were from Angus bulls with a known history for producing high-quality offspring.

Direct comparison of U.S. and Japanese production systems. More recently, Texas A&M University completed a comparison of the performance of Angus and Wagyu steers raised to either a typical U.S. endpoint (525 kilograms; 1,100 pounds) or a Japanese endpoint (650 kilograms; 1,400 pounds). In this study, the steers were fed either corn- or hay-based diets. The primary purpose of this investigation was to determine if Wagyu steers would out-perform Angus steers if the animals were fed to a typical U.S. endpoint, or if the Wagyu steers would have to be raised to the Japanese endpoint in order to demonstrate superior carcass quality. U.S. cattle grow more slowly when fed the lower-energy, hay diets, but it was not known how Wagyu cattle would perform when fed the higher-energy, corn diets.

The corn-fed steers were fed for 8 or 16 months past weaning, so they were 16 and 24 months of age at slaughter. The hay-fed steers were fed for 12 or 20 months past weaning, and were 20 and 28 months of age at slaughter. The corn-fed and hay-fed Angus steers were the same body weight at the early slaughter point (1,100 pounds; U.S. endpoint) and at the later slaughter point (1,400 pounds; Japanese endpoint) (**Figure 22**).

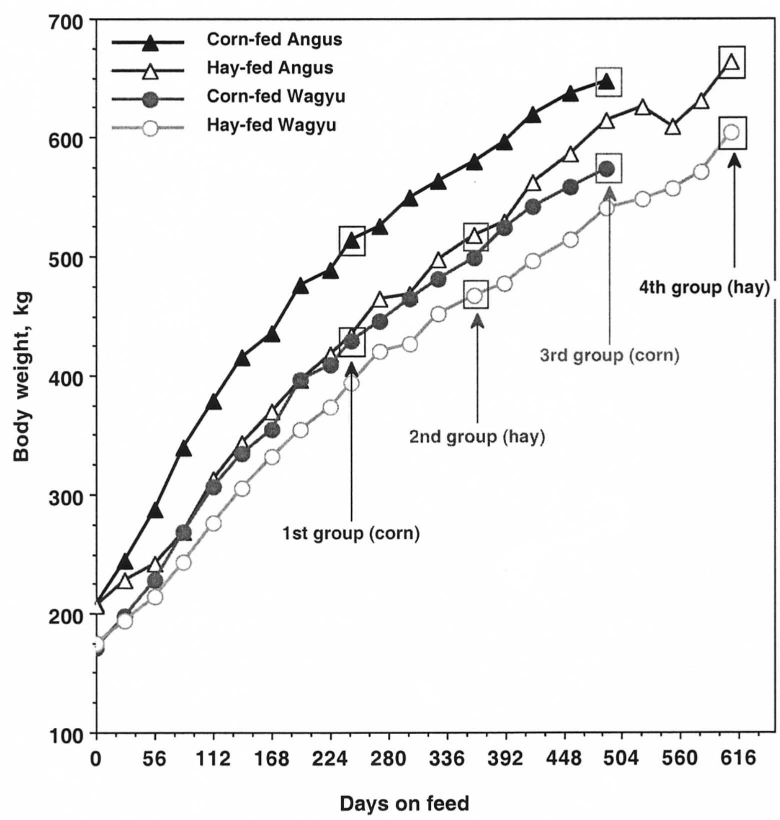

Figure 22. Body weights (kilograms) of Angus and Wagyu steers fed to either the U.S. endpoint (1st group corn and 2nd group hay) or the Japanese endpoint (3rd group corn and 4th group hay). Boxes indicate the weights at which each of the groups was sampled. The corn-fed, Angus steers had an especially fast rate of gain at the beginning of the trial, so that they weighed 90 to 100 kilograms (200 to 220 pounds) more than the corn-fed Wagyu steers at the 1st and 3rd slaughter dates. Hay-fed Angus steers grew slightly faster than the hay-fed Wagyu steers. The hay-fed Angus calves were 40 kilograms (88 pounds) heavier than the hay-fed Wagyu steers at weaning (0 days on feed), and 50 to 60 kilograms (110 to 120 pounds) heavier than Wagyu steers at the 2nd and 4th slaughter dates. Lunt et al. (2005)

The Wagyu steers were supposed to achieve the same body weights and the Angus steers at each sampling time, but the Wagyu steers grew more slowly. The corn-fed, Angus steers had an especially high rate of gain at the beginning of the trial, so that they weighed 90 to 100 kilograms (200 to 220 pounds) more than the corn-fed Wagyu steers at the 1st and 3rd slaughter dates. Hay-fed Angus steers grew slightly faster than the hay-fed Wagyu steers. The hay-fed Angus calves were 40 kilograms (88 pounds) heavier than the hay-fed Wagyu steers at weaning (0 days on feed), and 50 to 60 kilograms (110 to 120 pounds) heavier than Wagyu steers at the 2nd and 4th slaughter dates. This is the first set of information to indicate that corn-fed Wagyu steers do not grow as rapidly as corn-fed Angus steers, and just marginally faster than hay-fed Wagyu steers. We conclude that there is only a marginal benefit gained from feeding corn-based diets to

Wagyu steers, which likely is offset by the cost of the supplemental corn.

Corn-fed Angus steers not only grew faster than Wagyu steers, their carcasses had higher marbling scores than those of Wagyu steers at the U.S. endpoint (**Figure 23**). In general, marbling scores were lower in hay-fed steers than in corn-fed steers at both the U.S. and Japanese weight endpoints, even when cattle were raised to the same body weights. At the U.S. endpoint, corn-fed Angus steers had higher marbling scores than corn-fed Wagyu steers. However, by the time the cattle reached the Japanese endpoint, both corn-fed and hay-fed Wagyu steers had much higher marbling scores than Angus steers.

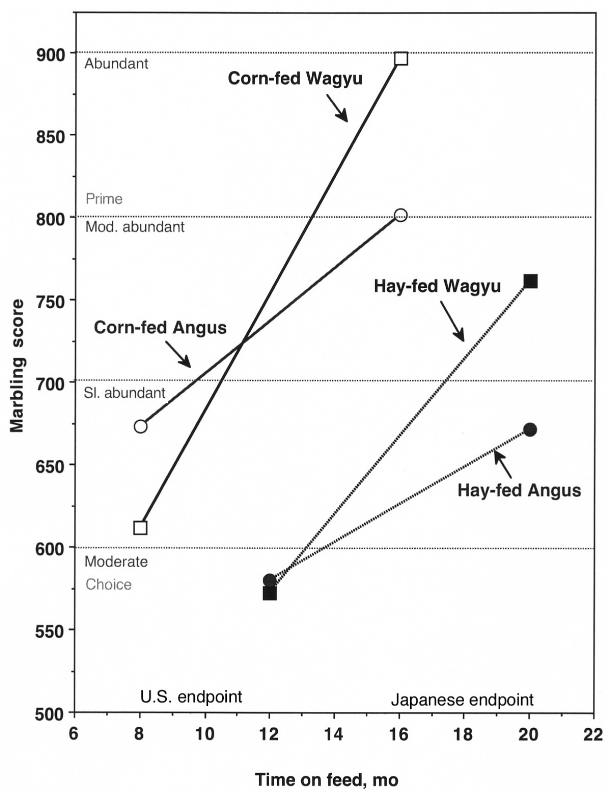

Figure 23. Marbling scores of Angus and Wagyu steers fed either a corn- or a hay-based diet. Marbling scores were lower in hay-fed steers than in corn-fed steers at both the U.S. and Japanese weight endpoints. At the U.S. endpoint, corn-fed Angus steers had higher marbling scores than corn-fed Wagyu steers. However, by the time the cattle reached the Japanese endpoint, both corn-fed and hay-fed Wagyu steers had much higher marbling scores than Angus steers. Chung et al. (2006)

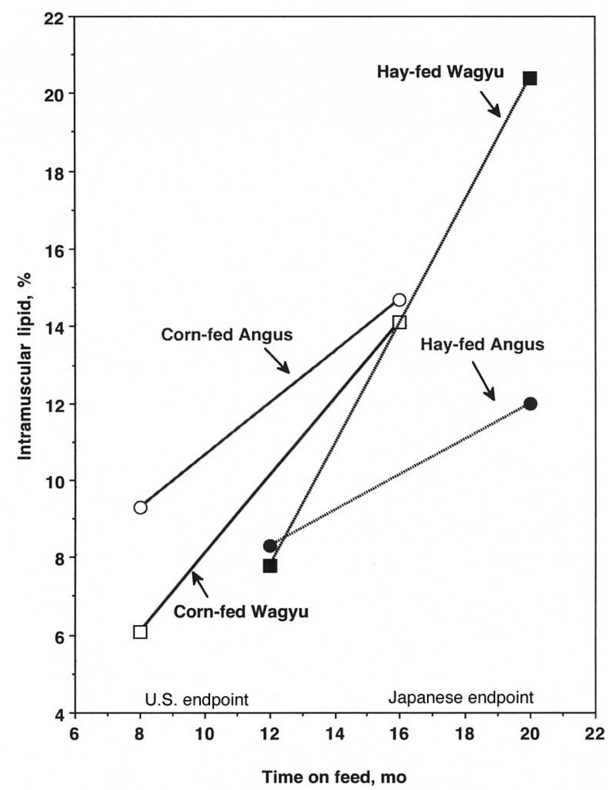

Figure 24. Intramuscular lipid (marbling) in the ribeye muscle of Angus and Wagyu steers fed either a corn- or a hay-based diet. The intramuscular lipid in beef from hay-fed Angus steers and even corn-fed Angus steers was much less than intramuscular lipid in hay-fed Wagyu steers. Also, intramuscular lipid in hay-fed Wagyu steers exceeded that in corn-fed Wagyu steers, regardless of whether the steers were raised to the U.S. endpoint or the Japanese endpoint. Chung et al. (2006)

It is especially noteworthy that, on the hay-based diet, marbling scores in Wagyu steers were the same as those in hay-fed Angus steers at the U.S. endpoint, and vastly exceeded those of hay-fed Angus steers at the heavier weights of the Japanese endpoint. In fact, the marbling score of the hay-fed Wagyu fed to the Japanese endpoint was nearly as high as the marbling score of corn-fed Angus steers raised to the same endpoint. This is in spite of the fact that body weight in the Angus steers consistently exceeded that of the Wagyu steers. One of the many conclusions that we can make from this study is that Wagyu steers can achieve superior marbling scores when fed hay- or pasture-based diets. This is a trait that is missing from the breed types typically raised in the U.S.

In addition to carcass measurements such as marbling score, the total amount of lipid within the longissimus muscle (i.e., ribeye) was measured (**Figure 24**). Marbling is distributed differently in Wagyu cattle than in other breed types. Rather than occurring as discrete strands, clusters of marbling adipoctyes in Wagyu beef are very finely distributed, more reminiscent of frost. For this reason, a high degree of marbling in Japanese beef is called "shimo furi" or "fallen frost" (literally, "frost fallen).

Carcass graders trained in the U.S. system cannot adequately classify the marbling of Wagyu cattle, so the USDA system of classifying marbling does not capture the true difference between Wagyu and other breed types. The corn-fed Angus steers raised to the Japanese endpoint accumulated as much intramuscular lipid as corn-fed Wagyu steers, but their marbling did not exhibit the same shimo furi appearance. By far the greatest amount of intramuscular lipid was seen in the hay-fed Wagyu steers fed to the Japanese endpoint.

These results differ considerably from marbling scores, but this stresses the importance of using intramuscular lipid when describing differences in marbling between Wagyu and other breed types. It is intramuscular lipid that has the greatest impact on the perceived superior flavor and mouthfeel of Wagyu beef.

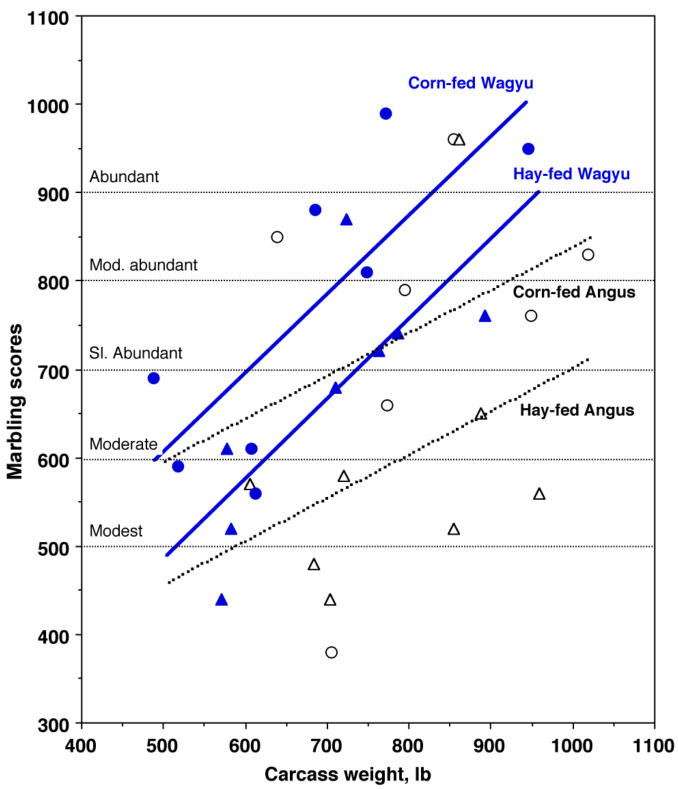

Figure 25. Marbling scores as a function of carcass weight. Marbling scores are highly correlated with carcass weight in corn-fed and hay-fed Wagyu steers (R^2 = 0.70), but only poorly correlated to carcass weight in corn-fed and hay-fed Angus steers (R^2 = 0.14). Also, the rate of increase in marbling scores is nearly twice as high in Wagyu steers as in Angus steers. It is important to note that, at typical carcass weight (650 lb), there is only a small difference in marbling scores between Wagyu and Angus steers. Lunt et al. (2005)

The composition of the fatty acids that comprise the intramuscular lipid of Wagyu beef are important not only for flavor and mouthfeel, but also for the healthfulness of the beef, as indicated above. Clearly, a high concentration of MUFA and a low concentration of SFA are desirable in beef fat. There are several factors that influence the MUFA:SFA ratio: 1) the desaturase enzyme that produces the MUFA increases with activity as the cattle become older; 2) certain breed types naturally have higher activity of the desaturase enzyme; and 3) certain diets cause higher activity of the desaturase. This was demonstrated clearly in our comparison of hay- and corn-fed steers fed to U.S. or Japanese endpoints. There was a large increase in the MUFA:SFA ratio of backfat lipids with time on feed, regardless of diet (**Figure 26**). The highest value was seen in lipids from the hay-fed Wagyu steers fed to the Japanese endpoint, although corn-fed Angus and Wagyu steers also achieved high MUFA:SFA ratios after 16 months on feed. The lowest MUFA:SFA ratios were seen in lipids from hay-fed Angus steers.

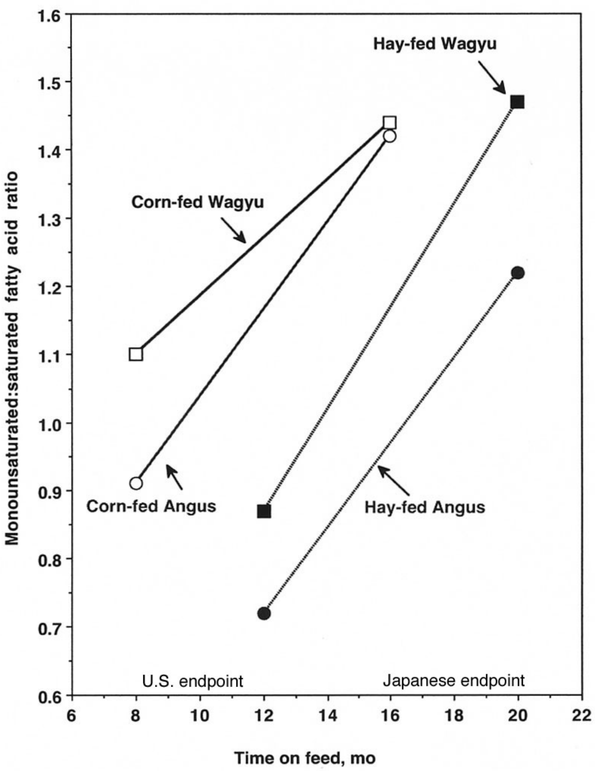

Figure 26. Monounsaturated fatty acid: saturated fatty acid (MUFA:SFA) ratio of lipids from backfat of Angus and Wagyu steers fed either a corn- or a hay-based diet. The MUFA:SFA ratio increased with time in all groups, but the highest rate of increase was in the hay-fed Wagyu steers. Chung et al. (2006)

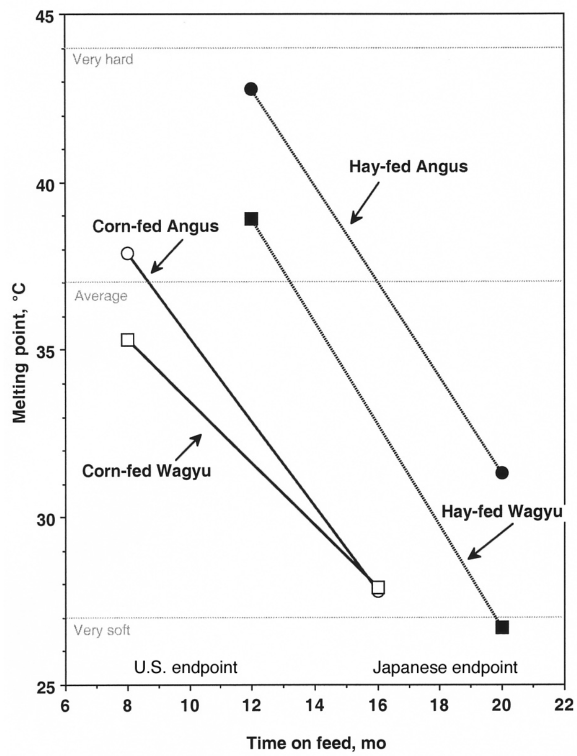

Figure 27. Melting point of lipids from backfat of Angus and Wagyu steers fed either a corn- or a hay-based diet. The lowest melting point was observed in hay-fed Wagyu steers fed to the Japanese endpoint. Fat from the lighter-weight hay-fed Angus steers was deemed unacceptably hard. Chung et al. (2006)

The differences in the MUFA:SFA ratios were reflected in the melting points of the lipids (**Figure 27**). Lipids from hay-fed Angus steers had an unacceptably high melting point (hard, saturated fat) at the U.S. endpoint, although this declined dramatically by the time the cattle reached the Japanese endpoint. Lipids from the Wagyu steers at all times had acceptably low melting points (soft, unsaturated fat), and the melting point of lipids from hay-fed Wagyu steers raised to the Japanese endpoint was especially low. This would result in very soft fat that is highly palatable.

Conclusions

Wagyu cattle represent a unique breed type with a production history that distinguishes from the British, European, and Brahman breed types that typically are produced in the U.S. Meat produced from Wagyu cattle is highly marbled (**Figure 28**), and the fat contained within the steak is softer, with a nutritionally better blend of fatty acids. What is remarkable about Wagyu cattle is that they can produce carcasses that are highly marbled, with a high concentration of monounsaturated fatty acids, even when fed hay- or pasture-based diets.

Figure 28. Ribeye steak from a Wagyu steer fed to the Japanese endpoint. Marbling is abundant, and is dispersed throughout the steak.

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