The Production of High-Quality Beef with Wagyu Cattle

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# Production of Wagyu Beef

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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 is 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 ( Wagyu 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.

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, also known as Korean native cattle), which means “original style cattle”. As in other parts of far east Asia, these cattle served as draft animals for plowing or turning grist mills (Figure 4). Hanwoo cattle first were imported into the Shikoku region of Japan, 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.

Japanese Brown cattle consist of two substrains, Tosa and Higo, which were created by adaptation of Korean native cattle to Japanese native cattle approximately 120 years ago. Native Japanese cattle are *Bos taurus* and are representatives of the Turano-Mongolian type. Tosa and Higo cattle have similar phenotypes in body shape and coat color. Sasazaki et al. (2006) reported that the origins of the Higo and Tosa substrains of Japanese Brown cattle were Japanese ancient cattle and Japanese Black cattle in spite of the introgression of Korean and European cattle into the Japanese Brown line.

Some portion of the Japanese Brown breed was produced by mating with Korean and European cattle since 1906 in the Kumamoto and Kochi prefectures. The Tosa Japanese Brown native cattle were improved through the introduction of Korean native cattle, whereas the Higo Japanese Brown cattle were crossed with Simmental and Devon breeds. The Japanese Brown breed type currently 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 United States.

Three of these Tsuru-ushi (also pronounced Zuru-ushi, literally “inbred lines of cattle”) 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 6th and 12th 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 Buddhism and Shintoism (Lunt, 1991; Japan Livestock 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 6th-7th thoracic rib interface (Figure 5; JMGA, 1988). In contrast, carcasses in the U.S. are graded at the 12th-13th 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). (It should be noted that, currently, intramuscular lipid in Japanese A5 cattle exceeds 50%) 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. One of the earliest reports describing the ability of Japanese cattle to accumulate large amounts of marbling was that of Yamazaki (1981), which indicated that Japanese beef marbling scores (BMS) increased to 24 months of age and then attained a plateau. However, Zembayashi et al. (1999; Figure 7) demonstrated a linear increase in extractable lipid of the longissimus thoracis muscle (hence, BMS) in Japanese Black cattle over 1,100 days of age, with no indication of a plateau. In contrast, Charolais X Japanese Black/Holstein crossbred cattle contained less extractable lipid in the longissimus thoracis muscle than purebred Japanese Black cattle, and there was no further increase in intramuscular lipid after 800 d of age in the Charolais crossbred cattle (Zembayashi et al., 1999). We have established that the BMS of American Wagyu steers is significantly higher (7.3) than that of Angus steers (4.5) raised under identical conditions for the Japanese market (Lunt et al., 1993). Reports to date support the hypothesis that Japanese Black cattle are genetically predisposed to deposit marbling over longer periods of time than British or Continental European beef cattle.
Figure 7. Relationship between slaughter age and longissimus thoracis muscle % intramuscular lipid for various breeds of cattle. Each data point represents an individual animal. B, Japanese Black; BHo, Japanese Black Holstein; BBHo, Japanese Black Japanese Black/Holstein; RBHo, Japanese Brown X Japanese Black/ Holstein; CBHo, Charolais X Japanese Black/Holstein; NBHo, Japanese Shorthorn X Japanese Black. There was a high correlation between age and intramuscular lipid ($r^2 = 0.61$) for the purebred Japanese Black cattle. (Zembayashi et al., 1999)

The enormous capacity of Wagyu cattle to accumulate marbling is based on their unique distribution of marbling adipocytes within their muscles (Figure 8). Marbling adipocytes are rarely observed in microscopy samples of muscle from North American breed types. However, 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 8. 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 (JMG A, 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 9). 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.
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Figure 9. 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 10).

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.

*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 11). 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).
Cattle fed a standard, corn-based finishing diet in the U.S. produce backfat and marbling fat that has consistently low melting points. 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°F). 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. (Figure 11; Smith et al., 1998). 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), 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.

![Figure 11. 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.](image1)

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 12). Thus, unlike the situation observed in Australian cattle, fat in U.S. cattle becomes softer the longer the cattle are on feed.

![Figure 12. 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. Huerta-Leidenz et al., (1996).](image2)
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 13). 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 13).

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 14 and 15). Therefore, even lean beef that has had all of its marbling physically removed is high in MUFA if it comes from Wagyu cattle.
Figure 14. 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.

Figure 15. 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.

A microsatellite pedigree analysis of cattle produced from sires from the Hyogo, Shimane, and Tottori regions of Japan indicate some degree of cosanguination (inbreeding) (Figures 16 & 17; Smith et al., 2001).

Figure 16. Top. Pedigree analysis of six Hyogo progeny. Open squares, males; open circles, females; closed symbols indicate progeny from which carcass data and(or) microsatellites were determined; double lines between mating pairs indicate cosanguination.

Figure 17. Pedigree analysis of three Tottori progeny. Symbols and sires are defined in Figure 15. Hy2, Hy5, Sh1, Sh2, and Tot indicate the sires Tayasufuku, Takaei, Itozakura, Itomatsu, and Sugita, respectively. Bottom. Pedigree analysis of three Shimane progeny. Smith et al., 2001.
Cows and heifers (n = 92) were bred by artificial insemination and raised at the Kyoto University Livestock Research Farm over several generations. The calves (n = 145) were 252 days of age and weighed 361 to 675 lb at the beginning of the finishing phase. Cattle produced from sires from the three regions differed significantly in days on feed. Carcass data were collected from 48, 36, and 19 offspring from the Hyogo, Shimane, and Tottori sires, respectively. There was no difference in slaughter weight (1,210 lb). Blood and muscle samples were used for the collection of DNA from 58, 30, and 18 offspring from the Hyogo, Shimane, and Tottori sires, respectively.

There were significant differences in allelic frequencies for several microsatellite markers across regions. These data are consistent with the geographical isolation of the different lines of Japanese Black cattle during their development. Cattle from the Hyogo region had a greater rate of accumulation of intramuscular lipid in the 6th thoracic rib section (33 mg per 100 grams loin muscle per day) than cattle from the Shimane and Tottori regions (both 23 mg per 100 grams loin muscle per day). (Smith et al., 2002). For the 12th thoracic rib, where U.S. cattle are graded, the rates of intramuscular gain in cattle from the Hyogo, Shimane, and Tottori regions were 23, 23, and 10 mg per 100 grams loin muscle per day, respectively. Average daily gains for cattle from the Hyogo, Shimane, and Tottori regions were 1.44, 1.70, and 1.86 lb/day. Thus, cattle from the Hyogo prefecture gain intramuscular fat at greater rates than cattle from the Shimane and Tottori prefectures, but also grow more slowly. Intramuscular lipids from Hyogo cattle had a higher MUFA:SFA ratio (1.93) than lipids from the Shimane cattle (1.47) or Tottori cattle (1.72), although this may have been related to the greater time on feed for the Hyogo cattle than for cattle from the Shimane and Tottori regions to achieve the same final body weights.

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 18). Virtually no grains intended for animal production are grown in Japan, and livestock production itself is restricted to the foothills.

Figure 18. 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)
The average Wagyu producer owns only three cows, and 65% of the farmers own 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 (Zembayasahi, 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 rarely used in Japan, because land is too valuable to commit to maintaining a bull. Instead, cows are impregnated by artificial insemination, which is seen in small farms, larger industrial farms, and university research centers in Japan (Figure 19).

Figure 19. 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 compared Wagyu steers (i.e., Japanese Black steers produced in the U.S.) to Angus steers. 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 Korean Hanwoo cattle, the national beef breed of Korea (Figure 20). As described above, the Korean Hanwoo contributed to the genetic base for the ultimate development of the Japanese Brown breed type, and in fact resembles the Japanese Brown phenotypically. 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, 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.

As in Japan, animal production in Korea is limited to the foothills and margins of the flatlands (Figure 21), but the cattle produce highly marbled beef with a minimum of external fat trim. 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 22; 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).

**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 23). 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 (Figures 24 & 25). 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. 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)
When data were plotted based on carcass weights (rather than days on feed), for the steers fed the hay-based diet, marbling scores in Wagyu steers were the same as those for the 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 weights of the Angus steers consistently exceeded those 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/pasture-based diets. This is a trait that is missing from the breed types typically raised in the U.S.

![Figure 24. 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)](image1)

![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)](image2)

In addition to carcass measurements such as marbling score, the total amount of lipid within the longissimus muscle (i.e., ribeye) was measured (Figure 26). Marbling is distributed differently in Wagyu cattle than in other breed types. Rather than occurring as discrete strands, clusters of marbling adipocytes in Wagyu beef are very finely distributed, more reminiscent of frost. For this reason, a high degree of marbling in Japanese beef is called “shimofuri” 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 furii 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.

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 27). 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. The differences in the MUFA:SFA ratios were reflected in the melting points of the lipids (Figure 28). 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.

Figure 27. 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 28. 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)

Fatty acids and cardiovascular disease. Cardiovascular disease (CVD) is the leading cause of death within the U.S. Risk factors include total and low-density lipoprotein cholesterol (LDLC, the unhealthy cholesterol), and can be favorably influenced by diet; the exact nature of what constitutes favorable dietary change is contentious. In 2015, 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. 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-C and increasing high-density lipoprotein cholesterol (HDL-C, the good 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 lipoprotein cholesterol.** We have published three controlled, human trials (Adams et al., 2010; Gilmore et al., 2011; 2013). The fatty acid composition of the ground beef used in the three trials is summarized in Table 1. These represent the only studies that have reported the effects of high-fat ground beef on risk factors for CVD. Our studies were designed to test the effects of ground beef high in SFA (from grass-fed cattle or purchased as chub pack ground beef) versus ground beef naturally enriched with MUFA (from grain-fed Angus, Wagyu, or Akaushi cattle).

**Table 1. Characteristics of ground beef used in three randomized controlled trials**

<table>
<thead>
<tr>
<th>Item</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty acid, g/114 g patty</td>
<td>Grass-fed, Wagu</td>
<td>Grass-fed, Angus Prime</td>
<td>Chub pack, Akaushi</td>
</tr>
<tr>
<td>Myristic, 14:0</td>
<td>1.00</td>
<td>0.99</td>
<td>0.74</td>
</tr>
<tr>
<td>Myristoleic, 14:1n-5</td>
<td>0.43</td>
<td>0.28</td>
<td>0.18</td>
</tr>
<tr>
<td>Palmitic, 16:0</td>
<td>9.60</td>
<td>8.78</td>
<td>6.06</td>
</tr>
<tr>
<td>Palmitoleic, 16:1n-7</td>
<td>1.18</td>
<td>0.85</td>
<td>0.64</td>
</tr>
<tr>
<td>Stearic, 18:0</td>
<td>6.14</td>
<td>5.57</td>
<td>4.46</td>
</tr>
<tr>
<td>Oleic, 18:1n-9</td>
<td>15.0</td>
<td>10.1</td>
<td>8.6</td>
</tr>
<tr>
<td>Linoleic, 18:2n-6</td>
<td>0.91</td>
<td>0.56</td>
<td>0.31</td>
</tr>
<tr>
<td>-Linolenic, 18:3n-3</td>
<td>0.06</td>
<td>0.09</td>
<td>0.04</td>
</tr>
<tr>
<td>Total 18:1 trans</td>
<td>1.72</td>
<td>1.34</td>
<td>1.59</td>
</tr>
<tr>
<td>Total SFA</td>
<td>16.7</td>
<td>15.3</td>
<td>11.3</td>
</tr>
<tr>
<td>Total MUFA</td>
<td>17.1</td>
<td>11.2</td>
<td>10.0</td>
</tr>
<tr>
<td>Total PUFA</td>
<td>0.97</td>
<td>0.65</td>
<td>0.32</td>
</tr>
<tr>
<td>Total fat, g/114 g patty</td>
<td>40</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>MUFA:SFA ratio</td>
<td>0.95</td>
<td>0.71</td>
<td>0.86</td>
</tr>
</tbody>
</table>

1Trial 1 ground beef: fat trim of Wagu and conventional cattle, grass-fed (Low) or grain-fed (High), mixed with conventional lean trim. Trial 2 ground beef: plate and flank of grass-fed (Low) and grain-fed Angus steers (High). Trial 3 ground beef: chub pack ground beef (Low) or ground beef from Akaushi cattle (High).

2Data are means for n = 3 batches of ground beef for each trial.
In Trial 1, the very high fat ground beef intervention increased plasma triacylglycerols (TAG) and decreased HDL-C concentrations (Adams et al., 2010) (Table 2). This ground beef, from grass-fed cattle, was unusually high in total SFA and trans-fatty acids (TFA). Following consumption of the high-MUFA ground beef produced from Wagyu cattle, and plasma TAG and HDL-C concentrations returned to normal. Trials 2 and 3 used ground beef containing 24% total fat (Gilmore et al., 2011) or 20% total fat (Gilmore et al., 2013) and demonstrated that high SFA ground beef (from grass-fed cattle or chub pack ground beef) had no effect on HDL-C concentrations, whereas high-MUFA ground beef (from USDA Prime Angus steers or Akaushi cattle) increased HDL-C in men and women.

Table 2. Plasma lipids for three ground beef intervention trials

<table>
<thead>
<tr>
<th>Item</th>
<th>Low MUFA</th>
<th>High MUFA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Grass-fed cattle</td>
</tr>
<tr>
<td>TAG</td>
<td>204.8 ± 60.8</td>
<td>312.0 ± 96.8§</td>
</tr>
<tr>
<td>VLDL-C</td>
<td>32.8 ± 10.0</td>
<td>74.4 ± 27.2§</td>
</tr>
<tr>
<td>LDL-C</td>
<td>142.8 ± 9.2</td>
<td>132.4 ± 13.2</td>
</tr>
<tr>
<td>HDL-C</td>
<td>40.8 ± 2.4</td>
<td>35.2 ± 2.4§</td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>Grass-fed Angus</td>
</tr>
<tr>
<td>TAG</td>
<td>102.4 ± 4.8</td>
<td>100.0 ± 8.8</td>
</tr>
<tr>
<td>TC</td>
<td>189.2 ± 4.0</td>
<td>185.6 ± 6.4</td>
</tr>
<tr>
<td>LDL-C</td>
<td>121.6 ± 3.6</td>
<td>118.0 ± 6.4</td>
</tr>
<tr>
<td>HDL-C</td>
<td>46.8 ± 0.8</td>
<td>48.0 ± 1.6</td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>Chub pack</td>
</tr>
<tr>
<td>TAG</td>
<td>96.8 ± 10.4</td>
<td>89.6 ± 8.8</td>
</tr>
<tr>
<td>VLDL-C</td>
<td>12.4 ± 1.2</td>
<td>13.6 ± 1.6</td>
</tr>
<tr>
<td>LDL-C</td>
<td>122.8 ± 6.0</td>
<td>127.6 ± 5.6</td>
</tr>
<tr>
<td>HDL-C</td>
<td>60.4 ± 2.4</td>
<td>64.0 ± 2.4</td>
</tr>
</tbody>
</table>

*Significantly different baseline concentrations ($P < 0.05$). §Significantly different from High-MUFA ($P < 0.05$).

Results for three separate human studies are summarized in Figure 30. Ground beef from corn-fed Wagyu, Akaushi, and Angus steers fed to USDA prime reduced plasma triglycerides and significantly increased HDL cholesterol. It is likely that beef from high-quality Wagyu cattle, raised under a Japanese production system, would provide even greater health benefits.
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 31), even when both were fed to the Japanese endpoint. The consumer panel indicated that the degree of difference was primarily “slight” to “moderate”.

The major qualitative traits used to describe differences in eating quality were tenderness, juiciness, and flavor (Figure 32). 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.

![Graph showing qualitative descriptors assessed by consumers who correctly identified a difference between Wagyu and Angus beef.](image)

**Figure 32.** Qualitative descriptors as assessed by the consumers who correctly identified a difference between Wagyu and Angus beef. (May et al. (1993))

**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 33), 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.

![Photo of a ribeye steak from a Wagyu steer fed to the Japanese endpoint.](image)

**Figure 33.** Ribeye steak from a Wagyu steer fed to the Japanese endpoint. Marbling is abundant, and is dispersed throughout the steak. Photo by D. K. Lunt.
Selected References


