The relationship between subcutaneous fat and marbling

Literature Review by
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Overview

- **The biological and financial relationship between subcutaneous fat (referred to as "external" fat when discussing carcasses) and intramuscular fat (marbling) is an important consideration when feeding cattle.**
- **Excessive subcutaneous fat results in lower carcass yields and higher costs of gain, whereas lack of marbling results in lower carcass value and generally lower consumer eating satisfaction.**
- **The relationship between subcutaneous fat and marbling is moderate, at best, and is not a good method of evaluating the marbling potential of finished cattle.**
- **It is possible to manage cattle to produce carcasses with acceptable levels of subcutaneous fat and marbling.**

Introduction

The relationship between fat and marbling is fairly well-studied, with several scientific and Extension publications providing details into the inherent relationship. A recent report from the 2011 National Beef Quality Audit evaluated the relationship between subcutaneous fat and marbling and found a positive correlation of around 0.35, indicating that as subcutaneous fat increases, marbling does as well. However, the most important considerations when discussing subcutaneous fat and marbling are economic. Economic considerations involve utilizing knowledge about the USDA grading system, carcass buying grids of various packers, and the growth of fat in feedlot cattle to maximize profit potential. So the ultimate question is how to grow cattle to market weights that can maximize economic returns by maximizing marbling scores, and limiting discounts due to excessively fat carcasses.

USDA Yield and Quality Grading

The economic impacts of levels of marbling and subcutaneous fat are directly tied to USDA grading. Quality grading is a function of the amounts of intramuscular fat (marbling) and the physiological age of the carcass. The vast majority of fed cattle are considered "young" by USDA, which is approximately less than 42 months of age, so marbling is the most important factor. There are several good explanations of marbling and grading available, so they won't be covered here. However, please note that several of the figures in this paper refer to marbling score. Most often a marbling score of 400 = Small 0, which is the minimum amount of marbling for a carcass to grade USDA Choice. A marbling score of 500 is Modest 0, which is the amount of marbling needed to qualify for most "premium Choice" or "Upper 2/3 Choice" program, for example Certified Angus Beef, and a score of 700 is Slightly Abundant 0, which the amount need to grade USDA Prime.

For yield grading, it is important to understand the relationship between subcutaneous fat, which is measured at the 12th rib, and the final USDA yield grade. For external fat, every 0.1 inch of additional external fat, measured at the 12th rib, increases the yield grade by 0.25 units, with a "base" yield grade of 2.0. For example, assuming average-muscled cattle, 0.1 inches of external fat will have a USDA Yield Grade of around 2.25, 0.2 inches YG 2.5, and so on, with 0.4 inches being a YG 3, and 0.8 inches being a YG 4.

Historical Grading Information

First a little background information. Figure 1 shows the distribution of USDA-reported Quality Grade distribution since 1990. The percentage of USDA Choice carcasses decreased substantially from the early 90's until 2007, when the percent Choice increased to the current levels of approximately 65% Choice. The initial decrease in quality grades was likely a combination of changes in genetics and management, which focused on growth at the expense of marbling. The more recent increase in USDA Quality Grade may be due to increased emphasis on producing cattle with higher quality grades and an increase in cattle with higher potential for marbling, especially Angus-influenced genetics.

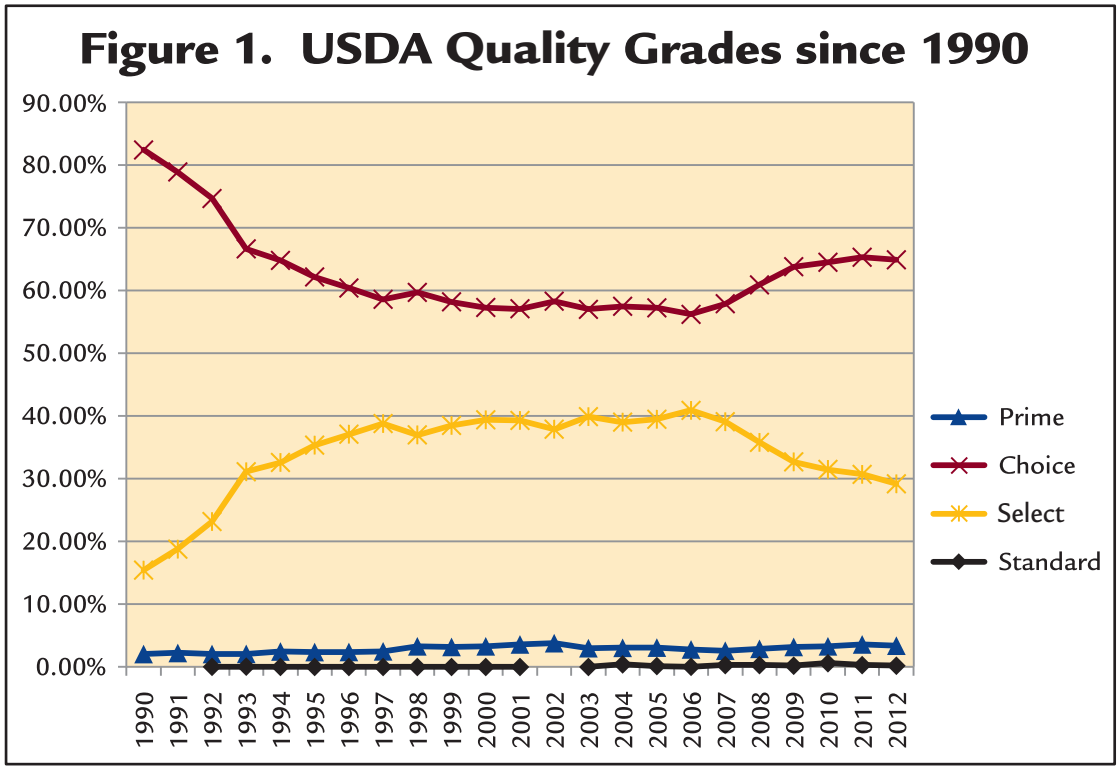


Figure 2 shows USDA Yield Grades since 1990. Note that yield grades are been fairly constant, with a decrease in YG 2, and an increase in YG 3 and 4 carcasses. Yield grade 2 and 3 carcasses still account for over 80% of carcasses yield graded, with the percentage of YG 4 caresses increasing from around 5% in 1990 to around 10% currently. Increased carcass weights, combined with average muscling levels in current cattle types explain part of the reason for the higher percentage of lower yielding carcasses.

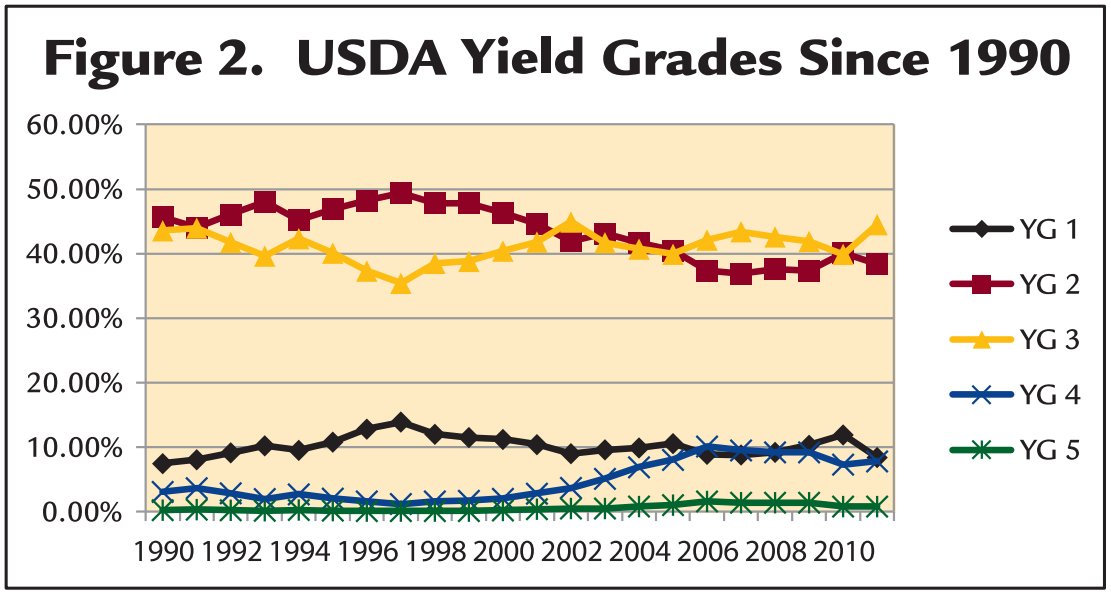


Table 1 shows the distribution of carcasses by USDA Quality and Yield Grades from the 2011 National Beef Quality Audit. It is interesting to note that the percentage of USDA Prime YG 1 cattle is the same as USDA Standard (Other) YG 5 carcasses. The largest percentages of carcasses are YG 2 and 3 Low Choice. Fat is only one component of the USDA yield grade equation, but this provides evidence that cattle that are likely excessively fat, that is YG 4 and 5, do not necessarily have higher quality grades than YG 2 and 3 carcasses. This also shows the large amount of variation in the US beef cattle herd.

Table 1. Distribution (%) of carcasses (N=2,427,074) by USDA quality and yield grades

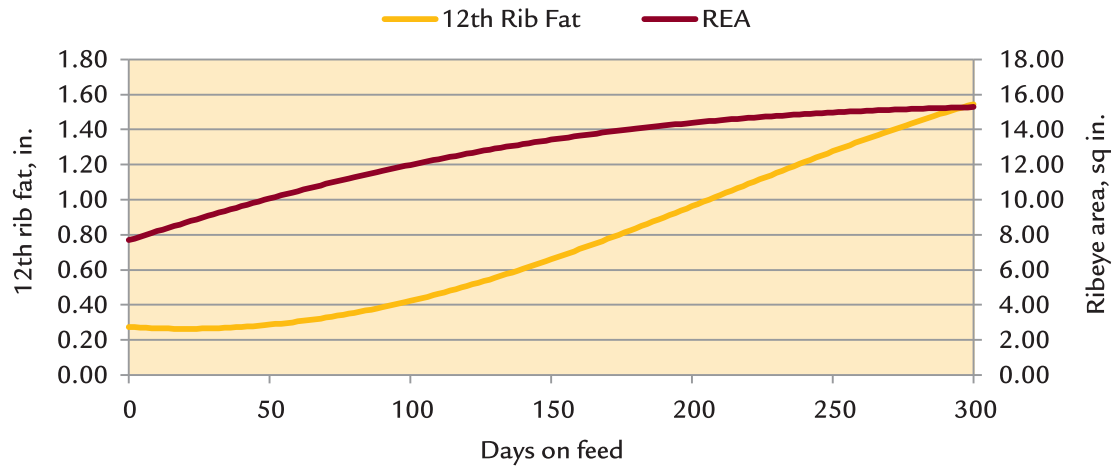
Yield Grade	Prime	Top Choice	Commodity Choice	Select	Other (Standard, No Roll)
1	0.03	0.81	4.09	9.28	1.53
2	0.47	6.92	17.01	14.97	1.65
3	1.30	11.0	14.32	6.33	0.89
4	0.72	3.71	2.96	0.87	0.22
5	0.13	0.45	0.26	0.07	0.03

Data from the 2011 National Beef Quality Audit

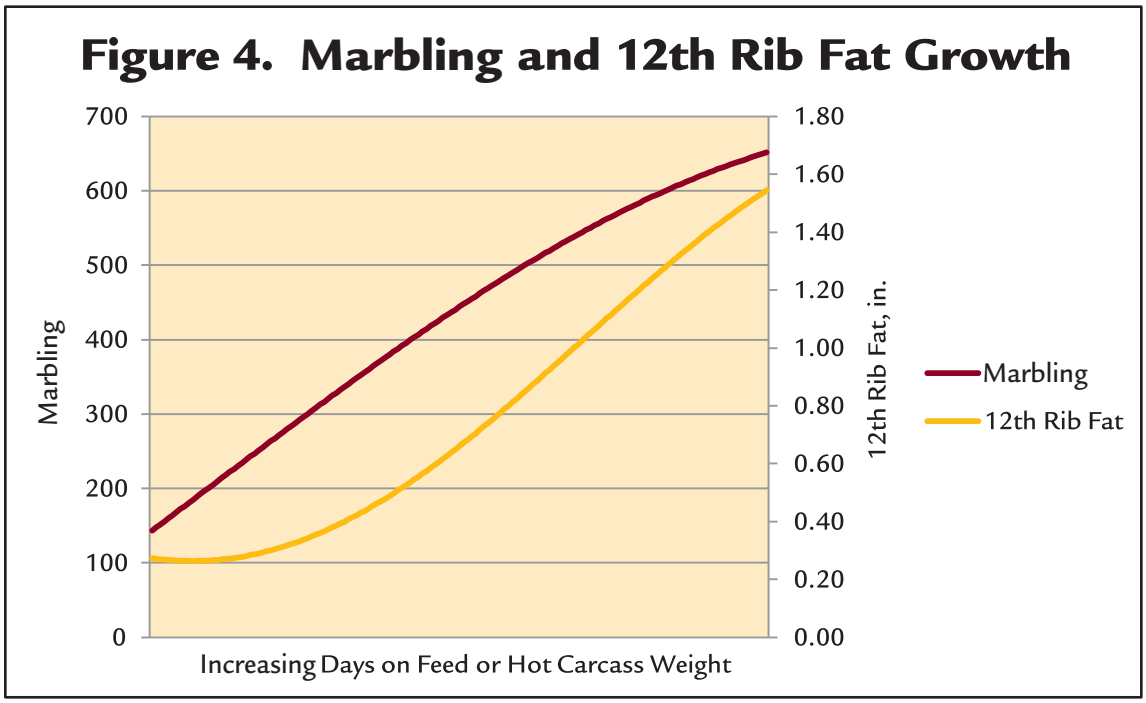
Growth of Carcass Components

To understand the relationship between subcutaneous fat and marbling, it is important to first understand growth of cattle. Calories are first used to meet bone growth, then muscle growth, followed by fat development. For all classes of cattle, bone growth occurs rapidly, then as the skeleton become mature, quickly levels off, with little increase in bone as a percentage of the carcass. Muscle growth starts out slowly, and then increases quickly as the animal reaches mature weight, when muscle growth slows considerably. Fat growth also starts slowly, but grows quickly as the animal approaches maturity, and then levels out as the animal reaches a finished weight. Figure 2 shows the relative growth of muscling, as measured by ribeye area, and fat, as measured by 12th rib fat depth, over time for feedlot cattle. Marc Bauer, Associate Professor at North Dakota State University developed models of carcass growth based on published literature and the data from several close-outs of cattle from various research projects. These models were used to develop the following graphs, which show the relationship among various carcass traits.

Figure 3. Fat and Muscling Growth of Feedlot Cattle



There are four distinct area of fat deposition in cattle: 1. Subcutaneous (external fat), 2. Intermuscular (seam fat), 3. Perinephric (Internal fat, KPH), and 4. Intramuscular (marbling). It has long been thought that marbling is a late developing tissue. This philosophy is based on the body's prioritization of fuel use. Cattle will first develop internal fat, followed by seam fat, the subcutaneous, and finally marbling. However, as cattle reach the feedlot, most of the internal fat, and much of the seam fat has already been developed, leaving subcutaneous fat and marbling as the fat depots that will primarily develop in the feedlot. Figure 4 shows the relative growth of subcutaneous fat and marbling in feedlot cattle. Notice that marbling development is essentially linear. Marbling growth occurs at a relatively constant rate throughout finishing/fattening. The linear growth of marbling in feedlot cattle is likely due to management, which has cattle consuming a large number of calories. The high caloric intake of cattle in the feedlot allows the body to deposit marbling at the same time as it deposits subcutaneous fat.



Research conducted at South Dakota State University provides further evidence that marbling growth is linear, that is marbling is not necessarily the last fat depot to develop, rather marbling grows continuously as the animal grows. External carcass fat, on the other hand, increases at an increasing rate until the animal is excessively fat and cannot consume enough feed under normal conditions to continue to add external fat. Initially, subcutaneous fat growth is slower than marbling growth, but increases and matches marbling growth for most of the feeding period. The relationship between marbling growth and subcutaneous fat growth explains why visual evaluations of subcutaneous fat are typically used to determine when cattle are "finished" and ready to be marketed.

This information leads to two key points:

- **As long as the caloric and nutritional needs of growing cattle are met, energy in excess of requirements for growth will result in marbling development no matter the age of the cattle.**
- **When calories in excess of growth requirements are available, marbling will develop to the genetic potential of the cattle.**

Economic Relationship between Subcutaneous fat and Marbling Growth

Ultimately, the relationship between marbling growth, subcutaneous fat, and USDA Quality and Yield Grades is what is especially important. Figure 5 shows the relationship between marbling and USDA Yield Grade. Notice that yield grade will become higher (less desirable) at an increasing rate as days on feed are increased. Table 2 reports data from Certified Angus Beef LLC, which shows the relationship between 12th rib fat and USDA Quality Grade. As 12th rib fat increases, marbling score increases, however the greatest increase occurs between 0.3 and 0.5 inches of 12th rib fat, with little gain in marbling as fat increases past 0.6 inches. There is a continued increase in marbling as cattle gain more external fat, however, this is mostly due to extended feeding times, rather than biological causes. There is a limit to the amount of calories cattle can consume, ultimately causing cattle to reach a maximum level of fatness under normal conditions using modern genetics.

Figure 5. Changes in USDA Yield Grade and Marbling Score Over Days on Feed

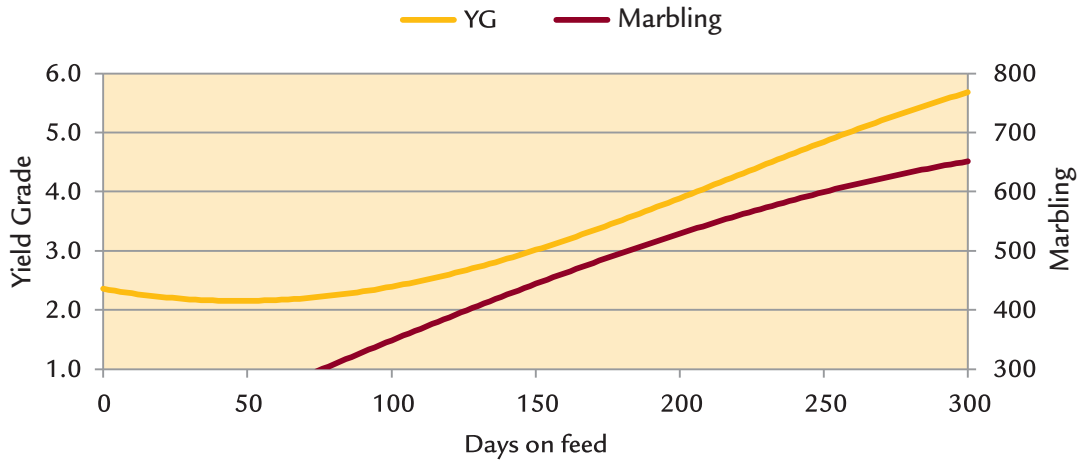


Table 2. Compositional End Point Data for Angus Cattle

	12th Rib Fat, inches								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Average Marbling Score	368	392	409	430	450	460	470	478	477
USDA Choice and Prime, %	28.3	42.4	50.4	60.1	69.2	73.6	75.4	79.8	79.6
CAB Acceptance Rate, %	2.2	4.5	9	13.2	17.7	22	21.4	17.4	12.7
USDA YG 4 and 5, %	0.7	0.2	0.3	0.7	2.0	5.6	18.8	35.2	56.1
USDA Choice, %		44.5			66.8			78.3	
Premium Choice and Prime, %		10.1			21.7			27.1	

Data from Certified Angus Beef LLC

Due to changes in marketing conditions, it is difficult to model carcass value, so I'm not going to attempt it here. However, by examining close outs and data from the American Angus Association in Table 2, it is possible to determine a general economic principle: **Cattle should be fed until a point where excessive external fat and carcass weight result in discounts greater than any premium that can be obtained from higher marbling scores.** Practically, this results in carcasses that weight over 850 pounds, and have less than 0.8 inches of 12th rib fat. At these market endpoints, cattle with the genetic potential to reach USDA Choice Average or higher will have optimized their marbling growth without receiving weight or YG discounts.

Management for Marbling While Avoiding Excessive Subcutaneous Fat

To optimize marbling versus subcutaneous fat development, some simple biological principles can be used. If we assume that marbling growth occurs at a constant rate, to increase marbling we need to do one of three things 1) Extend the growth curve by feeding for more days; 2) increase the starting point of intramuscular fat of cattle entering the feedlot, or; 3) increase the slope (growth rate) of marbling. The limit at which marbling growth will eventually stop is mostly after the cattle have reached an external fat level that would be considered "finished" and is likely not economically feasible. A good example of this is the production of Kobe beef in Japan, where Wagyu cattle are fed for over 48 months. Combined with a high genetic potential for marbling, feeding Wagyu or Japanese Black cattle for this extended period can result in extremely high marbling scores, as much as three times USDA Prime. Cattle that enter the feedlot with a greater amount of marbling will end up with higher marbling levels when finished. Higher levels of marbling entering the feedlot can be accomplished by having older cattle entering the feedlot, such as yearlings. Lastly the rate at which marbling grows can be increased by selecting cattle with high genetic potential for marbling. In addition, management practices that may increase marbling growth, including proper use of implants, avoiding health issues and proper nutrition (caloric intake) at all stages of feeding and finishing. Proper management can be used to optimize marbling growth without producing excess subcutaneous fat.

Managing for Marbling and Subcutaneous Fat

Genetics

The genetic potential for cattle to grow marbling can vary greatly. Researchers at the University of Nebraska compared six high-marbling and six low-marbling sires of the same breed. The two groups differed greatly in EPD for marbling but were similar in EPDs for birth weight, weaning weight, ribeye, and fat cover. Progeny were fed until they reached the same estimated levels of fat cover over the ribeye. The high marbling sire progeny averaged 20 pounds lighter when started on feed, gained at about the same rate, were slightly more efficient in feed conversion, and were fed 18 days fewer to reach the same fatness, resulting in slaughter weights that were 80 pounds lighter. Yield Grades were similar between the two genetic lines, but the high-marbling sire group graded 74% USDA Choice, compared to 47% USDA Choice for the low-marbling sire group.

An additional consideration is late maturing versus early maturing types of cattle. If maturity is defined as the point when cattle will be considered "finished" then early maturing cattle will have more subcutaneous fat and higher marbling scores at the same carcass weight than later maturing cattle. Early maturing cattle should be marketed at lighter weights to prevent discounts for excessive subcutaneous fat.

Time on Feed (Days on Feed)

Research investigating days on feed of steers from sires of the same breed with EPDs of either high-marbling/low-fat or low-marbling/average-fat found that the combination of genetics and time on feed can greatly affect marbling score and subcutaneous fat amounts. Steer progeny of sires with high and low marbling EPD's were fed for two lengths of time. In the shorter-fed cattle, the two sire groups averaged about the same fat thickness and USDA Yield Grade, but the high-marbling/low-fat group had 12% higher USDA Choice. In the longer-fed cattle, the high-marbling/low-fat sire group had about 0.1-inch less fat and more desirable Yield Grades. Feeding cattle longer can increase percentage USDA Choice by 15 to 20 percentage point. So it is possible, through intensive concurrent genetic selection, to improve both Quality Grade and Yield Grade at the same time, but this is an issue for seed stock producers.

Implants

Implants change the rate of marbling and subcutaneous fat growth. Research at South Dakota State University investigated the effect of an implant on marbling development and determined that steers receiving a TBA implant when entering the feedlot had lower marbling scores than steers that never received an implant, while those receiving a TBA implant after about 55 days on feed had marbling scores that were not different from those steers that were never implanted. The biological explanation is that the early implant redirected calories from fat growth to additional muscle growth, which delayed marbling growth. Later implanted steers were consuming adequate calories to meet both muscle and marbling growth requirements. In addition, implants reduce subcutaneous fat growth as well, with implanted steers typically having less subcutaneous fat at the same carcass weight when compared to non-implanted steers.

Age of Cattle Entering the Feedlot

Early weaning research also supports the theory that marbling is an early developing tissue. For example, comparing traditional weaning times versus early weaning shows that early-weaned calves that were started on feed immediately after weaning have higher marbling scores and more subcutaneous fat than calves weaned at more traditional times (around 200 days of age). Even though early weaned calves have lower average daily gains in the finishing phase they typically have a caloric intake early in life that is above and beyond what was need to support normal growth, resulting in higher marbling scores.

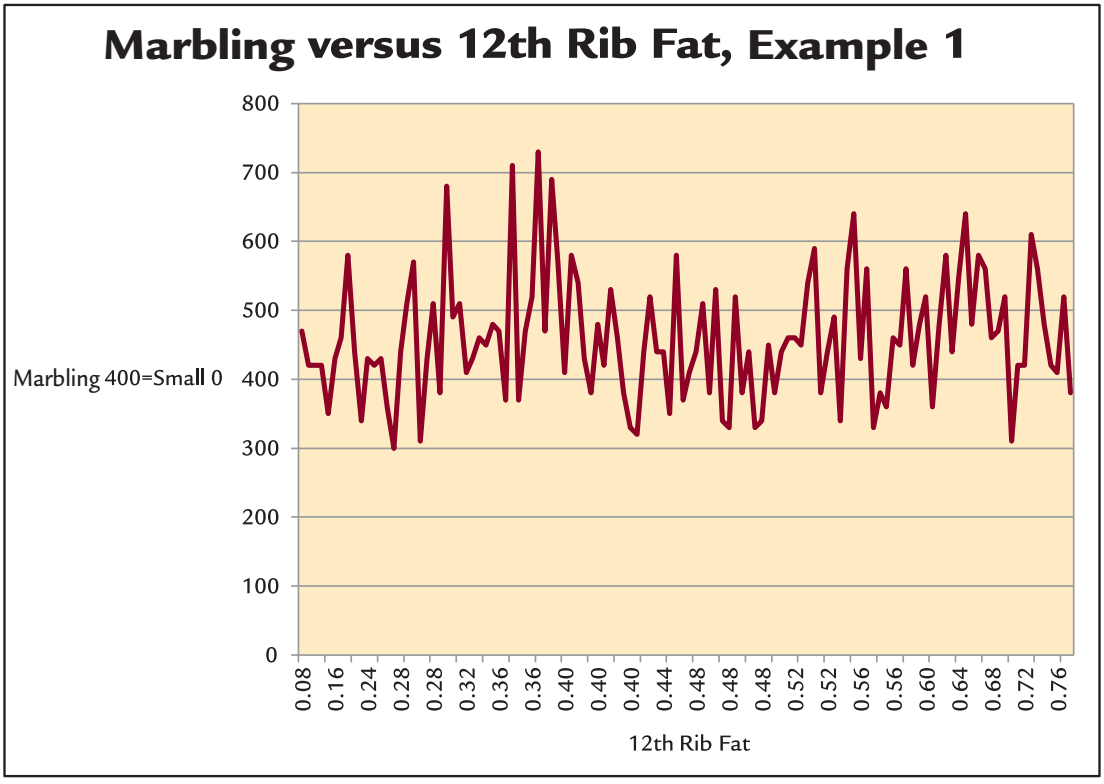
Other Management Considerations

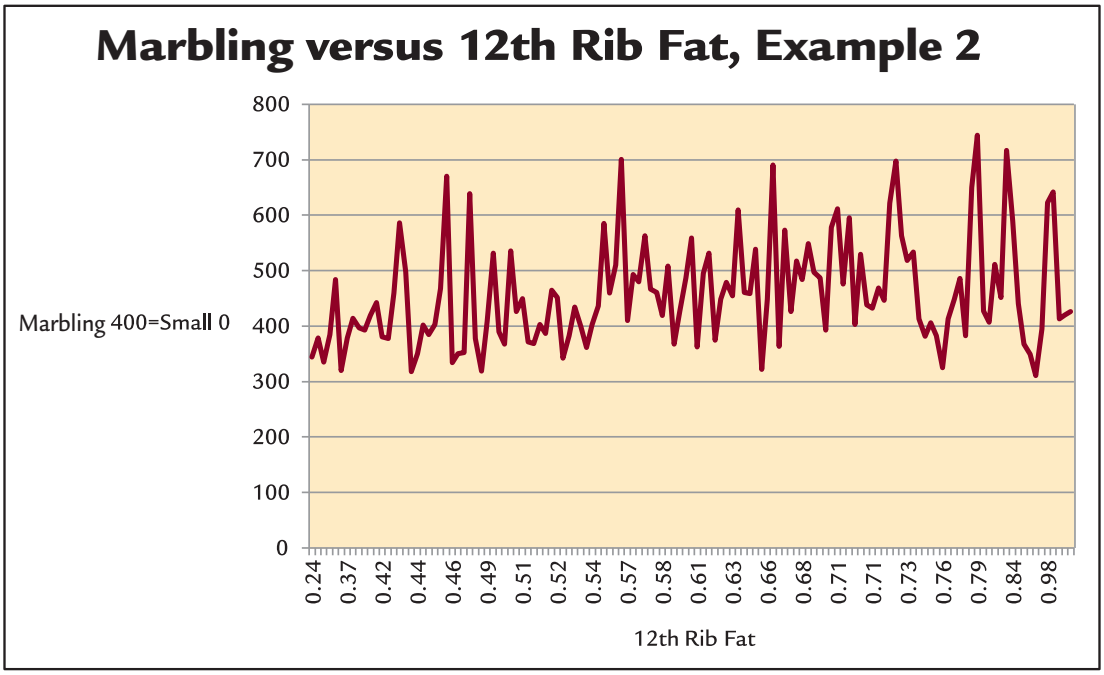
It is important for us to remember the prioritization of a fuel source for normal growth, when making management decisions that may alter the growth curve of a steer. Likewise, health status and starting diets have a dramatic impact on marbling development. The fact that marbling grows throughout growing and finishing may also explain why sick cattle also tend to have lower quality grades than cattle that have not been sick. Typically, when cattle get sick either on arrival into the lot or during feeding, feed intake is suppressed, resulting in a time of lower calorie intake and less marbling growth. There is also no evidence of compensatory growth of marbling, so one cattle fall behind, they may never "catch up" and reach their genetic potential for marbling. If an implant is administered at this time the effect is compounded.

Other issues is that these primary factors that affect fat growth are all related, and there are other factors such as animal health, diet, use of growth promotants such as Optaflexx (ractopamine) and Zilmax (zilpaterol), and even prenatal influences on fat growth that all impact marbling and subcutaneous fat growth. Overall, anything that redirected consumed calories from fat growth will affect both marbling growth and subcutaneous fat growth.

Conclusions

The final two figures are taken from close-outs of cattle produced at North Dakota State University. These figure show cattle of similar genetic type that were managed in a similar fashion. Note that the relationship between marbling and 12th rib fat appears to be essentially random. These data support the fact that within a pen of cattle with similar genetics and similar management, there is little correlation between subcutaneous fat and marbling development. However, when genetics, pre-weaning and weaning management, including age at weaning, implant use, and time on feed differs, the relationship between subcutaneous fat growth and marbling growth can be more clearly seen.





Summary

According to our best knowledge, the relationship between subcutaneous fat growth and marbling growth is low to moderate, which leads to the ultimate management considerations.

- **Consider options other than evaluating external fat as an indicator of marbling; utilize technologies such as ultrasound to decide if an acceptable level of marbling has been obtained by feedlot cattle.**
- **Or, purchase cattle with genetics that will allow for desired levels of marbling with acceptable levels of subcutaneous fat.**
- **And, manage cattle to optimize marbling growth, by proper use of implants, proper feeding, and proper health management, while deciding on the most profitable finished weight and subcutaneous fat level according to your marketing plan.**

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