Fat Reduction in Animals and the Effects on Palatability and Consumer Acceptance of Meat Products

Michael E. Dikeman*

Introduction

In Biblical times, when the "fatted calf" was slaughtered and roasted for special occasions, guests knew they were to be treated to a feast of tasty, tender beef. In those days, "cost of production" was an unheard-of phrase, and there was no awareness of efficiency, carcass or meat composition, meat nutritional value or diet-health issues. In recent years, the livestock and meat industry has been forced by economics, prompted by research and pressured by consumers to become quite aware of these factors. Consumers have always requested tender, flavorful meat, but because of economics and their concern about fat and cholesterol intake, they now are demanding meat and meat products that are low in fat.

Because muscle consists of 70% to 75% water, the above-maintenance feed-energy cost for muscle growth is little more than one-fourth that for fat, even though energy costs for tissue protein and fat are both about 54 kj/g (Thorbek, 1977; Pullar and Webster, 1977). Thus, reducing fat in market animals would improve feed efficiency substantially. It would also improve processing efficiency, if excess fat would not have to be trimmed from carcasses and meat. Therefore, it seems clear that the livestock and meat industry should reduce fat in meat animals to improve efficiency of production and to meet consumer demands for lower-fat meat. On the other hand, there is a lower limit to which fatness can be reduced without detrimental effects on meat quality and palatability, unless specific postmortem technologies are utilized. The primary focus of this manuscript is to determine to what extent fatness can be reduced without such detrimental effects.

Relationships of Fatness to Palatability and Consumer Acceptance of Beef

Results of a National Consumer Retail Beef Study (Cross et al., 1986) found that consumers believe that beef is too fat, and their definition of "leanness" is related to "plate waste," not differences in marbling. The contribution of marbling to beef palatability has been researched for several decades, and this relationship often is debated by various segments of the industry and by researchers. In general, beef production has been oriented towards *one* quality "target," which has been Choice-grade beef. Breeding, feeding, management, packer procurement, processing and retail merchandising have all been oriented primarily to Choice-grade beef. Cattle have been fed to attain 70% to 80% Choice carcasses, and the 20% to 30% that have graded lower than Choice have been merchandised as "no-roll" carcasses at a discount price. This emphasis on the Choice grade has been primarily for merchandising rib and loin steaks only. For other cuts from the carcass, the value of Choice quality is neutral to negative.

The industry is beginning to realize that now several "targets" of quality are necessary to meet the real or perceived needs of consumers. No single quality/fatness level will satisfy specific demands from different consumer segments. Numerous "branded beef" programs have emerged in the last few years and they vary widely in emphasis on "visual quality" (marbling, color, etc.). Excel's branded beef program utilizes only carcasses in the upper one-third of Choice or higher, whereas most of the "lean" or "lite" beef programs place little emphasis on marbling. The "typical" retail or institutional type of beef fits in between or overlaps portions of these two extremes of "visual quality."

Although marbling is the "fat" component in determining USDA quality grades and has been the primary focus of beef quality studies, subcutaneous fatness is the basic "visual appraisal" tool for evaluating quality grade in live animals. In addition, fat thickness has received some attention in recent years for its relationship to palatability. Ideal or desirable carcass descriptions commonly include a measurement of fat thickness because of its relationship to carcass cutability and also to carcass quality. Fat thickness is highly correlated with marbling, indicates the extent to which cattle have been fed high-energy diets, and has a more direct effect on early postmortem changes in muscle than does marbling.

Although marbling is significantly related to palatability, it accounts for only about 10% to 15% of the variation in beef palatability. Several reviews have been published on these relationships (Jeremiah et al., 1970; Smith and Carpenter, 1974; Zmolek et al., 1981). It is generally thought that when beef is cooked to high endpoint temperatures, the contribution of marbling to meat palatability increases. However, a review by F.C. Parrish, presented at the National Beef Grading Conference (Zmolek et al., 1981), suggested that this is not necessarily true. However, degree of doneness has a great effect on beef palatability with higher internal temperatures resulting in less tender and less juicy meat (Parrish et al., 1973; Cross et al., 1976; Moller et al., 1980; Prior et al., 1986). The "initial juiciness" (first impression) of meat is most

*M.E. Dikeman, Department of Animal Sciences & Industry, Kansas State University, Manhattan, KS 66506.

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affected by degree of doneness and method of cookery, whereas "sustained juiciness" is related more to intramuscular fat content. According to Smith and Carpenter (1974), fatness has a low-to-moderate relationship to juiciness in beef. These authors further stated that the basic meaty flavor is nonlipid in origin but some fat is undoubtedly necessary to make beef taste rich, full and "beefy." Yet, several research articles show little difference in beef flavor due to marbling or fatness differences (Naumann et al., 1961; Romans et al., 1965; Campion et al., 1975; Garcia-de-Siles et al., 1977).

Tenderness is the third and most important beef palatability trait, and it can be significantly influenced by events that occur postmortem. Tenderness is the most important beef palatability trait and, therefore, deserves the most attention. The *psoas major* muscle is rather bland in flavor and yet is the most valuable muscle per unit weight because it is consistently very tender. This indicates the importance of tenderness.

Assuming that the retail supermarket will be the primary marketing channel for beef, this "target" probably should receive the most emphasis when discussing the effects of reducing fat in meat animals on meat palatability and consumer acceptance. Choice-grade beef has been the typical quality level for retail beef and "Choice" became an important marketing name. However, the inefficiencies of producing the excess fat associated with feeding cattle to a high percentage of Choice carcasses and the recent consumer resistance to meat with excess fat are critical reasons for considering changes in the industry.

It has been shown that "accelerated" or "tailored" production systems (cattle fed high-energy diets beginning shortly after weaning and slaughtered younger than 15 mo) result in excellent meat palatability even though faster-growing, more muscular cattle types will not attain a high percentage of Choice carcasses at this young age (Dikeman et al., 1985a; Dikeman et al., 1985b). Cattle on the "accelerated" system had mostly high-slight marbling but were somewhat more tender than conventially-fed Choice cattle.

In another comprehensive study (1005 carcasses) on the relationship between marbling and palatability of cooked beef (Table 1), Smith et al. (1984) reported that there were no significant differences in loin steak flavor, juiciness, tenderness, overall palatability or shear force value between A-maturity carcasses with slight (Good grade) or small marbling (lower one-third of the Choice grade). However, for A- and B-maturity carcasses combined, carcasses with small marbling had significantly higher flavor, juiciness and overall palatability scores than carcasses with slight marbling. So, marbling may be more important as maturity advances and this is reflected in the USDA beef grade standards.

In a very extensive study conducted by the U.S. Meat Animal Research Center and Kansas State University involving numerous breed types managed on a semi-accelerated production system, carcasses with small marbling were not different from those with slight marbling in taste panel tenderness, flavor or juiciness (Dikeman et al., 1979). Carcasses with small marbling did have significantly lower shear values, but the numerical difference (0.13 kg) was too small to be of

Table 1. Mean Sensory Panel Ratings for Loin (Longissimus Dorsi Muscle) Steaks from Carcasses with Different USDA Marbling Scores in the Ribeye (12-13th ribs).

			Sensory panel rating[g]				
Maturity group population	*Marbling score*	*N*	*Flavor*	*Juiciness*	*Amount of connective tissue*	*Tenderness*	*Overall palatability*
A	Mod. Abund.	32	6.27[a]	5.52[a]	6.60[ab]	6.60[a]	6.18[a]
A	Sl. Abund.	42	6.05[ab]	5.44[a]	6.71[ab]	6.41[a]	6.00[a]
A	Moderate	55	6.01[b]	5.31[a]	6.77[ab]	6.32[a]	5.93[ab]
A	Modest	58	5.76[c]	4.97[b]	6.81[a]	6.30[a]	5.73[bc]
A	Small	60	5.75[c]	4.92[bc]	6.81[a]	6.01[b]	5.60[cd]
A	Slight	59	5.60[c]	4.80[bc]	6.72[ab]	5.88[b]	5.43[d]
A	Traces	44	5.36[d]	4.58[d]	6.51[b]	5.37[c]	5.01[e]
A	Prac. Devoid	34	4.88[e]	4.73[cd]	6.08[c]	4.90[d]	4.51[f]
A+B[h]	Mod. Abund.	57	6.13[a]	5.56[a]	6.55[a]	6.45[a]	6.07[a]
A+B	Sl. Abund.	64	5.96[a]	5.39[ab]	6.63[a]	6.29[a]	5.90[ab]
A+B	Moderate	89	5.92[a]	5.30[b]	6.69[a]	6.21[a]	5.82[ab]
A+B	Modest	92	5.73[b]	5.00[c]	6.74[a]	6.21[a]	5.69[b]
A+B	Small	92	5.67[b]	4.98[c]	6.69[a]	5.86[b]	5.48[c]
A+B	Slight	94	5.37[c]	4.79[d]	6.55[a]	5.70[b]	5.20[d]
A+B	Traces	71	5.17[d]	4.72[d]	6.27[b]	5.10[c]	4.80[e]
A+B	Prac. Devoid	46	4.68[e]	4.81[cd]	5.96[c]	4.65[d]	4.28[f]

[abcdef]Means in the same column and for the same maturity group population (e.g., A+B) bearing a common superscript letter are not significantly different (P>.05).

[g]8 = extremely desirable in flavor, extremely juicy, no connective tissue, extremely tender and extremely desirable in overall palatability; 5 = slightly desirable in flavor, slightly juicy, slight amount of connective tissue, slightly tender, slightly desirable in overall palatability; 4 = slightly undesirable in flavor, slightly dry, moderate amount of connective tissue, slightly tough, slightly undesirable in overall palatability.

[h]A+B = data from all carcasses of A (n = 399) and B (n = 279) maturities.

From Smith et al. (1984).

practical importance. These results indicate that beef rib steaks from young cattle with slight marbling (Good grade), managed on a semi-accelerated production system, are essentially equal in palatability to those from carcasses with small marbling (the lower one-third of the Choice grade).

The National Consumer Retail Beef Study (NCRBS) was conducted in the cities of Philadelphia, Kansas City and San Francisco to evaluate beef top-loin steaks from Prime, Choice, Good and Standard grade carcasses (Phase I). Detailed results of this study were presented at the 1986 RMC (Cross et al., 1986). Consumers in Philadelphia were more critical of beef from the lower grades (perhaps because they tended to cook beef to greater degrees of doneness). Consumers in San Francisco rated steaks from all grades about the same. Phase II of the study was conducted in Philadelphia and San Francisco to determine specific demand for price and level of fat trim. Steaks from the round, loin, rib and chuck were trimmed to three fatness levels. Results showed that consumers ranked "*taste*" as their most important reason for purchasing beef. Of their concerns/dissatisfactions about beef, price was listed highest and was followed closely by fatness and cholesterol. Consumers in San Francisco preferred to purchase Good grade beef (called "Select" in the study), even when priced higher than Choice. Steaks from both Choice and Select were highly acceptable to consumers in both cities. Choice was liked for taste but disliked for fatness, whereas Select was liked for leanness but disliked for taste and texture. Results from this extensive study demonstrate that loin steaks with slight marbling are quite acceptable to consumers and that excess fat or "plate waste" is not acceptable.

In a study by Francis et al. (1977), 806 consumers rated steaks from carcasses with either slight$^+$ or modest$^+$ marbling. The sample tasted first (whether modest$^+$ or slight$^+$ marbling) rated about two units more desirable than the second sample. On a six-point scale, the consumer panel advantage for modest$^+$ marbled steaks over slight$^+$ marbled steaks averaged .13 ($P<.02$) for flavor, .20 ($P<.01$) for juiciness, .10 ($P>.10$) for tenderness and .14 ($P>.02$) for overall acceptability. These authors concluded that two distinct marbling levels were difficult for consumers to differentiate in steaks cooked to the same degree of doneness from young cattle fed similarly.

The point at which subcutaneous fat has an effect on meat palatability, particularly tenderness, may be in the fat thickness range where its insulatory value for preventing too rapid of a temperature decline in the *longissimus* muscle is marginal. If the temperature of the *longissimus* muscle drops below 10 C before the pH drops below 6.0, cold-toughening can occur (Chrystall, 1976). Most cattle with marbling sufficient to grade Choice will have adequate fat cover to prevent the possibility of cold-toughening. However, carcasses with marbling in the lower half of slight may not have enough fat cover for adequate insulation. Therefore, the concept of requiring a minimum fat thickness for carcasses with slight marbling has merit. Dikeman et al. (1979) demonstrated that carcasses with less than .64 cm (.25 in) of fat thickness had significantly higher shear values and lower tenderness and flavor scores than carcasses with .64 to 2.54 cm of fat thickness (Table 2). Most other research has focused on a minimum of .76 cm (.30 in) of fat thickness in combination with a minimum slight degree of marbling. Dolezal et al. (1982) found that assigning carcasses to three expected palatability groups based on fat thickness was at least equivalent to the use of USDA quality grades. They reported progressive increases in palatability as fat thickness increased up to .76 cm, but fat thickness greater than .76 cm did not improve palatability. Unpublished data from the Germ Plasm Evaluation project (Table 3) show that steaks from carcasses with a minimum of 7.6 cm fat thickness and slight marbling were superior in palatability to steaks from carcasses with Choice marbling that had *less than* .76 cm fat thickness. Riley et al. (1983) recommended that the USDA beef grade standards could be revised to allow young carcasses with slight marbling and at least .76 cm fat thickness to grade Choice. Since such a proposal to USDA by the National Cattlemen's Association (1981) failed to be implemented, it is unlikely that this concept will be promoted in the future. However, these results do provide evidence that a minimum fat thickness provides additional assurance for palatability. In addition, fat thickness provides a much more objective trait for live animal appraisal (or measurement) than does marbling.

A minimum fat thickness requirement of .76 cm would mean that cattle would have to be fed to an *average* of at least 1.0 cm fat thickness in order for nearly all cattle to have the minimum. Requiring a minimum fat thickness is antagonistic to maximizing carcass yields of muscle and efficiency

Table 2. Means for Warner-Bratzler Shear Values and Taste Panel Scores for Beef Carcasses in Five Fat Thickness Groups.[a]

Fat thickness, cm	*N*	*Warner-Bratzler shear value, kg.*	*Taste Panel*		
			Tenderness[b]	*Flavor*[b]	*Juiciness*[b]
<.64	97	3.47[c]	6.8[d]	7.2[e]	7.1
.64 to 1.27	407	3.35[d]	7.2[c]	7.5[d]	7.2
1.28 to 1.91	210	3.29[de]	7.4[c]	7.5[cd]	7.3
1.92 to 2.54	40	3.22[de]	7.4[c]	7.5[cd]	7.3
>2.54	5	3.20[e]	7.8[c]	7.9[c]	7.6

[a]From Germ Plasm Evaluation Project, U.S. Meat Animal Research Center, Clay Center, NE and Kansas State Univ., Manhattan.
[b]9 = extremely tender, intense or juicy; 1 = extremely tough, bland or dry.
[c,d,e]Means in the same column with different superscript letters are significantly different ($P<.05$).

Table 3. Palatability of Rib Steaks from USDA Choice Carcasses, and Carcasses with a Minimum Fat Thickness and Slight Marbling[a].

Trait	*Choice*	*Choice, but less than .76 cm fat*	*Good and at least .76 cm fat*	*Good and at least 1.0 cm fat*
Warner-Bratzler shear force, kg	3.22[c]	3.49[d]	3.27[c]	3.31[c]
Tenderness[b]	7.4[c]	6.9[d]	7.3[c]	7.3[c]
Flavor[b]	7.5	7.4	7.5	7.5
Juiciness[b]	7.3	7.2	7.2	7.2

[a]Unpublished data from the Germ Plasm Evaluation Project, U.S. Meat Animal Research Center, Clay Center, NE and Kansas State Univ., Manhattan.
[b]Score of 9 = extremely tender, flavorful and juicy;
[b]Score of 1 = extremely tough, bland or dry.
[c,d]Means in the same row with different superscripts differed statistically (P<.05).

of feed utilization; however, there are some trade-offs between cattle that are extremely lean and those that are in the early stages of fattening. In a study involving numerous breed types (Dikeman et al., 1979), carcasses with a mean fat thickness of .48 cm (.19 in) had 4.1% lower dressing percentage and .08 kg less gain per day than carcasses with a mean fat thickness of .81 cm (.32 in; Table 4). Carcasses with .48 cm fat thickness had a 4.4% advantage in boneless, closely-trimmed retail product. Therefore, cattle with .81 cm fat thickness were essentially equal in efficiency of producing a unit of trimmed retail product to cattle with .48 cm fat thickness. So, there is almost no advantage in slaughtering cattle at an extremely lean endpoint, such as .48 cm fat thickness, and this contradicts Topel's (1986) proposed ideal fat thickness of .5 cm.

The Agriculture Marketing Service of the USDA has proposed that the name of the Good grade be changed to "Select" with the thought that this grade then will be used much more by the industry than it has been. Research that I have discussed earlier clearly indicates that palatability of meat from this grade will be very acceptable for retail or institutional beef. Savell and Cross (1986) presented evidence that supports the merits of "Select" as a retail or institutional grade of beef. By using a unique approach of evaluating muscle lipid content and caloric density of muscle, they have proposed that a minimum of 3% intramuscular lipid is essential for acceptable meat palatibility (Figure 1). Three percent lipid corresponds to a minimum slight degree of marbling (Campion et al., 1975; Savell et al., 1986) or to the minimum of the proposed "Select" grade. Savell and Cross (1986) also address the contribution of lipid in two servings of beef to the caloric and saturated fat intake recommended by the American Heart Association. Upon critical evaluation of Figure 1, one could conclude that *minimum* slight, or 3.0% lipid, is questionable for acceptable palatability because there is a decrease in palatability from average slight (about 3.5% lipid) to average traces (about 2.5% lipid). This might suggest that average slight (slight[50]) marbling should be the minimum level of fat for acceptable palatability. Based on my earlier discussion on fat thickness, requiring a minimum of .64 cm fat thickness would provide additional assurance that carcasses with 3% to 4.5% intramuscular lipid would be very acceptable in palatability.

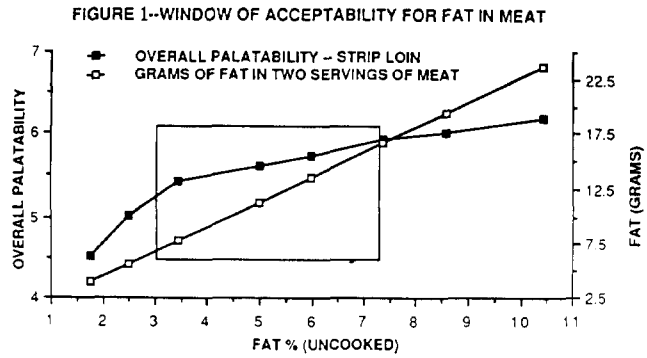
In reviewing the effects of small and higher degrees of marbling on beef palatability, data indicate that palatability of steaks with modest and higher degrees of marbling is higher than of those with small or lower degrees of marbling (Dikeman et al., 1979; Smith et al., 1984). Consequently, research on relationships of marbling and/or subcutaneous fat with beef palatability indicate the potential for three basic "targets" for beef quality. These "targets" are presented in Table 4. One target is for "white tablecloth" or "gourmet" restaurants who want to minimize any chances of an unacceptable eating experience by their customers. The

Table 4. Average Daily Gains, Dressing Percents and Retail Product Percents for Cattle with Differing Fat Thicknesses[a].

Fat thickness, cm	*A.D.G., kg*	*Dressing %*	*Retail Product %*
.48	.96[c]	55.4[d]	78.5[b]
.81	1.04[b]	59.5[c]	73.9[c]
1.19	1.09[b]	60.4[b]	68.2[d]

[a]From Germ Plasm Evaluation Project, U.S. Meat Animal Research Center, Clay Center, NE and Kansas State Univ., Manhattan.
[b,c,d]Means in the same column with different superscript letters are significantly different (P<.05).

Figure 1



From Savell and Cross (1986).

Table 5. Quality "Targets" for Beef.

1) "White tablecloth" or "gourmet" restaurants. Modest and higher marbling.
2) Retail supermarket and institutional trade. Small (Ch⁻) and slight ("Select") marbling.
3) "Lean" or "Lite" market. Slight or lower marbling. Carcasses *less than* 1.0 cm fat cover.

second and largest "target" is the retail supermarket/institutional market. Assuming that the "white tablecloth" market would use a high proportion of carcasses with modest or higher marbling, a large majority of Choice beef available for retail markets would be that with small marbling. Based on this and my previous discussion, I believe that the retail supermarket/institutional market could merchandise beef from low Choice *or* the new "Select" grade *or* both under a brand name. I believe a minimum .64 cm (.25 in) of white fat cover would provide additional assurance that beef from the Select grade would be very acceptable in palatability.

The third target I have identified is the "lite" (lean), "organic" beef type of market. A maximum fatness may be a very important criterion for carcasses in this category. Carcasses with more than .76 cm (.30 in) fat cover would not fit this "target" very well. A significant proportion of "Select" carcasses would fit this system, plus those with less marbling. Medium to large-framed bulls would be especially appropriate, when the goal is "organic" or "natural" in addition to "lite" or "lean."

Because of the strong message from consumers that excess fat must be removed from beef, I believe it is feasible that, in the future, yield-grade 2 beef carcasses will either receive a price premium over yield-grade 3 carcasses or that yield-grade 2 beef will become the basis for pricing and yield-grade 3 carcasses will be discounted. Average yield-grade 2 carcasses will have about 6% less fat trim than yield-grade 3 carcasses. Subcutaneous fat can be trimmed from yield-grade 3 carcasses (though inefficient) but it is difficult to remove seam fat.

If the impetus in the marketing of "branded" beef continues (or becomes greater, as I believe it will), USDA quality "grading" likely will be utilized less and "certification" of carcasses for branded programs may become a more important role for USDA. Then maturity, color of fat, color of lean or other characteristics can be specified to meet specifications for "branded" beef.

Relationships of Fatness to Palatability and Consumer Acceptance of Pork

For pork production, *one type* of market hog should work for all segments of the industry. There are no "quality" targets or *a* single target for which the industry aims, and there is not much concern about "quality" in pork. The expression that "pork is pork" just about describes industry's interest in differences in pork quality. And, until the last two or three years, consumers have not been overly concerned about either the quality or composition of pork. Tenderness and flavor have not been considered problems for pork from typical market-weight barrows and gilts, and most everybody expects pork to *not* be very juicy because of the high endpoint temperatures to which pork is usually cooked.

However, consumers recently have become quite critical of the composition of pork, and their definition of "quality pork" would likely be cuts with a high lean-to-fat ratio and an acceptable, fresh color. Yet, fresh pork sausage and bacon routinely contain up to 50% and 80% fat, respectively. Data from Christians (1984) presented in Table 6 show that the fatness of carcasses in carcass shows actually increased from 1980 to 1984. Six hundred eighty-seven carcasses from the 1984 National Barrow Show averaged 34.3 mm fat depth at the 10th rib. This hardly shows any industry responsiveness to consumers' concerns about calories and diet-health issues.

The message from consumers is now clear that the fat content of pork must be significantly reduced. If the industry responds fully to this message, the effects that this would have on meat palatability must be evaluated. Most of the earlier research on the relationships between fatness of pork and meat palatability involved cooking pork to 82 to 85 C (180 or 185 F). Cooking to this high endpoint temperature should show more of an advantage for highly marbled pork than cooking to more moderate temperatures of 66 to 77 C (150 to 170 F). Naumann et al. (1960) reported that a laboratory panel found no clear-cut preference for chops of different marbling levels. However, a 216-member consumer panel preferred cooked chops with high marbling, and higher marbling resulted in lower shear values. Murphy and Carlin (1961) reported that marbling did have a positive relationship with tenderness, juiciness and flavor. Saffle (1962) found that marbling was positively correlated with juiciness but not tenderness or flavor. However, consumers actually discriminated against marbling of fresh cuts. Backfat thickness had very little effect on meat palatability, and the relationship

Table 6. Five-Year Averages for Pork Carcass Shows[a].

				Carcass data adjusted to 105 kg		
Year	*Total hogs in show*	*Total carcasses evaluated*	*Weight, kg*	*Length, cm*	*10th-rib fat, cm*	*Loin-eye area, cm^2*
1980	12,787	12,787	100.7	81.5	2.43	33.3
1981	11,970	11,970	100.2	82.0	2.36	33.8
1982	10,438	3,264	104.3	81.8	2.41	34.1
1983	8,969	2,888	104.8	81.8	2.59	33.7
1984	7,637	3,350	106.6	81.5	2.67	33.4

[a]From Christians (1984).

Table 7. Frequency of Individual Judgements of Tenderness within Sessions on Grilled Eye Muscle or Eye Muscle from Roasted Pork Loin Joints[a,b].

Ranked texture judgement	*Grilled eye muscle*			*Roasted loin joint*		
	Fattest	*Intermediate*	*Leanest*	*Fattest*	*Intermediate*	*Leanest*
Least tender	33	41	57	48	56	61
Intermediate	40	54	36	52	60	51
Most tender	57	35	37	64	48	52
		x^{2***}			x^{2} n.s.	

[a]From Rhodes (1970).
[b]Backfat ranged from 1.0 to 4.0 cm.

between backfat thickness and marbling was very low. In a study by Skelly et al. (1973), chops from 263 hogs were cooked to an internal temperature of 75 C. Correlations of marbling or *longissimus* chemical fat with palatability traits were very low and all nonsignificant.

Rhodes (1970) studied the palatability of pork carcasses ranging in fatness from 10 to 40 mm (.40 to 1.57 in). His overall conclusion was that although meat from fatter pigs *tended* to be judged more tender in direct comparisons, the overall results did not support the contention that fatness of the carcass is associated with meat tenderness. However, some other observations of his data are noteworthy. He categorized carcasses into three fatness groups and determined frequencies for judgements of tenderness (Table 7) of grilled loin chops (83 C endpoint temperature). Carcasses in the leanest group had a significantly higher proportion of "least tender" scores, and those in the fattest group had a higher proportion of "most tender" scores. These results may not be surprising because high endpoint temperatures may favor fatter cuts of meat, i.e., fatter cuts may take more "cookery abuse." When whole loins were roasted, there were no significant differences among fatness groups for tenderness scores. This indicates that the slower cookery method of roasting minimizes the palatability differences that might otherwise exist.

In the research by Rhodes (1970), panelists also judged loin roasts in the raw state, expressing their preferences for fatness and overall attractiveness. The preferred backfat thickness was 18 mm (.71 in), which indicates a discrimination against fatness but also against extreme leanness.

Numerous studies have been conducted on the effects of cooking on pork palatability (Webb et al., 1961; Weir et al., 1963; Carlin et al., 1965; and Pengilly and Harrison, 1966). These researchers observed increased juiciness and cooked yields of pork loin roasts with decreased internal temperature. Simmons et al. (1985) grilled or roasted loin chops to internal temperatures of 60, 70 and 80 C for sensory and objective evaluations. Juiciness and tenderness increased and cooking losses decreased for both cooking methods as temperature decreased (Table 8). On the other hand, pork flavor intensity of roasted loins increased as temperature increased. Warner-Bratzler shear values were not affected

Table 8. Means and Standard Error Values for Various Traits of Pork Loin Chops Oven-Prepared or Grilled to Three Internal Temperatures.

	Kind of preparation							
	Oven				*Grill*			
	Internal temperature (°C)				*Internal temperature (°C)*			
Trait	*60*	*70*	*80*	*S.E.*	*60*	*70*	*80*	*S.E.*
Total cooking loss (%)[d]	21.62[a]	29.32[b]	36.68[3]	±0.61	26.16[a]	32.97[b]	41.66[c]	±0.91
Moisture (%)	66.73[a]	63.96[b]	60.27[c]	±0.26	67.44[a]	64.62[b]	60.24[c]	±0.58
Lipid (%)[e]	15.76[a]	17.06[a]	17.47[a]	±0.50	11.67[a]	12.30[a]	14.29[b]	±0.24
Tenderness[f]	10.90[a]	10.15[b]	8.49[c]	±0.18	11.26[a]	10.82[a]	9.14[b]	±0.31
Juiciness[f]	11.77[a]	9.69[b]	6.96[c]	±0.24	11.36[a]	9.42[b]	6.06[c]	±0.28
Pork flavor intensity[f]	8.51[a]	9.93[b]	11.40[c]	±0.21	9.79[a]	10.12[a]	10.17[a]	±0.19
Off flavor intensity[g]	11.76[a]	12.33[ab]	13.10[b]	±0.19	13.32[a]	13.74[b]	13.96[b]	±0.13
Warner-Bratzler shear value[h]	3.47[a]	3.49[a]	4.34[b]	±0.37	3.26[a]	2.99[a]	3.15[a]	±0.12

[a,b,c]Mean values in the same row bearing unlike superscripts differ significantly ($P<.05$).
[d]Cooking losses calculated as a percentage of raw chop weight.
[e]Dry matter basis.
[f]Means derived from sensory panel scores with possible range from 0-15 where 0 = extremely tough, dry or bland, and 15 = extremely tender, juicy or flavorful.
[g]Means derived from sensory panel scores with possible range from 0-15, where 0 = extreme off flavor and 15 = no off flavor.
[h]kg per 1.27 cm core.
From Simmons et al. (1985).

for grilled chops but higher temperatures resulted in higher shear values for roasted chops.

From results on the effects of cooking and fatness on pork palatability, it appears that the slight reduction in palatability that might result from producing hogs with significantly less fat could *at least* be compensated for by reducing the recommended endpoint temperatures for pork by 6 to 8 C or more.

There likely are limits to the extent that fatness can be reduced without having physiological effects on hogs and negative effects on pork quality. Kempster et al. (1986) and Wood et al. (1986) conducted studies on the effects of fat thickness on pork quality as assessed by butchers, consumers and laboratory and trained taste panels. Their fat thickness groups averaged 8, 12 and 16 mm of fat which, by U.S. standards, would all be lean. They found that the lipid content of subcutaneous fat decreased drastically as fatness decreased and, in addition, the incidence of fat separation from muscle increased dramatically. The lower quality of fat in the lean group was presumably due to the grey, "sloppy" appearance of underdeveloped fat tissue (Wood, 1984). Forty-five butchers found significantly more drip loss and more "floppy" (apparently soft and wet) muscles from the lean (8 mm) group than from the intermediate (12 mm) and fat (16 mm) groups. Overall, butchers preferred the intermediate fatness group. Consumers and trained panelists were only given the comparison of the lean and fat group and did not evaluate the intermediate group. Consumers preferred the visual appearance of the lean (8 mm fat) loin chops but gave higher tenderness scores to chops from the fat group. The trained panel gave higher juiciness scores to chops from the fat group but found no other differences in palatability.

An additional concern about reducing fatness of pork carcasses too extensively is the possibility of cold-shortening when very rapid chilling is used. Dransfield and Lockyer (1985) found that excised pork *longissimus* muscles cold-shortened when chilled at 3 C or below. After aging for 5 d at 3 C, muscles chilled at −1 C were twice as tough as those chilled to 10 C in 26 h. These authors speculated that for carcasses with about 12 mm (.47 in) or less of fat cover over the loin, and chilled to 10 C or less within 3 h, about 20% would have cold-toughened *longissimus* muscles. These authors concluded that the projected increased introduction of very rapid cooling, particularly in conjunction with lean pig production and hot deboning of pork (in the United Kingdom), could toughen all cuts in about 60% of carcasses.

From the research results presented, it appears that reducing the fatness of market hogs to a certain point is essential, but fat reduction beyond that point may result in quality and palatability problems. Reducing fat thickness over the *longissimus* muscle to less than 12 to 13 mm could result in a significant incidence of fat separation from muscle, a gray, sloppy appearance of fat, and more drip loss from muscle. It could also result in cold-toughening, particularly with the introduction of very rapid chilling systems. Although the relationship of fatness to meat palatability is not strong, there is a trend for pork from extremely lean carcasses and/or with low marbling to be less juicy and less tender than that from carcasses with 17 to 18 mm (.70 in) or more fat thickness over the loin. The minor decreases in palatability associated with reducing the fatness of carcasses from current levels (estimated 2.9 cm or 1.15 in) can be more than offset by reducing the recommended cooking temperature endpoint by 6 to 8 C. Kauffman (1982) and Dikeman (1982) proposed that the "ideal" fat thickness on pork carcasses should be 15 mm (10th rib) and 18 mm (last rib), respectively, which would essentially describe the same carcass.

Malphrus et al. (1975) conducted an extensive study on consumer preference for pork cuts with varying degrees of marbling. Bacon, fresh ham and chops representing light, medium and heavy marbling were presented frozen to 900 consumers (300 for each type of cut) and interviews were conducted regarding preference. Only one type of cut (representing the three marbling levels) was presented to an individual consumer. Means for chemically-determined fat content of cuts with the different degrees of marbling are presented in Table 9. It is interesting that bacon from the light marbling group contained 45.9% fat and bacon from the heavy marbling group contained 79.6% fat! The lightly-marbled pork chops were preferred by 75.7% and the heavy-marbled chops were preferred by only 4.6% of the 300 consumers interviewed (Table 10). Eighty-four percent of those who would pay more for the chops they preferred chose chops with light marbling. Subcutaneous fat was trimmed identically for all cuts.

Bacon with low fat was preferred by 57% of the consumers interviewed, and the fattest bacon was preferred by only

Table 9. Fat Content of Pork Cuts with Varying Degrees of Marbling as Determined by Ether Extract Analysis, June 1974[a].

Cut	*Light marbling*	*Medium marbling*	*Heavy marbling*
	percent of fat		
Bacon[b]	45.9	59.8	79.6
Ham[c]	2.6	5.8	11.9
Pork Chop[d]	2.1	4.6	7.9

[a]Average of three pieces of meat for each degree of marbling for each cut.
[b]Includes total strip consisting of abdominal muscles and fat.
[c]Includes semimembranosus, semitendinosus and biceps femorus muscles and seam fat.
[d]Includes longissimus muscle only and excludes seam fat.
From Malphrus et al. (1975).

Table 10. Consumer Preference for Pork Chops with Varying Degrees of Marbling, Clemson Area[a], South Carolina, 1974.

Preference[b]	*Proportion of consumers*
	Percent
Light marbling	75.7
Medium marbling	17.0
Heavy marbling	4.6
No preference	2.7
Total	100.0[c]

[a]One chain store in each – Clemson, Pendleton, and Seneca.
[b]Based on responses from consumers viewing samples in a cardboard tray and covered with clear plastic wrapping material.
[c]Total number interviewed was 300 consumers.
From Malphrus et al. (1975).

Table 11. Consumer Preference for Bacon with Varying Degrees of Fatness, Clemson Area[a], South Carolina, 1974.

Preference[b]	*Proportion of consumers*
	Percent
Leanest	57.0
Medium fatness	33.3
Fattest	8.7
No preference	1.0
Total	100.0[a]

[a]Total number interviewed was 300 consumers.
From Malphrus et al. (1975).

8.7% of consumers (Table 11). Sixty-one percent of those who would pay more for the bacon of their preference chose the leanest bacon. Consumers showed no strong preference for marbling level in fresh ham slices.

Malphrus et al. (1975) concluded that consumers preferred lean pork chops and bacon and were willing to pay a few cents more per pound for the lean cuts they preferred. These authors also concluded that emphasis on increasing marbling does not seem justified. I would speculate that if a consumer study similar to this one was conducted in 1987, consumer preferences for leanness and their willingness to pay more to get it would be even greater than in 1975.

Relationships of Fatness to Palatability and Consumer Acceptance of Lamb

A majority of U.S. consumers do not eat lamb, and it is mostly consumed by ethnic and religious groups. However, there may be a "new wave" of consumers who like trying new things and who are quite affluent (ASPC, 1981). Lamb is not competitively priced with poultry or pork and it is consumed primarily for its unique taste or for its use in religious customs. Generally, lamb has not been included in the fat, diet-health controversy and consumers of lamb do not worry much about its fatness. The lamb slaughter/processing industry is not concerned about carcass composition, as evidenced by rare use of USDA yield grading. Therefore, it is unlikely that the fatness of lambs will be reduced significantly, unless producers are forced to reduce fatness to improve efficiency. Consequently, a discussion of the effects of reduced fatness on lamb palatability may be mostly academic.

Carpenter and King (1965) evaluated the effects of cooking method, marbling and other traits on tenderness of lamb rib chops. Tenderness was most affected by cooking method and core position. Although significant, correlations between muscle fat content and tenderness were low in magnitude. Smith et al. (1970a,b) evaluated the relationships between carcass quality traits and palatability of leg roasts and rib, loin and sirloin chops of 240 lamb carcasses. A maximum of 17% of the variation in palatability was accounted for by USDA quality grade traits. Mean differences in shear values and taste panel scores among Prime, Choice and Good grades were too low to be of practical importance, although chops and roasts from Prime carcasses had the highest proportion of "desirable" taste panel ratings.

Jeremiah et al. (1971) evaluated the relationship between marbling and palatability of individual muscles from leg chops. They concluded that increased marbling was of little importance for tenderness but did contribute to increased juiciness of three of the leg muscles.

The influence of both subcutaneous fat and marbling on lamb palatability was evaluated by Smith et al. (1976). Their data support the hypothesis that increased subcutaneous fat results in increased tenderness via changes in postmortem chilling rate (Table 12). When carcasses were divided into four fat thickness groups (.76, .40, .23 and .10 cm, Table 13), carcasses with .23 cm (.09 in) fat thickness generally had considerably lower juiciness and tenderness scores and higher shear force values than carcasses with .40 cm and .76 cm (.16 and .30 in, respectively) fat thickness. Carcasses with .10 cm (.04 in) fat thickness had distinctly lower palatability scores than carcasses with .40 cm fat thickness. These results indicate that Kauffman's (1982) and Dikeman's (1982) recommended fat thickness values of .25 cm, and .25 to .35 cm, respectively, may not be sufficient for desirable palatability, unless electrical stimulation and other postmortem technologies are utilized to enhance palatability.

To this point, my discussion of the effects of fatness on lamb palatability has focused on tenderness and juiciness, but not on flavor. Field et al. (1983) concluded that there was no convincing evidence that fatness or plane of nutrition has a significant influence on lamb flavor. It does appear that type of feed likely is more related to flavor than fatness.

Table 12. Palatability Means for Two Muscles from Three Finish Groups of Lambs[a].

	Longissimus Finish group[b]			*Biceps femoris Finish group[b]*		
Trait	*Thick*	*Int.*	*Thin*	*Thick*	*Int.*	*Thin*
Juiciness	6.1[c]	6.1[c]	6.0[c]	5.4[c]	5.1[c]	5.0[c]
Myofibrillar tenderness	6.6[c]	6.6[c]	5.4[d]	7.3[c]	6.2[d]	5.4[d]
Connective tissue	6.7[c]	6.6[c]	5.7[d]	6.6[c]	5.6[d]	5.2[d]
W.B. Shear	4.6[c]	6.1[e]	7.5[e]	4.9[c]	5.0[c]	6.0[d]

[a]From Smith et al. (1976).
[b]Thick = >.75 cm, Int. = .25 to .75 cm, Thin = <.25 cm.
[c,d,e]Means in the same row within muscle with different superscripts are significantly different (P<.05).

Table 13. Shear Values and Sensory Scores for Two Muscles for Lamb Carcasses in Four Fat Thickness Groups[a].

	Average fat thickness, cm			
Trait	*.76*	*.40*	*.23*	*.10*
Fragmentation[b]				
Longissimus	7.3[c]	6.3[d]	6.8[cd]	5.5[e]
Biceps femoris	7.2[c]	6.4[d]	5.6[e]	5.0[e]
Connective tissue[b]				
Longissimus	6.8[c]	6.7[c]	6.5[c]	5.6[d]
Biceps femoris	6.6[c]	6.1[c]	5.3[d]	5.2[d]
W.B. shear force, kg				
Longissimus	4.4[c]	6.0[d]	6.3[d]	7.9[c]
Biceps femoris	4.5[c]	5.5[de]	5.0[cd]	5.9[c]

[a]From Smith et al. (1976).
[b]Higher scores equal greater ease of fragmentation and less connective tissue.
[c,d,e]Means in the same row with different superscripts are significantly different (P<.05).

Savell and Cross (1986) recommended a minimum of 3% chemical fat for acceptable palatability of loin and rack chops and 2% for leg roasts. Carcasses grading low Choice or higher should have at least these levels of intramuscular fat. Therefore, it seems reasonable that the industry should market lambs that will grade a very high percentage of Choice carcasses and have .40 to .50 cm (.16 to .20 in) of fat thickness. This should result in an approximately equal proportion of yield-grade 2 and 3 carcasses.

Conclusions

No single beef quality/fatness level will satisfy all demands of different consumer segments. The industry must realize that there are now several "targets" of beef quality to consider. These "targets" include: 1) "white tablecloth" or "gourmet" restaurants requiring a high level of marbling and not discriminating against excess carcass fatness; 2) retail supermarket/institutional trade which will use low Choice *or* the proposed "Select" grade *or* both under a branded name; and 3) "lean" or "lite" market for meat with almost no subcutaneous and intermuscular fat. The impetus for "branded" beef programs likely will become greater in the future. A highly efficient beef production/processing system would result from marketing cattle at an average marbling score in the upper half of slight and/or an *average* fat thickness of .90 to 1.0 cm, and the leanness and palatability of the end-product would be very desirable for the retail supermarket/institutional trade. Producing cattle with *less* than slight marbling or *less* than 3% to 3.5% intramuscular fat will be *detrimental* to the demand for beef and will result in only minor production/processing efficiency advantages.

The fatness of market hogs and the fat content of pork products must be reduced significantly to meet consumer concerns for nutrition and diet-health issues. The slight reduction in palatability that might result from decreasing the last rib backfat of market hogs from the current estimated 2.9 cm (1.15 in) to an average of about 1.8 cm (.71 in) could be more than offset by reducing the recommended endpoint temperature for pork by 6 to 8C. Pork from carcasses with *less* than 1.25 cm (.50 in) backfat could have palatability and other quality problems, particularly with the introduction of very rapid chilling. Because of only moderate genetic correlation between backfat thickness and marbling and the short generation interval in swine, selection for both marbling and trimness could be successful.

Lamb probably will continue to be consumed only by a relatively small proportion of our society, and its price or composition likely will not be nearly as important to consumers. Lambs could be marketed at a young age with .40 to .50 cm (.16 to .20 in) fat thickness, produce nearly 100% Choice (and Prime) carcasses, and yield chops and roasts with very desirable composition and palatability.

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Discussion

M. Price: Mike, I really enjoyed your talk and I agreed with most of what you said. We in Canada are debating a great deal about a lower limit for fat, with respect to quality. I belong to the school that doesn't believe there's a lower limit. I think we can sell carcasses with no fat at all, at a lower price to a different market. You mentioned stratifying the market, and I think that is important. I wish to make a point and you may wish to comment on it. One of the points that you made was that we need a minimum amount of fat in order to protect the carcass against the severe chilling techniques that our plants are using, that seems illogical. We certainly recognize that our plants are using some very severe chilling techniques, including spray chilling. It seems to just add to the problem by saying we can overcome the severity of the chill by adding an insulation layer to the carcass at great cost by putting on more fat. I wonder why can't we instead reduce the severity of chill for lean carcasses, instead of putting all carcasses into the same chiller? Preserve some chillers for those carcasses that have less finish and reduce the severity of chill, which would again reduce the cost of the chill process itself.

M. Dikeman: Thanks, I'm not sure I'm the one that needs to answer your question. I think the industry needs to answer that. On a couple of different occasions, I proposed the possibility of using different chilling environments for carcasses with different levels of fatness. And I got an overwhelming response from people in the meat packing business, the beef packing business, that it was impractical to have different chilling options for carcasses with different levels of fat. So I can't disagree with what you are saying, but the response I hear from industry is that they are probably not going to do anything such as modifying chilling rates for different levels of fat.

Price: Well, it is comforting to know that your industry is as illogical as ours is anyway (laughter).

D. Meeker: I don't have a question, Mike, but I've got a few short comments to set the record straight. The pork industry is concerned with the reduction of fat and consumer acceptance. NPPC, in particular, has placed the highest priority on fat reduction and quality improvement. Data from Hormel and Oscar Meyer indicates that the pork industry has continued its 30-year trend toward leaner hogs during the early 80's, even though we haven't made the progress possible. It's true that carcass show data show the trend toward fatter pork. These are not representative of the industry, but are a biased sample because of misguided trends of judging of live hogs, in an attempt to affect traits with more economical awards than leanness.

Dikeman: I think that was a good comment, David. One of the reasons I kept my emphasis on that is that I believe the ideal market hog description published by NPPC two to four years ago had as an ideal fatness 0.75 inches of fat, which would be about 1.8 centimeters, that I discussed. And according to the numbers of estimates that I got from the USDA, we are about 1.2 inches on the average, so we're still about a half-inch away from being near that ideal or that target. And I think the industry has been struggling in the 1980's in terms of which direction they wanted to go. I agree, I think a lot of the purebred breeders, carcass shows and judges have got the industry fairly confused, in terms of going in the same direction and making continued progress.