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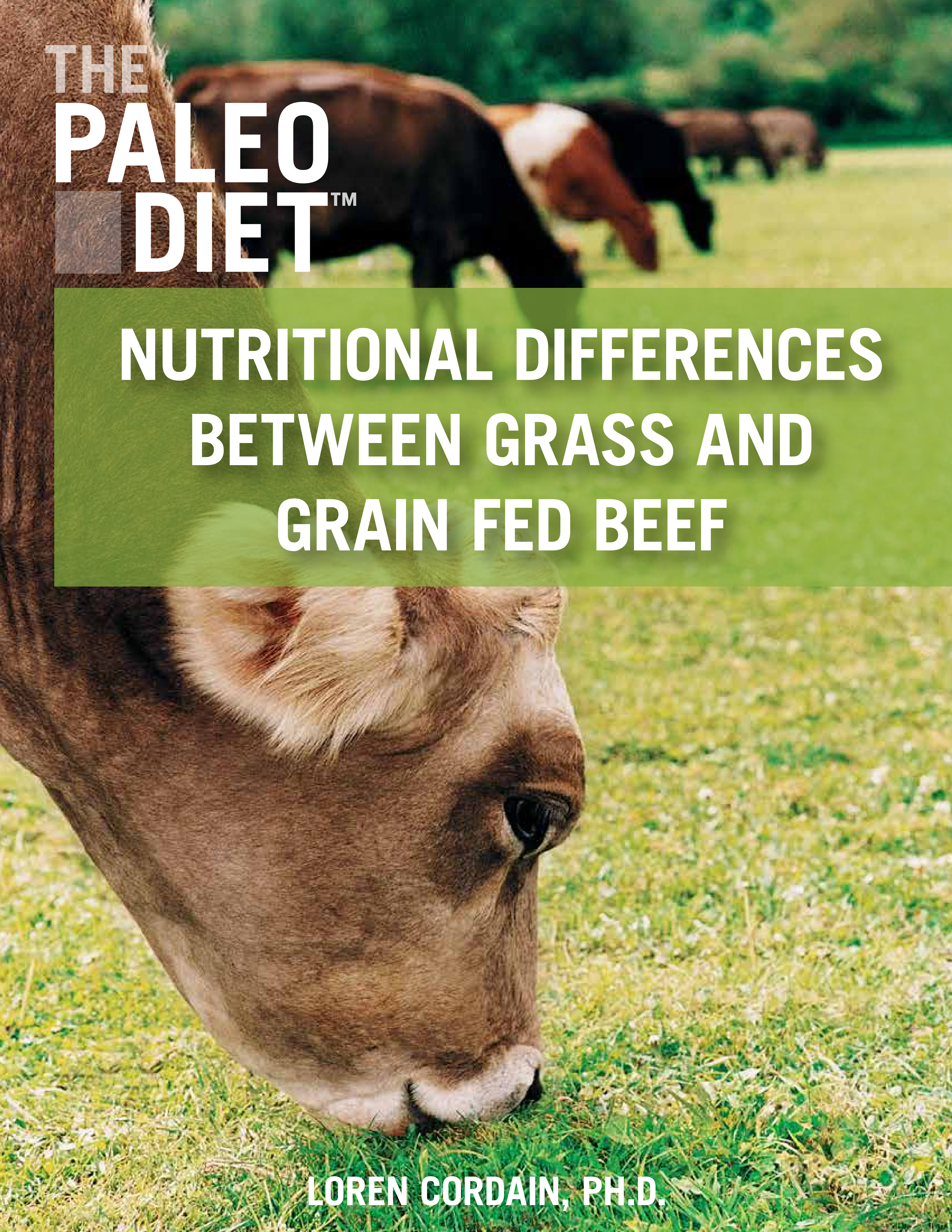
# NUTRITIONAL DIFFERENCES BETWEEN GRASS AND GRAIN FED BEEF



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# NUTRITIONAL DIFFERENCES BETWEEN GRASS AND GRAIN FED BEEF

By Loren Cordain, Ph.D., Professsor

## INTRODUCTION

Beginning in the mid 1980's a series of key publications in mainstream medical and nutrition journals[1-4] triggered an increased awareness of the relevance of ancestral human diets to the health and well being of contemporary people. Because of these insights as well as others gleaned from a variety of medical branches of learning, an entirely new academic discipline dubbed "evolutionary medicine" was born.[5] The primary tenet of evolutionary medicine is that the profound changes in the environment (e.g. in diet and other lifestyle conditions) that began with the introduction of agriculture and animal husbandry approximately 10,000 years ago occurred too recently on an evolutionary timescale for the human genome to adjust.[1-5] In conjunction with this discordance between our ancient, genetically-determined biology and the nutritional, cultural and activity patterns of contemporary western populations, many of the so-called diseases of civilization have emerged.[1-5]

With regard to diet and health, food staples and food processing procedures introduced during the Neolithic and Industrial era have fundamentally altered seven crucial nutritional characteristics of ancestral hominin diets: 1) glycemic load, 2), fatty acid composition, 3) macronutrient composition, 4) micronutrient density, 5) acid/base balance, 6) sodium/potassium ratio, and 7) fiber content. Each of these nutritional factors either alone or combined with some, or all, of the remaining factors underlie the pathogenesis of a wide variety of chronic diseases and maladies which almost universally afflict people living in western, industrialized societies.[6] In this regard, dramatic changes in cattle husbandry practices in the past 200 years have caused fundamental changes in the nutritional characteristics of domesticated beef that may adversely impact human health by altering the fatty acid composition, the macronutrient composition, and the micronutrient composition.[6]

## CHANGES IN CATTLE HUSBANDRY AND FEEDING PRACTICES SINCE THE INDUSTRIAL REVOLUTION

Since their initial domestication, almost 800 breeds of cattle have been developed[7] as specific traits (milk production, meat, heat tolerance, behavior etc.) were selected by humans overseeing breeding and reproduction. Throughout most of recorded history, cattle were typically fed by providing them free access to pastures, grasslands and range land.[8] Only in the

past 150-200 years have these animal husbandry practices substantially changed.

Technological developments of the early and mid 19th century such as the steam engine, mechanical reaper, and railroads allowed for increased grain harvests and efficient transport of both grain and cattle, which in turn spawned the practice of feeding grain (corn primarily) to cattle sequestered in feedlots.[9] In the U.S., prior to 1850 virtually all cattle were free range or pasture fed and typically slaughtered at 4-5 years of age.[9] By about 1885, the science of rapidly fattening cattle in feedlots had advanced to the point where it was possible to produce a 545 kg steer ready for slaughter in 24 months and which exhibited "marbled meat".[9] Wild animals and free ranging or pasture fed cattle rarely display this trait.[10] Marbled meat results from excessive triacylglycerol accumulation in muscle interfascicular adipocytes. Such meat typically has greatly increased total and saturated fatty acid contents, reduced protein (by energy), a lower proportion of w-3 fatty acids, higher w-6 fatty acids and a higher w-6/w-63 fatty acid ratio.[10, 11]

Modern feedlot operations involving as many as 100,000 cattle emerged in the 1950s and have developed to the point where a characteristically obese (30 % body fat)[12] 545 kg pound steer can be brought to slaughter in 14 months.[13] Although 99% of all the beef consumed in the U.S. is now produced from grain-fed, feedlot cattle[14], virtually no beef was produced in this manner as recently as 200 years ago.[9] Accordingly, cattle meat (muscle tissue) with high total fat, low protein (by energy), high absolute saturated fatty acid content, low w-3 fatty acid content, high w-6 fatty acid content and an elevated w-6/w-3 fatty acid ratio represents a recent component of human diets that may adversely influence health and well being.[4, 10, 11]

## GRAIN FED, FEED LOT CATTLE: NUTRITIONAL CONSEQUENCES FOR HUMANS

The practice of feeding grain and concentrated feed to cattle sequestered for long periods in feedlots is not necessarily benign, but rather yields meat with a number of potentially deleterious nutritional characteristics, particularly when compared to either wild animals or grass fed cattle.[10, 11] Table 1 summarizes a number of potential nutritional differences that have been identified between the meat of feed lot and grass fed beef cattle.

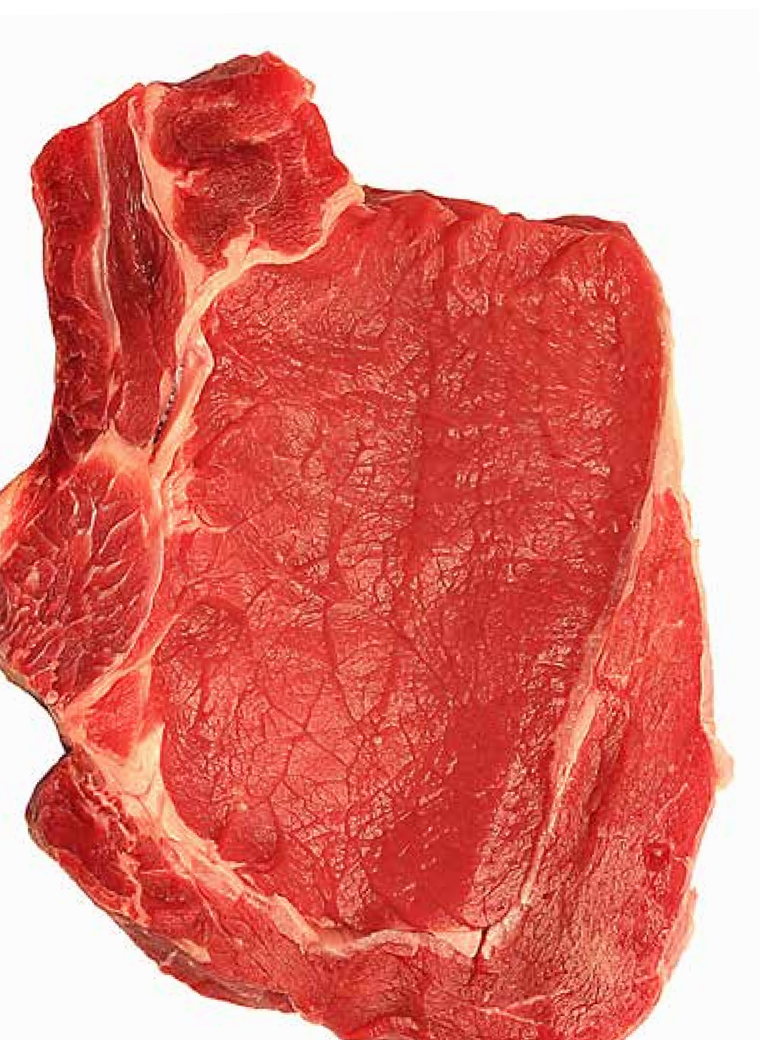
Before each of these nutritional qualities is examined

Table 1. Potential nutritional differences between feed lot and grass fed beef.

| Nutrient | Grass | Feed Lot | References |
|---|---|---|---|
| w-3 fatty acids | Higher | Lower | (11, 15-30, 40, 47, 48) |
| w-6 fatty acids | Lower | Higher | (15, 16, 18, 21, 27, 48) |
| w-6/ w-3 ratio | Lower | Higher | (11,15-21,27-30, 40, 47, 48) |
| Long chain fatty acids (both w-3 and w-6) | Higher | Lower | (11,15, 16, 17, 21, 28, 29, 47) |
| Fat content | Lower | Higher | (11, 15, 16, 18-21, 27, 40) |
| Saturated fatty acids | Lower | Higher | (11, 15-18, 27) |
| P/S Ratio | Higher | Lower | (11,15-18, 21, 27) |
| Conjugated linoleic acid | Higher | Lower | (11,15,17, 30-36) |
| Vitamin E | Higher | Lower | (25, 37-40) |
| Vitamin C | Higher | Lower | (40) |
| Beta carotene | Higher | Lower | (37, 40-42) |
| Protein content | Higher | Lower | (43) |

in more detail a few important points need to be brought up in. First, the fatty acid concentrations in grass and feed lot produced meat typically are reported in the literature in two ways: 1) as a percentage of total fatty acids, or 2) gravimetrically as (mg fatty acid/100 g muscle tissue). The former procedure may be misleading because the relative percentage of any fatty acid does not reveal the absolute amount of the fatty acid in the sample.[18] Hence, the latter method of reporting fatty acid concentrations is more useful from a human nutritional perspective.[21]

Secondly, fatty acid comparisons between grass and grain produced beef are not only dependent upon the type of feed, but also upon the total amount of feed used in finishing, which in turn influences the total fat and fatty acid content of the beef. For instance, in U.S. feedlot produced beef, there is a progressive increase in total fat with time on feed.[16, 49] Concurrent with this increase in fatness are increases in total saturated fatty acids, w-6 fatty acids, the w-6/ w-3 fatty acid ratio, along with declines in total w-3 fatty acids and the polyunsaturated/saturated (P/S) ratio.[16] Additionally, because of differing feeding practices as well as differing genetics, European grain produced cattle are frequently leaner than their grass fed counterparts[21, 29, 47] and much leaner than U.S. grain fed cattle.[21, 29, 47, 48] Consequently, comparisons of certain fatty acids between grass and grain produced beef in Europe and the U.S. may be confounded by total fat contents that are greatly dissimilar.

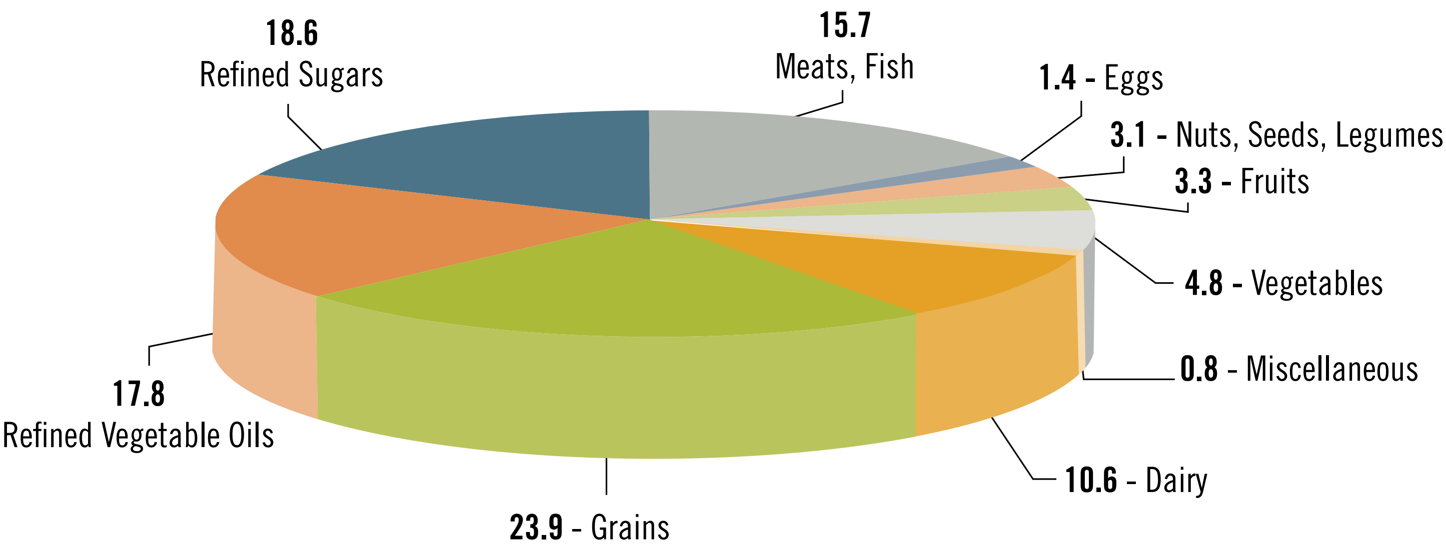


The total fat (triglyceride) content of a beef cut is typically measured by trimming the meat's surface of visible fat and epimysial connective tissue and then measuring the remaining fat by weight. This fat is frequently referred to as "intramuscular fat"[16, 51] which sometimes is used synonymously with the term "marbling fat". In fact, the majority of total triglycerides in a cut of beef occurs not within muscle cells themselves (e.g. intramuscular fat), but rather within adipocytes located between the muscle bundles (fasiculi) of a muscle. Accordingly, intramuscular storage of triglyceride is small compared to that in interfascicular adipocytes.[52]

Finally, certain statistically significant nutritional differences between grass and grain produced beef, may have little or no physiological relevance because: 1) the relative difference is small compared to the daily recommended intakes (DRI), or 2) the nutrient difference pales in comparison to contributions of the same nutrient by another food group. For instance, pasture raised beef contains 58.9 % more vitamin C than grain produced beef.[40] However the absolute difference in vitamin C concentration between pasture produced beef (25.3 µg/g beef) and grain produced beef (15.92 µ/g beef) amounts to 5.38 µg. Relative to the DRI for vitamin C for adult males (90 mg), the vitamin C contribution by either pasture or grain produced beef is so small that it has no nutritional relevance. Similar arguments could be made for beta carotene and vitamin E as both grass and grain produced beef represent negligible human dietary sources of either nutrient.[40] The central human nutritional issue here is not vitamin C, E or beta carotene concentrations in either grass or grain produced beef, but rather the contribution of these nutrients by other food groups which are rich sources of these dietary elements.

Figure 1 depicts the relative contribution of various food groups to the typical U.S. diet. Note that meats and fish supply 15.7 % of the total energy to the average

Figure 1. Relative contribution of energy by various food groups in the U.S. diet.[43]




U.S. diet, and within this food group, the daily per capita beef consumption amounts to 82 grams.[44] Many of the current health problems and chronic diseases which afflict the American public result from excessive consumption of refined sugars, grains, vegetable oils, fatty meats and dairy products.[2, 4, 6] Human health and well being could potentially be improved by including more lean grass fed beef into the U.S. diet at the expense of fatty, feedlot-produced meats, refined sugars, grains, vegetable oils and high fat dairy products.

## GRASS VS. GRAIN FED BEEF: OMEGA 3 AND OMEGA 6 FATTY ACIDS

There is little argument that grass fed cattle accumulates more w-3 fatty acids in their tissues than grain fed cattle.[11, 15-30, 40, 47, 48] This nutrient amplification in tissues occurs because the concentration of 18:3n3 (alpha linolenic acid [ALA]) in pasture grass is 10 to 15 times higher than in grain or typical feedlot concentrates.[30] Despite the biohydrogenation of dietary polyunsaturated fatty acids (PUFA) that occurs in the rumen, sufficient 18:3n3 escape the rumen intact and available for absorption in a variety of tissues, including muscle and liver.[45] In mammals the liver represents the primary tissue which chain elongates and desaturates 18:3n3 into long chain w-3 fatty acids (20:5n3, 22:5n3 and 22:6n3) which then can be deposited in muscles and other tissues.[46]

Not only do feed lot cattle maintain lower w-3 fatty acids in their tissues than grass fed cattle, but a characteristic increase in the total w-6 fatty acids occurs [15, 16, 18, 21, 27, 48] as a result of grain feeding.[16] Because typical cereals fed to cattle such as maize (w-3/ w-6 = 70.7) and sorghum (w-6/ w-3 = 16.2) contain very little 18:3n3 and much higher 18:2n6 (50), the cattle's tissues reflect the fatty acid balance of the grains they consume. Table 2 displays concentrations of w-3 and w-6 fatty acids in grass produced beef reported in the literature, and Table 3 reports the counterpart for grain produced beef.

Figure 2 shows that an average 100 g sample of grass fed beef contains 3.2 times more 18:3n3, 2.1 times more long chain w-3 fatty acids and 2.4 times more total w-3 fatty acids than an average sample of grain produced beef, whereas the total w-6 content of grain fed beef is 1.7 times greater than grass fed beef.

## GRASS VS. GRAIN FED BEEF: TOTAL FAT, SATURATED FATTY ACIDS, MONOUNSATURATED FATTY ACIDS AND POLYUNSATURATED FATTY ACIDS

Tables 4 and 5 list total fat, saturated, polyunsaturated and monounsaturated fatty acids differences between grain and grass fed beef that have been reported in the literature. As was previously mentioned, the total fat content of feedlot produced beef is highly dependent upon the time on feed (TOF). Because this variable was not reported in all studies in Tables 4 and 5, it is more useful to evaluate how TOF influences total fat

Figure 2. Literature summary (n=7 studies) of w-3 and w-6 fatty acid differences between grass and grain produced beef. LC w-3 (20:5n3, 22:5n3, 22:6n3).

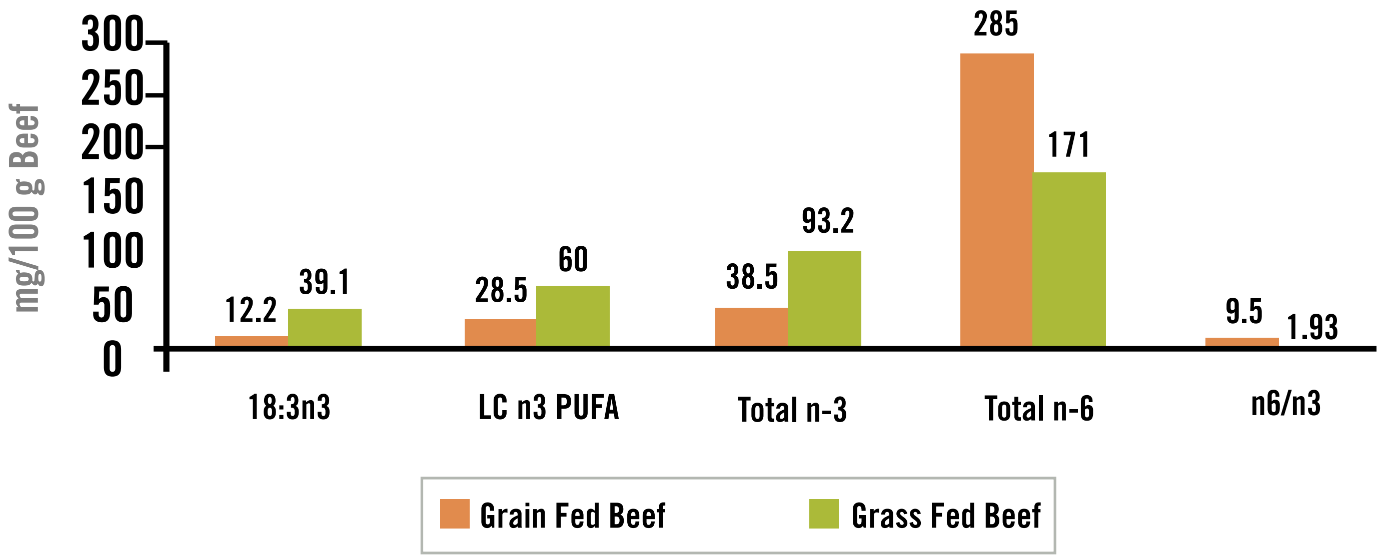



Table 2. Concentrations of w-3 and w-6 fatty acids in grass fed beef (mg fatty acid/100 g muscle tissue). LC w-3 (20:5n3, 22:5n3, 22:6n3).

| 18:3n3 | LC w-3 | Total w-3 | Total w-6 | w-6/ w-3 | Tissue | Reference |
|---|---|---|---|---|---|---|
| na | na | 52 | 139 | 2.67 | muscle | (27) |
| 68 | na | na | na | na | biceps | (19) |
| 35 | na | na | na | na | longissimus | (19) |
| 24 | 37 | 61 | 138 | 2.26 | semitendinosus | (18) |
| 36.3 | 52.8 | 89.1 | 115 | 1.29 | triceps | (21) |
| 32.7 | 39.4 | 72.1 | 95 | 1.32 | longissimus | (21) |
| 48.5 | 69.5 | 118 | 160 | 1.36 | gluteobiceps | (21) |
| 34.5 | 49.5 | 84 | 120 | 1.43 | gluteus | (21) |
| 23.4 | 36.6 | 60 | 250 | 4.17 | longissimus | (16) |
| 35.3 | 51 | 86.3 | 98 | 1.2 | longissimus | (29) |
| 47.4 | 61.2 | 108.6 | 148 | 1.4 | longissimus | (29) |
| 48.9 | 104.9 | 154.7 | 334 | 2.16 | rump cut | (15) |
| 32.4 | 65.2 | 97.6 | 192 | 1.96 | strip loin cut | (15) |
| 42.1 | 93.0 | 135.1 | 258 | 1.91 | blade cut | (15) |
| **(Mean + SD)** | | | | | | |
| (39.1+ 2.0) | (60.0+22.3) | (93.2+31.4) | (171 + 74) | (1.93 + 0.85) | | |

Table 3. Concentrations of w-3 and w-6 fatty acids in grain fed beef (mg fatty acid/100 g muscle tissue). LC w-3 (20:5n3, 22:5n3, 22:6n3).

| 18:3n3 | LC w-3 | Total w-3 | Total w-6 | w-6/ w-3 | Tissue | Reference |
|---|---|---|---|---|---|---|
| na | na | 16 | 275 | 17.2 | muscle | (27) |
| 18 | na | na | na | na | biceps | (19) |
| 14 | na | na | na | na | longissimus | (19) |
| 11 | 35 | 46 | 183 | 5.28 | semitendinosus | (18) |
| 16 | 29 | 45 | 325 | 7.22 | psoas | (18) |
| 9 | 18 | 27 | 240 | 8.89 | longissimus | (18) |
| 9 | 16.7 | 25.7 | 251 | 9.76 | triceps | (21) |
| 10.4 | 13.9 | 24.3 | 224 | 9.20 | longissimus | (21) |
| 10.9 | 19.5 | 30.4 | 315 | 10.35 | gluteobiceps | (21) |
| 9.4 | 6.8 | 16.2 | 245 | 15.2 | gluteus | (21) |
| 9.5 | 18 | 27.5 | 397 | 14.45 | longissimus | (16) |
| 9.6 | 17.8 | 28.8 | 283 | 9.28 | longissimus | (29) |
| 5.3 | 19.3 | 24.6 | 332 | 13.7 | longissimus | (29) |
| 21.4 | 75.3 | 96.6 | 399 | 4.13 | rump cut | (15) |
| 14.9 | 48.4 | 63.3 | 254 | 4.01 | strip loin cut | (15) |
| 15.1 | 52.8 | 67.8 | 272 | 4.01 | blade cut | (15) |
| **(Mean + SD)** | | | | | | |
| (12.2+4.2) | (28.5+19.5) | (38.5 + 23.1) | (285 + 62) | (9.5 + 4.4) | | |

and saturated fatty acid content. Figure 3 demonstrates how fat content increases by both weight and energy with increasing TOF in feedlot produced beef. Figure 4 depicts increases in saturated fat with TOF in feedlot produced beef. Table 6 lists seven common USDA beef quality grades and the associated amount of marbling and fat percentage by weight with these cuts of meat. Figure 5 illustrates how these quality grades translate into total fat percentages by energy.

Figure 3. Changes in fat content of feedlot produced beef with time on feed.[16]

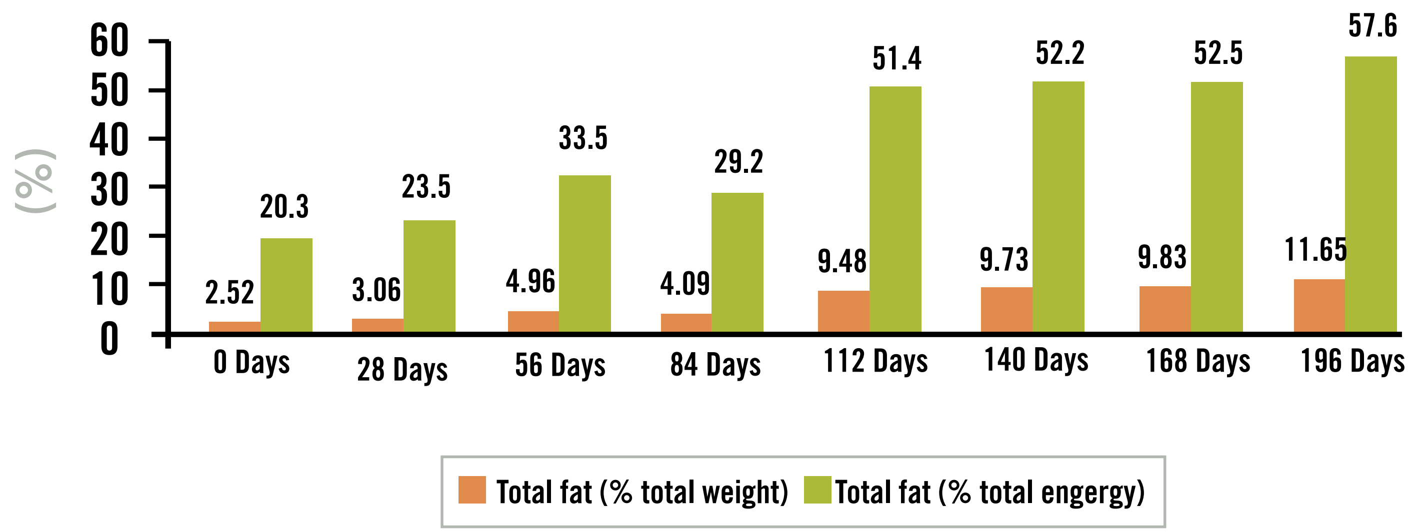



Table 4. Concentrations of various fatty acids in grass fed beef. (mg fatty acid/100 g muscle tissue). SAT: saturated fatty acids, PUFA: polyunsaturated fatty acids, MUFA: monounsaturated fatty acids

| Total fat | SAT (mg) | PUFA (mg) | PUFA/SAT | MUFA | Tissue | Reference |
|---|---|---|---|---|---|---|
| 2400 | 933 | 191 | 0.20 | 1276 | muscle | (27) |
| 2040 | na | na | na | na | biceps | (19) |
| 2650 | na | na | na | na | longissimus | (19) |
| 3080 | 910 | 1055 | 1.16 | 1115 | semitendinosus | (18) |
| 2650 | 1022 | 204 | 0.20 | 1424 | triceps | (21) |
| 2860 | 1220 | 167 | 0.14 | 1473 | longissimus | (21) |
| 3390 | 1231 | 278 | 0.23 | 1881 | gluteobiceps | (21) |
| 2240 | 856 | 205 | 0.24 | 21 | gluteus | (21) |
| 2520 | 1192 | 310 | 0.26 | 1018 | longissimus | (16) |
| 3940 | 1773 | 224 | 0.13 | 1943 | longissimus | (29) |
| 1980 | 892 | 280 | 0.31 | 808 | longissimus | (29) |
| 2792 | 1118 | 489 | 0.43 | 1185 | rump cut | (15) |
| 2120 | 900 | 289 | 0.32 | 931 | strip loin cut | (15) |
| 2138 | 801 | 393 | 0.49 | 944 | blade cut | (15) |
| **(Mean ± SD)** | | | | | | |
| (2629 ± 559) | (1071 ± 267) | (340 ±243) | (0.34 ± 0.28) | (1235 ± 382) | | |

Table 5. Concentrations of various fatty acids in grain fed beef (mg fatty acid/100 g muscle tissue). SAT: saturated fatty acids, PUFA: polyunsaturated fatty acids MUFA: monounsaturated fatty acids.

| Total fat | SAT (mg) | PUFA (mg) | PUFA/SAT | MUFA | Tissue | Reference |
|---|---|---|---|---|---|---|
| 5000 | 2028 | 291 | 0.14 | 2681 | muscle | (27) |
| 4330 | na | na | na | na | biceps | (19) |
| 5630 | na | na | na | na | longissimus | (19) |
| 4760 | 1909 | 2196 | 1.15 | 1525 | semitendinosus | (18) |
| 1570 | 540 | 277 | 0.51 | 753 | triceps | (21) |
| 2100 | 821 | 248 | 0.30 | 1031 | longissimus | (21) |
| 2010 | 692 | 345 | 0.50 | 973 | gluteobiceps | (21) |
| 1780 | 633 | 262 | 0.41 | 885 | gluteus | (21) |
| 9480 | 4798 | 424 | 0.09 | 4258 | longissimus | (16) |
| 4540 | 2083 | 346 | 0.17 | 2111 | longissimus | (29) |
| 1700 | 707 | 370 | 0.52 | 623 | longissimus | (29) |
| 4824 | 1865 | 496 | 0.27 | 2463 | rump cut | (15) |
| 3614 | 1568 | 317 | 0.20 | 1729 | strip loin cut | (15) |
| 3175 | 1172 | 340 | 0.29 | 1663 | blade cut | (15) |
| **(Mean + SD)** | | | | | | |
| (3894 ± 2140) | (1568 ± 1178) | (493 ± 541) | (0.38 ± 0.28) | (1725 ± 1044) | | |

Figure 4. Changes in saturated fat content of feedlot produced beef with time on feed.[16]

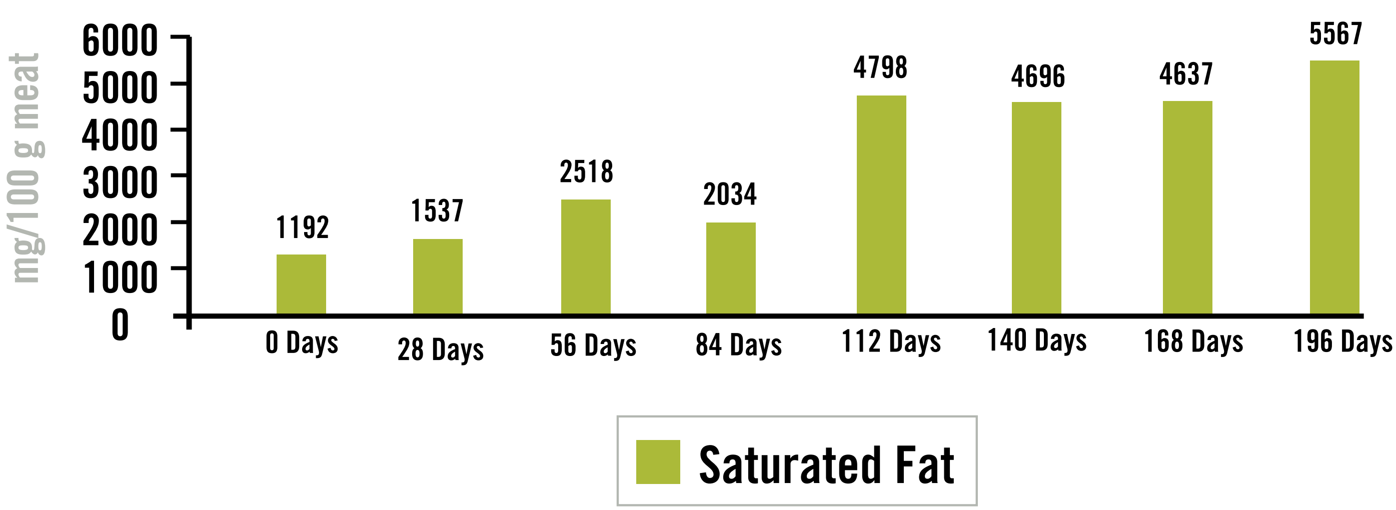


Table 6. Seven USDA beef quality grades and conversion to marbling scores and total fat percentage by weight.[51]

| Quality Grade | Marbling Degree | Marbling Score | Total fat % (by weight) |
|---|---|---|---|
| Select (-) | Slight (0 -- 40) | 4.0 - 4.4 | 2.3 - 3.0 |
| Select (+) | Slight (50 - 90) | 4.5 - 4.9 | 3.1 - 3.9 |
| Choice (-) | Small (0 - 90) | 5.0 - 5.9 | 4.0 - 5.7 |
| Choice (o) | Modest (0 - 90) | 6.0 - 6.9 | 5.8 - 7.6 |
| Choice (+) | Moderate (0 - 90) | 7.0 - 7.9 | 7.7 - 9.7 |
| Prime (-) | Slightly Ab (0 - 90) | 8.0 - 8.9 | 9.9 - 12.1 |
| Prime (o) | Moderately Ab (0 - ) | 9.0 - | 12.3 - |

Tables 4 and 5 and Figures 3 to 6 demonstrate that typical feedlot produced beef contains 2-4 times more total and saturated fat than grass fed beef. Additionally, with increasing TOF, there is a proportional increase in both total and saturated fat which is positively correlated with the marbling score.

## GRASS VS. GRAIN FED BEEF: CONJUGATED LINOLEIC ACID

Table 7 lists a number of studies evaluating differences in CLA concentrations between grass and grain produced beef. On average the concentration of CLA is between 2 to 3 times higher in grass fed beef on a per fat weight basis. Because the fat content of grass fed beef is approximately 2 to 3 times lower (Tables 4, 5; Figures 3-5) than grain produced beef, the concentration of CLA between two 100 g samples of grass and grain produced would be approximately equal. However, the nutritional advantage of grass fed beef would be that less total fat and saturated fat would be consumed to achieve an approximately equal CLA intake.

Figure 5. Seven USDA beef quality grades and total fat percentage by % weight and by % total energy.[51]

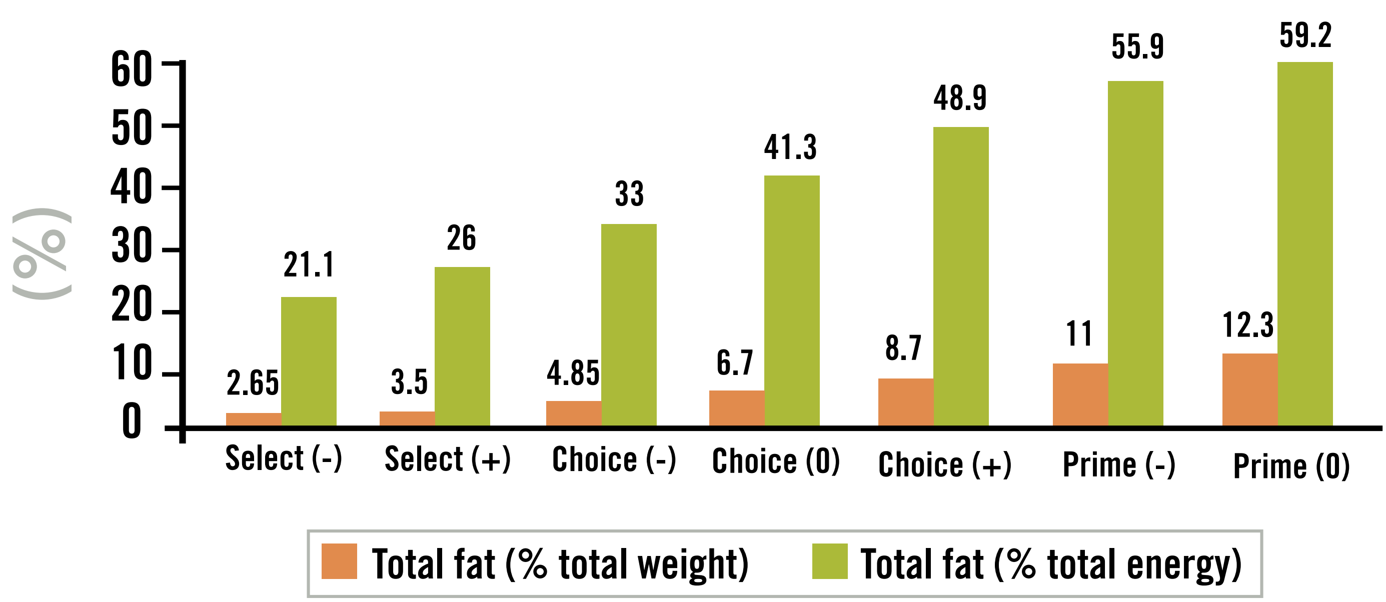


Table 7. Literature summary (n= 5 studies) of CLA (cis-9, trans-11 18:2) differences between grass and grain produced beef (mg CLA/g fat).

| Grass Fed | Grain Fed | Tissue | Reference |
|---|---|---|---|
| 4.1 | 2.6 | longissimus | (11) |
| 3.2 | 2.8 | semitendinosus | (11) |
| 5.2 | 3.1 | supraspinatus | (11) |
| 11.3 | 5.2 | rump cut | (15) |
| 6.7 | 4.5 | strip loin | (15) |
| 8.0 | 4.9 | blade cut | (15) |
| 10.8 | 3.7 | longissimus | (17) |
| 8.4 | 7.5 | longissimus (a) | (30) |
| 8.7 | 7.2 | longissimus (b) | (30) |
| 8.0 | 3.2 | longissimus | (33) |
| **(Mean + SD)** | | | |
| (7.4 + 2.7) | (4.5 + 1.8) | | |

## GRASS VS. GRAIN F ED BEEF: PROTEIN

On a per weight basis, the average 100 gram sample of grass fed beef contains 2.6 g of total fat (Table 4), whereas a comparable sample of grain fed beef contains 3.9 g fat (Table 5). However, this value for grain fed beef may be low, as demonstrated by Table 6 which lists the average fat contents of USDA quality beef grades. In the U.S., Choice Beef [either Choice (o) or Choice (+)] averaging between 5.8 and 9.7 % fat by weight are more representative of the average cut preferred by consumers.[53]

Because of the relative constancy of the protein content of the fat free mass (FFM), the energy density of edible cuts of beef is almost entirely dependent upon the percentage of fat in the sample.[42] As the fat content (by weight) of beef samples increase, there is a linear increase in the energy density of the sample (Figure 6).[42] Associated with the increase in fat content (by weight) is a characteristic decline in the protein content by energy that can be described by the cubic relationship depicted in Figure 7.[42]

Figure 6. Regression of percentage fat weight to energy (kcal/100 g) in raw cuts of beef (n = 86).

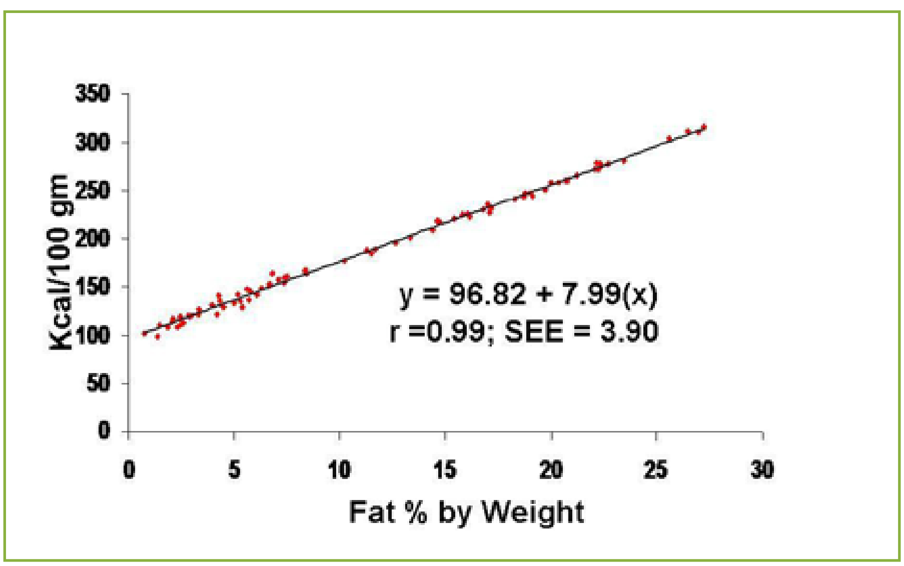


Figure 7. Regression of percentage fat weight to percentage protein energy (kcal/100 g) in raw cuts of beef (n = 86).

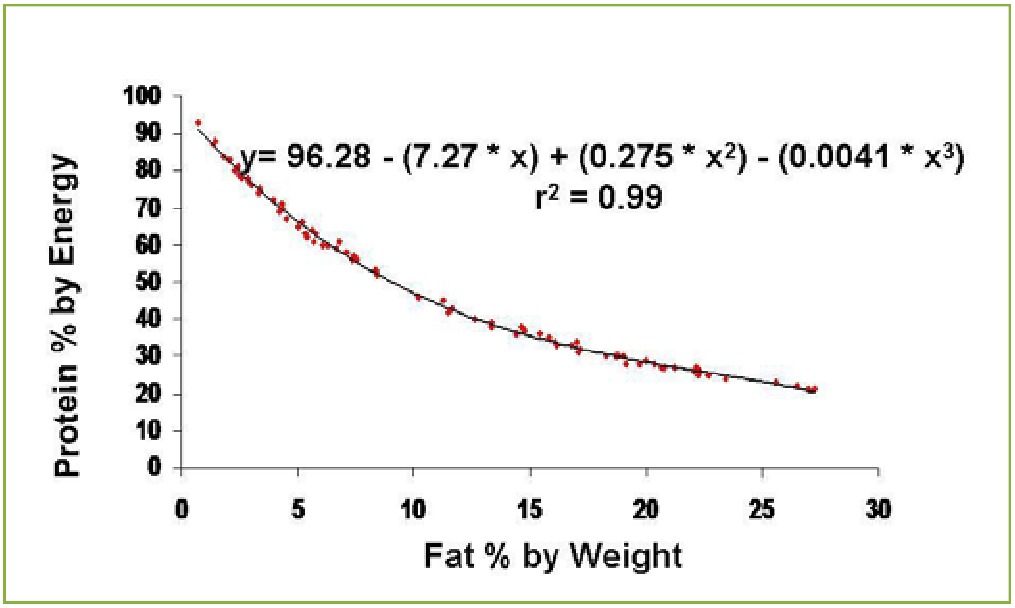



Figure 9 shows the cubic decline in the protein content of a beef sample as fat increases. Note that grass fed beef contains 76.5 % of its total energy as protein, whereas the preferred USDA Choice (+) only contains 48. 9 % of its total energy as protein.

These data indicate that increased consumption of fattier cuts of meat have the capacity to reduce the dietary protein intake as well as the important trace nutrients (Fe, Zn, vitamins B12, B6 and niacin) concentrated in the lean muscle component of beef.

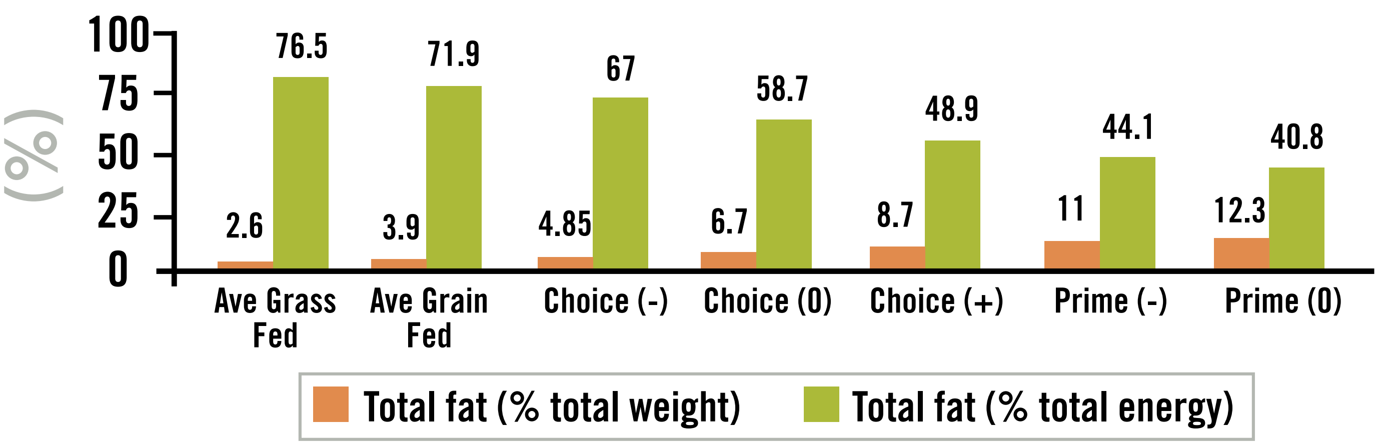
## POTENTIAL HEALTH IMPROVEMENTS BY INCREASING GRASS FED BEEF CONSUMPTION

A number of scenarios involving improvements in human health can be envisioned by including more and more lean grass fed beef into the diets of U.S. citizens. These scenarios are dependent upon the specific foods and food groups that would be potentially displaced by grass fed beef and by the amount of grass fed beef that would included in the diet. The health impact of such scenarios could range from minimal to highly significant.

## DIETARY SATURATED FAT

From per capita data it can be inferred that the average U.S. citizen consumes 82 g of beef per day[44], with ground beef (42%), steaks (20%), and processed beef (13%) comprising the bulk of the beef consumed[54]. Ground beef, choice and prime USDA quality steaks and processed beef (frankfurters, lunch meats etc) represent some of the highest total fat and saturated fat sources found in any cuts of beef. An 82 g serving of fatty (22% fat) ground beef can contain 8.8 g or more of saturated fat, whereas a comparable serving of lean (2.5% fat) grass fed beef may contain as little as 1.2 g of saturated fat. Hence a

Figure 9. The exponential decline in the protein energy of various beef samples with increasing fat % by weight.[42]



daily reduction of up to 7.6 g of saturated fat could be achieved in this scenario involving only displacement of high fat beef with lean grass fed beef.

Saturated fat intakes of < 10 % total energy are recommended to reduce the risk of cardiovascular disease[55]. Accordingly in a 2,200 kcal diet, saturated fat (9 kcal/g) should be limited to 24.4 g. Thus, the savings accrued (7.6 g of saturated fat) in this scenario by replacing fatty ground beef with lean grass fed beef represents a substantial 31 % reduction in total saturated fat. By employing the Howell equation [$\Delta$ serum CHOL (mg/dL) = 1.918 x $\Delta$SAT - 0.900 x $\Delta$PUFA + 0.0222 x $\Delta$CHOL] [56], it is possible to calculate how changes in dietary saturated fat (SAT), polyunsaturated fat (PUFA) and dietary cholesterol (CHOL) influence blood cholesterol concentrations. This single reduction in saturated fat (7.6 g), by itself, would reduce blood cholesterol concentrations by 14.5 mg/dl. Hence borderline high blood cholesterol concentrations (200 - 239 mg/dl) could be brought into desirable ranges (< 200 mg/dl) to reduce the risk of cardiovascular disease.

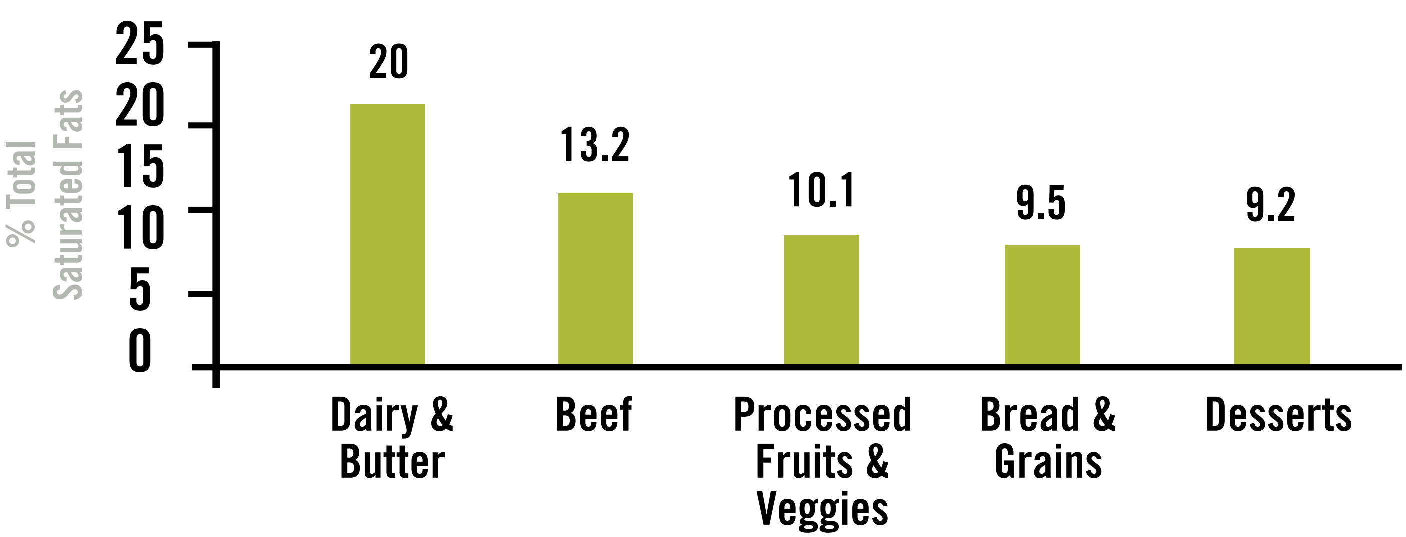
The previous example represents a best case scenario when lean cuts of grass fed beef replace high fat beef cuts. Clearly, better improvements could be realized for individuals consuming more than 82 g of fatty beef. Additionally, lesser, but clinically significant improvements in the blood lipid profile could be accrued by partial replacement of fatty beef with lean beef. Finally, it goes without saying that additional servings of lean grass fed beef (above and beyond the 82 g per capita intake) that displace other high dietary sources of saturated fat such as whole milk, cheese, and processed foods would have beneficial effects upon LDL and total cholesterol concentrations. Figure 10 lists the major sources of saturated fat in the U.S. Diet [57].

## DIETARY PROTEIN

Because of it's inherently low fat content (2.6 % by weight), grass fed beef is also a high protein food averaging 76.5 % protein by total energy (Figure 9). Contrast these values to USDA Choice (+) beef with only 48.7 % protein by energy, or USDA Prime (o) beef with 40.8 % protein by energy, or worse still, fatty ground beef with 20.3 % protein by energy. A litany of recent human studies demonstrates that isocaloric replacement of dietary fat by lean protein has numerous health promoting effects.

Numerous short term human dietary interventions have demonstrated the therapeutic effect of lean, animal based protein upon blood lipid parameters. Wolfe and colleagues have shown that the isocaloric substitution of protein (23% energy) for carbohydrate in moderately hypercholesterolemic subjects resulted in significant decreases in total, LDL and VLDL cholesterol, and triglycerides while HDL cholesterol increased[58]. Similar blood lipid changes have been observed in normal healthy subjects[59] and in type II diabetic patients in conjunction with improvements in glucose and insulin metabolism[60, 61]. A litany of more recent studies has confirmed that elevations in dietary protein have a beneficial effect upon blood

Figure 10. The primary sources of saturated fat in the U.S. diet.[57]



lipid profiles.[62-68] The mechanism or mechanisms of action of high protein diets upon blood lipid chemistry are not clear; however animal studies suggest that the beneficial effects are caused by their powerful inhibition of hepatic VLDL synthesis, perhaps by altering apoprotein synthesis and assembly in the liver.[69]

The relationship between protein intake and blood pressure has been comprehensively examined in observational population studies, and support the notion that higher protein intake can lower blood pressure.[70-72] A substantial number of randomized controlled trials have demonstrated that higher dietary protein either from soy[73-75], mixed dietary sources[68] or from lean red meat[76] significantly lower blood pressure.

In addition to reducing CVD risk by improving the blood lipid profile and reducing blood pressure, higher protein diets have been shown to improve insulin sensitivity and glycemic control[62, 64, 67, 77-79] while promoting greater weight loss[63, 66, 67, 80, 81] and improved long term sustained weight maintenance[82, 83] than low fat high carbohydrate calorie restricted diets. The weight loss superiority of higher protein, calorie restricted diets over either calorie restricted (low fat/ high carbohydrate) diets or calorie restricted (high fat/low carbohydrate) appears to be caused by the greater satiety value of protein compared to either fat or carbohydrate.[80, 83-86] Of the three macronutrients (protein, fat, carbohydrate), protein causes the greatest release of a gut hormone (PYY) that reduces hunger[86] while simultaneously improving central nervous system sensitivity to leptin[80], another hormone that controls appetite and body weight regulation.

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