Exploring Nutrient Content of Meats Using Research Protocols at the Nutrient Data Laboratory

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Scientists at USDA's Nutrient Data Laboratory (NDL) study and report the nutrient content of foods. This paper highlights the content of lipids (fats) and other nutrients in beef and the effect of cooking on these nutrients in some grass- and grain-fed lamb and beef cuts. Data from NDL studies are available in the USDA National Nutrient Database for Standard Reference (USDA, 2017a). The data from direct analysis of nutrient components found in over 9000 foods are used for national intake surveys, labeling, policy, and other purposes (Ahuja et al., 2013).

NDL meats research study methods include these key steps:

a. Determine what research is needed, often in cooperation with industry/university collaborators, based on objective information such as market research, consumption data, mandatory labeling cuts/nutrient, and market shares.

b. Develop protocols and quality control procedures using standard operating procedures, validated analytical methods and analytical labs.

c. Produce a statistical sampling plan specifying number and type of samples required from representative sources.

d. Collect and prepare representative samples of meat from sources such as packing plants or suppliers or retail stores, using the sampling plan. Experienced university meat scientists fabricate samples into retail cuts when necessary. They weigh and dissect the meat sample components such as bone, cartilage, fat, and lean meat. This is done for both raw and cooked samples. The fat and the lean components are then separately homogenized and packaged before being sent to laboratories for nutrient analysis.

e. Analyze nutrient content at USDA-validated laboratories using official analytical methods such as AOAC (AOAC, 2000) and quality assurance procedures such as standard reference materials (SRMs), in-house control materials, and blind duplicates.

f. Evaluate data for consistency and for detecting potential outliers.

g. Prepare data products available for public dissemination.

GRASS- AND GRAIN-FINISHED LAMB STUDY

Colorado State University (CSU) conducted a study with input from NDL and the American Lamb Board for the purpose of obtaining nutrient and composition data for 11 widely purchased retail domestic lamb cuts. The estimated per capita intake of lamb in the US was 1.0 pound in 2015, with higher popularity among specific population groups (USDA ERS, 2017).

Samples for cuts of domestically-raised grain-finished and grass-finished lamb were collected during all four seasons from retail suppliers providing the majority of the market. Grass-finished lamb cuts were obtained from the two representative sources which had seasonal supply: The Intermountain West region and the West Coast region. Grain-finished cuts were obtained from three sources: 2 in the Intermountain West region and 1 from the West Coast region.

Raw samples (n=24 per grain-finished and n=10 per grass-finished cut) were dissected using standard protocols. Each cut's total weight and the weight of each component, including separable lean, separable fat, and refuse, were recorded. ["Separable lean" pertains to muscle, connective tissue, and intramuscular fat that are considered edible. "Separable fat" is the seam fat and the fat on the outside of the cut.]

Cuts designated to be grilled were prepared on a two-sided grill preheated to 195° C until a 60° C internal temperature was attained. Cuts assigned to be roasted were cooked on racks in roasting pans in preheated 160° C convection oven to 60° C internal temperature. Ground lamb was pan-grilled in a non-stick anodized skillet preheated to 195° C and removed from heat at 74° C internal temperature. Post-cooking weights for all cuts were recorded. Cuts were refrigerated for at least 12 hours. Cooked samples were dissected and weighed using standard protocols for the components previously described.

Laboratories were validated by NDL as having the ability to accurately analyze samples using established methodology in order to participate in the study. Nutrient data quality protocols included use of quality control samples in each analytical batch of samples, in-house laboratory control materials, and random blind duplicates. The separable lean, seam fat, and external fat components were homogenized and analyzed at CSU for proximates, fatty acids, and cholesterol. Minerals and vitamins were analyzed at other laboratories. Estimated nutrient values were developed for raw and cooked cuts as "separable lean only" and "separable lean and fat" profiles.

In this study, saturated fatty acids (SFA) were the sum of 10:0, 12:0, 14:0, 15:0, 16:0, 17:0, 18:0, 20:0, 22:0, and 24:0. Monounsaturated fatty acids (MUFA) were summed 14:1, 15:1, 16:1, 17:1, 18:1, 20:1, 22:1, and 24:1. Polyunsaturated fatty acids (PUFA) were the sum of 18:2 n-6, 18:2 CLA, 18:3 n-3 (ALA), 20:2 n-6, 20:4, 20:5 n-3 (EPA), 22:2, 22:4, 22:5 n-3 (DPA), 22:6 n-3 (DHA). *Trans* fatty acids (TFA) were summed 16:1t, 18:1t, and 18:2t.

Grass- and grain-finished lamb results

For these results, data for separable lean from all cuts were combined to create datasets for cooked grass-finished, cooked grain-finished, raw grass-finished, and raw grain-finished. Results for total fat were expressed as g/100 g edible tissue, while fatty acids were expressed as g/100 total fat.

The primary SFA were 16:0 (palmitic) and 18:0 (stearic). The primary PUFA was 18:2 n-6 (linoleic). The primary MUFA was 18:1 (oleic). The main TFA was 18:1t, primarily 18:1 t11 (vaccenic acid). Initial results indicated that total fat for raw was lower in grass-finished (5.2 g) compared to grain finished (5.4 g) expressed as g/100 g edible tissue. For these raw and cooked cuts, SFA, PUFA, total CLA, & TFA (especially vaccenic acid), were higher in grass- compared to grain-finished, expressed as g/100 g fat. MUFA was lower in grass- compared to grain-finished. When the effect of cooking was examined, total fat was 7.8 g in cooked grain-finished compared to 5.2 g grass-finished raw (per 100 g edible tissue), which appeared to be 32% higher in cooked than the raw counterpart. In grain-finished, total fat was 8.7 g in cooked and 5.4 g in raw, making cooked appear to be 63% higher than raw. Differences were observed for cooked compared to raw for SFA, MUFA, PUFA, and TFA, as well. However, sample size was not large enough to determine statistical significance when comparing data among cuts from this study; thus, these should be viewed as preliminary results. Further studies are necessary.

Our general observations for total fat, SFA and MUFA are similar to those of a meta-analysis by Popova et al. (2015), in which SFA increased ($p<0.05$), while total fat and MUFA decreased ($p<0.05$) in grass- compared to grain-finished. Results suggest that pasture raising can be a successful strategy for improving lamb's nutritional quality (Popova et al. 2015). Applications from this study and a grass-fed beef study will be discussed later in this report. Regarding the effect of cooking, a higher concentration of fat and other specific nutrients compared to raw has been observed in other studies, as well. Possible reasons for this occurrence are the infiltration of fat from adjacent fatty tissue (removed after cooking) (Slover et al., 1987) and higher percent moisture loss in relation to the degree of fat lost (Garrett and Hinman, 1971). Concerning *trans*-fat, however, cooking had a minimal effect when the concentration of intramuscular fat due to cooking was considered, in a study of pasture-fed lamb and beef (Purchas et al., 2015).

Gifford et al (2016) evaluated data for each individual cut in this study, finding that total fat content varied among cuts. For example, total fat was higher in raw separable lean from grass-finished shoulder arm chops, whole shoulder, frenched rib chops, rib chops and sirloin chops than their grain-finished counterparts. However, the total fat in the 6 other cuts was lower in grass-finished compared to grain-finished. In the cooked cuts in the study, total fat content was higher in each grain-finished cut than its grass-finished counterpart (Gifford et al., 2016). In contrast, a meta-analysis published in 2015 found that grazing lambs were lower in total fat than lambs raised indoors, in most studies (Popova, Gonzales-Barron and Cadavez, 2015). Gifford et al. (2016) suggested that a reason for the cuts having higher fat in the grass-finished compared to grain-finished in their study was that they may have possessed a greater proportion of phospholipids compared to the other cuts. Gifford et al (2016) found that the majority of fatty acid content in the separable lean was composed of palmitic acid (16:0), stearic acid (18:0) and oleic acid (18:1 n9) for the grass-finished and grain-finished lamb cuts. Of the separable lean's total fatty acid profile, 59% of the profile for raw grain-finished cuts and 57% of the profile for raw grass-finished cuts was composed of polyunsaturated fatty acids (PUFA), monounsaturated fatty acids (MUFA), and stearic acid (Gifford et al., 2016).

GRASS-FED BEEF STUDY

This study was conducted to determine the nutrient composition of US-raised grass-fed beef, in collaboration with the Beef Checkoff Program, America's Beef Producers, Texas Tech University (TTU), and NDL, and was published in 2008 (Leheska et al., 2008). The estimated per capita intake of beef in the US was 53.9 pounds in 2015, (USDA ERS, 2017). While grass-fed beef represents <2% of total beef sales, grass-fed beef demand grew by 40% in 2016 (Johnson, 2017). Consumer research suggests that increased demand for grass-fed beef will not slow in the near future (Williams, 2013). Grass-fed ground beef and strip steak samples were obtained on 3 occasions from 15 producers representing 13 states (AL, AR, CA, CO, GA, ID, KY, MN, MO, MT, NM, TX, VA). Two steaks were obtained from 3 different animals for each of the 3 times, from each producer. Steaks were fabricated from the 13th rib area of the strip loin. Similarly, 85% lean ground beef was collected from 3 different carcasses at 3 different times from each producer. If 85% lean was unavailable, the next leanest ground beef (e.g., 88%) was provided. Control ground beef and strip steak samples were obtained at 3 different times in each of 3 US regions.

Steak samples were weighed and dissected to separate the lean, fat, and refuse components for each steak. All components were weighed and the edible portions were homogenized for analysis. Aliquots for steak and ground beef were prepared for analysis using study protocols. TTU analyzed proximate nutrients, while validated commercial laboratories analyzed fatty acids, cholesterol, thiamin, vitamin B12, and mineral content. Quality control was monitored using certified reference materials and blind duplicates. NDL scientists validated all data. Nutrient data for raw grass-fed ground beef and strip steaks, along with study documentation, were released in SR in 2008.

In this study, SFA was the sum of 8:0, 10:0, 12:0, 14:0, 15:0, 16:0, 17:0, 18:0, 20:0, and 22:0. MUFA was the sum of 14:1, 15:1, 16:1, 18:1, and 20:1. PUFA was the sum of 18:2, 18:3n-3 (ALA), 18:4, 20:2n-6, 20:3n-6, 20:4n-6, 20:5n-3 (EPA), 22:5n-3 (DPA), 22:6n-3 (DHA). TFA was the sum of 16:1t, 18:1t, and 18:2t.

Ground beef and strip steaks: Grass-fed and control results

Total fat was significantly lower in grass-fed steak (n=41) than in the control (n=9) ($p < 0.05$) and was also lower in grass-fed ground beef (n=42) than in the control (n=9) (Figure 1). Total SFA, n-3 fatty acids, total CLA, and vaccenic acid were significantly higher in grass-fed than control ($p<0.05$; Figures 2-4). Total MUFA was significantly lower in grass-fed than controls ($p<0.05$; Figure 2). N-6, total *trans*, total PUFA fatty acids and cholesterol results showed no significant difference between grass-fed and controls (Figures 3, 5-7). (Editor's note: However, the n-6:n-3 ratio is quite different between grass-fed and controls when comparing bars in figure 3. Grass-fed n-6:n-3 ratio is less than 4 [≈2.0] due to the elevated level of n-3.) The primary SFAs were stearic and palmitic acids. The primary MUFA was oleic acid. The primary PUFA was linoleic acid.

The effect of grass-feeding on beef fatty acids seems to be influenced somewhat by breed, the response of different muscles to the diet, growing season, harvest time, and other factors (Van Elswyk and McNeill, 2014; Duckett et al., 2009). Despite these variables, these results (Leheska et al., 2008) are similar to others comparing grass- to grain-finished beef for total fat, SFA, MUFA, PUFA, and cholesterol (Van Elswyk and McNeill, 2014).

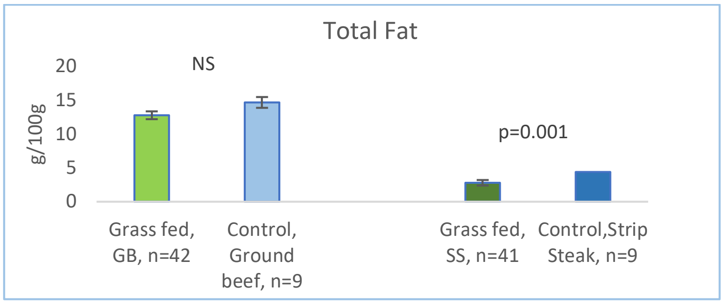

Figure 1. Total fat (g/100 g edible tissue) content of grass-fed and control ground beef (GB) and strip steaks (SS). Grass-fed GB included 3 composite samples from 13 grass-fed producers plus 1 composite sample from 2 grass-fed producers. Grass-fed SS included 3 composite samples from 13 grass-fed producers, 1 composite from another producer, plus 2 composite samples from 1 grass-fed producer. Control GB and SS included samples from 3 US regions on 3 occasions. (Data from Leheska et al., 2008).

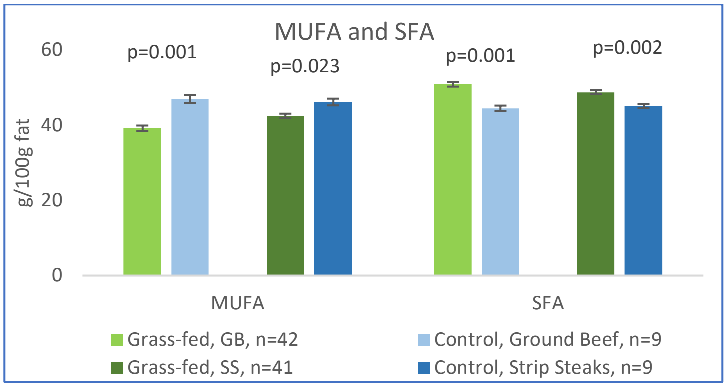

Figure 2. MUFA and SFA (g/100 g fat) content of grass-fed and control ground beef (GB) and strip steaks (SS). Grass-fed GB included 3 composite samples from 13 grass-fed producers plus 1 composite sample from 2 grass-fed producers. Grass-fed SS included 3 composite samples from 13 grass-fed producers, 1 composite from another producer, plus 2 composite samples from 1 grass-fed producer. Control GB and SS included samples from 3 US regions on 3 occasions. (Data from Leheska et al., 2008).

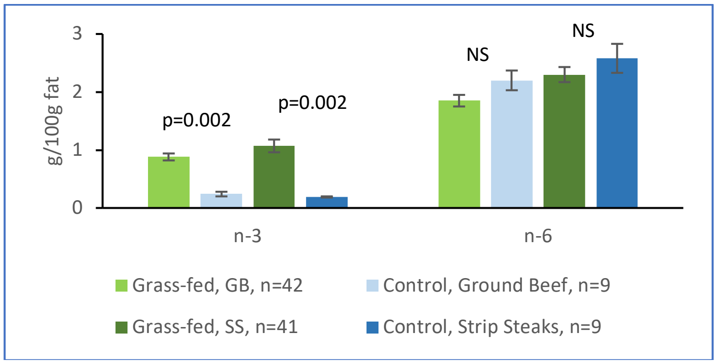

Figure 3. N-3 and n-6 (g/100 g fat) content of grass-fed and control ground beef (GB) and strip steaks (SS). Grass-fed GB included 3 composite samples from 13 grass-fed producers plus 1 composite sample from 2 grass-fed producers. Grass-fed SS included 3 composite samples from 13 grass-fed producers, 1 composite from another producer, plus 2 composite samples from 1 grass-fed producer. Control GB and SS included samples from 3 US regions on 3

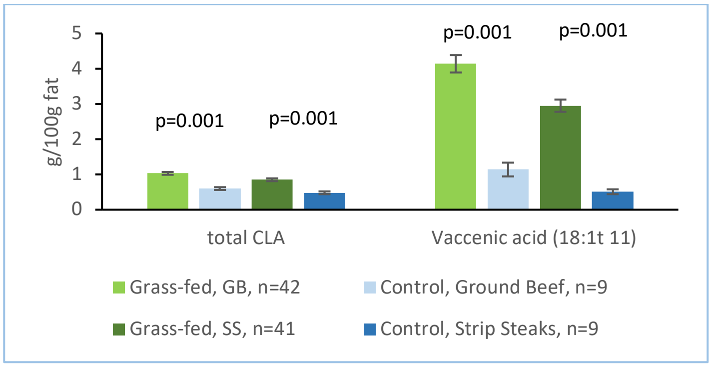

Figure 4. CLA and vaccenic (g/100 g fat) content of grass-fed and control ground beef (GB) and strip steaks (SS). Grass-fed GB included 3 composite samples from 13 grass-fed producers plus 1 composite sample from 2 grass-fed producers. Grass-fed SS included 3 composite samples from 13 grass-fed producers, 1 composite from another producer, plus 2 composite samples from 1 grass-fed producer. Control GB and SS included samples from 3 US regions on 3

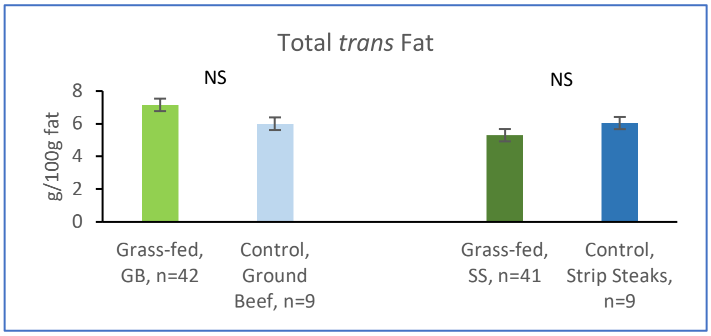

Figure 5. Total trans content (g/100 g fat) of grass-fed and control ground beef (GB) and strip steaks (SS). Grass-fed GB included 3 composite samples from 13 grass-fed producers plus 1 composite sample from 2 grass-fed producers. Grass-fed SS included 3 composite samples from 13 grass-fed producers, 1 composite from another producer, plus 2 composite samples from 1 grass-fed producer. Control GB and SS included samples from 3 US regions on 3

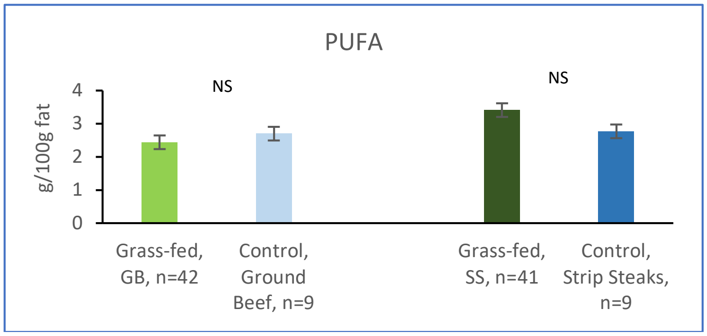

Figure 6. PUFA content (g/100 g fat) of grass-fed and control ground beef (GB) and strip steaks (SS). Grass-fed GB included 3 composite samples from 13 grass-fed producers plus 1 composite sample from 2 grass-fed producers. Grass-fed SS included 3 composite samples from 13 grass-fed producers, 1 composite from another producer, plus 2 composite samples from 1 grass-fed producer. Control GB and SS included samples from 3 US regions on 3 occasions. (Data from Leheska et al., 2008).

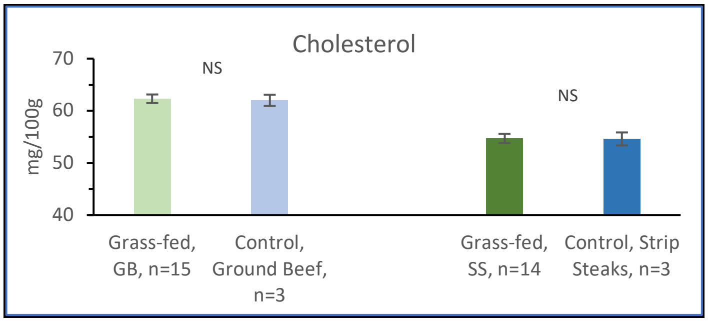

Figure 7. Cholesterol content (mg/100 g edible tissue) of grass-fed and control ground beef (GB) and strip steaks (SS). Grass-fed GB and SS included 1 composite sample from each grass-fed producer. Control GB and SS included a single composite sample for each region from which samples were collected. (Data from Leheska et al., 2008).

Lamb and beef: Grass vs grain nutrient trends and health applications

The main trends observed between grass- and grain-fed in these specific studies that were common to beef and lamb were: a) Lower total fat and lower total MUFA (as % total fat) in grass-fed compared to controls; b) Higher total SFA, vaccenic acid, and total CLA (as % total FA) in grass-fed compared to controls. Additional research is needed to confirm these observations.

Individual fatty acids are worth noting, because although reduction in total fat and SFA intake has been recommended based on specific correlations between diet and health, specific individual fatty acids seem to vary in their effect (Daley et al., 2010). For example, the primary SFA in beef and lamb regardless of feeding regime are stearic acid (the only SFA which shows a neutral effect on LDL cholesterol) and palmitic acid (which shows less cholesterol-raising effect than other SFAs in these meats) (Daley et al., 2010).

The primary MUFA in beef and lamb, oleic acid, is known for its cholesterol-lowering effect (Daley et al., 2010). Lower MUFA concentration in grass-fed compared to grain-fed beef and lamb, as well as the role of MUFA intake in promoting cardiovascular (CV) health, is well documented (Popova et al., 2015; Van Elswyk and McNeil, 2014).

PUFA content in beef and lamb in both feeding regimes is low, primarily present as omega-6 fatty acid linoleic acid (C18:2 n-6) (Van Elswyk and McNeill, 2014). Among the omega-3s, small increases of ALA and trace or no increases in EPA, DHA, and DPA in grass- vs grain-fed were noted in ours and other studies; therefore, lean cuts from either feeding method could provide modest amounts of omega-3s (Van Elswyk and McNeill, 2014).

The main TFA in animal products is usually vaccenic acid (C18:1 t11) (VA). VA is produced in ruminants and a precursor of conjugated linoleic acid (CLA) (C18:2 c9 t11). While some studies suggest CLA and VA may have health benefits (Purchas et al., 2015, Van Elswyk and McNeill, 2014), others indicate that effects of VA require further investigation (Gebauer et al., 2015). Although higher VA and total CLA concentrations expressed as percent fat were seen in grass-fed, the amounts are modest when converted to intakes per serving. Thus, amounts in grass- and grain-fed meat are nearly the same, since grass-fed meat is typically lower in total fat (Van Elswyk and McNeill, 2014). For SFA as well, although higher in grass-fed than grain-fed when expressed as percent total fat, it can translate to a lower amount per serving (Van Elswyk and McNeill, 2014).

The cholesterol content of beef and lamb are similar to that of other meats in the USDA food composition database between grass- vs grain-fed beef the difference was significant in only one US study (Rule et al., 2002; Van Elswyk and McNeill, 2014).

BEEF NUTRIENT DATA IMPROVEMENT STUDY

Following changes in the beef industry in feeding practices, age of animal at harvest, breeds, and new retail cuts, the Nutrient Data Improvement Study (NDI) was conducted through advice from the beef industry to obtain nutrient data for selected contemporary nationally representative retail beef cuts. A comparison of the lower fat levels of sirloin steak in 2010 to those in 1963 and 1990 (Figure 8; NCBA, 2014) exemplifies the magnitude of the changes over time.

The research team collaborating with USDA included National Cattlemen's Beef Association (NCBA), Texas A & M University (TAMU), TTU, CSU, and a statistician. Samples were obtained at packing plants in 6 different states (TX, WI, NE, KS, CO, AZ) from at least 12 carcasses in each state. The effects of cooking method and cut on cooking yield were reported as % of each cut's raw to cooked weight. The effects on fat concentration were reported as a percentage (g/100 g) of each cut's total edible lean and separable fat. Full details were reported by Roseland et al., 2015.

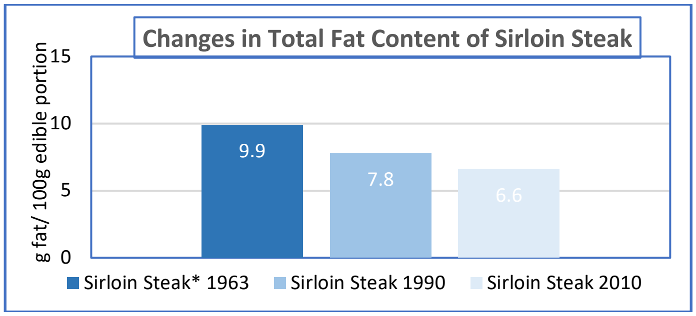

Figure 8. Total fat levels of sirloin steak compared over time. Sirloin Steak* 1963 data reported by Watt and Merrill (1963); 1990 and 2010 data reported by USDA food composition database (USDA, 2018). (Graph used by permission, NCBA, 2014)

Effect of cooking on cuts comparing chuck, round, and loin

The effect of cooking methods on different cuts had varied effects on nutrient content and cooking yield, with some effects significant ($p<0.05$). During cooking, most cuts lost fat and all cuts lost moisture. Cooked cuts had a higher concentration of fat and other nutrients compared to raw cuts, likely due to the higher percent moisture lost than percent fat lost in each cut (Acheson, 2013; Garrett and Hinman, 1971; Martin et al., 2013; Roseland et al., 2015; West et al., 2014).

Cooking yields differed among the 3 roasted cuts studied ($p<0.05$; Figure 9). Roasted chuck eye and tenderloin had the highest yields (84% and 82%, respectively) compared to ribeye roast (76%). In contrast, among the 3 grilled cuts, ribeye had the highest cooking yield (83%) compared to chuck eye and tenderloin ($p<0.001$; Roseland et al., 2015). Fat and moisture concentrations were different among the roasted cuts ($p<0.001$) (Figure 10). As fat increased, moisture decreased for the roasted cuts and the grilled cuts.

The ribeye cuts were highest in total fat, SFA, MUFA, PUFA, and TFA (g/100 g of cut's edible lean and fat), while the tenderloin cuts were lowest (both steaks and roasts) when ribeye, chuck, and tenderloin were compared. Detailed results of this study have been published (Roseland et al., 2018).

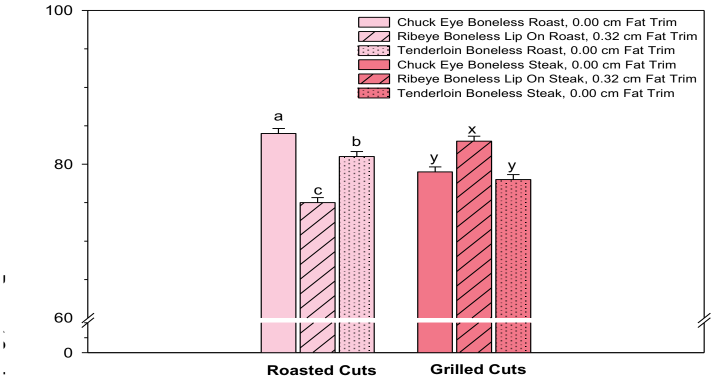

Figure 9. Cooking yields for roasted and grilled beef cuts from 3 primals. N=36 per cut. (Roseland et al., 2015)

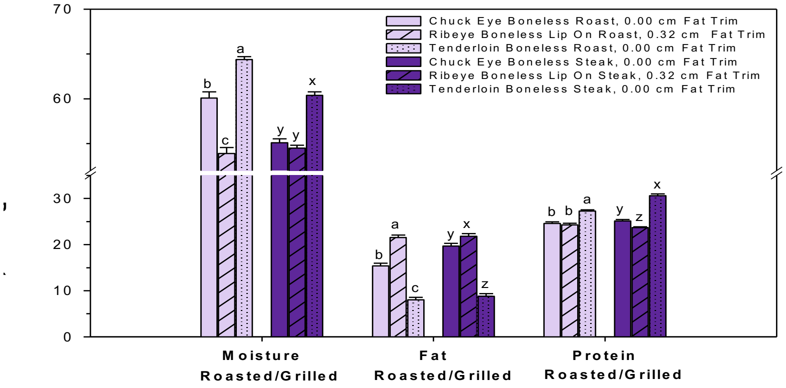

Figure 10. Proximate content of roasted and grilled beef cuts from 3 primals. N=36 per cut. (Roseland et al., 2015)

Effect of cooking on pairs of chuck, round, and loin cuts

Cooking methods affected cooking yields, fat, and fatty acid concentrations when comparing roasting, grilling, and braising. A pair-wise evaluation of comparable cuts confirmed that roasted chuck and tenderloin cuts had higher cooking yields ($p<0.05$) than their respective grilled steaks. Conversely, roasted ribeye had lower cooking yields than the grilled steak counterparts, whether boneless or with bone (Figure 11; Nguyen et al., 2014).

Fat concentrations were lower in roasted cuts than in corresponding grilled cuts. Fat was lower in grilled cuts than in corresponding braised cuts. For example, fat was 23% lower in grilled shoulder steak than in its corresponding braised cut ($p<0.001$) and was lower in three roasted cuts (chuck eye, tenderloin, and ribeye) than in corresponding thinner grilled steaks (Figure 12; Roseland et al., 2015).

The lower cooking yield of the roasted ribeye compared to grilled was unexpected, since higher final endpoint temperatures and higher cooking temperatures, as in grilling, are typically associated with lower cooking yield due to higher endpoint temperature (Wahrmund-Wyle et al., 2000a). The unusual finding could be due to the ribeye's composition, since the fat and moisture concentrations of the ribeye steak vs roast were not significantly different. On the other hand, grilled tenderloin and chuck steaks had higher fat and lower moisture than roasted counterparts, coinciding with lower cooking yields for these steaks compared to roasts ($p<0.05$). Thus, the higher moisture levels in the tenderloin and chuck roasts, plus the lower endpoint temperatures in roasting, were related to these roasts' higher cooking yields (Roseland et al., 2015).

Total SFA, MUFA, and TFA were lower in roasted ribeye, chuck eye, and tenderloin compared to grilled counterparts. Conversely, braised shoulder values were higher than or equal to grilled shoulder for SFA, MUFA, PUFA, and TFA, but only PUFA was significantly different ($p<0.05$). The higher concentrations observed in the braised cuts could be the result of using higher internal temperatures (85°C) than for other methods, possibly causing a relatively greater concentration effect, compared to cuts cooked to lower internal temperature (70°C). Detailed results of this study will be published.

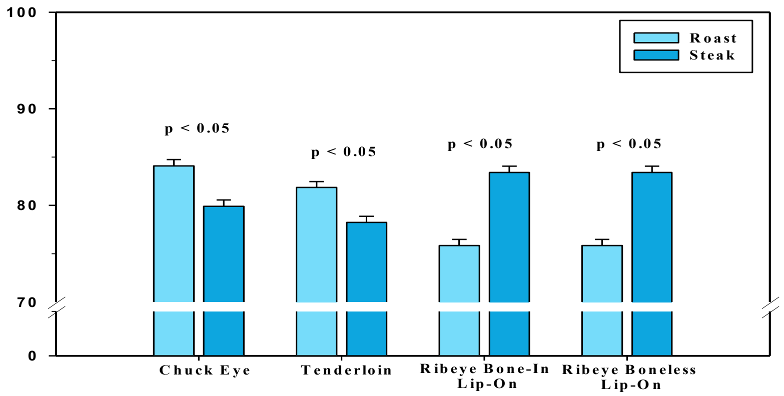

Figure 11. Cooking yields for pairs of roasted and grilled beef cuts from 3 primals. N=36 per cut. (Nguyen et al., 2014)

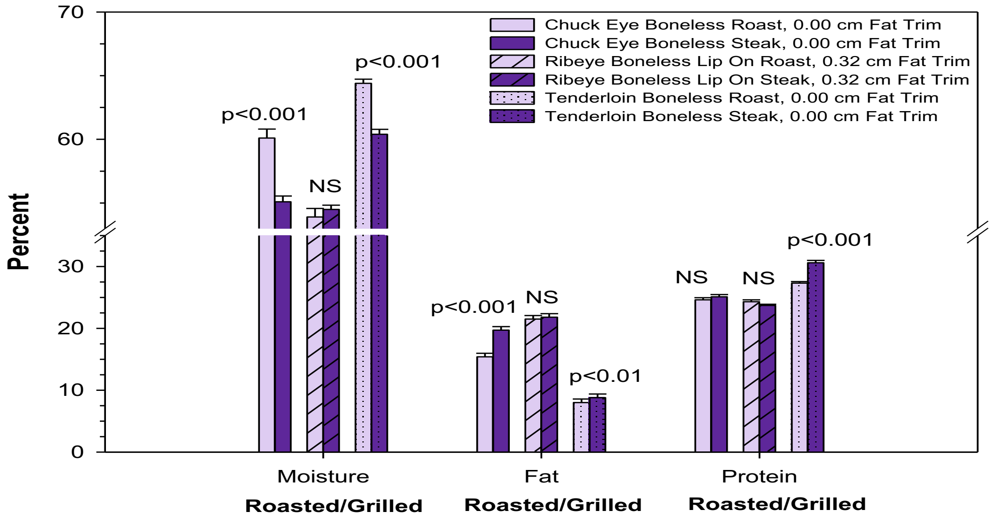

Figure 12. Proximate content of paired roasted and grilled beef cuts from 3 primals. N-36 per cut. (Roseland et al., 2015)

NATIONWIDE GROUND BEEF STUDY

A study was designed by NDL in collaboration with America's Beef Producers, University of Wisconsin (UW), and Texas Tech University to obtain ground beef nutrient data over a range of fat levels. A goal was to establish the mathematical relationship between the total fat content of raw ground beef and various nutrients, using regression techniques (USDA, 2017b). Retail samples of ground beef (n=72) labeled from 4 to 30% fat were purchased using a sampling plan developed for NDL's National Food and Nutrient Analysis Program (Pehrsson et al., 2000; Perry et al., 2003). The basis of this plan divided the US into 4 regions, each having 3 consolidated metropolitan statistical areas (CMSA), where samples were collected from stores in each CMSA in 2000 and in 2011. Samples were cooked as broiled patties, pan-broiled patties, loaves, and crumbles. Patties were made from 112 g samples pressed into molds and oven-broiled for 8.7 minutes or pan-broiled in an electric skillet for 11.75 minutes. Crumbles were pan-browned for 5.3 minutes; loaves were baked in 325°F/163°C oven for 41 minutes. All samples were cooked to 160°F/71°C internal temperature.

Raw and cooked samples were chemically analyzed for proximates, cholesterol, fatty acids, vitamins, and minerals by qualified laboratories using AOAC or other validated methodology (AOAC, 2000), duplicate samples, and reference materials. Data were evaluated using mixed model regression analysis with SAS (SAS, 2004) to obtain prediction equations. Estimated mean values for each nutrient covered the range of products from 3-30% labeled fat, showing the relationship between analytical raw fat and analytical nutrient values.

Ground beef study results

As fat in raw cuts increased, values for all 3 fatty acid classes increased as positive linear relationships ($p<0.05$; Roseland et al., 2016a). The effect of cooking showed a non-linear relationship between analytical raw fat and cooked fat, and also for cooked SFA, MUFA, and PUFA, reflecting the result of fat and moisture loss. Values for cooked fat (g/100 g) varied by cooking method. For example, cooked fat levels ranged from 3.65-16.44 in pan-broiled patty and from 4.0-16.50 in loaf (Roseland et al., 2016b).

Nutrient values for ground beef in the raw form and for four cooking methods, from samples analyzed in 2001 and 2012, been made available in the USDA food composition database (USDA, 2017a) for selected fat levels (3, 5, 7, 10, 15, 20, 25, and 30%) of raw ground beef. In addition, a ground beef calculator was developed by NDL, providing predicted nutrient profiles for raw and cooked ground beef at fat levels from 3 to 30%.

COOKING YIELD STUDIES

Cooking yield data are useful tools for making decisions regarding food plans and food preparation, such as cases where maximizing cooking yields is a desired outcome (Roseland et al., 2014). Cooking yields are gauges of changes in food weights due to moisture loss or fat gain/loss during cooking. NDL studies allow use of raw data to estimate cooked values and to determine amounts to purchase. Also, these available data--for over 175 cuts of beef, lamb, pork, poultry, and other meats--benefit researchers, scientists, nutrition professionals, industry officials, and consumers by providing valuable information regarding the impact of cooking methods, meat type, and fat content on total cook-ing yield.

In an NDL study of cooking yields, data for three different beef and three different pork cuts were evaluated. Results varied according to cooking method, with broiling having the highest and braising having the lowest cooking yields (p<0.0001; Figure 13). Among the pork cuts, although cooking yields and moisture changes differed according to cut/cooking method (p<0.0001), no difference in fat was observed although all three cuts increased in fat concentration after cooking (Roseland et al., 2012).

In an NDL study of 7 types of ground broiled meats (i.e., beef, pork, bison), cooking yields were generally inversely related to cooked fat levels. Among the types analyzed, ground pork had lowest cooking yield, which was significantly different than all the other meats (p<0.0001) except ground beef (Figure 14) (Roseland et al., 2012).

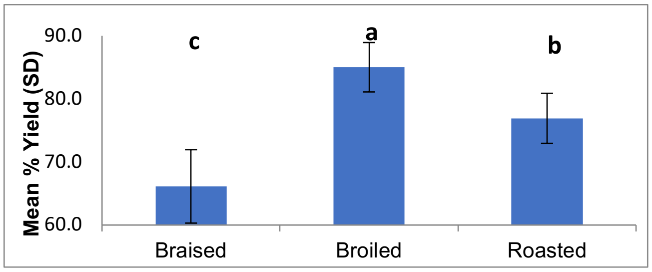

Figure 13. Cooking yields and standard deviations (SD) for beef and pork cuts prepared using 3 different methods. N=83 for Braised (71 beef shoulder roasts + 12 pork shoulder roasts); N=49 for Broiled (36 beef ribeye steaks + 12 pork loin chops); N=47 for Roasted (35 beef ribeye roasts + 12 pork center loin roasts).

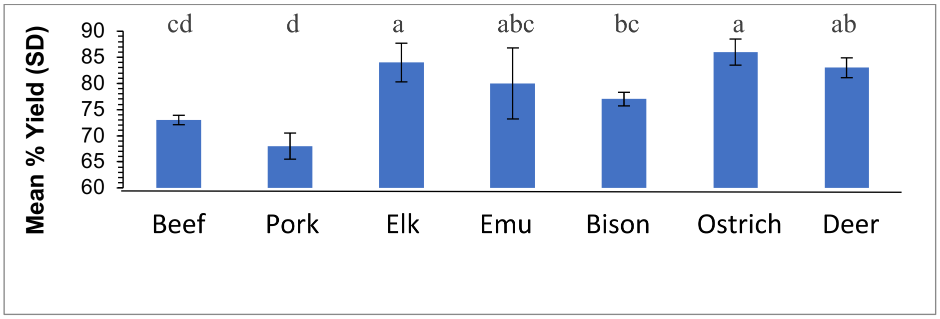

Figure 14. Cooking yields and standard deviations (SD) for seven types of ground broiled meat. N=6 for Emu, Bison, Ostrich; N=5 for Elk; N=4 for Beef, Pork; N=3 for Deer.

IMPACT OF NDL STUDIES

Obtaining nutrient composition and cooking yield data for specific cuts and cooking methods supports research examining nutrient intake and health. Further research into factors affecting nutrient composition, variability, and yield can benefit researchers, purchasers, and other database users. These studies provide “reference” data, which may be used to make general comparisons with other global sources to support trade and research, both domestically and abroad. Collaborative research protocols have been developed to conduct these studies, which have yielded representative data for scientists’ use in conducting subsequent studies. Current data from the studies can be helpful for estimating US intake, conducting further research, and establishing nutrition guidelines. The data and user-friendly tools developed by the USDA/Nutrient Data Library are accessible at: https://www.ars.usda.gov/ba/bhnrc/ndl, including a) On-line nutrient analytically-based data for over 9000 foods in SR and brand name information for over 175,000 foods in the

Branded Food Products Database; b) USDA Nutrient Data Sets for Beef and Lamb Retail Cuts to assist retailers with nutrient labeling including 28 nutrients (USDA, 2017c; USDA, 2013); c) Ground beef calculator; d) USDA Cooking Yields Tables for Meat and Poultry (USDA, 2014). Future research plans at NDL will encompass investigations of factors affecting nutrient content and variability of meat and dairy products, such as source, breed, season, animal diet and other agricultural practices, in order to attain better health outcomes in the US populations particularly among vulnerable populations.

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References

Acheson, R.J., D.R. Woerner, J.N. Martin, K.E. Belk, T.E. Engle, T.R. Brown, C.J. Brooks, A.M. Luna, L.D. Thompson, H.L. Grimes, A.N. Arnold, J.W. Savell, K.B. Gehring, L.W. Douglass, J.C. Howe, K.Y. Patterson, J.M. Roseland, J.R. Williams, A. Cifelli, J. Leheska, and S.H. McNeil. 2015. Nutrient database improvement project: Separable components and proximate composition of raw and cooked retail cuts from the beef loin and round. Meat Sci. 110:236-244.

Ahuja, J.K., A.J. Moshfegh, J.M. Holden, and E. Harris. 2013. USDA food and nutrient databases provide the infrastructure for food and nutrition research, policy, and practice. J. Nutr. 143(2):241S–249S.

AOAC, Official Methods of Analysis of AOAC International. 2000. 17th edition, AOAC International, Gaithersburg, MD. Daley C.A., A. Abbott, P.S. Doyle, G.A. Nader, S. Larson. 2010. A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. Nutr. Journal 9:10

Duckett, S.K., J.P.S. Neel, J.P. Fontenot, W.M. Clapham. 2009. Effects of winter stocker growth rate and finishing system on: III. Tissue proximate, fatty acid, vitamin, and cholesterol content. J. Anim. Sci. 87:2961-2970.

Garrett, W.N. and N. Hinman. 1971. Fat content of trimmed beef muscles as influenced by quality grade, yield grade, marbling score and sex. J. Anim. Sci. 33(5):948-957.

Gebauer, S.K., F. Destaillats, F. Dionisi, R.M Krauss, D.J. Baer. 2015. Vaccenic acid and trans fatty acid isomers from partially hydrogenated oil both adversely affect LDL cholesterol: a double-blind, randomized controlled trial. Am. J. Clin. Nutr. 102:1339-46.

Gifford, C.L., D.R. Woerner, J.N. Martin, T.E. Engle, K.E. Belk, and M.A. Harris. 2016. Complete Nutrient Analysis of Grain Finished and Grass Finished Lamb. Master's Thesis. Retrieved from Colorado State University, Digital Repository.

Johnson, N. September 22, 2016. The steaks have never been higher. Retrieved February 17, 2017 from http://grist.org/briefly/grass-fed- beef-sales-jumped-40-percent-in-2015/

Leheska, J.M., L.D. Thompson, J.C. Howe, E. Hentges, J. Boyce, J.C. Brooks, B. Shriver, L. Hoover, and M.F. Miller. 2008. Effects of conventional and grass-feeding systems on the nutrient composition of beef. J. Anim. Sci. 86(12):3575–3585.

Martin, J.N., J.C. Brooks, L.D. Thompson, J.W. Savell, K.B. Harris, L.L. May, A.N. Haneklaus, J.L. Schutz, K.E. Belk, T. Engle, D.R. Woerner, J.F. Legako, A.M. Luna, L.W. Douglass, S.E. Douglass, J. Howe, M. Duvall, K.Y. Patterson, and J.L. Leheska. 2013. Nutrient database improvement project: the influence of U.S.D.A. Quality and Yield Grade on the separable components and proximate composition of raw and cooked retail cuts from the beef rib and plate. Meat Sci. 95(3):486-494.

National Cattlemen's Beef Association (NCBA). 2014. Lean Matters: Chronicling Beef's Change from Gate to Plate – A Distinctive Public–Private Collaboration. Retrieved December 27, 2016 from http://www.beefissuesquarterly.com/CMDocs/BeefResearch/Nutrition/LeanMatters_Web.pdf

Nguyen, Q.V., J.M. Roseland, and J.R. Williams. 2016. Fat and other key nutrients in retail lamb cuts in the United States, Australia and New Zealand. Abstract and poster for National Nutrient Databank Conference, May 2016, Alexandria, VA.

Nguyen, Q.V., J.M. Roseland, J.R. Williams, J.C. Howe, and L.W. Douglass. 2014. Comparison of cooking yields and fat and moisture retentions in retail beef cuts. Abstract and poster for National Nutrient Databank Conference, May 2014, Portland, OR.

Pehrsson, P.R., D.B. Haytowitz, J.M. Holden, C.R. Perry, and D.G. Beckler. 2000. USDA's National Foods and Nutrient Analysis Program: food sampling. J. Food Compos. Anal. 23:379-389.

Perry, C.R., P.R. Pehrsson, and J. Holden, 2003. A revised sampling plan for obtaining food products for nutrient analysis for the USDA National Nutrient Database. Proceedings of the American Statistical Association. Section on Survey Research Methods [CD-ROM], Alexandria, VA. American Statistical Association. San Francisco.

Popova, T., U. Gonzales-Barron, and V. Cadavez. 2015. A meta-analysis of the effect of pasture access on the lipid content and fatty acid composition of lamb meat. Food Res. Intl. 77:476-483.

Purchas, R.W., Wilkinson, B.H.P., Carruthers, F., Jackson, F. 2015. A comparison of the *trans* fatty acid content of uncooked and cooked lean meat, edible offal and adipose tissue from New Zealand beef and lamb. J. Food Compos. Anal. 41:151-156.

Roseland, J.M., J.R. Williams, M.B. Duvall, B.A. Showell, K.Y. Patterson, J.C. Howe, J.M. Holden. 2012. Effect of meat type and cooking method on meat yields.

International Congress of Meat Science and Technology. August 14, 2012. Montréal, Canada.

Roseland, J.M., J.C. Howe, K.Y. Patterson, J.R. Williams, J.M. Holden, L.W. Douglass, J.C .Brooks, L.D. Thompson, J.W. Savell, K.B. Harris, D.R. Woerner, S.H. McNeill, A.M. Cifelli. 2014a. Nutrient results from a collaborative nationwide beef study to update data in the USDA database, 2007 to 2013. Abstract and poster for National Nutrient Databank Conference, May 2014, Portland OR,

Roseland, J.M., Q.V. Nguyen, J.R. Williams, L.W. Douglass, K.Y. Patterson, J.C. Howe, J.C. Brooks, L.D. Thompson, D.R. Woerner, T.E. Engle, J.W. Savell, K.B. Gehring, A.M. Cifelli, S.H. McNeill. 2015. Protein, fat, moisture, and cooking yields from a U.S. study of retail beef cuts. J. Food Compos. Anal. 43:131-139.

Roseland, J.M., Q.V. Nguyen, J.R. Williams, K.Y. Patterson, L.W. Douglass, J.C. Howe. 2016a. Nutrient values for ground beef products ranging from 3 to 30% fat for four cooking methods, from USDA research study. Abstract and poster for Reciprocal Meat Conference, June 19-22, 2016, San Angelo, TX.

Roseland, J.M., Q.V. Nguyen, J.R. Williams, K.Y. Patterson, L.W. Douglass. 2016b. Retail Ground Beef Identified as “Lean” from USDA Research Study. Abstract and poster at Academy of Nutrition and Dietetics conference, October 15-18, 2016, Boston, MA.

Roseland, J.M., Q.V. Nguyen, L.W. Douglass, K.Y. Patterson, J.C. Howe, J.R. Williams, L.D. Thompson, J.C. Brooks, D.R. Woerner, T.E. Engle, J.W. Savell, K.B. Gehring, A.M. Cifelli, S.H. McNeill. 2018. Fatty acid, cholesterol, vitamin, and mineral content of cooked beef cuts from a national study. J. Food Compos. Anal. 66:55-64.

Rule, D.C., K.S. Broughton, S.M. Shellito, G. Maiorano. 2002. Comparison of muscle fatty acid profiles and cholesterol concentrations of bison, beef cattle, elk, and chicken. J. Anim. Sci. 80:1202-1211.

SAS System (version 9.1). SAS Institute Inc. Cary, NC.

Slover, H.T., E. Lanza, R.H. Thompson Jr., C.S. Davis, G.V. Merola. 1987. Lipids in raw and cooked Beef. J. Food Compos. Anal. 1: 26-37.

US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2014. USDA Table of Cooking Yields for Meat and Poultry. Retrieved February 9, 2017 from https://www.ars.usda.gov/northeast-area/beltsville-md/beltsville-human-nutrition-research-center/nutrient-data-laboratory/docs/yield-and-retention

US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2013. USDA Nutrient Data Set for Retail Beef Cuts From SR, Release 3.0. Retrieved December 27, 2016 from https://www.ars.usda.gov/ARSUserFiles/80400525/Data/Beef/Retail_Beef_Cuts03.pdf

US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2017a. USDA National Nutrient Database for Standard Reference. Version Retrieved February 20, 2017 from http://www.ars.usda.gov/nutrientdata

US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2017b. Ground Beef Calculator. Retrieved February 9, 2017 from https://ndb.nal.usda.gov/ndb/beef/show

US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. 2017c. USDA Nutrient Data Set for Retail Lamb Cuts from SR. Retrieved February 9, 2017 from https://www.ars.usda.gov/ARSUserFiles/80400525/Data/Meat/Lamb_Labeling_Doc.pdf

US Department of Agriculture, Economic Research Service 2017. Livestock and meat domestic data. Quarterly red meat supply and disappearance and per capita disappearance Retrieved February 2, 2017 from https://www.ers.usda.gov/data-products/livestock-meat-domestic-data

Van Elswyk, M.E. and S.H. McNeill, 2014. Impact of grass/forage feeding versus grain finishing on beef nutrients and sensory quality: The U.S. experience. Meat Sci. 96:535-540.

Wahrmund-Wyle, J.L., K.B. Harris, J.W. Savell. 2000a. Beef retail cut composition: 1. Separable tissue components. J. Food Compos. Anal. 13(3):233-242.

Watt, B.K., and A. Merrill 1963. Composition of foods: Raw, processed, prepared. Department of Agriculture, Agriculture Handbook No. 8. Washington, DC, USA: United States Department of Agriculture.

West, S.E., K.B. Harris, A.N. Haneklaus, J.W. Savell, L.D. Thompson, J.C. Brooks, J.K. Pool, A.M. Luna, T.E. Engle, J.S. Schutz, D.R. Woerner, S.L. Arcibeque, K.E. Belk, L. Douglass, J.M. Leheska, S. McNeill, J.C. Howe, J.M. Holden, M. Duvall, K. Patterson. 2014. Nutrient database improvement project: the influence of USDA quality and yield grade on the separable components and proximate composition of raw and cooked retail cuts from the beef chuck. Meat Sci. 97(4):558-567.

Williams, A. The future of grassfed: Laying out the promise and challenges. Graze e-magazine November 1, 2013. Accessed 29 November 2016. http://www.grazeonline.com/grassfedpromisechallenge