THESIS

COMPLETE NUTRIENT ANALYSIS OF GRAIN FINISHED AND GRASS FINISHED LAMB CUTS

Submitted by

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ABSTRACT

COMPLETE NUTRIENT ANALYSIS OF GRAIN FINISHED AND GRASS FINISHED LAMB CUTS

Health conscious consumers continue to search for foods that are nutrient dense. Nutrient labeling of foods allows consumers to select foods based on nutrient composition. The objective of this study was to analyze nutrient composition of eleven raw and cooked grain-finished and grass-finished lamb cuts to update nutrient data in the USDA National Nutrient Database for Standard Reference (SR). Packages of foreshanks, whole legs, sirloin chops, whole loins, loin chops, whole frenched rib roasts, frenched rib chops, whole rib roasts, rib chops, whole shoulders, shoulder blade chops, shoulder arm chops, stew meat, and ground lamb (IMPS # 210, 234, 1245, 232A, 1232A, 204D, 1204D, 204B, 1204B, 208, 1207B, 1207A, 295 and 296) were collected in original packaging from three U.S. suppliers during all seasons. Packages were shipped to Colorado State University Meat Laboratory for retail cut dissection, cooking, and nutrient analysis. Single composites of separable lean homogenates were formed for each cut for analysis of proximates, fatty acids, vitamins and minerals. Single composited seam and external fat from each cut were analyzed for proximates, fatty acids, vitamins and minerals. Results from this study generated greater fatty acid profiles, resulted in lower fat content, established nutrient composition for grass-finished cuts and provided updated nutrient composition for inclusion into the SR.

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CHAPTER I

INTRODUCTION

Since the release of the Dietary Goals for the United States in 1977, Americans have been encouraged to reduce dietary intake of total fat, saturated fat, and cholesterol. Since 1977, per capita consumption of beef, pork and lamb have decreased, whereas per capita consumption of turkey, chicken and fish have increased in efforts to consume animal protein foods lower in total fat and saturated fat. The 2010 and 2015 Dietary Guidelines for Americans recommend consumption of nutrient dense foods while emphasizing that intake of total fat, saturated fat, *trans* fat, sugar, refined grains, sodium and alcohol should be limited (USDA & USDHH, 2010). The 2015 Dietary Guidelines for Americans accentuate the collective benefit of consuming nutrient dense food from all five food groups as part of a healthy eating pattern while limiting saturated fat, added sugar, sodium and alcohol (USDA & USDHH, 2015).

As the emphasis on consuming nutrient dense foods, continues, it is paramount to have current nutrient data available to consumers and nutrition professionals. Data currently available in the United States Nutrient Database for Standard Reference (SR) for U.S. Lamb are largely outdated. Lamb data currently available in the SR originated from the work of Ono et al. (1984) and Lin et al. (1988). Lamb nutrient data needed to be updated to reflect the current U.S. lamb population reflecting grain-finishing and grass-finishing systems. Additionally with increased consumer interest for grass-finished red meat products, it is important to provide data for U.S. grass-finished lamb cuts.

Additional nutrient labeling of food items allows consumers access to nutrient information to make informed food purchasing decisions to select food options that provide favorable nutrient content. According to Code of Federal Regulations (CFR) for "Nutrient

content claims for fat, fatty acids, and cholesterol content." (9 CFR 317.362), products that are "lean" must have less than 10 g fat, less than 5 g of saturated fat, and less than 95 mg of cholesterol per 100 g; and products that are "extra lean" must have less than 5 g fat, less than 2 g saturated fat, and less than 95 mg of cholesterol per 100 g (USDA-FSIS, 2015). Products that can be labeled under the "Heart-Check" certification program from American Heart Association must have less than 5 g of total fat, less than 2 g of saturated fat, less than 95 mg of cholesterol, less than 0.5 g *Trans*-fat and less than 360 mg of sodium (AHA, 2015). Labeling claims (9 CFR 381.454) for "excellent source of" requires a product to contain a nutrient that is 20 percent or more of the Reference Daily Intake (RDI) and "good source of" requires a product to contain a nutrient that provides10 to 19 percent of the RDI (USDA-FSIS, 2015).

The objective of this study was to analyze nutrient composition of eleven raw and cooked grain-finished and grass-finished lamb cuts to update nutrient data in the USDA National Nutrient Database for Standard Reference (SR). Current nutrient data reflective of the grain-finished and grass-finished lamb supply will allow consumers and health professionals to identify beneficial nutrient content of lamb as part of a healthy meal.

CHAPTER 2

REVIEW OF LITERATURE

Since 1970, consumption of red meat has decreased due to health concerns and increased purchase cost compared to other protein sources. Specifically, per capita consumption of retail lamb was 2.9 pounds in 1970 and most recently was 1 pound per person per year in 2015 representing a much lower consumption of lamb in the U.S. since that time (USDA-ERS, 2015). The Dietary Guidelines for Americans have recommended that consumers reduce consumption of total fat, saturated fat and cholesterol since 1977. Currently, the 2015 Dietary Guidelines for Americans recommend limiting saturated fat, added sugar and sodium consumption to 10 percent of total daily calories. Additionally, these guidelines recommend following a healthier United States (U.S.) eating pattern. The U.S. population can meet this recommendation by ingesting a variety of lean protein foods, consuming at least half of all grains in the form of whole grains, consuming three servings of low-fat dairy daily, and eating a variety of fruits and vegetables that make up half of an individual's plate (USDA-USDHH, 2015).

Protein

Protein is constructed from amino acids that are formed by bonds. Protein is the result of folding and linking a polypeptide chain. There are 20 amino acids that make up mamalian peptides and protein. Protein serves a variety of functions within the human body including maintaining body supportive roles through supporting tissue and muscle including the function of collagen in body support, transportation such as through hemoglobin, myoglobin or transportation proteins in phospholipid cell membranes, regulatory functions such as gene transcription and translation as well as in growth factors, regulating and comprising hormones, and comprising enzymes in metabolic events (Stipanuk, 2000). Proteins and amino acids are

differentiated by their functional properties and due to the amount of nitrogen that they contain. They contain far more nitrogen (approximately 16%) than other compounds (Stipanuk, 2000).

The 20 amino acids available to synthesize protein and satisfy other metabolic demands are classified as either essential or nonessential amino acids. Essential amino acids are considered to be required in the diet because there is no metabolic pathway established to synthesize those amino acids in the body. Nonessential amino acids are not required in the body because they can by synthesized through the use of enzymes and anabolic pathways. The nine amino acids that are essential or that cannot be synthesized in the body are phenylalanine, valine, tryptophan, threonine, isoleucine, methionine, histidine, lysine and leucine. The remaining amino acids are considered to be nonessential due to the body being capable of synthesizing alanine, argininie, asparagine, aspartate, cycsteine, glutamate, glutamine, proline, glycine, serine, and tyrosine. However, arginine, proline, glutamine and glycine are considered to be conditionally essential since the rate of use for these amino acids may be greater than the rate of synthesis in the body (Stipanuk, 2000).

Protein and amino acid composition reflect protein quality. Protein quality is defined as the measure of protein bioavailability, which is dependent on digestibility, availability of the amino acids in a protein, and the amino acids that make up the protein. Digestibility refers to the proportion of the dietary protein that is digested and absorbed compared to the amount of protein that passes through the gastrointestinal tract. Digestibility is commonly referred to as the percent of protein digested and utilized (Stipanuk, 2000). Red meat is approximately 94% digestible compared to beans (78%) and corn (86%) (FAO, 1991). The World Health Organization (WHO) has adopted the protein digestibility corrected amino acid score (PDCAAS) method to further classify digestibility of protein foods. According to WHO, red meat protein foods such as beef

have a PDCAAD score of 0.9 compared to other plant protein foods that range from 0.5 to 0.7 on this scoring system. Availability refers to whether individual amino acids can be absorbed, and if so, whether or not they are incorporated into a metabolic pathway to be utilized. The other factor is determining the amino acid composition in a protein to determine how efficient the protein is. Red meat including beef, veal, pork and lamb are excellent sources of protein (Esteve et al., 2002; Williams, 2007; McNeill et al., 2012; Murphy et al., 2012; McNeill, 2014; Perham, 2014; Acheson et al., 2015). During maintenance, the dietary intake of all amino acids is equal to the amino acid losses that occur from metabolism and digestion resulting in protein balance. Disease, injury or growth can increase the demand for an amino acid and consequently protein, and could affect the rate or if the amino acid is synthesized endogenously (Stipanuk, 2000). The synthesis and degradation of protein will be affected during these events in order for the body to try to correct and maintain protein balance. An individual's metabolic state and physical well-being determine the demand for various amino acids and protein. The recommended allowance for dietary protein to keep a healthy adult in protein balance is 0.8 grams per kilogram of body weight every day (IOM). On average, this calculates to the average woman requiring 46 grams of dietary protein per day and the average man requiring 56 grams of dietary protein based on normal, healthy body weights across all ages. Dietary protein needs increase when protein synthesis is greater than protein degradation such as during injury, disease, growth, pregnancy and lactation. The acceptable macronutrient distribution range (AMDR) is another method of measuring protein intake. The AMDR for protein intake is 10-35% of total daily calories for adult men and women.

Lipids

Lipids are a category of small molecules essential to biological functions in the human body. Some major functions of lipids within the human body include energy storage, structural roles in cell membranes, signaling molecules, cell signaling properties, receptors, antigens, sensors, electrical insulators, biological detergents, storage and transportation of lipid soluble vitamins, and serve as membrane anchors for protein. While the majority of media and health publications suggest limiting dietary fat, some level of fat is required in the diet to maintain these lipid functions. Since lipids do not share one unique chemical structure similarity, lipids are categorized into classes based on chemical structure. Classes of lipids include non-esterified fatty acids, glycerolipids, glycerophospholipids, steroids, eicosanoids, sphingolipids, isoprenoids and biological waxes (Stipanuk, 2000).

Fatty Acids

Fatty acids are characterized by a hydrocarbon chain tail and a carboxylic acid head. Fatty acids are commonly classified by chain length; however, this classification is not strictly defined. Short chain fatty acids contain 2 to 6 carbons, medium chain fatty acids contain 8 to 14 carbons, and long chain fatty acids contain greater than 14 carbons. Fatty acids are additionally classified based on the degree of unsaturation or the presence of double bonds within a fatty acid chain. Additional classification from degree of unsaturation results in differentiating fatty acids as either saturated, monounsaturated, or polyunsaturated fatty acids (Stipanuk, 2000).

Saturated Fatty Acids

Saturated fatty acids (SFA) are chains comprised of linear CH_2 (methyl) groups linked with a single, covalent bond without any double or triple bonds in the chain. Physical properties of saturated fatty acids include requiring an increased melting point temperature when compared

to unsaturated fatty acids of the same chain length and remaining solid at room temperature (Stipanuk, 2000).

It has been well communicated by health professionals and researchers that there is an association between saturated fat intake and cardiovascular disease. Previous clinical nutrition and epidemiological research studies have concluded that saturated fat is implicated in increasing total and low-density lipoprotein (LDL) blood cholesterol levels. While most research continues to conclude that intake of saturated fat is associated with heart disease, a recent meta-analysis contradicted those results concluding that results did not support reducing saturated fat intake and increasing consumption of polyunsaturated fat as a substitute for the reduction in saturated fat intake (Chowdhury et al., 2014).

Unsaturated Fatty Acids

Unsaturated fatty acids are chains of carbon molecules that contain at least one double bond between two adjacent carbon atoms within the chain. Unsaturated fatty acids are further classified based on the number of carbon double bonds. Monounsaturated fatty acids (MUFAs) contain one double bond linking adjacent carbons, and fatty acids containing more than one double bond between carbon molecules are classified as polyunsaturated fatty acids (PUFAs) (Stipanuk, 2000). Due to their chemical properties and structure, unsaturated fatty acids include physical properties consisting of having a lower melting temperature than saturated fatty acids of the same chain length, remaining liquid at room temperature, and oxidizing more readily. The 2015 Dietary Guidelines for Americans suggest that 30% or less of an individual's daily caloric intake should be from fat. Of that amount, the majority of calories from fat should be consumed in the form of PUFA's and MUFA's while limiting the amount of SFA's that are consumed (USDA-USDHH, 2015).

Endogenous lipogenesis is an enzymatic process that allows the human body to synthesize many unsaturated fatty acids. However, the lacking desaturase enzyme that adds a double bond beyond the ninth carbon of an 18-carbon fatty acid in mammals prevents omega-3 and omega-6 fatty acid synthesis. As a result, omega-3 and omega-6 are essential fatty acids, and these must be consumed in the diet (Stipanuk, 2000).

Trans Fatty Acids

Trans fatty acids are described as unsaturated fatty acids with one or more double bonds configured in the trans position. The *trans* configuration refers to two substituent groups residing on the opposite side of a double bond (Stipanuk, 2000). *Trans* fatty acids formed either through rumen hydrogentation of lipids or through the process of partially hydrogenated vegetable oils most commonly used in highly processed food products (Stipanuk, 2000). *Trans* fatty acids that collectively comprise *trans* fat have long been described as being implicated in cardiovascular disease and other health risks leading to *trans* fat being required on nutrition labels. However, previous researchers have concluded that *trans* fatty acids formed by ruminant biohydrogentation may not be considered detrimental to health. Huth (2007) described an association between *trans* fat from partially hydrogenated vegetable oil and a higher risk of developing coronary heart disease, but no association was established between *trans* fatty acids from ruminant hydrogenated sources. Conjugated linoleic acid refers to a mixture of geometric and positional isomers of linoleoic acid (C18:2) (Stipanuk, 2000). The major isomer of conjugated linoleic acid in fat derived from ruminants is cis-9, trans-11 (Stipanuk, 2000; Yang et al., 2015). A review by Yang (2015) concluded that conjugated linoleic acid may play a role in modulating atherosclerosis, diabetes, obesity and cancer.

Triglycerides

Glycerolipids or acylglycerides are formed by individual fatty acids being connected via ester linkages to a three carbon glycerol backbone. The majority of fatty acids exist as acylglycerides rather than free fatty acids. The number of fatty acids linked to a glycerol backbone are classified as either mono-, di-, or tri-acylglycerides. Triglycerides are the most abundant lipid in the human body. Triglycerides are the major stored energy form in the human body (Stipanuk, 2000).

Glycerophospholipids (Phospholipids)

Glycerophospholipids or phospholipids are structurally comprised of glycerol esterified to two fatty acids and a phosphate group. The five common phospholipids that can be produced are phosphatidylcholine, phosphaditlyethanolamine, phosphatidylserine, phosphatidylinositol or phosphatidylglycerol. Phospholipids are formed by esterifying glycerol to choline, ethanolamine, serine, inositol or glycerol polar phosphate head groups and fatty acids. The addition of the polar phosphate head groups results in amphiphilic properties of phospholipids where the hydrophilic charged polar phosphate heads are pulled outward toward polar charges while the hydrophobic fatty acid chains collect away from the aqueous environment effectively forming a lipid bilayer with all fatty acid chains in the inside of the bilayer. Phospholipids serve important functions as membrane phospholipids to cells and intracellular organelles. Additional components support and engage in membrane function with phospholipids including cholesterol, protein, and sphingolipids. These components contribute to functions of phospholipid membranes, plasma membrane proteins are organized to contribute to organized molecular transport in small vesicles or to exchange signals in second messenger systems. Sphingolipids are formed by adding fatty

acids or sugars to a long chain amino alcohol referred to as sphingosine. Sphingolipids serve multiple cell signaling and cell recognition functions in mammalian cells.

Cholesterol

Cholesterol is a lipid classified as a sterol in the steroid group. Cholesterol is comprised of four hydrocarbon rings, a hydrocarbon tail and a hydroxyl group. Cholesterol is transported and stored in the form of a Cholesterol ester which is formed by adding a bond between the hydroxyl group of Cholesterol and the Carboxylate group of another fatty acid. Cholesterol is most often associated with food products due to its presence in phospholipid membranes. Cholesterol, as described previously with phospholipids, is essential to contributing to permeability, fusibility, thickness, organization, and to modulating compressibility in membranes. Cholesterol also serves as the parent compound for biosynthesis of steroid hormones in the body such as androgens, estrogens, progestagens, glucocorticoids, and mineralocoticoids. Additionally, cholesterol serves as the precursor for biosynthesis of bile salts or bile acids in the liver. Cholesterol is modified by removing carbons 25-27, adding multiple hydroxyl groups and oxidizing carbon 24 into a carboxylic acid group to form a bile acid. The bile acid is further modified by adding a peptide link from the terminal carboxylic acid group to either a taurine or glycine amino acid. The added amino acid is polar and hydrophobic resulting in amphiphilic properties of the bile acid that allow bile acids to emulsify fat and fat soluble vitamins in the digestion process in the small intestine in addition to emulsifying cholesterol in bile as a mechanism for removing cholesterol from the body (Stipanuk, 2000). Cholesterol enhances the permeability barrier properties to prevent free unregulated passage of small molecules into and out through the membrane (Stipanuk, 2000).

Minerals

Minerals are classified as either major or trace minerals. Major minerals include calcium, magnesium, phosphorus, potassium, chloride and sulfur. Trace minerals include iron, copper, zinc, manganese, fluoride, selenium, and cobalt. Minerals contribute to several functions in the body such as acting in messaging systems, functioning in osmotic balance and electrical gradients, providing structural roles to other compounds, acting as catalysts, or incorporated in binding events. Beef, pork, lamb, and veal provide significant sources of numerous minerals (Esteve et al., 2002; Williams, 2007; McNeill et al., 2012; Murphy et al., 2012; McNeill, 2014; Perham, 2014).

Selenium

Selenium is an essential micronutrient in the human diet. A form of selenium, selenate, is reduced into selenide to be used in the co-translational conversion of serine bound to tRNA. Selenium incorporated into amino acids is catalyzed to form selenoproteins which function as antioxidant enzymes. Glutothione peroxidases are the best studied antioxidant enzymes which are capable of quenching reactive oxygen species (ROS) that are capable of oxidative damage to cells. Selenium is an indirect antioxidant at adequate nutritional status (Stipanuk, 2000). The recommended daily dietary intake of selenium is 55 micrograms for men and women aged 19 to 50 (IOM, 2005). Animal protein foods generally contain excellent sources of selenium (Williams, 2007; McNeill et al., 2012; McNeill, 2014; Perham, 2014) that are as high as 48 micrograms per 100 grams (USDA-ARS, 2015). Generally, plant protein foods contain very low sources of selenium per 100 grams.

Iron

Iron is an essential constituent in numerous proteins including hemoglobin and myoglobin which are important proteins involved in the transportation and metabolism of oxygen. Heme and non-heme iron are both important to protein function throughout the body. Heme iron functions in heme proteins as an oxygen carrier in hemoglobin in erythrocytes and myoglobin in myocytes, cytochrome proteins in the electron transport chain, and functions as an antioxidant by being incorporated in peroxidases which metabolize reactive oxygen hydroperoxides. Non-heme iron is utilized in mononuclear and dinuclear non-heme enzymes that are involved in several reactions including hydroxylation of aromatic amino acids, the conversion of ribonucleotides to deoxynucleotides, lipid epoxidation, desaturation of fatty acids, fatty acyl-CoA desturases and the redox reaction of iron. Iron in the form of Heme-Iron is more readily available from foods derived of animal origin. Heme iron from animal sources has a higher bioavailability compared to non-heme iron from plant sources (Stipanuk, 2000).

Iron deficiency can greatly impact mental development and motor skills in children. Additionally, iron deficiency can cause adverse pregnancy outcomes, neurological deficits, and is the major cause of anemia. Although iron deficiency symptoms are not immediate, the recommended daily dietary intake of iron is 8 milligrams for men and 18 milligrams for men aged 19 to 50 years (IOM, 2005). Beef is considered the third best source of iron in the American diet providing 1 to 3 milligrams of iron per 100 grams of beef. However, lamb is comparable to the level of iron that beef provides per 100 grams. Beef, pork, lamb and veal all provide significant sources of iron (Esteve et al., 2002; Williams, 2007; McNeill et al., 2012; Murphy et al., 2012; McNeill, 2014; Perham, 2014). Varieties of legumes contain up to 3 to 5 grams of iron per 100 grams, but the absorption of non-heme iron from these legumes is lower. It is estimated

that 2 to 20% of non-heme iron is absorbed compared to 15 to 35% of heme iron. Food sources such as lean meat that are higher in heme-iron can improve the absorption of non-heme by up to three times that of legumes and dark leafy green vegetables by themselves.

Zinc

Zinc is an essential micronutrient that is required for the activation of at least 200 metalloenzymes as well as other enzymes important to multiple biological pathways within the human body. Zinc can function as an indirect antioxidant within the body as a structural role in the superoxide dismutase enzyme responsible for regulating reactive oxygen species and their conversion to hydroperoxide that is further metabolized in order to fully quench ROS (Stipanuk, 2000). Zinc is a very important mineral to functions in the body; however, the recommended daily dietary intake is 8 milligrams and 11 milligrams for women and men aged 19 to 70 years, respectively (IOM, 2005). Zinc is readily available in the food supply, and the most concentrated sources are derived from beef and red meat, liver, veal, dark poultry, crab and oysters (Brewer et al., 2010). It is estimated that the majority of zinc is provided by red meat (Williams, 2007; McNeill et al., 2012; Murphy et al., 2012; McNeill, 2014; Perham, 2014)., poultry and fish.

Calcium

Calcium is involved in multiple biological functions including serving as a cytosolic intracellular second messenger in cell signaling, binding to calcium dependent proteins to cause conformational change to alter cellular activity such as with troponin C in muscle contraction, the activation of other proteins, phospholipase activity, as well as proteins that bind calcium for osteoblast proliferation and anti-resorptive activity in bone metabolism (Stipanuk, 2000). The recommended daily dietary intake of calcium is 1000 milligrams for men and women aged 19 to 50 years and 1200 milligrams for men and women older than 70 years of age (IOM, 2005).

Phosphorus

Phosphorus is involved in multiple biological functions including cell growth, energy metabolism including structural properties of Adenisine Triphosphate (ATP), serving as an acid-base buffer for pH balance, structurally utilized in DNA and RNA, incorporation of phosphate into lipids such as in phospholipid membranes, cell signaling, reversible covalent modification of protein, and is crucially important in the mineralization of bone (Stipanuk, 2000). Red meat provides significant sources of phosphorus (Williams, 2007; McNeill et al., 2012; McNeill, 2014; Perham, 2014).The recommended daily dietary intake of phosphorus is 700 milligrams for men and women aged 19 to70 years (IOM, 2005).

Magnesium

Magnesium is a crucial micronutrient in the neutralization of anion charges associated with polyphosphates. Magnesium serves as a structural role in ATP and ADP energy molecules, DNA and RNA and is associated with carboxylates. Magnesium functions as a second messenger system in association with hormone, neurotransmitter and cellular signals arising from cellular membrane binding. Additionally, magnesium works inversely to calcium in intercellular and extracellular calcium flux in muscle contraction (Stipanuk, 2000). A depletion of magnesium during muscular contraction events is associated with muscular cramps, hypertension and vasospasms. The recommended daily dietary intake of magnesium is 420 milligrams for men and 320 milligrams for women aged 19 to70 years (IOM, 2005).

Potassium

Potassium is a free hydrated ion that can weakly bind to molecules. Potassium is essential to maintaining osmotic fluid balance between intracellular and extracellular environments in conjunction with sodium. Additionally, potassium is essential in triggering action potentials that

initiate muscle contraction and nerve impulse transmission. However, when potassium concentration remains high following a nerve impulse transmission event, the membrane can depolarize leading to muscle weakness. Potassium additionally is involved in interactions with macroions such as protein and nucleic acid interactions, and in activating some enzymatic processes (Stipanuk, 2000). Red meat provides significant sources of potassium (McNeill et al., 2012; McNeill, 2014; Perham, 2014).The recommended daily dietary intake of potassium is 4700 milligrams for men and women aged 19 to70 years (IOM, 2005).

Sodium

Sodium is a free hydrated ion that can weakly bind to molecules in the body. Sodium is an essential mineral that functions to stabilize osmotic balance between intracellular and extracellular fluid, electric gradient formation, stabilizes macroions such as proteins and nucleic acids, and is involved in activating some enzymes throughout the body. The activation of the magnesium ion dependent adenyltriphosphatase enzyme requires sodium and potassium presence to bind to the enzyme with ATP in order to function as a Sodium-Potassium pump that phosphorylates and dephosphorylates the enzyme while also exchanging sodium and potassium to opposite sides of the cell membrane (Stipanuk, 2000). The 2015 Dietary Guidelines for Americans recommends that adult Americans consume no more than 2300 mg of sodium per day and all adults aged 51 and older, African Americans, children, or anyone that has diabetes, hypertension or chronic kidney disease may benefit from lowering intake to less than 1500 mg of sodium per day. While sodium is an essential mineral to several functions within the human body including cellular fluid balance and cellular gradient events, numerous researchers have concluded that Americans tend to drastically over consume sodium. The majority of over consumption of sodium occurs in the form of processed meats, processed foods including breads

and baked products, and canned vegetables (Stipanuk, 2000). However, red meat has low concentration of sodium when prepared without added sodium during cooking. The recommended daily dietary intake of sodium is 1500 milligrams for men and women aged 19 to50 years (IOM, 2005).

Copper

Copper is an essential trace mineral involved in enzymes that form collagen, synthesize neuropeptides and neurotransmitters, involved in oxidative phosphorylation and iron metabolism, and has a functional role in quenching ROS (Stipanuk, 2000). The recommended daily dietary intake of copper is 900 milligrams for men and women aged 19 to70 years (IOM, 2005).

Manganese

Manganese is an important mineral that is essential for enzymes involved in carbohydrate metabolism, urea formation, cartilage formation, and functions to quench ROS from producing free radicals (Stipanuk, 2000). The recommended daily dietary intake of manganese is 2.3 milligrams for men and 1.8 milligrams for women aged 19 to70 years (IOM, 2005).

Vitamins

Vitamins have a role in numerous functions throughout the body including serving as a co-factor to multiple enzymes in metabolic processes, precursors for hormone synthesis, antioxidants, visual pigments, carbohydrate equivalent molecules in carbohydrate metabolism and adenosine diphosphate (ADP) functions, and can have transcription and gene interaction properties. Vitamins are classified as either water-soluble or fat-soluble depending on each vitamin's physical solubility properties (Stipanuk, 2000). Vitamins that are soluble in water include all of the B-vitamins (thiamin, riboflavin, niacin, pantothenic acid, vitamin B6, biotin,

folic acid, and vitamin B12) and vitamin C. Vitamins that are soluble in fat and able to be stored in adipose tissue throughout the body include vitamin A, vitamin D, vitamin E, and vitamin K. Beef, pork, lamb, and veal are important sources of vitamins (Esteve et al., 2002; Williams, 2007; McNeill et al., 2012; Murphy et al., 2012; McNeill, 2014; Perham, 2014).

Thiamin (Vitamin B1)

Thiamin is an important water soluble vitamin involved in the synthesis of nucleotides for the synthesis of ATP, DNA, ribose and NAD. NAD is important in energy metabolism. Additionally there are several proteins that utilize thiamin as a cofactor including decarboxylases, transketolases, oxidoreductases and dehydrogenases. Thiamin functions as a cofactor in three enzyme complexes that are involved in energy and amino acid metabolism within the mitochondria (Stipanuk, 2000). The recommended daily dietary intake of thiamin is 1.2 milligrams for men and 1.1 milligrams for women aged 19 to70 years (IOM, 2005).

Riboflavin (Vitamin B2)

Multiple proteins have been identified as utilizing Riboflavin as a cofactor. Proteins that require riboflavin include functions such as fatty acid oxidation, electron transfer as part of ATP synthesis, DNA replication and repair, redox regulation, neurotransmitter catabolism, cell methylation, and immune function. Riboflavin is a precursor to the formation of flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD) that serves as an energy equivalency molecule during metabolic events in the mitochondrial TCA cycle (Stipanuk, 2000). Red meat is an important source of riboflavin (Esteve et al., 2002; Williams, 2007; McNeill et al., 2012; Murphy et al., 2012).The recommended daily dietary intake of riboflavin is 1.3 milligrams for men and 1.1 milligrams for women aged 19 to70 years (IOM, 2005).

Niacin (Vitamin B3)

The most obvious function of niacin is a precursor to metabolic equivalents in redox reactions during metabolic events. Nicotinamide adenine dinucleotide (NAD) is utilized in more reactions than any other molecule derived from vitamin sources. The hydrogenated form of NAD is NADH. Together NAD and NADH are important energy equivalents utilized in anabolic pathways. Nicotinamide adenine dinucleotide phosphate (NADP) and its hydrogenated form NADPH are important catabolic molecules (Stipanuk, 2000). Red meat is a significant source of niacin (Williams, 2007; McNeill et al., 2012; Murphy et al., 2012; McNeill, 2014).The recommended daily dietary intake of niacin is 16 milligrams for men and 14 milligrams for women aged 19 to70 years (IOM, 2005).

Pantothenic Acid (B-Vitamin)

Pantothenic acid is a crucial vitamin that serves as the precursor to coenzyme A (CoA) that is a co-activation enzyme for multiple metabolic pathways. Further esterification of acetic acid and CoA produces Acetyl-CoA that is a common compound involved in fat and carbohydrate metabolism. Additionally, pantothenic acid can form the acyl carrier protein (ACP) that is an essential carrier protein during fatty acid synthesis (Stipanuk, 2000). The recommended daily dietary intake of pantothenic acid is 5 milligrams for men and women aged 19 to70 years (IOM, 2005).

Vitamin B6

Dietary sources that are high in vitamin B6 include cereals, grains, vegetables, red meat, poultry, fish, and other juices and seeds. Vitamin B6 exists in three forms: Pyridoxine, Pyridoxal, and Pyridoxamine. The latter two forms are found in animal derived food sources, and have a higher bioavailability compared to pyridoxine which is a plant derived form of B6 that contains a

glucoside derivative. Pyridoxal phosphate is the active form of the vitamin. Compared to vitamin B12, this vitamin plays a more significant role in catabolism of homocysteine. vitamin B6 is additionally involved as a coenzyme in amino acid metabolism such as transamination and decarboxylation reactions. The active form of vitamin B6 also serves as a cofactor in heme synthesis and in lipid and carbohydrate metabolism (Stipanuk, 2000). Beef, pork, lamb and veal provide significant sources of vitamin B6 (Esteve et al., 2002; Williams, 2007; McNeill et al., 2012; Murphy et al., 2012; McNeill, 2014; Perham, 2014).The recommended daily dietary intake of vitamin B6 is 1.3 milligrams for men and women aged 19 to50 years (IOM, 2005).

Choline (B-Vitamin)

Choline exists in both water-soluble and lipid-soluble forms. Choline is available from both plant and animal derived food sources, but animal sources of food tend to have greater concentration of choline biologically available. Phosphatidylcholine is the predominate phospholipid in mammalian cells. This form is utilized by the liver for membrane synthesis, bile formation, very low density lipoprotein (VLDL) secretion, sphingomyelin synthesis, conversion to betaine as a factor in transporter molecules, neurotransmitter capabilities as acetylcholine, cognitive function, cell signaling and secretory actions within the golgi apparatus (Stipanuk, 2000). The recommended daily dietary intake of choline is 550 milligrams for men and 425 milligrams for women aged 19 to70 years (IOM, 2005).

Vitamin B-12

With the exception of some algae and other fortified foods, vitamin B12 is available almost exclusively only from animal sources. Vitamin B12 is coupled to proteins and released during digestion by pepsin in the stomach. Temporarily vitamin B12 is bound to Salivary R-binder until the complex is hydrolyzed in the small intestine by pancreatic proteases. Intrinsic

factor (IF) produced by the gastric parietal cells binds vitamin B12 in the small intestine. The major absorptive pathway involves cubilin receptors in the distal ileum that are localized in polarized cells by an amnionless protein. Calcium allows the IF-B12 complex to be recognized and bound to cubilin for receptor mediated endocytosis which begins a lengthy process of cleaving and releasing B12 into the cytosol for eventual delivery into portal circulation. Bioavailability of this micronutrient is dependent on the presence in dietary sources and by absorptive mechanisms (Stipanuk, 2000).

Vitamin B12 is a required cofactor for two mammalian enzymes: cytosolic methionine synthase and mitochondrial methylmalonyl-CoA mutase. Methionine synthase is a large zinc metalloprotein that operates in combination with vitamin B6 and folic acid to remehylate homocysteine to synthesize the methionine amino acid. Buildup of Homocysteine, a damaging amino acid, due to the deficiency of any of the B-vitamins B6, Folate or B12 can lead to an increase in atherosclerotic activity by blood vessel damage from superoxide radical activity occurring from homocysteine levels. Vitamin B12 also serves as a cofactor for methylmalonyl-CoA mutase. This enzyme converts methylmalonyl-CoA derived from the oxidation of odd chain fatty acids and catabolism of isoleucine, valine, methionine and threonine into succinyl-CoA. This substrate is able to enter into the TCA cycle to produce intermediates for ATP energy synthesis or can be utilized in heme synthesis. In addition to the function of these two enzymes, adequate vitamin B12 levels prevent megaloblastic anemia, hyperhomocysteinemia that could lead to vascular disease, and can convert low levels of nitrous oxide back to nitrogen in order to prevent oxidative effects of hydroxyl radicals (Stipanuk, 2000). Beef, pork, lamb, and veal provide significant sources of vitamin B12 (Esteve et al., 2002; Williams, 2007; McNeill et al.,

2012; Murphy et al., 2012; McNeill, 2014; Perham, 2014).The recommended daily dietary intake of vitamin B12 is 2.4 milligrams for men and women aged 19 to70 years (IOM, 2005).

Vitamin D and 25-Hydroxy Vitamin D

There are multiple forms of vitamin D. Vitamin D can be synthesized or readily derived. An epidermis synthesized compound referred to as 7-Dehydrocholesterol is a precursor to cholesterol synthesis, and can be transformed to previtamin D3 when photon energy from UV light causes an interaction. Thermal isomerization from normal body temperature forms Vitamin D3 and assists in the translocation of this provitamin into blood. Ergocalciferol (D2) from marine plant sources or supplements and Cholecalciferol (D3) from dietary sources, supplements or endogenous synthesis, can travel to the liver through post absorptive circulation. Circulating vitamin D2 or D3 forms undergo hydroxylation in the liver to form the active form, 25-hydroxy vitamin D. Absorption of vitamin D from food sources can lead to a direct uptake of vitamin D by adipose cells for storage purposes. This can result in an increased vitamin D demand in order to produce the active form of vitamin D in the liver. The parathyroid stimulates the expression of the gene that encodes the enzyme responsible for metabolizing the active 25-hydroxy vitamin D into 1,25-dihydroxy-vitamin D. This vitameric form is highly regulated by the kidney in association with calcium and phosphorus plasma levels. This vitameric form can bind to vitamin D receptors located throughout the body to cause an interaction with specific gene promoter regions on DNA to increase transcription for expression of proteins that can increase the resorption of calcium and bone mineralization (Stipanuk, 2000). The recommended daily dietary intake of vitamin D is 15 milligrams for men and women aged 19 to70 years (IOM, 2005).

Vitamin E

Vitamin E is comprised of eight vitamers classified as four tocopherols and four tocotrienols. Normal metabolic functions can generate carbon and oxygen centered free radicals

such as superoxide, lipid alkoxyl and peroxyl radicals. Alpha-tocopherol is the active form of Vitamin E that functions to quench lipid peroxyl radicals by donating a phenolic hydrogen atom to a free radical. This forms a tocopheroxyl radical that can be reduced to tocopherol by water soluble substances such as ascorbic acid. Vitamin E acts as an antioxidant by preventing the oxidation of unsaturated fatty acids on cell membranes. Vitamin E is a lipid soluble vitamin that is found in red blood cells, plasma, all tissues and especially in adipose tissue (Stipanuk, 2000). The recommended daily dietary intake of vitamin E is 15 milligrams for men and women aged 19 to70 years (IOM, 2005).

Effect of Finishing System

Initial consumer interest in finishing systems being utilized for beef production has been variable. However, the increase in perceived health benefits from consuming grass-finished beef has resulted in grass-finished beef becoming available to consumers. Historically, the majority of U.S. retail lamb has been marketed through a conventionally-fed, grain-finishing system. In comparison to grass-finished beef, grass-finished lamb has increased availability in retail stores in a more recent time frame. Similar to the perceived increase in health benefits that occurred with grass-finished beef; grass-finished lamb is now of more interest to consumers due to perceived health benefits. Still, conventionally fed lamb continues to comprise the large majority of retail lamb sold to consumers.

While red meat comprises numerous nutrients of importance to human health and daily homeostatic functions in the human body, the greatest impact that finishing systems have on red meat is differences in total fat and fatty acid profiles. Concentration of protein and minerals are very similar between grain-finished and grass-finished beef (Duckett et al., 2007, 2009, 2013; Leheska et al., 2008). A review conducted by Van Elswyk and McNeill (2014) concluded that

there is no practical, meaningful difference in concentration of calcium, potassium, sodium, and protein between grain-finished and grass-finished beef based on the work of Leheska et al. (2008) and Duckett et al. (2009).

Several research studies have indicated that finishing system can have an impact on fat content and fatty acid profile of beef (Duckett et al., 2007, 2009, 2013; Neel et al., 2007; Leheska et al., 2008; Daley et al., 2010). Meat products from ruminants fed on a grain-finishing system have higher total fat content, higher subcutaneous fat content and higher intramuscular fat content compared to animals fed on a grass-finished system (Duckett et al., 2007, 2009, 2013; Neel et al., 2007; Leheska et al., 2008; Daley et al., 2010). Leheska et al. (2008) reported higher fat content and lower moisture content in beef strip steaks and ground beef from grain-finished cattle compared to grass-fed cattle. Similarly, research studies have indicated that meat products from lamb finished on a high concentrate diet have higher total fat content compared to meat products from lamb finished on a grass-finished diet (Popova, Gonzales-Barron and Cadavez 2015).

Finishing system can impact fatty acid profiles in large and small ruminants. Biohydrogenation of the rumen generally leads to smaller effects in ruminants than in non-ruminants. Although some researchers have reported that grass-finished cattle compared to grain-finished cattle in these studies had higher saturated fatty acid (SFA) content, lower monounsaturated fatty acid (MUFA) content, and similar polyunsaturated fatty acid (PUFA) content (Leheska et al., 2008; Duckett et al., 2009), others have determined that grass-finished cattle had greater PUFA content.

Previous researchers have demonstrated that forage based diets result in higher concentrations of omega-3 fatty acids and conjugated linoleic acid in beef (Duckett et al., 2007,

2009, 2013; Neel et al., 2007; Leheska et al., 2008; Daley et al., 2010) and in lamb (Santos-Silva, Bessa and F. Santos-Silva, 2002). A recent meta-analysis conducted by Popova, Gonzales-Barron and Cadavez (2015) concluded that grass-finished lambs or lambs that had access to pasture had decreased total fat, higher saturated fatty acid concentration, lower monounsaturated fatty acid concentration and higher omega-3 polyunsaturated fatty acid concentration. Meat products from grass-finished lamb have greater PUFA n-3 fatty acid content than do meat products from grain-finished lamb

Role of Red Meat in a Healthy Diet

The recently released 2015 Dietary Guidelines for Americans recommends limiting saturated fat consumption to ten percent or less of daily total calories by consuming foods from all five food groups including lean meats, poultry, fish, legumes, seeds, nuts, fruits and vegetables, whole grains, and low-fat dairy. The current dietary guidance suggests consuming nutrient dense foods as part of the Healthy U.S.-Style Eating Pattern to maintain energy balance and a healthy weight. The 2015 Dietary Guidelines for Americans describe protein foods, such as lean red meat, as being important sources of protein, B-vitamins such as niacin, riboflavin, B6 and B12; selenium, choline, phosphorus, zinc, copper, vitamin D and vitamin E. Specifically, red meat provides the most zinc and provides heme-iron, the more bio-available form of iron (USDA&USDHHS, 2015).

Due to the effect on quality of life, mental health and leading causes of death, obesity has become the most serious public health concern of the century. Obese individuals have an increased risk for developing hypertension, type 2 diabetes (T2DM), dyslipidemia, coronary heart disease, stroke, gallbladder disease, osteoarthritis, sleep apnea, cancer, poor quality of life, poor physical function, and mental illness such as depression, anxiety or other mental disorders

(CDCb, 2015). Obesity is defined as an individual that has a body mass index greater than 30 kg/m2. Recent surveillance data showed that 16.9 % of children aged 2 to 19 years and 34.9 % of adults aged 20 years and older are obese (Ogden et al., 2014). Protein is a highly satiating macronutrient that is an important component in mediating excessive hunger and consumption of calories found in less nutrient-dense, lowly satiating foods. Although not all studies agree several researchers have determined that an increase in dietary protein (30% of total daily calories from protein) at the expense of dietary carbohydrate and fat could result in greater satiety during and between meals that could lead to weight loss due to lower energy intake (Noakes et al., 2005; Weigle et al., 2005). These researchers observed greater weight loss and increased fat loss in overweight subjects with elevated blood triaglyceryl concentractions from adhering to a high protein diet (Noakes et aol., 2005; Weigle et al., 2005). Weigle et al. (2005) described fat loss being highest in individuals who consumed a high protein diet (at least 25% of total daily calories from protein) in both short-term (6 month adherence) and long-term (12 month adherence) studies. Increased satiety during and between meals is most likely the reason that more weight and fat loss was observed in these studies. In a randomized control trial comparing high protein (protein 25% of total daily calories) and high carbohydrate diets (protein 12% of total daily calories), a higher protein diet significantly decreased body weight and body fat in overweight and obese individuals (Scov et al., 1999). In addition to providing high quality protein in a healthy diet that researchers have shown to decrease weight and adiposity in individuals, high protein diets utilizing lean red meat combined with resistance training in elderly persons at risk for sarcopenia can help to preserve lean body mass (Morris and Jacques, 2013; Daly et al., 2014).

Obesity is a risk factor for cardiovascular disease, hypertension, hyperglycemia, diabetes, and is associated with a diet high in sodium and *trans* fat, physical inactivity and tobacco use (CDC, 2013). Additionally, heart disease and stroke is responsible for one in three deaths in Americans every year and over 200,000 deaths are considered preventable by making healthy living changes (CDC, 2013). Due to media reports and epidemiological studies blaming red meat in the diet as an associated factor in developing heart disease, many consumers believe that red meat is consistently high in saturated fat, *trans* fat, and cholesterol, and that they should decrease their consumption of red meat. However, there is no direct, current evidence that associates lean red meat with an increased risk of developing CVD when lean red meat is included as part of a healthy diet and eating pattern. The current dietary guidance recommends including lean red meat in the Healthy U.S. Eating Pattern (USDA&USDHHS, 2015). Additionally, changes in livestock genetic and breeding decisions, feeding practices and increased external fat trimming have helped to decrease fat levels in red meat. Currently, red meat is being produced and further trimmed to have 80% less external fat (McNeill et al., 2012). Lipid improvements have been made in the beef industry where beef has continually become leaner especially in the past two decades (McNeill et al., 2014). Approximately two-thirds of the red meat available at retail to consumers is lean (based on USDA classifications for labeling red meat lean).

Lean red meat including lean beef, pork, veal and lamb, are nutrient-dense foods that should be included as part of a healthy diet and healthy eating pattern. Although fatty acid composition differs among red meat species, red meat in general is comprised of at least 50% MUFA or PUFA. The Dietary Guidelines for Americans (USDA&USDHHS, 2015) recommend including lean red meat as part of incorporating healthy protein foods into a healthy eating pattern. The current dietary guidelines also suggest limiting saturated fat to 10% or less of daily

caloric intake leaving room for lean red meats (that are also low in saturated fat) in a healthy diet and healthy eating pattern (USDA&USDHHS, 2015). The major saturated fatty acid in red meat is stearic acid which is not associated with increased cholesterol and risk for CVD. Stearic acid is a ruminant derived *trans* fatty acids that contribute no increased risk to CVD and may have positive health effects.

Davidson et al. (1999) and Scott et al. (2010) concluded that in a lipid-lowering diet, lean red meat was just as effective as white meat (chicken or fish) with no comprising action to the lipid-lowering benefits of the diet. A 6-week randomized cross-over study comparing the blood lipid levels of men and women assigned to consuming a Healthy American Diet (HAD), Dietary Approaches to Stop Hypertension diet (DASH), Beef in an Optimal Lean Diet (BOLD) (5 oz. of lean beef per day), and BOLD+ diet (7 oz. of lean beef per day), concluded that the DASH, BOLD, and BOLD+ diets all reduced blood triglyceride, total cholesterol and LDL levels indicating that the improvement of blood lipid levels from lean beef can lower the risk for developing CVD (Roussell et al., 2012). In addition to reducing body weight, waist circumference, triglyceride and insulin levels, McAuley et al. (2004) described a high protein diet (30% of total daily calories from protein) significantly reduced LDL cholesterol consistently in a short-term (eight week) study among insulin-resistant overweight and obese women randomly assigned to either a high-protein, high-carbohydrate, or high-fat diet.

Among the many factors that contribute and increase the risk for CVD is Type-2 Diabetes Mellitus (T2DM) which is the seventh leading cause of death. There are approximately 22 million U.S. people diagnosed with diabetes (CDCa, 2015). Of these individuals, 90-95% have T2DM (CDCa, 2015). Type 2 Diabetes Mellitus is the result of pancreatic beta-cell insensitivity or decreased insulin production. Known risk factors for T2DM are age, obesity, family history,

gestational diabetes history, impaired glucose tolerance, physical inactivity and race or ethnicity (CDCa, 2015). A meta-analysis comparing high versus low consumption of total meat, red meat, and processed meat compared to relative risk of developing T2DM conducted by Aune et al. (2009) revealed that several cohort studies concluded that a Western dietary pattern has an associated risk of T2DM, but were not able to specify which food components of the Western dietary pattern contributed to the risk of T2DM. McNeill (2014) indicates that the majority of epidemiological cohort studies typically describe a western diet pattern as comprising of high intakes of refined grains, sugar, red meat and other animal derived foods, and foods high in fat. Additionally, Aune et al. (2009) revealed that total meat consumption was not associated with an increase in the risk of T2DM, but processed meat and red meat may increase the risk of developing T2DM by 41% and 21%, respectively. However, this meta-analysis also included studies that did not statistically adjust for physical activity, overweight and obesity.

While Steinbrecher et al. (2011) and Barnard, Levin and Trapp (2014) along with numerous other researchers have concluded that all meat consumption increases the risk for developing T2DM, other studies have demonstrated that higher fat processed meats only are associated with an increased risk for developing T2DM (van Dam et al., 2002; Song et al., 2004; Pan et al., 2011; Fretts et al., 2012; Lajous et al., 2012). A study conducted by Fung et al. (2004) concluded that even though red meat and processed meat are large components in the western dietary pattern, the association of T2DM with this dietary pattern is not fully linked by various meat products, but other food components in this dietary pattern contribute to the higher risk of developing T2DM. Fung et al. (2004) also concluded that red meat was associated with an increased risk of developing T2DM before adjusting for body weight and body mass index. Farnsworth et al. (2003) concluded that in a short-term feeding study with similar fat levels

between a high-protein diet and a high-carbohydrate diet, the higher protein diet did not result in individuals losing weight or body fat. However, the high protein diet resulted in decreased post-prandial blood glucose and blood triglyceride levels in overweight men and women (Farnsworth et al., 2003). In a recent randomized-control cross-over trial, individuals with a normal body mass index randomly assigned to consuming a normocaloric diet with protein comprised of either chicken or lamb for only eight weeks resulted in individuals with similar body weights, but the group consuming lamb had decreased blood triglyceride and insulin levels (Graffe et al., 2013).

In contrast to studies concluding in red meat posing a risk of developing T2DM, a clinical trial conducted by Boden et al. (2005) concluded that obese individuals had lowered and normal glucose levels, increased insulin sensitivity, and decreased A1C levels after following a high-protein, low-carbohydrate diet for 14 days. High-protein diets generally result in decreased body weight and energy intake (Scov et al., 1999; Leslie et al., 2002; Boden et al., 2005; Campbell and Tang, 2010). Additionally, high-protein, low-carbohydrate diets decrease fasting blood glucose concentrations and A1C concentractions (Gannon et al., 2004). A review by Layman et al. (2008) concluded that a diet with increased calories derived from protein is a positive method to improve blood lipid, lipoprotein and glycemic levels in addition to being effective at weight maintenance.

Labeling of Red Meat

As consumers, health professionals and other nutrition entities continue to become concerned with the nutrient profile of various foods, an increased effort is being made to provide the most current and relevant nutrition information. To accomplish this, the USDA continually updates the National Nutrient Database for Standard Reference (SR). The SR and the Dietary

Guidelines for Americans are resources available to provide nutrition information to the public in order for consumers and other organizations to make the most informed food purchasing decisions to follow a healthy eating pattern and healthy diet.

Previously, nutrition labeling for fresh meat was voluntary for retailers. Since March 2012, the Food Safety Inspection Service (FSIS) has required the nutritional facts label to be included on applicable individual retail cuts of meat following the publication of the Nutrition Labeling of Single-Ingredient Products and Ground or Chopped Meat and Poultry Products Final Rule (9 CFR 317.344). Under the final rule, major lamb cuts requiring mandatory nutritional labeling are the following: shank, shoulder blade chop, shoulder arm chop, rib roast, loin chop, and leg (whole, sirloin half, or shank half). Additionally, ground lamb would be mandated to require a nutrition fact label, especially to specify fat levels in ground lamb.

Currently, nutrition labels included to be in compliance with the final rule are required to have "Nutrition Facts," "Amount per Serving," and "% Daily Value" headings. Nutrients and components that are required on nutrition labels are listed as the following: Calories, Total Fat, Saturated Fat, *Trans* Fat, Cholesterol, Sodium, Total Carbohydrate, Dietary Fiber, Sugars, Protein, Vitamin A, Vitamin C, Calcium, and Zinc. Vitamins and minerals included on the nutrition facts label are based on the recommended daily intake (RDI) values for a 2000 kcal diet. Other required items on a nutrition label are the following: name of the product, list of ingredients, net quantity of contents, an official inspection legend and number of the official USDA establishment producing the product.

According to Code of Federal Regulations (CFR) for "Nutrient content claims for fat, fatty acids, and cholesterol content." (9 CFR 317.362), products that are "lean" must have less than 10 g fat, less than 5 g of saturated fat, and less than 95 mg of cholesterol per 100 g; and

products that are “extra lean” must have less than 5 g fat, less than 2 g saturated fat, and less than 95 mg of cholesterol per 100 g (USDA-FSIS, 2015). Products that can be labeled under the “Heart-Check” certification program promoted by the American Heart Association must have less than 5 g of total fat, less than 2 g of saturated fat, less than 95 mg of cholesterol, less than 0.5 g Trans-fat and less than 360 mg of sodium (AHA, 2015). Additional labeling claims (9 CFR 381.454) for “excellent source of” requires a product to contain a nutrient that is 20 percent or more of the Reference Daily Intake (RDI) and “good source of” requires a product to contain a nutrient that is 10 to 19 percent of the RDI used to calculate % Daily Value of a nutrient (USDA-FSIS, 2015).

CHAPTER 3

MATERIALS AND METHODS

No live animals were used in this experiment. Therefore, Institutional Animal Care and Use Committee approval was not obtained. This study was conducted following nearly identical procedures for dissecting and analyzing samples to those described by Acheson et al. (2015) and Perham (2014).

Experimental Design

Grain-finished and grass-finished product sampling was representative of the majority of retail lamb products currently merchandized in U.S. retail markets. Retail lamb cuts trimmed to a maximum of 1/8" external fat (3.175 mm) from two lamb processing plants in Colorado and one lamb processing plant in California in the United States were collected. Collected samples comprised a national representation of U.S. lamb cuts merchandized in U.S. retail stores. Grain-finished and grass-finished lamb cuts in their original package (Table 1) were collected seasonally from January 1, 2014 through December 31, 2014 directly from three different harvest facilities.

Boneless whole legs, boneless whole shoulders, block ready whole loins, and whole foreshanks were vacuum packaged. Since at least 90% of lamb sold at the retail level from carcasses of the U.S. grade "Choice", the grade of lamb was not considered as a variable in product selection (USDA-AMS, 2015; American Sheep Industry Association, 2015). Two packages of each grain-finished lamb cut was collected during each season from each supplier. Two packages of each grass-finished cut was collected from another harvest facility during each season and from one other harvest facility during the summer season only since grass-finished lamb has limited supply availability resulting in freezing product after the summer season to

supply retail stores during the remainder of the year. Whole legs, shoulder blade chops and ground lamb were collected during the spring season and were split between raw and cooked analysis, so only one package of each of these cuts per supplier was used. Following the spring season collection, additional packages were collected in order for two packages of each of these three cuts to be represented per supplier per season. Supply of ground lamb from each lamb plant was variable throughout the entire collection (all seasons). All pieces within each package were utilized. Packages of retail lamb cuts had various piece numbers within each package described as the following: rib chops, frenched rib chops, and sirloin chops contained two or three pieces per package; shoulder arm chops contained one or two pieces per package; whole legs, whole shoulders, whole loins, whole rib racks, whole frenched rib racks, and shoulder blade chops contained one piece per package; foreshanks were packaged with variable pieces per package with one randomly selected piece utilized from each package; all contents within a one pound package of stew meat and ground lamb were utilized. All retail cuts were maintained at 0 to 4° C during transportation to Colorado State University Meat Laboratory. Product temperature was verified upon arrival by Colorado State University (CSU) personnel to ensure that product temperature was maintained at 0 to 4° C. All packages were inspected for packaging integrity. Any packages that did not maintain a seal were vacuum packaged, all packages were frozen at -20° C until cooking or raw dissection.

Cooking of Retail Cuts

Retail lamb cuts (Table 1) were tempered in a single layer at 0 to 4° C for 24 to 72 hours depending on cut thickness until internal temperature was at 0 to 4° C regardless of raw or cooking designation. After thawing, each individual cut was blotted to remove any surface moisture, weighed to the nearest 0.1 g, raw temperature was recorded, and any cuts not

meeting correct muscle specifications or external fat thickness of 1/8 inch (3.175 mm) were adjusted before cooking or raw dissection. Three cooking methods were utilized: Grilling, Roasting, and Pan-Grilling.

Grilling

Cuts assigned to "grilling" were loin chops and shoulder blade chops. Grilling cookery method described by Acheson et al. (2015) was used. A Salton two-sided grill (Model GRP99, Salton Inc., Lake Forest, IL) was pre-heated until a grill surface temperature of 195° C. The grill temperature was established by an infrared thermometer (Mastercool, Model 52224-SP, Randolph, NJ). All pieces within a package were cooked on the same grill at the same time with temperature monitoring using digital thermocouple thermometers and probes placed into the geometric center of the cut (Type Jor T Digi-Sense, Cole Parmer, Vernon Hills, IL). Each individual chop was flipped once at an internal temperature of 20° C was reached to ensure even cooking. All individual chops were removed from the grill surface once an internal temperature of 60° C was reached. Final internal temperature and cooked weight to the nearest 0.1 g were recorded. An additional internal temperature and cooked weight was measured 30 min. post cooking prior to each individual chop being placed on a wire rack at refrigerated temperature of 0 to 4° C for at least 12 h before cooked dissection occurred.

Roasting

Cuts assigned to "roasting" were boneless whole legs, block ready rib roasts and frenched rib roasts. Roasting cookery method described by Acheson et al. (2015) was used. Each individual cut was placed in a non-stick anodized aluminum roasting pan with rack (Calphalon Corp., Toledo, OH). A retail conventional gas powered oven was preheated to 160° C. Thermocouple probes were placed into the geometric center of each cut throughout

the cooking process in to monitor temperature (Type J or T Digi-Sense, Cole Parmer). Only one roasting pan consisting of one cut was placed into the absolute center of each oven. Once an internal temperature of 60° C was obtained, final internal temperature and cooked weight were recorded to the nearest 0.1 g. An additional internal temperature and cooked weight was measured and recorded 30 min. post cooking, then each individual chop was placed on a wire rack and refrigerated at 0 to 4° C for at least 12 h before cooked dissection occurred.

Pan Grilling

Ground lamb was cooked by pan-grilling. A non-stick anodized aluminum skillet pan (Calphalon Corp., Toledo, OH) was preheated to a surface temperature of 195° C. The pan surface temperature was established by an infrared thermometer (Mastercool, Model 52224-SP, Randolph, NJ). Ground lamb pre-cook weight was recorded to the nearest 0.1 g and temperature was recorded using a digital thermocouple thermometer (Digi-Sense; Cole Parmer, Vernon Hills, IL) before being placed into a pre-heated pan. Ground lamb was crumbled into the preheated pan. A stainless steel spatula was used to break apart ground lamb loaves to ensure even cooking. An infrared thermometer was used to monitor temperature until it reached 74° C, and the ground lamb was removed from the heat source, placed into a stainless steel colander, and a digital thermocouple thermometer was used to ensure that the average temperature obtained was a minimum of 74° C. Ground lamb was allowed to remain in a stainless steel colander for 10 min. before a post-cook weight was recorded to the nearest 0.1 g. Ground lamb was placed back into a colander and an additional temperature and weight was recorded 30 min. post cooking, and ground lamb was placed into a large tray refrigerated at 0 to 4° C for at least 12 h before cooked homogenization.

Cut Dissections

Standard methods for dissection of raw and cooked cuts were utilized. These methods required the recording of internal temperatures, pre-dissection weight to the nearest 0.1 g, post-dissection separable component weights, start and end dissection times for each individual cut. Dissections for all cuts were performed with limited exposure to light, and all cuts were handled with powder-free gloves to protect nutrients from degradation. Dissections were performed by CSU personnel in a 5 to 7° C environment utilizing stainless steel disposable scalpels (Miltex, York, PA) to yield separable components.

Separable components defined as: "separable lean" included any muscle, intramuscular fat and any light connective tissue deemed edible; "external fat" included adipose tissue located on the outer surface of the cut; "seam fat" included adipose tissue deposited between muscles extending to an external point not above the most dorsal side of the muscle; and "refuse" included any waste comprised of bone and heavy inedible connective tissue. A predetermined yield tolerance of 97.0 to 101.0% was established. Any samples not meeting yield tolerance were removed from the study and replaced with a new sample of the same cut, season and origin. All separable lean, external fat and seam fat originating from the same package were combined for homogenization immediately following dissection, and any cut dissections that were complete before homogenizing equipment were available were covered with cellophane plastic wrap to prevent any dehydration of separable components, maintained at refrigerated temperatures at 0 to 4° C, and homogenized within 2 h post-dissection. Since ground lamb is a comminuted product it was not dissected. Stew meat was procured following specification criteria of being devoid of external fat and heavy connective tissue with the only visible adipose tissue deriving from intramuscular fat, resulting in no dissection.

Homogenization

Dissected separable components were combined with all separable components of the same type derived from the same retail package for homogenization resulting in one lean, external fat and seam fat sample for each retail package. Standard methods of homogenization were adhered to, including homogenizing with the use of powder-free nitrile gloves and in the absence of direct light to protect samples from contamination and nutrient degradation. Separable lean from each package was placed into a stainless steel bowl containing liquid nitrogen until all pieces were completely frozen before being placed into a 7-quart (6.62-L) Robot Coupe BLIXER 6V (Robot Coupe USA Inc., Ridgeland, MS). Samples were blended for approximately 10 s on low speed at 1500 rpm and 30 s on high speed at 3500 rpm until samples were of a finely-powdered consistency. Immediately following homogenization, each sample was placed into a 54 oz. whirl-pak bag and placed into a -20° C freezer. External and seam fat samples were frozen following the same procedures as with lean. After samples were frozen, samples were placed into a 4-quart (3.79-L) Robot Coupe BLIXER 4V (Robot Coupe USA Inc., Ridgeland, MS) and blended into a finely-powdered consistency under the same time and speed protocols as with lean homogenization. Fat samples were immediately placed into 18 oz. whirl-pak bags and placed into a -20° C freezer. Once all samples were homogenized each day, homogenates were transferred from a -20° C freezer and remained double bagged in a -80° C freezer until compositing and analysis occurred.

Lean Compositing

All lean homogenates of the same feeding type (grain-finished or grass-finished), cut, and cooked status were combined in equal parts in weight. All lean samples were combined into a single composite for each cut of grain-finished and grass-finished feeding type and of

raw and cooked status. Homogenized lean for vitamin D, vitamin E and selenium analysis were further composited by combining lean from all cuts of raw or cooked grain-finished or grass-finished cuts into single national composites (raw grain-finished lean composite, raw grass-finished lean composite, cooked grain-finished composite, and cooked grass-finished composite). Compositing was performed following standardized procedures by combining equal homogenate weights of the same feeding and cooking status. All compositing procedures occurred by combining lean homogenates, blending composites in a 7-quart (6.62-L) Robot Coupe BLIXER 6V (Robot Coupe USA Inc., Ridgeland, MS) for approximately 10 s on low speed at 1500 rpm and 30 s on high speed at 3500 rpm until samples were of a finely-powdered consistency, aliquoting into Whirl-Pak bags in the presence of liquid nitrogen. All aliquots analyzed at an on-site laboratory were immediately placed back into a -80° C freezer until analysis occurred. All aliquots analyzed at off-site laboratories were shipped with dry-ice overnight.

Fat Compositing

All fat homogenates of the same feeding type (grain-finished or grass-finished), cut name, fat type and cooked status were combined in equal parts by weight. Once all fat composites were combined, equal parts in weight of each fat type of the same feeding type (grain-finished or grass-finished) and cooked status were combined among all cuts for a single national composite. All compositing procedures occurred by combining fat homogenates, blending composites in a 7-quart (6.62-L) Robot Coupe BLIXER 6V (Robot Coupe USA Inc., Ridgeland, MS) for approximately 10 s on low speed at 1500 rpm and 30 s on high speed at 3500 rpm until samples were of a finely-powdered consistency, aliquoting into Whirl-Pak bags in the presence of liquid nitrogen. All aliquots analyzed at an on-site laboratory were

immediately placed back into a -80° C freezer until analysis occurred. All aliquots analyzed at off-site laboratories were shipped with dry-ice overnight.

Nutrient Analysis

Nutrient analysis occurred at USDA-ARS approved laboratories, including Colorado State University (CSU) and other external laboratories, and pre-determined analyses were designated to each laboratory under the approval of USDA-NDL (Nutrient Database Lab). Data from raw rib chops, frenched rib chops and whole block ready loins were used to determine nutrient information for whole raw rib racks, whole raw frenched rib racks and raw loin chops. Laboratories analyzed USDA-ARS supplied quality control materials to demonstrate accurate and precise data prior to conducting analyses of samples. Standards (Beech Nut Brand Chicken Baby Food and Beech Nut Brand Beef Baby Food, Canajoharie, NY) obtained from Food Analysis Laboratory Control Center (FALCC; Virginia Polytechnic Institute and State University, Blacksburg, VA) and the National Institute of Standards and Technology standard reference material 1546a Meat Homogenate (MHA) (NIST, Gaithersburg, MD) were used to validate nutrient determinations (Montgomery, 2008) and to ensure the accuracy and precision of data among all laboratories. Beef baby food, chicken baby food, and MHA materials were analyzed with each analysis group to ensure values existed within the acceptable range established by the FALCC for proximate analysis (protein, ash, fat, and dry matter), inductively coupled plasma mass spectrometry (ICP) minerals, fatty acids, and total cholesterol. Beef baby food and chicken baby food were used as standards to validate Vitamin E, choline, selenium, and Vitamin B assays. Pork and egg standard obtained from FALCC (FALCC; Virginia Polytechnic Institute and State University, Blacksburg, VA) were used to validate Vitamin D and 25-hydroxy Vitamin D analyses as described by Bilodeau et al. (2010). Chemical analyses were considered

valid by the USDA Nutrient Data Laboratory (NDL) when the standard value generated was within the standard error of the certified value.

Proximate Analysis

Proximate analysis was conducted to determine percent protein, ash, moisture and fat content for all lean composites for each cut of raw or cooked grain-finished and grass-finished product. Proximate analysis was conducted for a single national composite for grain-finished and grass-finished sources for external and seam fat of raw and cooked status.

Protein Analysis

Crude protein was determined following the AOAC Official Method 992.15 (2006) using a nitrogen determinator (Leco TruSpec CN or Leco FP-2000; Leco Corporation, St. Joseph, MI and Rapid N cube, Elementar, Hanau, Germany). Total percentage nitrogen was multiplied by a factor of 6.25 to calculate percent protein. Protein content was determined at CSU.

Ash Analysis

Ash content was determined using the ashing method described by AOAC 923.03 and 920.153 (1995). Approximately 1 g of sample was placed into a pre-weighed, dry crucible prior to placing the crucible into a Thermolyne box furnace at 600° C for 18 h. Percent ash was calculated by dividing the ash weight by the initial sample weight and multiplying by 100. Ash analysis was conducted at CSU.

Moisture Analysis

Moisture content was determined using the oven drying method described in AOAC 950.46 and 934.01 (AOAC, 1995). Approximately 1 g of sample was weighted into aluminum tins prior to placing the tins into a forced air drying oven for 24 h at 100° C. Samples were

placed into a desiccator, cooled, and weighed. Percent moisture content was determined from the formula: %MC=[(initial weight – dry weight) / initial weight] x 100. Moisture content was determined at CSU.

Fat Analysis

Fat content was determined suing the chloroform:methanol method described by Folch, Lees, and Stanley (1957). Approximately 1 g of sample was homogenized in 2:1 chloroform:methanol solution before placing it into an orbital shaker at room temperature for 20 min. Sample was filtered through ashless filter paper and 4 ml of 0.9% NaCL was added prior to being refrigerated for 24 h. Upon phase separation of the filtrate, aspirated low phase content was placed into a pre-weighed scintillation vial and dried under N_2 gas followed by vial air drying under a hood for 2 h. Vials were placed into a forced air drying oven for 12 h at 100° C. Percent total fat was calculated from the formula: %TF=[((Total volume of chloroform:methanol) / 10) x (final lipid weight / initial weight)] x 100. Total fat content was analyzed at CSU.

Fatty Acid Analysis

Fatty acid methyl esters (FAMES) were prepared as described by Parks and Goins (1994). Analysis of FAMES occurred by liquid chromatography using an Agilent Model 6890 Series II (Avondale, PA) gas chromatograph-fixed with a Series 7683 injector and flame ionization detector in addition to being equipped with a 100-m x 0.25-mm (id) fused silica capillary column (SP-2560 Supelco Inc. Bellefonte, PA). Fatty acid percentages were calculated based on the total FAME analyzed. Fatty acid analysis was conducted at CSU.

ICP Mineral Analysis

Inductively coupled plasma mass spectrometry minerals were determined for Ca, Mg, K, Na, Fe, Zn, Cu, Mn and P by using methods described by the AOAC Official Method 985.35 and USDA wet ashing procedure. Briefly, organic matrix is destroyed by dry ashing in a muffle furnace. The remaining ash is dissolved in diluted HNO3 acid. Analyte wass determined by atomic absorption spectrophotometry. Calorimetric method as described by AOAC Official Method 2.019, 2.095 and 7.098 was used to conduct Phosphorus analysis by ICP mineral determination was conducted by Covance Laboratories (Madison, WI).

Cholesterol Analysis

Standard methods as described by Dinh et al. (2008) were used to determine Cholesterol analysis. Briefly, samples were accurately weighted before placing into a 125-mL flask boiling with 10 mL of 95% ethanol and 2 mL of 50% potassium hydroxide in water. The flask was refluxed for 15 min and allowed to cool to room temperature. Ten mL of Toluene was added, mixed and transferred to a separatory funnel and washed. The toluene solution containing the extracted cholesterol fraction was mixed with an internal standard comprised of 5-alpha-cholestane. It was then placed in a 2.0 mL gas chromatography vial and gas chromatography equipped with a DB-17 capillary column was used for gas chromatography analysis. The inlet temperature was 250°C and split ratio was 10:1. Cholesterol content was analyzed at CSU.

Selenium Analysis

Selenium analysis was determined by using the AOAC 986.15 hydride-generation method (AOAC, 2005). Perchloric acid was used to digest samples before reducing with hydrochloric acid. The samples were reacted with sodium borohydride to produce a selenium

hydride volatile. This was measured by atomic absorption spectrometry and the quantitation limit of 30 ppb. Selenium analysis was conducted by Covance Laboratories (Madison, WI).

B Vitamins Analysis

B-Vitamins analysis was conducted for thiamin, niacin, riboflavin, pantothenic acid, vitamin B6 and vitamin B12 by using methods described as follows: vitamin B-12 – AOAC 952.20 and 960.46; vitamin B6 – AOAC 961.15; riboflavin – AOAC 960.46 and 940.3; niacin – AOAC 944.13 and 960.46; pantothenic acid – AOAC 945.74 and 960.46; thiamin – AOAC 942.23, 953.17, and 957.17. The fluorometric method was used to determine thiamin concentration. The microbiological method was used to determine concentration of riboflavin, niacin, pantothenic acid, vitamin B6 and vitamin b12. B-Vitamins analysis was conducted by Covance Laboratories (Madison, WI).

Total Choline Analysis

Total choline and metabolites were determined by extracting and partitioning metabolites into organic and aqueous phases using methanol and chloroform before being analyzed by isotope dilution mass spectrometry as described by Koc et al. (2002). Total choline and metabolites analysis was conducted by University of North Carolina Nutrition Research Institute (Chapel Hill, NC).

Vitamin E Analysis

Vitamin E analysis was determined using high performance liquid chromatography (HPLC) by pumping the sample mixture at high pressure through a normal phase column, and uses UV detection with external calibration, and internal standard recovery post analysis. Vitamin E analysis was conducted by Craft Technologies Laboratory (Wilson, NC).

Vitamin D and 25-Hydroxy-Vitamin D Analysis

Vitamin D analysis was conducted for Vitamin D_3 and 25-Hydroxy-Vitamin D_3 determined using a liquid chromatography-mass spectrophotometry method described by Huang et al. (2009). Vitamin D analysis was conducted by Covance Laboratories (Madison, WI).

Statistical Analysis

Least squares means with the probability difference procedure (PDIFF option) and analysis of variance were computed using the MIXED procedure of the Statistical Analysis Systems Institute software (SAS; version 9.3, Cary, NC). The fixed effects were cut and feeding type (grain-finished or grass-finished) season of collection and collection location were random variables. .

CHAPTER 4

RESULTS AND DISCUSSION

Separable Components

Least squares means showing dissected separable components of grain-finished and grass-finished raw and cooked lamb cuts are presented in Table 2 and Table 3, respectively. Since ground lamb is a result of comminuted lean and fat, these samples were not dissected. Raw grain-finished and grass-finished whole legs and whole shoulders had higher amounts of separable external fat and seam fat (Table 2). Observationally, noticeable amounts of intermuscular fat (seam fat) were detected within grain-finished and grass-finished whole shoulders during dissection. Additionally, raw grain-finished and grass-finished whole shoulders had the highest amount of separable seam fat (Table 2). Raw grain-finished and grass-finished stew meat had the most separable lean (Table 2 and Table 3). Raw grain-finished and grass-finished foreshanks had the highest amount (Table 2) and highest percentage (Table 3) of refuse due to the high proportion of connective tissue and bone present in the retail cut. Consequently, raw foreshanks also had the lowest percent of separable lean (Table 3).

Cooking Yield

Least squares means for cooking yields are presented in Table 4. Cooking resulted in grass-finished shoulder blade chops, loin chops, whole ribs, and ground lamb having higher cooking yields; and cooking resulted in grain-finished frenched whole ribs and whole legs having higher cooking yields (Table 4). Previous research concluded that cooking method and level of external fat can influence cooking yield (Jones, Savell, and Cross, 1992; Luchak et al., 1998; Wahrmund-Wyle, Harris, and Savell, 2000).

Proximate Composition

Protein

Generally, protein content was similar in raw grain-finished and grass-finished separable lean from retail lamb cuts (Table 5). Similar to Hoke et al. (1999) and Purchas et al. (2014), effect of cooking increased protein content in cooked cuts compared to raw cuts. Cooked grass-finished loin chops, whole block ready rib roasts and ground lamb were higher in protein content compared to grain-finished cuts; cooked grain-finished shoulder blade chops and frenched whole rib roasts were higher in protein content compared to grass-finished cuts; and protein content was similar between grain-finished and grass-finished whole legs (Table 6). Raw grain-finished and grass-finished external fat increased due to cooking, but effect of cooking decreased protein content in grain-finished and grass-finished seam fat (Table 15 and Table 16).

Fat

Results of total fat content varied among raw grain-finished and grass-finished separable lean from retail lamb cuts (Table 5 and Table 6). Grass-finished shoulder arm chops, whole shoulders, rib chops and sirloin chops had higher crude fat content, but all other grain-finished cuts had higher fat content (Table 5). However, Popova, Gonzales-Barron and Cadaves (2015) reported in a meta-analysis that grass-fed lamb was lower in total fat. Total fat content was higher in all grain-finished cooked cuts compared to grass-finished cooked cuts (Table 6). Total fat concentration in external fat from raw grain-finished and grass-finished lamb cuts was higher than seam fat from raw grain-finished and grass-finished lamb cuts (Table 7 and Table 8). In comparison, seam fat from lamb cuts was higher in moisture content regardless of cooking or if seam fat was from grain-finished or grass-finished lamb cuts (Table 7 and Table 8). Effect of cooking increased concentration of total fat in external fat from grain-finished and grass-finished

lamb cuts, but decreased concentration of seam fat in grain-finished and grass-finished lamb cuts (Table 7 and Table 8). Additionally, total fat content has generally decreased compared to SR-28 data (Table 9).

Ash

Overall, ash content was similar among separable lean from all raw cuts regardless of feeding type (grain-finished or grass-finished) (Table 5). However, separable lean from all rib chops and whole shoulders had the lowest ash content (Table 5). Ash content was higher in separable lean from all grass-finished cooked cuts compared to grain-finished cooked cuts (Table 6). Similar levels of ash content were reported previously by other researchers (Ono et al., 1984; Lin et al., 1988; Hoke et al., 1999; Kosulwat, Greenfield and James, 2003; Purchas et al., 2014). Generally, ash content in external and seam fat from raw and cooked grain-finished and grass-finished lamb cuts were similar; however, effect of cooking decreased ash content of external and seam fat from grain-finished lamb cuts more than in external and seam fat from grass-finished lamb cuts (Table 7 and Table 8).

Moisture

Generally, concentration of moisture had an inverse relationship to total fat content (Table 5). Separable lean from raw cuts that had higher total fat content tended to have lower moisture content (Table 5). Moisture results for ground lamb were much lower than moisture results from all other cuts. Previous researchers reported that there is an inverse association between moisture and total fat content within muscle (Lin et al., 1988; Hoke et al., 1999; Kosulwat, Greenfield and James, 2003; Leheska et al., 2008; Purchas et al., 2014). Total moisture content of cooked lamb cuts decreased due to moisture losses during cooking (Table 6).

Cholesterol

Cholesterol content from separable lean from raw grain-finished and grass-finished lamb cuts were variable; however, raw grain-finished and grass-finished frenched rib chops had the highest cholesterol content (Table 5). Cholesterol content from separable lean from cooked grain-finished and grass-finished lamb cuts was variable (Table 6). From separable lean, grass-finished shoulder blade chops and whole legs had higher cholesterol content than grain-finished cuts; grain-finished whole block ready rib roasts had higher cholesterol content than grass-finished cuts. Whereas, similar cholesterol content resulted for loin chops, frenched whole block ready rib roasts and ground lamb regardless of being from lamb produced on a grain-finished or grass-finished diet. Previous researchers reported that cooking increased cholesterol content in lamb muscle (Swize et al., 1991; Hoke et al., 1999; Purchas et al., 2014). Effect of cooking increased cholesterol concentration in external fat from grain-finished and grass-finished lamb cuts, but cooking decreased cholesterol concentration in seam fat from grain-finished and grass-finished lamb cuts (Table 7 and Table 8). Compared to SR-28, cholesterol content from raw grain-finished lamb cuts increased in the current study (Table 9).

Fatty acids

Fatty acid profiles for separable lean from raw grain-finished and grass-finished lamb cuts are presented in Table 10 and Table 11, fatty acid profiles for separable lean from cooked grain-finished and grass-finished lamb cuts are presented in Table 12 and Table 13, and fatty acid profiles for raw and cooked grain-finished and grass-finished external and seam fat are presented in Table 14 and Table 15. Fatty acid data included in SR-28 was limited regarding individual fatty acids in raw and cooked lamb cuts. Data from this study includes expanded fatty acid profiles for raw and cooked grain-finished lamb cuts. Proportionally, palmitic acid (16:0),

stearic acid (18:0) and oleic acid (18:1 n9) comprised the majority of fatty acid profiles for separable lean, external fat, and seam fat, for grain-finished and grass-finished lamb cuts.

ICP Minerals

Results of minerals analyzed by inductively coupled plasma mass spectrometry (ICP) from separable lean from raw and cooked lamb cuts are presented in Table 16 and Table 17. Results of ICP mineral analysis for separable lean from raw lamb cuts and ground lamb indicated that mineral content (mg/100g) was higher for iron content in grass-finished cuts. Conversely, potassium content was higher for separable lean from raw grain-finished lamb cuts. Results of calcium, copper, magnesium, manganese, and sodium content were similar among grain-finished and grass-finished lamb cuts. Results of phosphorus and zinc content were variable among raw grain-finished and grass-finished lamb cuts.

Mineral results for calcium, copper, magnesium, manganese, and sodium were similar among separable lean from cooked grain-finished and grass-finished lamb cuts (Table 17). Content of iron, phosphorus and zinc was higher in cooked grain-finished shoulder blade chops, whole block ready rib roasts and whole block ready frenched rib roasts whereas cooked grass-finished loin chops, whole legs and ground lamb was higher in iron, phosphorus and zinc content. Mineral content from external fat and seam fat from separable raw and cooked grain-finished and grass-finished lamb cuts are presented in Table 7 and Table 8. Similar to Hoke et al. (1999) and Purchas et al. (2014), effect of cooking generally increased concentrations of ICP minerals from external fat from grain-finished lamb cuts. Cooking decreased concentration of calcium content in external fat from grain-finished lamb cuts, and decreased concentration of ICP mineral content in seam fat from grain-finished lamb cuts, except for copper, iron and manganese (Table 7). Effect of cooking generally increased concentration of ICP minerals in

composited external fat and seam fat from grass-finished lamb cuts. Cooking decreased calcium concentration in external fat and seam fat from grass-finished lamb cuts, and decreased concentration of phosphorus, potassium, sodium and zinc in seam fat from grass-finished lamb cuts (Table 8).

Comparison of mineral results from separable lean from the current study to separable lean from SR-28 data indicates apparent changes mineral composition of grain-finished lamb (Table 9). Comparison of raw grain-finished lamb cuts to SR-28 resulted in decreased iron content in all cuts, except for shoulder arm chops, decreased zinc content in all cuts, except for shoulder blade chops; decreased calcium content in all cuts, except for foreshanks, and decreased magnesium and sodium in all grain-finished lamb cuts (Table 9). However, potassium content has increased in all grain-finished cuts compared to SR-28 data, and copper content is similar among current results and SR-28 data (Table 9). Comparison of phosphorus content is variable between results in the current study and SR-28 data. Phosphorus content increased for raw grain-finished shoulder arm chops, rib chops, whole loins, sirloin chops, whole legs and stew meat, but decreased for all other raw lamb cuts.

Selenium

Results of selenium content (µg/100g) from separable lean from raw and cooked grain-finished lamb cuts are presented in Table 16 and grass-finished in Table 17. Selenium content of separable lean from grain-finished raw and cooked lamb cuts was higher than separable lean from all raw and cooked grass-finished lamb cuts (Table 16). Effect of cooking increased selenium content in cooked grain-finished and grass-finished lamb cuts except for grain-finished shoulder blade chops, whole block ready rib roasts and loin chops. Selenium content of whole block ready rib roasts are compared to raw rib chops, selenium content of frenched rib chops are

compared to whole block ready frenched rib roasts, and selenium content of loin chops are compared to whole block ready loins (Table 16 and Table 17). Previous researchers reported that selenium content generally increases due to cooking as moisture decreases (Hoke et al., 1999; Purchas et al., 2014). Effect of cooking increased selenium content in external fat from grain-finished lamb cuts (Table 7), and increased selenium content in external fat and seam fat from grass-finished lamb cuts (Table 8). Selenium content from seam fat from cooked grain-finished lamb cuts was lower than from raw grain-finished lamb cuts (Table 7). Comparison of these data to SR-28 data indicates a drastic reduction in selenium content in separable lean from raw lamb cuts in the current study (Table 9).

B-Vitamins (Thiamin, Riboflavin, Niacin, Pantothenic Acid, B6 and B12)

Results of B-vitamin content from separable lean of raw grain-finished and grass-finished lamb cuts is presented in Table 18. Results of niacin (B_3) was higher in separable lean from raw grain-finished lamb cuts, except for foreshanks, shoulder arm chops, and whole loins; and B_{12} content was higher for grain-finished lamb cuts, except for shoulder blade chops, sirloin chops and whole legs. Content of thiamin (B_1), riboflavin (B_2), pantothenic acid (B_5) and vitamin B6 were similar among separable lean from raw grain-finished and grass-finished lamb cuts (Table 18).

Results of B-vitamin content from separable lean of cooked grain-finished and grass-finished lamb cuts is presented in Table 19. Pantothenic acid (B_5) was higher in separable lean from all cooked grain-finished cuts whereas vitamin B_6 was higher in all cooked grass-finished lamb cuts. Results of niacin (B_3) and B_{12} were variable among cooked grain-finished and grass-finished lamb cuts. Comparison of mineral content among grain-finished and grass-finished cooked lamb indicates that whole legs, whole block ready rib roasts and ground lamb are higher

in niacin (B_3) content; and cooked grain-finished loin chops, whole legs, whole block ready rib roasts and whole block ready frenched rib roasts are higher in vitamin B_{12} content. Results of thiamin (B_1), riboflavin (B_2), and vitamin B6 content were similar among cooked grain-finished and grass-finished lamb cuts.

Results of B-vitamin content from external fat and seam fat from raw and cooked grain-finished and grass-finished lamb cuts are presented in Table 7 and Table 8. Effect of cooking decreased concentration of riboflavin in external fat and seam fat from grain-finished lamb cuts, and vitamin B_{12} and niacin (B_3) in seam fat from grain-finished lamb cuts (Table 7). Effect of cooking decreased concentration of riboflavin in external fat from grass-finished lamb cuts and niacin in seam fat from grass-finished lamb cuts (Table 8).

Comparison of concentration of grain-finished B-Vitamins from separable lean of raw lamb cuts to SR-28 data indicates that content of riboflavin and vitamin B6 increased in separable lean all raw grain-finished cuts, and concentration of vitamin B12 increased in all raw grain-finished cuts except for rib chops, whole block ready loins, sirloin chops and whole legs (Table 9).

Vitamin D (D2, D3 and 25-Hydroxy Vitamin D)

Results of vitamin D content from raw and cooked grain-finished and grass-finished composited separable lean is presented in Table 20. Effect of cooking did not increase vitamin D2 or D3 content among grain-finished and grass-finished separable lean. Concentration of 25-hydroxy vitamin D3 were similar between raw and cooked grain-finished separable lean, but cooking resulted in a slight increase in concentration of 25-hydroxy vitamin D3 in separable lean from grass-finished lamb cuts. Similarly, cooking did not increase concentration of vitamin D2 or D3 in external fat and seam fat from grain-finished and grass-finished lamb cuts (Table 7 and

Table 8). Cooking resulted in decreased concentration of 25-hydroxy vitamin D3 from external fat and seam fat from grain-finished and grass-finished lamb cuts (Table 7 and Table 8).

Vitamin E (alpha-, beta-, delta-, and gamma-tocopherol)

Results of Vitamin E content from separable lean from raw and cooked grain-finished and grass-finished lamb cuts are presented in Table 20. Concentration of beta-tocopherol, delta-tocopherol or gamma-tocopherol were not detectable for grain-finished and grass-finished separable lean composites. Effect of cooking resulted in decreased concentration of alpha-tocopherol in grain-finished separable lean, but increased concentration of alpha-tocopherol in grass-finished separable lean (Table 20). Purchas et al. (2014) reported lower concentration of alpha-tocopherol in raw and cooked lamb. Only concentration of beta-tocopherol was detected in raw grain-finished seam fat. Presence of beta-tocopherol in all other fat samples, and delta-tocopherol and gamma-tocopherol in all fat samples were not detectable (Table 7). Concentration of alpha-tocopherol increased in external fat from cooked from grain-finished lamb cuts (Table 8). Concentration of alpha-tocopherol in seam fat from grain-finished lamb cuts and in external fat and seam fat from grass-finished lamb cuts decreased from cooking (Table 7) and Table 8).

Choline (Choline, Phosphocholine, Glycerophosphocholine, Phosphatidylcholine, Sphingomyelin, Betaine)

Results of choline concentration from grain-finished and grass-finished separable lean are presented in Table 20. Effect of cooking resulted in increased concentration of choline metabolites in separable lean from grain-finished and grass-finished lamb cuts, except for glycerophosphocholine level from grain-finished separable lean. Cooking resulted in decreased concentration of choline, phosphocholine, and phosphatidylcholine in external fat from grain-finished separable lean, and decreased concentration of phosphocholine and sphingomyelin in

seam fat from grain-finished lamb cuts (Table 7). Cooking decreased concentration of phosphocholine and sphingomyelin in seam fat from grass-finished lamb cuts (Table 8). Cooking resulted in increased concentration of total choline and total betaine from separable lean (Table 20) and from external fat and seam fat (Table 7 and Table 8) regardless of grain-finished or grass-finished lamb cut origin.

Lean and Extra Lean Labeling Claims and Lipid Profiles

Extra labeling claims must meet specific criteria from USDA for lean and extra lean labeling claims and additional criteria for American Heart Check labeling claims. According to 9 CFR 317.362, products that meet "lean" extra labeling claims must have less than 10 g fat, less than 5 g of saturated fat, and less than 95 mg of cholesterol per 100 g, wherein products meeting "extra lean" labeling claims must have less than 5 g fat, less than 2 g saturated fat, and less than 95 mg of cholesterol per 100 g (USDA-FSIS, 2010). All raw grain-finished and grass-finished lamb cuts from this study meet either lean or extra lean extra labeling claims, except for ground lamb (Table 21 and Table 22). Grain-finished foreshanks, whole shoulders, whole legs, and sirloins and grass-finished foreshanks and stew meat could potentially qualify for extra lean labeling claims (Table 21 and Table 22). The American Heart Association labeling criteria for products that could potentially be labeled under the "Heart-Check" certification program must have less than 5 g of total fat, less than 2 g of saturated fat, less than 95 mg of cholesterol, less than 0.5 g Trans-fat and less than 360 mg of sodium (AHA, 2015). Raw grain-finished and grass-finished lamb cuts from this study that potentially meet criteria for the "Heart-Check" certification program for additional labeling claims based on separable lean only data include grain-finished shoulder arm chops, sirloin chops, and whole legs; grass-finished stew meat; and grain-finished and grass-finished foreshanks (Table 21 and Table 22). Lamb cuts meeting extra

labeling claims could change upon USDA Nutrition Database Lab calculating the lipid profile and sodium content for the whole cut (separable lean, external fat, seam fat, and refuse).

Extra Labeling Claims

Additional labeling claims (9 CFR 381.454) for "excellent source of" requires a product to contain a nutrient that is 20 percent or more of the Reference Daily Intake (RDI) and "good source of" requires a product to contain a nutrient that is 10 to 19 percent of the RDI used to calculate % Daily Value of a nutrient (USDA-FSIS, 2015). Current U.S. cooked lamb cuts that could potentially qualify for the use of "excellent source of" and "good source of" labeling claims based on separable lean only data are presented in Table 23 and Table 24. Cooked grain-finished and grass-finished lamb cuts qualify for numerous extra labeling claims for protein and multiple B-vitamins and minerals. Cuts meeting extra labeling claims could change upon USDA Nutrition Database Lab calculating the B-vitamin and mineral content for the whole cut (separable lean, external fat, seam fat, and refuse).

Data Comparison to current Standard Reference Data

Additional fatty acids were identified for more inclusive fatty acid data for grain-finished lamb cuts. Currently the USDA National Nutrient Database for Standard Reference (SR) does not contain domestic grass-finished data for lamb produced in the U.S. Grass-finished data from this study will be used to add domestic grass-finished data to the SR. Data from this study used to compare differences resulted from separable lean only from lamb cuts trimmed to 1/8" external fat, but the existing data in the SR were derived from separable lean from lamb cuts trimmed to ¼" external fat, wherein this is the best comparison of nutrient data even though nutrient data from the SR may be influenced by additional external fat (Table 17). Vitamin E

metabolites beta-tocopherol, delta-tocopherol and gamma-tocopherol were non-detectable in separable lean in the current study.

CHAPTER 5

CONCLUSIONS

Results from this study provide current, relevant nutrition information indicative of the current U.S. lamb supply. This nutrient information will be adopted domestically for updated use on retail lamb cuts. These findings were submitted to the USDA Nutrient Database for Standard Reference (SR) to update nutrient information available for retail lamb cuts to consumers, the general public, health and nutrition organizations, as well as health professionals. Results from this study have been used to establish raw and cooked nutrient data for grass-finished lamb cuts in the SR. Additionally, fatty acid profiles for raw and cooked grain-finished lamb cuts were expanded compared to previous fatty acid data available in the SR. These data have been used to update the SR and provide current nutrient data for lamb cuts reflective of the current U.S. supply. Since this is the most comprehensive nutrient data available to be included in the SR currently for retail lamb cuts trimmed to a maximum of 1/8" external fat, all harvest facilities need to adopt trimming protocols to trim all lamb product to 1/8" external fat in order to utilize this data for on-pack nutrition labeling. This information will be available to provide support for including lamb as part of healthy eating as a beneficial protein food that provides excellent and good sources of protein, B-vitamins and several essential minerals.

Table 1. Description of grain-finished and grass-finished retail lamb cuts trimmed to a maximum of 1/8" external fat collected from three U.S. lamb harvest facilities among four seasons with raw or cooked designation and IMPS[1] Number.

Cut Name	IMPS Number	Analyzed as Raw, Cooked, or Both
Leg, Foreshank, 1/8" trim level	210	Raw
Leg, Whole, Boneless, 1/8" trim level[2]	234	Both
Leg, Bone-in, Sirloin Chop, 1/8" trim level	1245	Raw
Loin, Block-Ready Trimmed, 1/8" trim level[3]	232A	Raw
Loin Chop, 1/8" trim level[3]	1232A	Cooked
Rib, Rack, Roast-Ready, Frenched, Cap-off, 1/8" trim level[4]	204D	Cooked
Rib, Chop, Frenched, Cap-off, 1/8" trim level[4]	1204D	Raw
Rib, Rack, Roast-Ready, 1/8" trim level[4]	204B	Cooked
Rib Chop, IMPS 1/8" trim level[4]	1204B	Raw
Shoulder, Whole, Boneless, 1/8" trim level	208	Raw
Shoulder, Blade Chop, 1/8" trim level[2]	1207B	Both
Shoulder, Arm Chop, 1/8" trim level	1207A	Raw
Stew meat	295	Raw
Ground Lamb, IMPS	296	Both

[1]IMPS=Institutional Meat Purchasing Specifications

Table 2. Least squares means and standard error of separable components (g) derived from eleven raw and six cooked U.S. retail lamb cuts trimmed to a maximum of 1/8" external fat.

Retail cut, trim level (cm)	Separable lean (g)[1]		External fat (g)[2]		Seam fat (g)[3]		Refuse (g)[4]	
	Grain-finished	Grass-finished	Grain-finished	Grass-finished	Grain-finished	Grass-finished	Grain-finished	Grass-finished
Raw cuts								
Foreshank	260±5.9	235.3±2.6	230.9±3.0	22.2±2.6	23.9±4.4	13.6±2	236.3±6.5	248±8.3
Shoulder, Arm Chop	147.0±4.5	143.4±7.7	11.0±0.83	9.9±0.94	15.1±1.1	13.5±1.3	28.6±1.6	27.3±1.7
Shoulder, Blade Chop	184.1±6.5	183.4±5.4	16.8±1.0	13.8±1.8	39.8±2.4	29.6±1.9	70.4±3.4	89.7±5.4
Shoulder, Whole	1588±29	1596±44	282.±20	214.9±16.8	493±21	466±70	160±16	187±31
Rib Chop	63.9±1.5	56.7±2.1	12.1±0.68	11.3±0.48	11.7±0.53	12.3±0.77	21.8±0.61	24.4±0.84
Frenched Rib Chop	50.1±1	49±2	6.7±0.5	3.0±0.34	8.8±0.49	5.9±0.86	20.1±0.51	20.2±0.58
Loin, Whole	567.3±9	542±14	143.1±9	123.3±9.3	41.7±3.5	25±4.2	262±12	276±10
Sirloin Chop	120.6±7	122.9±3.9	19.7±1.1	18.6±1.1	14.5±1.6	11.4±1.1	31.5±1.9	36.5±2.4
Leg, Whole	2349±43	2181±54	342±21	302±10.8	188.8±9.8	160±11	225±17.2	215.8±8.9
Stew Meat	531.1±3	376±23	0	0	0.6±0.4	3.7±1.3	7.6±1.9	6.3±1.5
Ground Lamb	535±60.5	440±40	-	-	-	-	-	-
Cooked[5] lamb cuts								
Shoulder, Blade Chop	142.8±4.15	157.6±9.70	14.2±1.31	16.3±2.42	20.8±1.40	21.6±3.9	63.6±2.99	70.7±5.16
Loin Chop	63.3±1.07	62.2±1.42	5.8±0.44	6.7±0.30	2.4±0.18	2.1±0.13	27.3±0.64	29.0±0.57
Leg, Whole	1700.0±35.59	1661.1±20.24	216.8±12.08	159.5±8.36	177.4±8.32	111.4±11.10	159.3±14.44	159.3±16.76
Rib Roast	390.8±6.74	344.7±14.46	103.7±5.70	59.4±5.34	90.3±4.89	65.2±5.38	194.1±4.79	188.5±7.24
Frenched Rib Roast	370.6±4.10	312.8±9.56	63.3±3.12	49.2±6.24	70.4±3.76	59.2±3.55	164.0±3.80	176.6±5.78
Ground Lamb[6]	289.1±1.65	291.6±16.63	-	-	-	-	-	-

[1]Separable lean weight (g) includes any intramuscular fat. Separable lean, %: [separable lean (g)/ pre-dissection cut weight (g)] x 100.
[2]Seam fat weight (g) includes any fat which lies between muscles. Seam fat, %: [seam fat (g)/ pre-dissection cut weight (g)] x 100.
[3]External fat weight (g) includes all fat located on the outer surface of the cut. External fat, %: [external fat (g)/ pre-dissection cut weight (g)] x 100.
[4]Refuse weight (g) includes all bone and heavy connective tissue. Refuse, %: [refuse (g)/ pre-dissection (g)] x 100.
[5]Chop and roast cuts were cooked to an internal temperature of 60°C; ground lamb was cooked to an internal temperature of 74°C.
[6]Ground lamb was not dissected due to the comminuted lean and fat content

Table 3. Least squares means and standard error of separable components (%) of pre-dissected cut weight derived from eleven raw U.S. retail lamb cuts trimmed to a maximum of 1/8" external fat.

Retail cut, trim level (cm)	Separable lean (%)[1]		External fat (%)[2]		Seam fat (%)[3]		Refuse (%)[4]	
	Grain-finished	Grass-finished	Grain-finished	Grass-finished	Grain-finished	Grass-finished	Grain-finished	Grass-finished
Raw cuts								
Foreshank	46.3±0.88	44.3±0.78	5.3±0.59	4.2±0.46	4.2±0.69	2.5±0.37	42.4±0.91	47.1±0.70
Shoulder, Arm Chop	72±0.59	72.3±1.6	5.3±0.44	5.2±0.59	7±0.33	6.7±0.46	14±0.61	14.1±1.1
Shoulder, Blade Chop	58.2±1.5	57±1.1	5.1±0.37	4.2±0.55	12.9±0.76	9.3±0.82	22±1.2	27.8±1.6
Shoulder, Whole	62±0.85	63.6±0.53	10.8±0.77	8.5±0.85	18.9±0.7	18.2±2.2	6.3±0.64	7.5±1.4
Rib Chop	56.8±0.67	53.9±1.4	10.9±0.51	10.2±0.57	10.5±0.44	11.7±0.67	19.8±0.59	22.7±0.87
Frenched Rib Chop	57.4±0.44	61.5±1.2	7.3±0.38	3.8±0.37	10.1±0.55	7.4±1.1	23.5±0.61	25.6±1
Loin, Whole	55.3±0.83	55.5±1.1	13.8±0.87	12.5±0.89	4±0.33	2.5±0.4	25.3±1	28.1±0.63
Sirloin Chop	64.2±1.2	67.3±0.48	12.17±5.28	10.3±0.8	6.70±3.40	6±0.42	16.5±1.4	14.5 ±1.2
Leg, Whole	74.2±0.72	74.8±0.51	10.8±0.65	10.4±0.64	7.1±0.47	5.5±0.27	7.1±0.49	7.3±0.3
Stew Meat	97±0.53	96±1.1	0	0	0.2±0.15	1.4±0.49	2.3±0.56	2.3±0.57
Ground Lamb[5]	100±0	100±0	-	-	-	-	-	-

[1]Separable lean weight includes any intramuscular fat. Separable lean, %: [separable lean (g)/ pre-dissection cut weight (g)] x 100.
[2]Seam fat weight includes any fat which lies between muscles. Seam fat, %: [seam fat (g)/ pre-dissection cut weight (g)] x 100.
[3]External fat weight includes all fat located on the outer surface of the cut. External fat, %: [external fat (g)/ pre-dissection cut weight (g)] x 100.
[4]Refuse weight includes all bone and heavy connective tissue. Refuse, %: [refuse (g)/ pre-dissection (g)] x 100.
[5]Ground lamb was not dissected due to the comminuted lean and fat content

Table 4. Least squares means and standard error from cooking weights (g), cooking yield (%) and separable components (%) derived from six cooked U.S. retail lamb cuts trimmed to a maximum of 1/8" external fat

Retail cut, trim level (cm)	Shoulder, Blade Chop	Loin Chop	Rib Roast	Frenched Rib Roast	Leg, Whole	Ground Lamb
Cooking Information						
Pre-cooking raw weight, g						
Grain- finished	301.9±8.12	123.0±1.37	1032.0±7.26	844.2±7.74	3143.6±31.17	431.32±1.97
Grass- finished	323.3±13.42	124.4±2.19	854.3±11.84	803.3±26.13	2935.9±26.45	437.6±20.84
Hot cooked weight, g[5]						
Grain- finished	262.2±7.50	105.4±1.16	831.2±9.79	709.5±8.39	2469.9±31.98	305.5±1.88
Grass- finished	284.6±13.26	105.5±2.13	689.9±18.12	635.2±17.39	2284.0±34.99	307.1±18.06
30 min. post cooking weight, g[5]						
Grain- finished	252.1±7.00	102.3±1.06	809.2±9.84	690.5±7.94	2355.6±31.62	294.0±1.64
Grass- finished	273.7±13.18	103.2±2.07	684.9±17.82	617.2±16.31	2180.3±32.12	295.9±16.95
Cooking yield, %[6]						
Grain- finished	83.2±0.91	83.2±0.17	78.6±0.72	81.9±0.35	75.0±0.49	68.0±0.48
Grass- finished	84.7±1.35	83.2±0.64	80.2±1.09	77.4±2.46	74.4±0.56	68.0±1.34
Separable components						
Pre-dissection cut weight, g[5]						
Grain- finished	245.2±6.87	100.5±1.05	794.7±9.57	681.2±7.81	2296.3±31.32	289.1±1.65
Grass- finished	270.4±12.99	101.4±1.97	672.5±18.07	611.7±14.94	2127.8±30.21	291.6±16.63
Separable lean, %[1]						
Grain- finished	58.7±0.74	63.1±0.65	49.3±0.89	54.4±0.72	74.1±0.79	100.00[7]
Grass- finished	58.3±2.40	61.3±1.42	51.0±1.07	51.1±0.97	78.1±0.84	100.00[7]
External fat, %[2]						
Grain- finished	5.4±0.49	5.5±0.45	12.9±0.62	9.1±0.40	9.4±0.60	-
Grass- finished	55.8±0.81	6.5±0.22	8.8±0.62	8.0±0.92	7.6±0.48	-
Seam fat, %[3]						
Grain- finished	8.5±0.64	2.4±0.17	11.3±0.56	10.2±0.46	7.8±0.36	-
Grass- finished	8.0±1.38	2.0±0.14	9.8±0.77	9.7±0.64	5.3±0.50	-
Refuse, %[4]						
Grain- finished	25.8±0.66	27.3±0.61	24.6±0.64	24.4±0.45	6.9±0.62	-
Grass- finished	26.4±1.07	28.7±0.38	28.3±1.37	29.0±1.05	7.3±0.71	-

[1]Separable lean weight (g) includes any intramuscular fat. Separable lean, %: [separable lean (g)/ pre-dissection cut weight (g)] x 100.
[2]Seam fat weight (g) includes any fat which lies between muscles. Seam fat, %: [seam fat (g)/ pre-dissection cut weight (g)] x 100.
[3]External fat weight (g) includes all fat located on the outer surface of the cut. External fat, %: [external fat (g)/ pre-dissection cut weight (g)] x 100.
[4]Refuse weight (g) includes all bone and heavy connective tissue. Refuse, %: [refuse (g)/ pre-dissection (g)] x 100.
[5]Chop and roast cuts were cooked to an internal temperature of 60°C; ground lamb was cooked to an internal temperature of 74°C.
[6]Cooking yield (%): [Pre-cooking raw weight (g)/ pre-dissection cut weight (g)] x 100.
[7]Ground lamb was not dissected due to the comminuted lean and fat content.

Table 5 Proximate composition (% protein, % total fat,% ash, and % moisture) and Cholesterol content of raw grain-finished and grass-finished U.S. Lamb Cuts trimmed to a maximum of 1/8" external fat.

Cut	Protein (%)	Total Fat (%)	Ash (%)	Moisture (%)	Cholesterol mg/100 g
Foreshank					
Grain-Finished	20.83	3.14	1.05	75.41	75.4
Grass-Finished	20.10	2.41	0.95	76.28	78.1
Shoulder Arm Chop					
Grain-Finished	19.77	3.84	1.02	74.76	67.5
Grass-Finished	20.37	4.51	0.96	74.38	75.0
Shoulder Blade Chop					
Grain-Finished	18.25	7.22	0.92	72.09	78.9
Grass-Finished	19.69	6.52	1.04	72.22	71.3
Shoulder, Whole					
Grain-Finished	19.12	7.21	0.89	71.32	75.7
Grass-Finished	20.14	7.56	0.99	71.61	69.6
Rib Chop					
Grain-Finished	20.86	6.99	0.89	70.40	84.4
Grass-Finished	21.08	7.73	0.89	69.75	70.2
Frenched Rib Chop					
Grain-Finished	21.01	6.32	0.83	71.46	93.2
Grass-Finished	21.38	5.64	1.01	71.59	92.1
Loin, Whole					
Grain-Finished	20.76	5.45	1.04	72.66	71.9
Grass-Finished	21.32	4.70	1.10	73.10	68.7
Sirloin Chop					
Grain-Finished	21.19	4.41	1.11	73.12	79.7
Grass-Finished	20.82	4.52	0.97	73.82	70.5
Leg, Whole					
Grain-Finished	20.46	4.36	0.91	73.58	74.9
Grass-Finished	21.43	4.19	1.02	74.34	72.8
Stew Meat					
Grain-Finished	20.23	4.81	1.10	73.76	71.8
Grass-Finished	20.87	3.99	0.99	74.11	63.8
Ground Lamb					
Grain-Finished	16.70	14.77	1.05	63.85	65.6
Grass-Finished	16.74	14.67	0.92	65.22	63.8

Table 6. Proximate composition (% protein, % total fat,% ash, and % moisture) and cholesterol content of cooked grain-finished and grass-finished U.S. Lamb Cus trimmed to a maximum of 1/8" external fat.

Cut	Protein (%)	Fat (%)	Ash (%)	Moisture (%)	Cholesterol mg/100g
Loin Chop					
Grain-Finished	26.37	6.09	0.96	66.05	92.1
Grass-Finished	27.43	5.78	1.28	66.05	92.5
Leg, Whole					
Grain-Finished	26.91	7.62	0.89	64.24	81.8
Grass-Finished	26.87	6.44	1.49	64.63	89.2
Shoulder Blade Chop					
Grain-Finished	25.26	7.76	1.02	66.25	85.9
Grass-Finished	24.99	7.57	1.11	65.95	90.9
Rib Roast					
Grain-Finished	23.85	11.89	0.93	62.07	95.2
Grass-Finished	24.71	10.21	1.49	63.23	86.3
Frenched Rib Roast					
Grain-Finished	25.11	10.57	0.77	62.89	88.9
Grass-Finished	24.82	9.22	1.78	64.04	91.7
Ground Lamb					
Grain-Finished	25.17	13.47	1.03	59.08	88.5
Grass-Finished	26.94	12.86	1.22	57.93	88.5

Table 7. Proximate values and nutrient content of raw and cooked external fat and seam fat from grain-finished lamb cuts trimmed to a maximum of 1/8" external fat.

Proximate values and nutrient, units	External Fat		Seam Fat	
	Raw	Cooked	Raw	Cooked
Proximates				
Protein%	6.49	7.21	11.12	8.75
Fat%	61.25	63.21	43.88	55.13
Ash%	0.34	0.15	0.60	0.35
Moisture%	22.56	18.38	37.07	28.10
Nutrients				
Riboflavin (Vitamin B_2), mg/100g	0.19	0.13	0.20	0.14
Niacin (Vitamin B_3), mg/100g	1.86	2.83	3.09	2.86
Pantothenic Acid (Vitamin B_5), mg/100g	0.24	0.32	0.31	0.33
Vitamin B_6, mg/100g	0.06	0.10	0.11	0.12
Vitamin B_{12}, µg/100g	1.33	1.66	1.80	1.57
Cholesterol, mg/100g	73.2	88.0	88.0	81.0
Total Choline, mg/100g	27.41	28.80	36.67	37.72
Total Betaine, mg/100g	4.62	5.51	6.36	6.46
Vitamin D2, µg/100g	<0.10	<0.10	<0.10	<0.10
Vitamin D3, µg/100g	<0.10	<0.10	<0.10	<0.10
25 Hydroxy Vitamin D3, µg/100g	0.18	0.14	0.19	0.15
Selenium, µg/100g	5.44	14.7	7.33	5.55
AlphaTocopherol, µg/g	3.40	5.87	3.88	3.73
BetaTocopherol, µg/g	nd	nd	1.64	nd
Gamma Tocopherol, µg/g	nd	nd	nd	nd
Delta Tocopherol, µg/g	nd	nd	nd	nd
Vitamin B1, µg/g	0.05	0.05	0.06	0.06
Choline, nmol/g	113.25	112.27	115.74	120.37
P-Choline, nmol/g	55.75	53.82	54.98	50.28
Phosphatidylcholine, nmol/g	1902.81	1867.69	2448.26	2679.85
GP-Choline, nmol/g	181.90	284.78	297.72	308.00
Betaine, nmol/g	394.09	470.54	542.64	551.60
Sphingomyelin, nmol/g	377.65	445.94	603.27	462.94
Calcium, mg/g	25.0	14.0	20.4	13.7
Copper, mg/g	0.04	0.15	0.05	0.07
Iron, mg/g	0.62	1.56	0.94	0.97
Magnesium, mg/g	6.17	9.50	9.85	8.77
Manganese, mg/g	<0.007	<0.007	<0.007	<0.007
Phosphorus, mg/g	67.3	83.3	94.8	80.1
Potassium, mg/g	101.0	133.0	152.0	138.0
Sodium, mg/g	29.2	35.8	41.7	35.3
Zinc, mg/g	0.75	0.95	1.49	1.40

nd=concentration was not detectable, level was <0.10 µg/g

Table 8. Proximate values and nutrient content of raw and cooked external fat and seam fat from grass-finished lamb cuts trimmed to a maximum of 1/8" external fat.

Proximate values and nutrient, units	External Fat		Seam Fat	
	Raw	Cooked	Raw	Cooked
Proximates				
Protein (%)	8.41	8.85	12.15	10.42
Fat (%)	57.30	60.90	39.10	51.27
Ash (%)	0.44	0.59	0.50	0.53
Moisture (%)	25.19	20.90	40.67	32.24
Nutrients				
Riboflavin (Vitamin B_2), mg/100g	0.17	0.15	0.14	0.17
Niacin (Vitamin B_3), mg/100g	2.10	2.95	3.33	2.81
Pantothenic Acid (Vitamin B_5), mg/100g	0.24	0.32	0.27	0.32
Vitamin B_6, mg/100g	0.07	0.11	0.13	0.16
Vitamin B_{12}, µg/100g	1.44	1.85	1.70	1.78
Cholesterol, mg/100g	70.1	92.1	82.4	89.8
Total Choline, mg/100g	20.96	31.40	41.14	41.42
Total Betaine, mg/100g	4.06	5.38	5.34	6.17
Vitamin D2, µg/100g	<0.10	<0.10	<0.10	<0.10
Vitamin D3, µg/100g	<0.10	<0.10	<0.10	<0.10
25 Hydroxy Vitamin D3, µg/100g	0.19	0.14	0.14	0.13
Selenium, µg/100g	3.69	5.34	4.99	5.42
AlphaTocopherol, µg/g	8.13	4.17	9.06	6.13
BetaTocopherol, µg/g	nd	nd	nd	nd
Gamma Tocopherol, µg/g	nd	nd	nd	nd
Delta Tocopherol, µg/g	nd	nd	nd	nd
Vitamin B1, µg/g	0.04	0.06	0.06	0.06
Choline, nmol/g	99.19	127.43	138.45	160.97
P-Choline, nmol/g	44.53	49.82	56.70	48.69
Phosphatidylcholine, nmol/g	1588.89	2078.85	2829.58	2844.06
GP-Choline, nmol/g	176.73	293.82	336.77	351.70
Betaine, nmol/g	346.21	459.55	456.23	526.93
Sphingomyelin, nmol/g	423.31	464.76	587.72	571.26
Calcium, mg/g	22.5	18.9	23.9	13.3
Copper, mg/g	0.05	0.18	0.07	0.07
Iron, mg/g	0.73	1.61	1.01	1.21
Magnesium, mg/g	6.85	11.1	10.7	10.7
Manganese, mg/g	<0.007	0.009	<0.007	<0.007
Phosphorus, mg/g	69.7	93.3	103	89.6
Potassium, mg/g	111.0	148	163	150
Sodium, mg/g	28.9	38.4	45.7	37.8
Zinc, mg/g	0.81	1.25	1.68	1.60

nd=concentration was not detectable, level was <0.10 µg/g

Table 9. Comparison of current study raw nutrient values from grain-finished lamb cuts trimmed to a maximum of 1/8" external fat to USDA SR-28 nutrient values from grain-finished lamb cuts trimmed to ¼" external fat.

Cut	Foreshank	Arm Chop	Blade Chop	Shoulder, Whole	Rib Chop	Loin, Whole	Sirloin Chop	Leg, Whole	Stew Meat	Ground Lamb
Protein, %										
USDA NDL Value	21.08[1]	19.99[2]	19.29[3]	19.55[4]	19.98[5]	20.88[6]	20.55[7]	20.52[8]	20.21[9]	16.56[10]
Data Value	20.83	19.77	18.25	19.12	20.86	20.76	21.19	20.46	20.23	16.70
Fat, %										
USDA NDL Value[1]	3.29[1]	5.20[2]	7.63[3]	6.76[4]	9.23[5]	5.94[6]	5.08[7]	4.19[8]	5.28[9]	23.41[10]
Data Value	3.14	3.84	7.22	7.21	6.99	5.45	4.41	4.36	4.81	14.77
Ash, %										
USDA NDL Value[1]	1.05[1]	1.07[2]	1.03[3]	1.04[4]	1.01[5]	1.06[6]	1.07[7]	1.08[8]	1.06[9]	0.87[10]
Data Value	1.05	1.02	0.92	0.89	0.89	1.04	1.11	0.91	1.10	1.05
Moisture, %										
USDA NDL Value[1]	74.86[1]	74.14[2]	72.36[3]	72.99[4]	70.44[5]	72.55[6]	73.57[7]	74.44[8]	73.74[9]	59.47[10]
Data Value	75.41	74.76	72.09	71.32	70.40	72.66	73.12	73.58	73.76	63.85
Cholesterol, mg/100g										
USDA NDL Value[1]	69.0[1]	64.0[2]	67.0[3]	66.0[4]	66.0[5]	66.0[6]	66.0[7]	64.0[8]	65.0[9]	73.0[10]
Data Value	75.4	67.5	78.9	75.7	84.4	71.9	79.7	74.9	71.8	65.6
Riboflavin, mg/100g										
USDA NDL Value[1]	0.20[1]	0.23[2]	0.22[3]	0.22[4]	0.20[5]	0.23[6]	0.25[7]	0.25[8]	0.24[9]	0.21[10]
Data Value	0.32	0.54	0.37	0.34	0.35	0.58	0.71	0.38	0.59	0.27
Vitamin B_6, mg/100g										
USDA NDL Value[1]	0.17[1]	0.15[2]	0.16[3]	0.16[4]	0.16[5]	0.17[6]	0.17[7]	0.17[8]	0.16[9]	0.13[10]
Data Value	0.25	0.34	0.25	0.24	0.42	0.47	0.44	0.40	0.43	0.29
Vitamin B_{12}, µg/100g										
USDA NDL Value[1]	2.45[1]	2.67[2]	2.83[3]	2.78[4]	2.38[5]	2.21[6]	2.76[7]	2.64[8]	2.73[9]	2.31[10]
Data Value	2.49	3.43	3.10	3.04	1.99	1.90	2.28	2.47	2.89	2.76
Selenium, µg/100g										
USDA NDL Value[1]	24.0[1]	22.7[2]	22.0[3]	22.2[4]	22.3[5]	23.6[6]	23.4[7]	23.4[8]	22.8[9]	18.8[10]
Data Value	15.9	13.0	15.1	15.9	18.7	18.9	16.9	13.8	14.4	10.6
Calcium, mg/100g										
USDA NDL Value[1]	9.0[1]	12.0[2]	16.0[3]	15.0[4]	12.0[5]	12.0[6]	7.0[7]	6.0[8]	9.0[9]	16.0[10]
Data Value	10.3	8.99	10.4	5.6	8.88	7.7	7.5	4.5	4.6	7.7
Iron, mg/100g										
USDA NDL Value[1]	1.79[1]	1.74[2]	1.62[3]	1.66[4]	1.67[5]	1.91[6]	1.83[7]	1.82[8]	1.77[9]	1.55[10]
Data Value	1.70	1.83	1.61	1.43	1.69	1.89	2.07	1.79	1.96	1.44
Magnesium, mg/100g										
USDA NDL Value[1]	25.0[1]	25.0[2]	24.0[3]	24.0[4]	25.0[5]	27.0[6]	27.0[7]	27.0[8]	26.0[9]	21.0[10]
Data Value	20.7	22.2	19.8	19.0	22.1	25.1	24.6	23.5	23.0	17.6
Phosphorus, mg/100g										
USDA NDL Value[1]	187.0[1]	186.0[2]	183.0[3]	184.0[4]	181.0[5]	190.0[6]	189.0[7]	195.0[8]	189.0[9]	157.0[10]
Data Value	176.0	192.0	176.0	169.0	191.0	206.0	207.0	202.0	203.0	153.0
Potassium, mg/100g										
USDA NDL Value[1]	237.0[1]	287.0[2]	268.0[3]	274.0[4]	265.0[5]	276.0[6]	284.0[7]	290.0[8]	284.0[9]	222.0[10]
Data Value	294.0	311.0	304.0	277.0	319.0	329.0	328.0	323.0	340.0	246.0
Sodium, mg/100g										
USDA NDL Value[1]	79.0[1]	69.0[2]	70.0[3]	70.0[4]	72.0[5]	68.0[6]	64.0[7]	61.0[8]	65.0[9]	59.0[10]
Data Value	81.3	61.6	72.2	61.4	65.5	66.9	57.9	53.6	49.5	52.6
Zinc, mg/100g										
USDA NDL Value[1]	5.95[1]	4.15[2]	5.11[3]	4.77[4]	3.80[5]	3.19[6]	3.77[7]	3.89[8]	4.15[9]	3.41[10]
Data Value	5.65	4.14	5.20	4.32	3.22	2.82	3.42	3.66	3.35	2.99
Copper, mg/100g										
USDA NDL Value[1]	0.11[1]	0.12[2]	0.11[3]	0.11[4]	0.11[5]	0.13[6]	0.13[7]	0.12[8]	0.12[9]	0.10
Data Value	0.08	0.10	0.09	0.09	0.11	0.13	0.15	0.13	0.13	0.08

[1]USDA-ARS, Standard Reference number 17009: Lamb, domestic, foreshank, separable lean only, trimmed to ¼ " fat, choice, raw
[2]USDA-ARS, Standard Reference number 17047: Lamb, domestic, shoulder, arm chop, separable lean only, trimmed to ¼ " fat, choice, raw
[3]USDA-ARS, Standard Reference number 17055: Lamb, domestic, shoulder, blade chop, separable lean only, trimmed to ¼ " fat, choice, raw
[4]USDA-ARS, Standard Reference number 17039: Lamb, domestic, shoulder, whole boneless, separable lean only, trimmed to ¼ " fat, choice, raw
[5]USDA-ARS, Standard Reference number 17032: Lamb, domestic, rib, separable lean only, trimmed to ¼ " fat, choice, raw
[6]USDA-ARS, Standard Reference number 17026: Lamb, domestic, loin, separable lean only, trimmed to ¼ " fat, choice, raw
[7]USDA-ARS, Standard Reference number 17021: Lamb, domestic, leg, sirloin half, separable lean only, trimmed to ¼ " fat, choice, raw
[8]USDA-ARS, Standard Reference number 17017: Lamb, domestic, leg, shank half, separable lean only, trimmed to ¼ " fat, choice, raw
[9]USDA-ARS, Standard Reference number 17059: Lamb, domestic, cubed for stew or kabob (leg and shoulder), separable lean only, choice, raw
[10]USDA-ARS, Standard Reference number 17224: Lamb, domestic, ground

Table 10. Fatty acid profile of separable lean from raw grain-finished lamb cuts trimmed to a maximum of 1/8" external fat shown as fatty acid

Fatty acid	Foreshank	Shoulder, Arm Chop	Shoulder, Blade Chop	Shoulder, Whole	Rib Chop	Frenched Rib Chop	Loin, Whole	Sirloin Chop	Leg, Whole	Stew Meat	Ground Lamb
Myristic acid (14:0)	1.76	1.69	1.66	1.80	1.91	1.91	1.74	1.69	1.77	1.83	1.79
15:0	0.25	0.30	0.31	0.31	0.30	0.27	0.26	0.34	0.36	0.36	0.36
15:1 n6	0.32	0.29	0.28	0.31	0.34	0.35	0.29	0.31	0.36	0.32	0.30
Palmitic acid (16:0)	22.41	22.58	24.00	23.17	23.61	24.05	23.92	23.17	22.05	23.67	23.52
Palmitoleic acid (16:1 n7)	1.57	1.47	1.64	1.72	1.35	1.29	1.23	1.38	1.31	1.33	1.24
Margaric acid (17:0)	1.57	1.04	1.03	1.03	1.03	1.03	1.02	1.03	1.06	1.09	1.06
17:1 n8	0.49	0.48	0.46	0.48	0.45	0.49	0.51	0.48	0.51	0.46	0.44
Stearic acid (18:0)	16.62	16.52	16.31	16.41	16.42	17.10	16.18	16.28	17.49	17.19	17.61
C18:1 trans-6, 8	0.84	0.84	0.83	0.83	0.83	0.83	0.82	0.82	0.85	0.88	0.85
C18:1 trans-10	3.03	3.01	2.97	2.99	2.99	2.98	2.95	2.96	3.07	3.15	3.07
C18:1 trans 11	0.49	0.50	0.51	0.47	0.49	0.45	0.47	0.45	0.48	0.46	0.50
Linoleic acid (18:1 n6)	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19
Oleic acid (18:1 n9)	38.82	39.39	37.90	38.48	38.24	37.63	38.61	38.95	38.51	37.25	37.20
y-Linolenic acid(18:2 n6)	8.86	8.51	8.30	8.26	8.48	8.15	8.54	8.39	8.39	8.38	8.39
α-Linolenic acid (18:3 n3)	0.25	0.28	0.23	0.25	0.26	0.27	0.24	0.21	0.26	0.28	0.30
Arachidic acid (20:0)	0.27	0.24	0.29	0.28	0.24	0.25	0.26	0.23	0.25	0.30	0.28
unknown	0.12	0.18	0.15	0.16	0.14	0.12	0.14	0.15	0.19	0.13	0.13
CLA (18:2c9t11)	0.21	0.22	0.27	0.24	0.26	0.24	0.28	0.24	0.24	0.23	0.21
Eicosenoic acid (20:1 n9)	0.22	0.23	0.24	0.21	0.22	0.20	0.21	0.28	0.25	0.24	0.31
Arachidonic acid (20:4 n6)	2.23	2.06	2.45	2.39	2.22	2.19	2.17	2.47	2.42	2.27	2.25

Table 11. Fatty acid profile of separable lean from raw grass lamb cuts trimmed to a maximum of 1/8" external fat shown as fatty acid percentages.

Fatty acid	Foreshank	Shoulder, Arm Chop	Shoulder, Blade Chop	Shoulder, Whole	Rib Chop	Frenched Rib Chop	Loin, Whole	Sirloin Chop	Leg, Whole	Stew Meat	Ground Lamb
Myristic acid (14:0)	1.60	1.70	1.60	1.65	1.59	1.54	1.51	1.54	1.53	1.49	1.43
15:0	0.26	0.32	0.33	0.32	0.30	0.26	0.25	0.33	0.34	0.37	0.37
15:1 n6	0.31	0.39	0.40	0.42	0.36	0.31	0.30	0.39	0.41	0.44	0.45
Palmitic acid (16:0)	22.9	21.75	22.37	23.58	24.16	24.82	25.87	23.21	22.41	23.25	23.67
Palmitoleic acid (16:1 n7)	0.94	1.00	1.09	1.06	1.20	0.98	0.99	1.14	1.12	1.26	1.03
Margaric acid (17:0)	1.02	1.00	1.09	1.03	1.28	1.01	1.04	1.05	1.10	1.05	1.10
17:1 n8	0.46	0.45	0.50	0.47	0.58	0.46	0.47	0.48	0.50	0.48	0.50
Stearic acid (18:0)	20.85	21.10	20.24	19.90	20.20	20.56	21.26	22.69	22.41	21.57	20.48
C18:1 trans-6, 8	1.02	1.09	1.11	1.16	1.18	1.20	1.24	1.32	1.09	1.20	1.21
C18:1 trans-10	2.75	2.95	3.01	3.15	3.19	3.25	3.36	3.58	2.95	3.23	3.26
C18:1 trans 11	0.60	0.58	0.56	0.62	0.55	0.53	0.55	0.53	0.53	0.54	0.55
Linoleic acid (18:1 n6)	0.19	0.19	0.19	0.19	0.18	0.18	0.17	0.17	0.18	0.19	0.19
Oleic acid (18:1 n9)	34.39	33.90	34.37	33.83	32.65	32.73	31.04	31.49	33.28	32.44	33.02
y-Linolenic acid(18:2 n6)	8.25	8.78	8.51	8.01	8.16	7.90	7.76	7.87	7.85	8.10	8.25
α-Linolenic acid (18:3 n3)	0.54	0.60	0.58	0.57	0.55	0.54	0.53	0.53	0.53	0.55	0.56
Arachidic acid (20:0)	0.39	0.39	0.38	0.38	0.37	0.35	0.35	0.35	0.35	0.36	0.37
unknown	0.18	0.19	0.21	0.18	0.14	0.15	0.13	0.12	0.18	0.14	0.16
CLA (18:2c9t11)	0.49	0.50	0.44	0.48	0.46	0.41	0.40	0.41	0.45	0.46	0.47
Eicosenoic acid (20:1 n9)	0.35	0.33	0.32	0.32	0.31	0.30	0.31	0.30	0.30	0.31	0.31
Arachidonic acid (20:4 n6)	2.50	2.78	2.70	2.70	2.59	2.50	2.46	2.50	2.49	2.57	2.62

Table 12. Fatty acid profile of separable lean from cooked grain-finished lamb cuts trimmed to a maximum of 1/8" external fat shown as fatty acid percentage.

Fatty acid	Leg, Whole	Shoulder Blade Chop	Loin Chop	Rib Roast	Frenched Rib Roast	Ground Lamb
Myristic acid (14:0)	1.78	1.85	1.69	1.92	1.82	1.73
15:0	0.32	0.30	0.31	0.28	0.26	0.27
15:1 n6	0.33	0.32	0.33	0.33	0.32	0.33
Palmitic acid (16:0)	21.82	23.53	22.11	22.42	24.59	22.66
Palmitoleic acid (16:1	1.59	1.54	1.56	1.55	1.53	1.56
Margaric acid (17:0)	1.06	1.03	1.05	1.04	1.03	1.05
17:1 n8	0.51	0.50	0.50	0.50	0.49	0.50
Stearic acid (18:0)	16.90	16.37	16.64	16.53	16.30	16.61
C18:1 trans-6, 8	0.86	0.83	0.84	0.84	0.83	0.84
C18:1 trans-10	3.08	2.98	3.03	3.01	2.97	3.03
C18:1 trans 11	0.51	0.50	0.50	0.50	0.49	0.50
Linoleic acid (18:1 n6)	0.19	0.18	0.18	0.18	0.18	0.19
Oleic acid (18:1 n9)	38.60	38.06	39.13	38.83	37.30	38.60
y-Linolenic acid(18:2 n6)	8.91	8.63	8.77	7.71	8.59	8.76
α-Linolenic acid (18:3	0.26	0.25	0.26	0.26	0.25	0.26
Arachidic acid (20:0)	0.29	0.26	0.25	0.24	0.28	0.27
unknown	0.14	0.16	0.15	0.16	0.14	0.18
CLA (18:2c9t11)	0.29	0.24	0.23	0.25	0.21	0.22
Eicosenoic acid (20:1 n9)	0.28	0.26	0.21	0.23	0.21	0.23
Arachidonic acid (20:4	2.27	2.20	2.24	2.22	2.19	2.24

Table 13. Fatty acid profile of separable lean from cooked grass-finished lamb cuts trimmed to a maximum of 1/8" external fat shown as fatty acid percentages.

Fatty acid	Leg, Whole	Shoulder Blade Chop	Loin Chop	Rib Roast	Frenched Rib Roast	Ground Lamb
Myristic acid (14:0)	1.63	1.64	1.62	1.59	1.55	1.66
15:0	0.33	0.31	0.32	0.28	0.26	0.29
15:1 n6	0.41	0.39	0.39	0.34	0.31	0.35
Palmitic acid (16:0)	22.66	22.96	23.17	23.42	24.29	21.17
Palmitoleic acid (16:1 n7)	1.09	1.14	1.03	1.11	1.00	0.98
Margaric acid (17:0)	1.07	1.17	1.03	1.16	1.04	1.02
17:1 n8	0.49	0.53	0.47	0.53	0.47	0.46
Stearic acid (18:0)	20.22	20.31	20.35	20.73	21.29	21.17
C18:1 trans-6, 8	1.15	1.18	1.09	1.21	1.25	1.06
C18:1 trans-10	3.10	3.21	2.94	3.28	3.37	2.87
C18:1 trans 11	0.59	0.59	0.56	0.55	0.55	0.60
Linoleic acid (18:1 n6)	0.19	0.19	0.19	0.18	0.18	0.19
Oleic acid (18:1 n9)	34.19	33.66	34.06	33.24	32.45	34.93
y-Linolenic acid(18:2 n6)	8.32	8.19	8.51	8.16	7.97	8.59
α-Linolenic acid (18:3 n3)	0.58	0.57	0.58	0.55	0.54	0.57
Arachidic acid (20:0)	0.38	0.38	0.38	0.37	0.34	0.39
unknown	0.14	0.10	0.12	0.14	0.13	0.18
CLA (18:2c9t11)	0.46	0.48	0.46	0.44	0.41	0.50
Eicosenoic acid (20:1 n9)	0.32	0.32	0.32	0.31	0.30	0.35
Arachidonic acid (20:4 n6)	2.68	2.67	2.41	2.40	2.31	2.66

Table 14. Fatty acid profile of external and seam fat from raw and cooked grain-finished lamb cuts[1] trimmed to a maximum of 1/8" external fat on a single composite level[2] shown as fatty acid percentages.

Fatty Acid	External		Seam	
	Raw	Cooked	Raw	Cooked
Myristic acid (14:0)	1.75	1.73	1.65	1.70
15:0	0.35	0.30	0.35	0.34
15:1 n6	0.38	0.32	0.23	0.32
Palmitic acid (16:0)	23.83	22.99	23.05	23.59
Palmitoleic acid (16:1 n7)	1.54	1.54	1.31	1.53
Margaric acid (17:0)	1.04	1.03	1.04	1.03
17:1 n8	0.49	0.50	0.50	0.49
Stearic acid (18:0)	17.14	16.42	16.50	16.28
C18:1 trans-6, 8	0.84	0.83	0.84	0.82
C18:1 trans-10	3.01	2.990	3.00	2.96
C18:1 trans 11	0.48	0.50	0.50	0.49
Linoleic acid (18:1 n6)	0.18	0.18	0.18	0.18
Oleic acid (18:1 n9)	36.91	38.72	38.90	38.39
y-Linolenic acid(18:2 n6)	8.71	8.66	8.70	8.58
α-Linolenic acid (18:3 n3)	0.24	0.25	0.25	0.25
Arachidic acid (20:0)	0.26	0.24	0.26	0.26
unknown	0.15	0.12	0.08	0.16
CLA (18:2c9t11)	0.24	0.21	0.21	0.21
Eicosenoic acid (20:1 n9)	0.28	0.24	0.21	0.22
Arachidonic acid (20:4 n6)	2.18	2.21	2.22	2.19

[1]Ground lamb did not contribute fat to this data, as fat is not removed during dissection.
[2]Single National-level composite lean samples consist of lean from all three suppliers, all cuts, and all seasons.

Table 15. Fatty acid profile of external and seam fat from raw and cooked grass-finished lamb cuts[1] on a single composite level[2] shown as fatty acids percentages.

Fatty Acid	External		Seam	
	Raw	Cooked	Raw	Cooked
Myristic acid (14:0)	1.37	1.53	1.56	1.31
15:0	0.38	0.29	0.37	0.34
15:1 n6	0.45	0.35	0.44	0.41
Palmitic acid (16:0)	24.07	23.68	24.49	21.22
Palmitoleic acid (16:1 n7)	1.01	1.07	1.10	1.15
Margaric acid (17:0)	1.05	1.05	1.01	1.09
17:1 n8	0.48	0.48	0.46	0.50
Stearic acid (18:0)	19.43	22.10	18.44	22.92
C18:1 trans-6, 8	1.22	1.29	1.16	1.23
C18:1 trans-10	3.28	3.49	3.13	3.32
C18:1 trans 11	0.56	0.54	0.57	0.54
Linoleic acid (18:1 n6)	0.20	0.17	0.20	0.18
Oleic acid (18:1 n9)	33.58	31.47	34.17	32.91
y-Linolenic acid(18:2 n6)	8.39	7.86	8.54	7.99
α-Linolenic acid (18:3 n3)	0.57	0.53	0.58	0.54
Arachidic acid (20:0)	0.38	0.39	0.38	0.36
unknown	0.12	0.19	0.12	0.12
CLA (18:2c9t11)	0.48	0.41	0.49	0.43
Eicosenoic acid (20:1 n9)	0.32	0.30	0.32	0.30
Arachidonic acid (20:4 n6)	2.66	2.79	2.71	2.89

[1]Ground lamb did not contribute fat to this data, as fat is not removed during dissection.
[2]Single National-level composite lean samples consist of lean from all three suppliers, all cuts, and all seasons.

Table 16. Mineral values from raw grain-finished and grass-finished U.S. lamb cuts trimmed to a maximum of 1/8" external fat.

Cut	Calcium, mg/100g	Copper, mg/100g	Iron, mg/100g	Magnesium, mg/100g	Manganese, mg/100g	Phosphorous, mg/100g	Potassium, mg/100g	Sodium, mg/100g	Zinc, mg/100 g	Selenium, µg/100 g
Foreshank										
Grain-Finished	10.30	0.08	1.70	20.7	0.01	176	294	81.3	5.65	15.90
Grass-Finished	10.20	0.09	1.81	20.3	0.02	176	306	88.4	5.71	9.65
Shoulder Arm Chop										
Grain-Finished	8.99	0.10	1.83	22.2	0.01	192	311	61.6	4.14	13.00
Grass-Finished	8.36	0.13	1.88	22.8	0.01	196	331	63.8	4.02	8.61
Shoulder Blade Chop										
Grain-Finished	10.40	0.09	1.61	19.8	0.01	176	304	72.2	5.20	15.10
Grass-Finished	11.20	0.08	1.44	17.8	0.01	158	266	67.7	4.56	8.69
Shoulder, Whole										
Grain-Finished	5.60	0.09	1.43	19.0	0.01	169	277	61.4	4.32	15.90
Grass-Finished	9.85	0.10	1.61	20.8	0.01	182	301	65.2	4.69	12.70
Rib Chop										
Grain-Finished	8.88	0.11	1.69	22.1	0.01	191	319	65.5	3.22	18.70
Grass-Finished	7.07	0.11	1.79	21.8	0.01	181	291	62.5	2.94	11.10
Frenched Rib Chop										
Grain-Finished	8.01	0.12	1.84	23.4	0.02	196	317	61.1	3.07	15.10
Grass-Finished	8.93	0.12	1.85	23.4	0.01	184	318	57.8	2.71	10.30
Loin, Whole										
Grain-Finished	7.74	0.13	1.89	25.1	0.02	206	329	66.9	2.82	18.90
Grass-Finished	7.25	0.14	1.96	23.6	0.02	199	320	68.9	2.70	10.80
Sirloin Chop										
Grain-Finished	7.45	0.15	2.07	24.6	0.02	207	328	57.9	3.42	16.90
Grass-Finished	7.82	0.15	2.16	22.7	0.02	193	321	57.3	3.17	7.33
Leg, Whole										
Grain-Finished	4.49	0.13	1.79	23.5	0.02	202	323	53.6	3.66	13.80
Grass-Finished	4.43	0.15	1.83	22.2	0.01	193	326	53.0	3.47	12.30
Stew Meat										
Grain-Finished	4.55	0.13	1.96	23.0	0.01	203	340	49.5	3.35	14.40
Grass-Finished	5.30	0.14	2.29	25.4	0.02	200	341	45.3	3.39	11.40
Ground Lamb										
Grain-Finished	7.71	0.08	1.44	17.6	0.01	153	246	52.6	2.99	10.60
Grass-Finished	9.49	0.10	1.56	18.0	0.01	159	262	57.5	3.08	7.86

[1]Data from specific cuts can be extrapolated for values of similar cuts: raw whole loins and cooked loin chops; raw rib chops and cooked whole ribs; raw frenched rib chops and whole frenched ribs.

Table 17. Mineral values from cooked grain-finished and grass-finished U.S. lamb cuts trimmed to a maximum of 1/8" external fat.

Cut	Calcium, mg/100g	Copper, mg/100g	Iron, mg/100g	Magnesium, mg/100g	Manganese, mg/100g	Phosphorous, mg/100g	Potassium, mg/100g	Sodium, mg/100g	Zinc, mg/100g	Selenium, µg/100g
Loin Chop										
Grain-Finished	15.9	0.19	2.34	25.1	0.01	216	332	68.4	3.55	16.40
Grass-Finished	12.1	0.21	2.48	26.3	0.01	220	342	66.7	3.29	13.30
Leg, Whole										
Grain-Finished	6.21	0.17	2.14	25.3	0.02	222	330	55.1	4.78	18.90
Grass-Finished	5.70	0.17	2.35	26.0	0.01	226	329	58.3	4.96	17.00
Shoulder Blade Chop										
Grain-Finished	19.3	0.21	2.04	21.9	0.02	198	312	77.3	6.82	14.80
Grass-Finished	16.2	0.21	1.89	21.8	0.02	194	312	74.4	6.47	11.80
Rib Roast										
Grain-Finished	13.5	0.12	1.92	22.2	0.01	187	293	71.4	3.71	17.60
Grass-Finished	14.0	0.12	1.77	21.8	0.01	174	295	72.0	3.97	11.70
Frenched Rib Roast										
Grain-Finished	11.7	0.12	1.99	23.2	0.01	200	313	61.6	3.92	19.30
Grass-Finished	14.5	0.12	1.87	22.6	0.01	193	299	69.3	3.76	12.80
Ground Lamb										
Grain-Finished	12.0	0.12	2.13	24.1	0.02	220	359	72.1	4.64	15.70
Grass-Finished	23.9	0.14	2.32	28.0	0.01	252	399	80.5	4.83	12.40

Table 18. B-vitamin values from raw grain-finished and grass-finished U.S. lamb cuts trimmed to a maximum of 1/8" external fat.

Cut	Thiamin (B_1), µg/100g	Riboflavin (B_2), mg/100g	Niacin (B_3), mg/100g	Pantothenic Acid (B_5), mg/100g	Vitamin B_6, mg/100g	Vitamin B_{12}, µg/100g
Foreshank						
Grain-Finished	0.10	0.32	5.65	0.59	0.25	2.49
Grass-Finished	0.10	0.30	5.71	0.46	0.26	2.24
Shoulder Arm Chop						
Grain-Finished	0.14	0.54	6.17	0.55	0.34	3.43
Grass-Finished	0.11	0.37	6.78	0.50	0.31	3.28
Shoulder Blade Chop						
Grain-Finished	0.11	0.37	4.39	0.52	0.25	3.10
Grass-Finished	0.08	0.35	4.31	0.46	0.39	3.30
Shoulder, Whole						
Grain-Finished	0.11	0.34	5.20	0.53	0.24	3.04
Grass-Finished	0.14	0.47	4.64	0.53	0.25	2.86
Rib Chop						
Grain-Finished	0.12	0.35	8.02	0.46	0.42	1.99
Grass-Finished	0.12	0.31	6.95	0.45	0.40	1.84
Frenched Rib Chop						
Grain-Finished	0.14	0.33	7.80	0.53	0.44	1.76
Grass-Finished	0.13	0.40	7.52	0.42	0.44	1.67
Loin, Whole						
Grain-Finished	0.14	0.58	6.16	0.49	0.47	1.90
Grass-Finished	0.15	0.56	6.89	0.38	0.48	1.38
Sirloin Chop						
Grain-Finished	0.15	0.71	7.37	0.55	0.44	2.28
Grass-Finished	0.17	0.54	6.93	0.45	0.42	3.37
Leg, Whole						
Grain-Finished	0.14	0.38	7.50	0.55	0.40	2.47
Grass-Finished	0.17	0.50	7.10	0.53	0.40	2.86
Stew Meat						
Grain-Finished	0.14	0.59	7.88	0.58	0.43	2.89
Grass-Finished	0.17	0.55	6.96	0.49	0.46	2.39
Ground Lamb						
Grain-Finished	0.11	0.27	5.58	0.49	0.29	2.76
Grass-Finished	0.12	0.35	5.09	0.51	0.29	2.24

Table 19. B-vitamin values from cooked grain-finished and grass-finished U.S. lamb cuts trimmed to a maximum of 1/8" external fat.

Cut	Thiamin (B_1), µg/100g	Riboflavin (B_2), mg/100g	Niacin (B_3), mg/100g	Pantothenic Acid (B_5), mg/100g	Vitamin B_6, mg/100g	Vitamin B_{12}, µg/100g
Loin Chop						
Grain-Finished	0.15	0.56	7.88	0.59	0.51	2.73
Grass-Finished	0.16	0.64	9.39	0.46	0.58	2.47
Leg, Whole						
Grain-Finished	0.15	0.57	8.80	0.91	0.37	3.79
Grass-Finished	0.16	0.59	7.63	0.85	0.58	2.38
Shoulder Blade Chop						
Grain-Finished	0.12	0.48	5.55	0.65	0.28	4.65
Grass-Finished	0.12	0.48	6.20	0.59	0.32	4.82
Rib Roast						
Grain-Finished	0.14	0.46	7.95	0.71	0.40	2.64
Grass-Finished	0.13	0.49	6.13	0.47	0.42	2.58
Frenched Rib Roast						
Grain-Finished	0.14	0.47	5.74	0.68	0.42	2.99
Grass-Finished	0.14	0.41	7.45	0.54	0.47	2.55
Ground Lamb						
Grain-Finished	0.14	0.52	8.78	0.64	0.37	3.73
Grass-Finished	0.15	0.54	7.97	0.65	0.45	3.98

Table 20. Nutrient values of raw and cooked separable lean composited on a single national level[1] from U.S. grain-finished and grass-finished lamb cuts trimmed to a maximum of 1/8" external fat.

Nutrient, units	Grain-Finished Separable Lean		Grass-Finished Separable Lean	
	Raw	Cooked	Raw	Cooked
Vitamin D Metabolites				
Vitamin D2, µg/100g	<0.10	<0.10	<0.10	<0.10
Vitamin D3, µg/100g	<0.10	<0.10	<0.10	<0.10
25 Hydroxy Vitamin D3, µg	0.13	0.13	0.11	0.13
Vitamin E Metabolits				
AlphaTocopherol, µg/g[2]	2.56	1.88	3.11	3.78
Choline Metabloites				
Choline, nmol/g	134.89	162.88	162.49	169.55
P-Choline, nmol/g	69.32	78.20	71.53	74.78
Phosphatidylcholine, nmol/g	6101.01	8339.14	7103.97	8403.46
GP-Choline, nmol/g	727.24	714.56	743.37	764.71
Betaine, nmol/g	1115.80	1175.33	877.33	961.74
Sphingomyelin, nmol/g	574.37	924.88	661.25	926.18
Total Choline, mg/100g	79.24	106.46	91.07	107.70
Total Betaine, mg/100g	13.07	13.77	10.28	11.27

[1]Single National-level composite lean samples consist of lean from all three suppliers, all cuts, and all seasons.
[2]Data results for BetaTocopherol, DeltaTocopherol, and Gamma-Tocopherol were not detectable since results for these metabolites were below 0.1µg/g.

Table 21. Total lipid content of separable lean from raw grain-finished U.S. lamb cuts trimmed to a maximum of 1/8" external fat and USDA "Lean and Extra Lean" and American Heart Association (AHA) classifications from total fat, saturated fat, trans fat, cholesterol and sodium content.

Cuts	Total fat g/100g	Polyunsaturated fat g/100g [a]	Monounsaturated fat g/100g [a]	Total Omega-3 g/100g [a]	Total Omega-6 g/100g [a]	Omega 6:Omega 3 Ratio	Saturated fat g/100g [a]	*Trans* fat g/100g [a]	Cholesterol g/100g	Sodium mg/100g	USDA Classification	Heart Healthy Eligibility
Foreshank	3.14	0.36	1.31	0.01	0.36	36:1	1.35	0.14	75.4	81.3	Extra Lean	Yes
Shoulder, Arm Chop	3.84	0.42	1.61	0.01	0.42	42:1	1.63	0.18	67.5	61.6	Extra Lean	Yes
Shoulder, Blade Chop	7.22	0.79	2.94	0.02	0.81	40.5:1	3.15	0.33	78.9	72.2	Lean	No
Shoulder, Whole	7.21	0.79	2.98	0.02	0.80	40:1	3.10	0.33	75.7	61.4	Lean	No
Rib Chop	6.99	0.77	2.85	0.02	0.78	39:1	3.04	0.32	84.4	65.5	Lean	No
Frenched Rib Chop	6.32	0.67	2.54	0.02	0.69	34.5:1	2.82	0.28	93.2	61.1	Lean	No
Loin, Whole	5.45	0.60	2.24	0.01	0.61	61:1	2.36	0.25	71.9	66.9	Lean	No
Sirloin Chop	4.41	0.49	1.83	0.01	0.50	50:1	1.88	0.20	79.7	57.9	Extra Lean	Yes
Leg, Whole	4.36	0.48	1.79	0.01	0.50	50:1	1.87	0.20	74.9	53.6	Extra Lean	Yes
Stew Meat	4.81	0.53	1.91	0.01	0.54	54:1	2.14	0.23	71.8	49.5	Lean	No
Ground Lamb	14.77	1.62	5.86	0.04	1.64	41:1	6.59	0.68	65.6	52.6	None	No

[a] Values presented as a weight calculated from percentage of fatty acids of Total Fat from Proximate Data

[b] 9 CFR 317.362 USDA: Lean classifications per 100g include and are defined as 1) Lean: <10 g total fat, < 5g saturated fat, <95 mg cholesterol. 2) Extra Lean: < 5g fat, ≤2.5g saturated fat, <95mg of cholesterol

[c] Heart Healthy "Heart Check" requirements per 100g : <5 g total fat, < 2 g saturated fat, <95 mg cholesterol, <0.5 g Trans fat, <360mg Sodium.

Table 22. Total lipid content of seperable lean from raw grass-finished U.S. lamb cuts trimmed to a maximum of 1/8" external fat and USDA "Lean and Extra Lean" and American Heart Association (AHA) classifications from total fat, saturated fat, trans fat, cholesterol and sodium content.

Cuts	Total fat g/100g	Polyunsaturated fat g/100g [a]	Monounsaturated fat g/100g [a]	Total Omega-3 g/100g [a]	Total Omega-6 g/100g [a]	Omega 6:Omega 3 Ratio	Saturated fat g/100g [a]	Trans fat g/100g	Cholesterol g/100g	Sodium mg/100g	USDA Classification	Heart Healthy Eligibility [c]
Foreshank	2.41	0.27	0.88	0.01	0.27	27:1	1.13	0.12	78.1	88.4	Extra Lean	Yes
Shoulder, Arm Chop	4.51	0.55	1.64	0.03	0.55	18.3:1	2.09	0.05	75.0	63.8	Lean	No
Shoulder, Blade Chop	6.52	0.77	2.40	0.04	0.77	19.3:1	3.00	0.33	71.3	67.7	Lean	No
Shoulder, Whole	7.56	0.85	2.74	0.04	0.85	21.3:1	3.54	0.41	69.6	65.2	Lean	No
Rib Chop	7.73	0.87	2.73	0.04	0.87	21.8:1	3.70	0.42	70.2	62.5	Lean	No
Frenched Rib Chop	5.64	0.62	1.97	0.03	0.61	20.3:1	2.74	0.30	72.1	57.8	Lean	No
Loin, Whole	4.70	0.51	1.56	0.02	0.50	25:1	2.36	0.26	68.7	68.9	Lean	No
Sirloin Chop	4.52	0.49	1.54	0.02	0.49	24.5:1	2.22	0.26	70.5	57.3	Lean	No
Leg, Whole	4.19	0.46	1.50	0.02	0.46	23:1	2.02	0.21	72.8	53.0	Lean	No
Stew Meat	3.99	0.45	1.40	0.02	0.45	22.5:1	1.92	0.22	63.8	45.3	Extra Lean	Yes
Ground Lamb	14.67	1.68	5.21	0.08	1.69	21.1:1	6.96	0.81	69.6	57.5	None	No

[a] Values presented as a weight calculated from percentage of fatty acids of Total Fat from Proximate Data

[b] 9 CFR 317.362 USDA: Lean classifications per 100g include and are defined as 1) Lean: <10 g total fat, < 5g saturated fat, <95 mg cholesterol. 2) Extra Lean< 5g fat, ≤2.5g saturated fat, <95mg of cholesterol

[c] Heart Healthy "Heart Check" requirements per 100g : <5 g total fat, < 2 g saturated fat, <95 mg cholesterol, <0.5 g Trans fat, <360mg Sodium.

Table 23. Nutrients (Percentages of RDI[1]) from U.S. grain-finished cooked separable lean only from lamb cuts trimmed to a maximum of 1/8" external fat qualifying for USDA "Excellent Source of" and "Good Source of" extra labeling claims.

Nutrients (%)	Shoulder, Blade Chop[2]	Loin Chop[2]	Rib Roast[2]	Frenched Rib Roast[2]	Leg, Whole[2]	Ground Lamb[2]
Protein	51**	53**	48**	50**	54**	50**
B-Vitamins						
Thiamin (B_1)	8	10*	9	9	10*	9
Riboflavin (B_2)	28**	33**	27**	28**	34**	31**
Niacin (B_3)	28**	39**	40**	29**	44**	44**
Pantothenic Acid (B_5)	7	6	7	7	9	6
B_6	14*	26**	20**	21**	19*	19*
B_{12}	78**	46**	44**	50**	63**	62**
Minerals						
Calcium	2	2	1	1	1	1
Copper	11*	10*	6	6	9	6
Iron	11*	13*	11*	11*	12*	12*
Magnesium	5	6	6	6	6	6
Manganese	1	1	1	1	1	1
Phosphorus	20**	22**	19*	20**	22**	22**
Potassium	9	9	8	9	9	10*
Zinc	45**	24**	25**	26**	32**	31**
Selenium	21**	23**	25**	28**	27**	22**

[1] Reference daily intakes (RDI) dietary allowance (RDA) is the daily intake level of a nutrient that is considered to be sufficient to meet the requirements of 97-98% of healthy individuals in the United States.

[2] Raw separable lean was used in the assays to provide these results with the exception of ground lamb, wherein the nature of the product contains both lean and fat.

[a] **Percentage qualifies the cut to be labeled as an "excellent source" of the vitamin, providing over 20% of the RDI.

[b] *Percentage qualifies the cut to be labeled as a "good source" of the vitamin, providing between 10-19% of the RDI

Table 24. Nutrients (Percentages of RDI1) from U.S. Grass-finished cooked separable lean only from lamb cuts trimmed to a maximum of 1/8" external fat qualifying for USDA "Excellent Source of" and "Good Source of" extra labeling claims

Nutrients	Shoulder, Blade Chop[2]	Loin Chop[2]	Rib Roast[2]	Frenched Rib Roast[2]	Leg, Whole[2]	Ground Lamb[2]
Protein	50**	55**	49**	50**	54**	54**
B-Vitamins						
Thiamin (B_1)	8	11*	9	9	11*	10*
Riboflavin (B_2)	28**	38**	29**	24**	35**	32**
Niacin (B_3)	31**	47**	31**	37**	38**	40**
Pantothenic Acid (B_5)	6	5	5	5	9	7
B_6	16*	29**	21**	24**	29**	23**
B_{12}	80**	41**	21**	24**	29**	23**
Minerals						
Calcium	2	1	1	1	1	2
Copper	11*	11*	6	6	9	7
Iron	11*	14*	10*	10*	13*	13*
Magnesium	5	7	5	6	7	7
Manganese	1	1	1	1	1	1
Phosphorus	19*	22**	17*	19*	23**	25**
Potassium	9	10*	8	9	9	11*
Zinc	43**	22**	26**	25**	33**	32**
Selenium	17*	19*	17*	18*	24**	18*

[1] Reference daily intakes (RDI) dietary allowance (RDA) is the daily intake level of a nutrient that is considered to be sufficient to meet the requirements of 97-98% of healthy individuals in the United States.

[2] Raw separable lean was used in the assays to provide these results with the exception of ground lamb, wherein the nature of the product contains both lean and fat.

**Percentage qualifies the cut to be labeled as an "excellent source" of the vitamin, providing over 20% of the RDI.

*Percentage qualifies the cut to be labeled as a "good source" of the vitamin, providing between 10-19% of the RDI

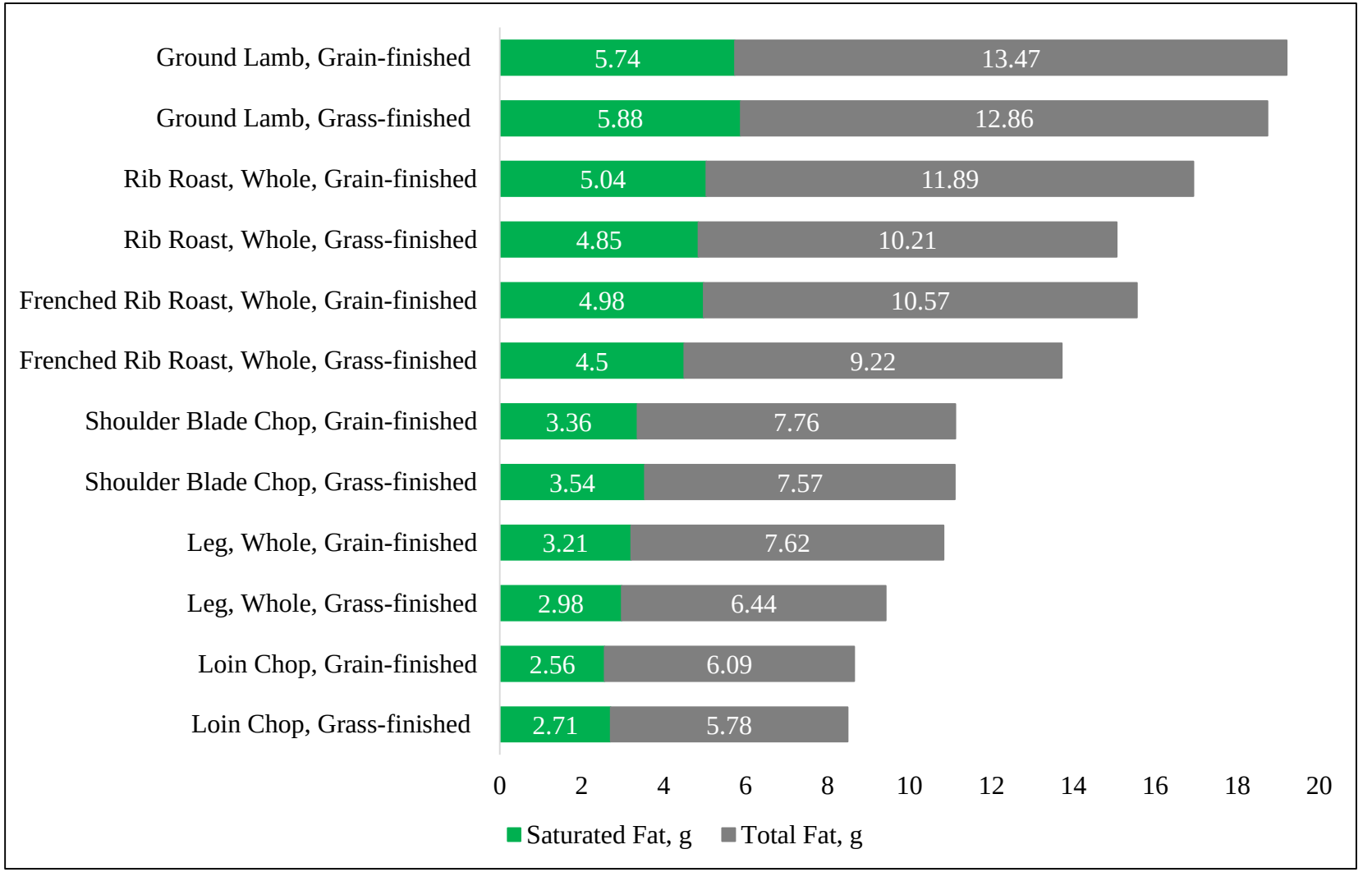

Figure 1. Saturated and total fat content (g/100 g of separable lean) from six grain-finished and grass-finished cooked separable lean from lamb cuts trimmed to a maximum of 1/8" external fat.

Nutrients	Shoulder, Blade Chop[3]	Loin Chop[3]	Rib Roast[3]	Frenched Rib Roast[3]	Leg, Whole[3]	Ground Lamb[3]
Protein	✓	✓	✓	✓	✓	✓
B-Vitamins						
Thiamin (B_1)	X	☑	X	X	☑	X
Riboflavin (B_2)	✓	✓	✓	✓	✓	✓
Niacin (B_3)	✓	✓	✓	✓	✓	✓
Pantothenic Acid (B_5)	X	X	X	X	X	X
B_6	☑	✓	✓	✓	☑	☑
B_{12}	✓	✓	✓	✓	✓	✓
Minerals						
Calcium	X	X	X	X	X	X
Copper	☑	X	X	X	X	X
Iron	☑	☑	☑	✓	☑	✓
Magnesium	X	X	X	X	X	X
Manganese	X	X	X	X	X	X
Phosphorus	☑	✓	☑	✓	✓	✓
Potassium	X	X	X	X	X	☑
Sodium	X	X	X	X	X	X
Zinc	✓	✓	✓	✓	✓	✓
Selenium	✓	✓	✓	✓	✓	✓

[1] ✓ = Meets "Excellent Source of" certification; ☑ = Meets "Good Source of" certification; **X** = Does not meet certification

[2] Reference daily intakes (RDI) dietary allowance (RDA) is the daily intake level of a nutrient that is considered to be sufficient to meet the requirements of 97-98% of healthy individuals in the United States.

[3] Raw separable lean was used in the assays to provide these results with the exception of ground lamb, wherein the nature of the product contains both lean and fat.

[a] Percentage qualifies the cut to be labeled as an "excellent source" of the vitamin, providing over 20% of the RDI.

[b] Percentage qualifies the cut to be labeled as a "good source" of the vitamin, providing between 10-19% of the RDI

Figure 2. Nutrients from U.S. grain-finished raw separable lean only from lamb cuts trimmed to a maximum of 1/8" external fat qualifying for USDA "Excellent Source of" and "Good Source of" extra labeling calculated from RDI[2].

Nutrients	Shoulder, Blade Chop[3]	Loin Chop[3]	Rib Roast[3]	Frenched Rib Roast[3]	Leg, Whole[3]	Ground Lamb[3]
Protein	✓	✓	✓	✓	✓	✓
B-Vitamins						
B1	X	☑	X	X	X	☑
B2	✓	✓	✓	✓	✓	✓
B3	✓	✓	✓	✓	✓	✓
B5	X	X	X	X	X	X
B6	☑	✓	✓	✓	✓	✓
B12	✓	✓	X	✓	✓	✓
Minerals						
Calcium	X	X	X	X	X	X
Copper	☑	☑	X	X	X	X
Iron	☑	☑	☑	☑	☑	☑
Magnesium	X	X	X	X	X	X
Manganese	X	X	X	X	X	X
Phosphorus	☑	✓	☑	✓	✓	✓
Potassium	X	X	X	X	X	☑
Sodium	X	X	X	X	X	X
Zinc	✓	✓	✓	✓	✓	✓
Selenium	☑	☑	☑	☑	✓	☑

[1] ✓ = Meets "Excellent Source of" certification; ☑ = Meets "Good Source of" certification; **X** = Does not meet certification

[2] Reference daily intakes (RDI) dietary allowance (RDA) is the daily intake level of a nutrient that is considered to be sufficient to meet the requirements of 97-98% of healthy individuals in the United States.

[3] Raw separable lean was used in the assays to provide these results with the exception of ground lamb, wherein the nature of the product contains both lean and fat.

[a] Percentage qualifies the cut to be labeled as an "excellent source" of the vitamin, providing over 20% of the RDI.

[b] Percentage qualifies the cut to be labeled as a "good source" of the vitamin, providing between 10-19% of the RDI

Figure 3. Nutrients from U.S. grass-finished raw separable lean only from lamb cuts trimmed to a maximum of 1/8" external fat qualifying for USDA "Excellent Source of" and "Good Source of" extra labeling calculated from RDI[2].

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