FOUNDATION FOR MEAT & POULTRY RESEARCH & EDUCATION

# A Guide to Meat Processing for the Nutrition Community


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## *1. Introduction*

Meat consumption has been a widely debated topic in the scientific community. The health benefits and potential adverse health outcomes of meat consumption are at the center of many scientific studies. Surrounding the meat consumption debate is confusion and misinformation on meat and processing nomenclature, product labeling claims, and ingredients, to name a few.

This white paper serves as a guide to nutrition experts and the scientific community. By reviewing existing published scientific information; this article assesses how meat is processed; common categories of processed meats and their characteristics; the meaning of different labeling claims; and an overview of the nutritional benefits of meat consumption and public health implications.

### *1.a. What is Meat?*

According to the American Meat Science Association, meat is skeletal muscle and its associated tissues from mammalian, avian, reptilian, amphibian and aquatic species harvested for human consumption. Edible offal such as organs and non-skeletal muscle tissues also are meat.[1] Products within the meat category are often subdivided into numerous other categories recognizable by consumers. Some meat subcategories include red, white, game, fresh, poultry, processed, and more. These subcategories do not adequately describe the unique properties associated with the various products and species, such as visual and cooked color, myoglobin content, lipid content, and nutrient profile, and are inappropriate to classify meats for health and nutritional purposes broadly.[2] Among the numerous meat[3] subcategories, there is an overlap of products that contribute to confusion among health professionals and consumers.

All meat is processed to varying levels. Meat processing is the conversion of a carcass into a final or finished product that is deemed desirable by consumers produced through various levels of physical or biochemical transformations. Meat is either minimally processed or further processed.[4]

> *Minimally Processed Meat (MPM)*: Raw, uncooked meat products have not been significantly transformed compositionally and contain no added ingredients. Products may be reduced in size by fabrication, mincing, grinding, and/ or a meat recovery system.

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[1] Seman, D. L., Boler, D. D., Carr, C. C., Dikeman, M. E., Owens, C. M., Keeton, J. T., ... & Powell, T. H. (2018). Meat science lexicon. Meat and Muscle Biology, 2(3), 1-15.
[2] *Id.*
[3] The term meat as used throughout the paper includes poultry.
[4] Seman, D. L., Boler, D. D., Carr, C. C., Dikeman, M. E., Owens, C. M., Keeton, J. T., ... & Powell, T. H. (2018). Meat science lexicon. Meat and Muscle Biology, 2(3), 1-15.

*Further Processed Meats (FPM):* Products that undergo an alteration, beyond minimal processing. Products may contain approved ingredients and/or be subjected to preservation through salting, curing, drying, or fermentation; thermal processing; batter/breading; or other processes to enhance sensory, quality, and safety attributes. Products may include ready-to-cook or not ready-to-eat and ready-to-eat products.

## *2. Meat Processes*

There are numerous ways meat can be prepared into minimally and further processed products for consumers. Meat is processed for many reasons, but often it is for sensory enhancement, storage extension, and, most importantly, food safety. Table 1: "Processes applied to meat to create minimally or further processed meat items," outlines a few of the common meat processes, defines them, describes the function or purpose of that process, and gives examples of products that undergo that process and whether the result is a minimally or further processed product.

### *2.a. Sensory Enhancement*

Providing consumers with a positive eating experience is essential to the success of the food industry by encouraging consumers to make repeat purchases, but it is also important for nutrition. People will not consume products they do not enjoy, and meat is a nutrient-dense product that provides essential nutrients as part of a healthy, balanced dietary pattern. Meat is an excellent source of many vitamins and minerals. People do not need to consume a lot of calories to get the essential nutrients that benefit them from having meat products in their diet.

Characteristics that enhance sensory and contribute to a positive eating experience include visual attributes, aroma, and palatability. Meat color has the greatest influence on consumer perception and visual acceptance of products.[5] Consumers desire both raw and cooked products to have an acceptable color. The ideal color for raw beef is a bright cherry-red color, raw pork should be reddish-pink, lamb should be pinkish-red, and cured meat should have a bright pink color. When addressing the aroma characteristics of meat, the largest concern is off-odors. Over time, off-odors can develop and alter consumers' acceptance of meat items. The biggest off-odors of concern include rancid, oxidized, sour, and putrid. The palatability of meat is determined by the tenderness, juiciness, and flavor of products. In many cases, meat items are processed to improve one of these sensory characteristics, with the largest influence on improving tenderness and flavor.

Processing meat for sensory reasons includes everything from adding spices and seasonings to enhance and add flavor to curing products to get an attractive bright pink color. Many meat products are processed to add or enhance flavor beyond the natural flavor inherent to

[5] Resurreccion, A. V. A. (2004). Sensory aspects of consumer choices for meat and meat products. Meat Science, 66(1), 11-20.

meat products. For example, pork loin may be marinated with teriyaki seasoning and spices to create a more desirable flavor preferred by consumers. On the other hand, ham is often cured to create the traditional pink color desired by consumers.

*2.b. Storage Extension*

Storage extension relates to both food safety and sensory enhancement. When meat is processed for storage extension, the goal is to provide consumers with an attractive and palatable product for as long as possible. The most common way of extending the storage time of meat is to reduce bacterial growth and product oxidation.[6] Products are processed multiple ways to slow or prevent the growth of spoilage microorganisms such as *Brochothrix thermosphacta*, *Carnobacterium* spp., *Enterobacteriaceae*, *Lactobacillus* spp., *Leuconostoc* spp., *Pseudomonas* spp. and *Shewanella putrefaciens*. Processing not only reduces the growth of spoilage bacteria but can reduce pathogen growth. Products are also processed to reduce lipid oxidization. Excessive spoilage bacterial growth and oxidation can lead to organoleptic deterioration resulting in discoloration, off-odors, and off-flavors.

Meat products are also regularly processed for storage extension purposes alone. For instance, drying (dried sausages or jerky) removes much of the water from meat, reducing the water activity and preventing the growth of numerous spoilage microorganisms. Reducing the growth of spoilage microorganisms and chemical reactions slows decomposition to extend storage length.

*2.c. Food Safety*

Food safety is the most important reason meat is processed. Numerous pathogens are inherent to meat products, including *Salmonella* spp., Shiga toxin-producing *Escherichia coli*, *Listeria monocytogenes*, *Clostridium perfringens*, and *Clostridium botulinum*. Processing meat can control, reduce, and/or eliminate some of these pathogens. Heat-treated meat items are a great example and reach temperatures high enough to kill or reduce pathogenic bacteria, which improves the safety, as well as, the storage life of the product. Other products have added ingredients that help control the growth of pathogenic microorganisms. For example, adding salt and nitrite to meat products inhibits the growth of numerous pathogens, such as *Listeria monocytogenes*, *Clostridium perfringens*, and *Clostridium botulinum*. Hot dogs have several added ingredients, such as nitrates and nitrites, and are also heat-treated to reduce bacterial growth. All ingredients are generally recognized as safe (GRAS) by the Food and Drug Administration and used within the USDA Food Safety and Inspection Service's (FSIS) regulatory parameters.

[6] Borch, E., Kant-Muermans, M. L., & Blixt, Y. (1996). Bacterial spoilage of meat and cured meat products. International journal of food microbiology, 33(1), 103-120.

### *3. Common Minimally and Further Processed Meats*

Meat packers and processors are constantly developing new products to meet consumer nutritional needs and changing preferences. As people grow, their nutritional needs evolve. Over time, a person may develop hypertension and require a low sodium dietary pattern. Some consumers have a soy allergy and need processed meat products without ingredients like hydrolyzed soy protein. Alongside changing nutritional needs, consumers often desire a variety of different flavors and products that can fulfill their adventurous eating habits. In response to consumer needs and preferences, the meat industry has developed thousands of items that meet a variety of nutritional needs while still providing palatable products. The broad array of minimally and further processed meat products available to consumers continues to grow to provide options to a diverse population.

#### *3.a. Types of Minimally Processed Meat*

Minimally processed meat (MPM) items are those that do not undergo any major transformation or have added ingredients. Steaks, chops, roasts, ground items (with no added ingredients, including spices and seasonings), and diced meat are all MPMs. These items vary in size, shape, and nutritional profile. There are thousands of different MPM products across the species (beef, pork, lamb, veal, chicken, and turkey) of products typically available to consumers today. Some common MPM products include beef strip steak, 90% lean ground beef, beef pot roast, chicken breast, chicken thigh, turkey drumstick, whole turkey, pork loin chop, pork tenderloin roast, lamb riblets, lamb stew meat, and many more.[7] There are also a few sub categories of minimally processed meat items that are occasionally used in products, including advanced meat recovery items and lean finely textured meat.

##### *3.a.1. Advanced Meat Recovery*

Advanced meat recovery (AMR) is a lean meat product made by applying mechanical pressure to remove meat from bones.[8] This process does not alter the composition of the meat. Products as a result of the AMR process cannot contain tissues from the central nervous system or bone. AMR products are produced with equipment that does not crush, grind, or pulverize bones. Following AMR processes, bones appear comparable to those that have been hand-deboned. To verify that bone is not introduced into the product, meat from advanced meat recovery systems must be tested regularly and cannot contain more than 0.15% (150 mg/100 g) of calcium.[9]

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[7] North American Meat Institute (US). (2014). *The Meat Buyer's Guide* 8th Edition.
[8] Seman, D. L., Boler, D. D., Carr, C. C., Dikeman, M. E., Owens, C. M., Keeton, J. T., ... & Powell, T. H. (2018). Meat science lexicon. Meat and Muscle Biology, 2(3), 1-15
[9] USDA. 2016. Definitions. 9CFR 301.2. (rr) Meat (2). https:// www.gpo.gov/fdsys/pkg/CFR-1998-title9-vol2/pdf/CFR-1998- title9-vol2-sec301-2.pdf. (accessed 18 April 18).
USDA. 2016. Definitions 9CFR 318.24 Product prepared using advanced meat/bone separation machinery; process control. https://www.gpo.gov/fdsys/pkg/CFR-2012-title9-vol2/pdf/ CFR-2012-title9-vol2-part318.pdf. (accessed 18 April 2018).

*3.a.2. Lean Finely Textured Meat*

Lean finely textured meat (LFTM) is lean meat derived from edible high fat trimmings that have been desinewed and subjected to a mild heat treatment to melt and separate the fat and allow recovery of the lean meat portion.[10] LFTM gets its fine texture from the process to remove the lean from the high-fat trimmings. The lean becomes very finely ground during the process of removing it from fat using a centrifuge, similar to the way milk is separated from cream. The resulting LFTM product is 94-97 percent lean meat.

*3.b. Types of Further Processed Meat*

Building on the range of MPM, many items can be further processed for specific food safety, sensory enhancement, and storage extension purposes. The further processing of meat products enhances sustainability. Further processing products can lengthen the storage life of products and reduce food waste. Less palatable meat items can be further processed into products consumers enjoy. Without further processing, there would be an enormous amount of food waste. Examples of further processed meat (FPM) products, including their description, processing methods, and common ingredients, can be found in Table 2. In addition to Table 2, there are other generalized categories further processed meat items fit into, including delicatessen meats (deli meat) and ready-to-eat (RTE) meats.

*3.b.1. Delicatessen Meats*

Delicatessen meats have numerous synonyms, including deli, luncheon, and lunch meat. Many deli meat items overlap with FPM items in Table 2. Deli meat refers to RTE items that are typically sliced and assembled in a sandwich for consumption.[11] Deli meats can be in the FPM ham category, sausage category, or others. There is an wide array of deli meat products that can meet almost every dietary requirement. Deli meat can be formulated to meet the food labeling regulations for low fat, reduced fat, low sodium, and reduced sodium, as well as the American Heart Association (AHA) certification, meeting AHA's Heart-Check program requirements. Additionally, deli meats come in a variety of different flavors like oven roasted, smoked, mesquite, cajun-style, or honey-flavored. Deli meat includes items like oven roasted turkey, black forest ham, mesquite chicken, roast beef, corned beef, pastrami, bologna, olive loaf, and many more.

*3.b.2. Ready-To-Eat Meats*

Ready-to-eat meats are items that are safe to eat without additional preparations, although some RTE meats may receive additional preparation for palatability or aesthetic, epicurean, gastronomic, or culinary purposes.[12] Most RTE meat items are thermally processed to achieve the lethality of pathogenic microorganisms. Many of the FPM items in Table 2 can be RTE or non-RTE including bacon, bologna, Canadian bacon, corned beef,

[10] *Id.*
[11] 9 CFR 430.1
[12] *Id.*

smoked ham, dry-cured ham[13], hot dogs, jerky, pastrami, cooked and smoked sausage, dry and semi-dry sausage, and some specialty meats.

### *4. Common Meat Processing Ingredients*

Further processed meat items can have a variety of ingredients. Ingredients may provide key functions during and after processing and affect product safety, storage life, and sensory characteristics. Some products require specific ingredients and processes. For example, bacon must be cured using salt, nitrate or nitrite, added water, and a cure accelerator (ascorbate or erythorbate). Cure accelerators (along with other ingredients) are often used in many cured meat products other than bacon but are only required in bacon. Bacon is often cooked at extremely high temperatures in a frying pan, and cure accelerators inhibit the formation of nitrosamines during high-temperature cooking.[14]

There are strict labeling requirements for all meat products. Any meat product with two or more ingredients must comply with FSIS' ingredient labeling regulations.[15] All ingredients must be included on the product label in descending order of predominance. A list of ingredients commonly used to further process meat is found in Table 3. Table 3 includes the ingredient name, description, function/use, regulatory level, and examples of when the ingredient is used.

#### *4.a. Spices and seasonings*

In addition to the ingredients found in Table 3, spices and seasoning are commonly used in further processed meat products. Spices are aromatic substances of plant origin and seasonings are any ingredient added to improve or modify flavor.[16] There are limitless combinations that give further processed meat items distinct sensory profiles formulated to meet consumer preferences. Some spices have natural antimicrobial and antioxidant properties that need to be considered during formulation and further processing.

Specific ingredients are required or prohibited in the formulation of certain products. These products must also follow specific processes to bear that specific product name, *e.g.*, meet a standard of identity. For example, pepperoni must be a dry sausage comprised of pork or pork and beef. Pepperoni can also have antioxidants present and may be dipped in a potassium sorbate solution to control mold growth. Additionally, extenders and binders, hearts, tongues, and other byproducts are not permitted ingredients in pepperoni.[17]

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[13] Dry cured hams do not undergo thermal processing but meet pathogen control through added ingredients, aging and water activity

[14] "A potentially carcinogenic compound formed from the reaction of nitrous acid and secondary amines in foods exposed to high heat treatment. Nitrosamine formation in cured meats is minimized through proper processing techniques and adherence to current production regulations including the use of antioxidants especially sodium ascorbate/erythorobate." (Seman et al. 2018).

[15] 9 CFR 317.2(f) and 381.118

[16] Aberle, E. D., & Forrest, J. C. (2001). *Principles of meat science*. Kendall Hunt.

[17] United States Department of Agriculture. Food Safety and Inspection Service. (August 2005). Food Standards and Labeling Policy Book.

Common spices used in further processed meat products include all spice, anise, bay leaves, cardamom, cassia, celery seed, cinnamon, clove, coriander, cumin, garlic, ginger, mace, marjoram, mustard, onion, paprika, pepper, sage, and thyme.[18]

*4.b. Binders, Extenders and Fillers*

Some of the non-meat ingredients in further processed meats are classified as binders, extenders, and fillers (BEFs). Binders, extenders, and fillers are non-meat ingredients that can be incorporated into comminuted and cured items. These ingredients have numerous functions, including improving batter stability, water binding capacity, texture and flavor, yield, slicing characteristics, and reducing formulation costs.[19] Binders, extenders, and fillers are characterized by high-protein content, as well as their ability to bind water and fat. Many BEFs have a meat-like texture, hydrate rapidly, and have an affinity for juice retention.

Common BEFs include hydrolyzed vegetable proteins (see Table 3) from soy, wheat, or peas. Dairy can also be used to make BEFs. For example, nonfat dried milk solids, calcium-reduced nonfat dried milk, dried whey, and reduced whey are BEFs derived from milk. Other BEFs include sodium caseinate, carrageenan, modified food starch, and textured vegetable proteins.

*4.c. Efforts to reduce sodium*

Adding sodium to muscle tissues can improve the quality of the meat and poultry products. Sodium chloride, sodium phosphates, sodium nitrite, and sodium lactate are all commonly used compounds. Compounds such as sodium chloride have important quality, shelf-life, myofibrillar functionality, and food safety properties. However, there are numerous concerns with high levels of sodium in the diet. Consumer health is a driving force in producing meat. The meat industry offers nutrient dense protein food products while continuously improving and maintaining safety. In response to public requests, the industry has been and remains actively involved in efforts to reduce sodium in meat products. The meat industry is constantly undergoing product reformulation to reduce the level of sodium and offer numerous products that meet the low and lower sodium labeling claims.

## *5. Nutritional Benefits of Minimally and Further Processed Meats*

Minimally and further processed meat products provide consumers with a convenient and balanced dietary source of all essential amino acids. These products are important sources of micronutrients, such as iron, selenium, vitamins $B_{12}$, $B_6$, thiamin, riboflavin, niacin, and potassium. Per serving, meat provides more protein than dairy, eggs, legumes, cereals, vegetables, or nuts. The iron and zinc in MPM and FPM is also more bioavailable than

[18] Aberle, E. D., & Forrest, J. C. (2001). *Principles of meat science*. Kendall Hunt.
[19] *Id.*

from other sources; meaning these minerals are more easily absorbed and utilized by the body. Both MPM and FPM are excellent sources of protein and micronutrients, especially to vulnerable populations.

*5.a. Protein*

Protein is an important macronutrient that supports various metabolic and physiologic functions, including the regulation of appetite, food intake, body weight, and body composition.[20] Protein is critical for developing, maintaining, and repairing muscles. In children, protein is key for growth and brain development. In aged populations, protein is essential in preventing muscle loss.[21] Research has also highlighted meat's high protein and low carbohydrate content provides both weight control benefits and diabetes management.[22] Scientific literature demonstrates the importance of protein in the diet and that not all proteins are created equal. Dietary protein supplies the body with nitrogen and amino acids. There are nine amino acids that are essential and classified as indispensable in the diet including histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Protein is found in all living things, but is present in different proportions and varies in total amino acid composition, including the number and levels of indispensable amino acids. Of the indispensable amino acids, some are limiting including leucine, lysine, methionine, and tryptophan. These limited indispensable amino acids play important roles in different metabolic functions. For example, leucine activates the mammalian target of the rapamycin (mTOR) pathway which signals protein synthesis in human skeletal muscle.[23] Leucine also stimulates insulin secretion from pancreatic ß cells.[24] Lysine can synthesize carnitine, and carnitine deficiencies are associated with fatty acid oxidation and metabolic disorders.[25] Tryptophan plays a key role in the production of the neurotransmitter, serotonin. Deficiencies in tryptophan can result in lower serotonin levels, which can lead to mood disorders like anxiety and depression.[26] Because meat has

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[20] Górska-Warsewicz H, Laskowski W, Kulykovets O, Kudlińska-Chylak A, Czeczotko M, Rejman K. Food Products as Sources of Protein and Amino Acids-The Case of Poland. Nutrients. 2018;10(12):1977. Published 2018 Dec 13. doi:10.3390/nu10121977

[21] Campbell, W. W., et al. (1999). "Effects of an omnivorous diet compared with a lactoovovegetarian diet on resistance-training-induced changes in body composition and skeletal muscle in older men." Am J Clin Nutr 70(6): 1032-1039.

[22] Leidy, Mattes. Higher protein intake preserves lean mass and satiety with weight loss in pre-obese and obese women. *Obesity*. Obes Res. 2007; 15: 421-429.

Layman, D. K., et al. (2009). A moderate-protein diet produces sustained weight loss and long-term changes in body composition and blood lipids in obese adults. J Nutr 139(3): 514-521.

Paddon-Jones, D., et al. (2008). Protein, weight management, and satiety. Am J Clin Nutr 87(5): 1558S-1561S.

Leidy, H. J., et al. (2010). The influence of higher protein intake and greater eating frequency on appetite control in overweight and obese men. Obesity. 18(9): 1725-1732.

Leidy, H. J., et al. (2011). The effects of consuming frequent, higher protein meals on appetite and satiety during weight loss in overweight/obese men. Obesity. 19(4): 818-824.

[23] Drummond MJ, Rasmussen BB. Leucine-enriched nutrients and the regulation of mammalian target of rapamycin signaling and human skeletal muscle protein synthesis. Curr Opin Clin Nutr Metab Care. 2008;11(3):222–226. doi:10.1097/MCO.0b013e3282fa17fb

[24] Yang J, Chi Y, Burkhardt BR, Guan Y, Wolf BA. Leucine metabolism in regulation of insulin secretion from pancreatic beta cells. Nutr Rev. 2010;68(5):270–279. doi:10.1111/j.1753-4887.2010.00282.x

[25] Hoppel, C. (2003). The role of carnitine in normal and altered fatty acid metabolism. American Journal of Kidney Diseases, 41, S4-S12.

[26] Jenkins TA, Nguyen JC, Polglaze KE, Bertrand PP. Influence of Tryptophan and Serotonin on Mood and Cognition with a Possible Role of the Gut-Brain Axis. Nutrients. 2016;8(1):56. Published 2016 Jan 20. doi:10.3390/nu8010056

greater amounts of limited indispensable amino acids than other foods, it is the best source of high quality protein. Minimally and further processed meats also have a higher protein to energy ratio and are more digestible than other foods.

*5.b. Micronutrients*

Minimally and further processed meat products contribute more zinc, vitamin $B_{12}$, phosphorus, and iron than plant foods.[27] For example, a three-ounce serving of a lean beef item like a top sirloin steak typically has less than 120 calories and is an excellent source of six nutrients, including protein, zinc, vitamin $B_{12}$, vitamin $B_6$, niacin, and selenium; and is a good source of four nutrients—phosphorous, choline, iron, and riboflavin.[28] In addition, more than 65 percent of beef cuts sold at retail meet government standards for "lean," including 17 of the 25 most popular cuts, while seven pork cuts meet USDA "lean" guidelines.[29] Pork is also lean and nutrient-rich. A three-ounce serving of pork tenderloin is a source of nine key essential nutrients—an excellent source of thiamin, selenium, protein, niacin, vitamin $B_6$, and phosphorus; and a good source of riboflavin, zinc, and potassium in less than 125 calories.[30] Among pork consumers, fresh lean pork accounts for 23 percent of total protein intake, 25 percent or more of total intakes of selenium and thiamin, and 10 percent or more of total intakes of phosphorus, potassium, zinc, and B vitamins.[31] Lamb is also nutrient dense and, on average, a 3-ounce cooked portion provides greater than 20 percent of the daily value of zinc, vitamin $B_{12}$, niacin, and protein in about 175 calories.[32]

*5.c. Consumption Importance in Vulnerable Populations.*

Meat consumption is beneficial to numerous at-risk populations. Up to 16 percent of adults in the U.S. and over 20 percent of individuals over age 60 are marginally depleted in vitamin $B_{12}$. $B_{12}$ deficiencies increase with age, resulting in six percent of adults age 70 and older being vitamin $B_{12}$-deficient.[33] Several studies demonstrate meat intake decreases bone fracture risk, which is crucial to the aging population because bone fractures can be a critical life event.[34] Meat plays an integral role in ensuring adequate vitamin and mineral

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[27] Górska-Warsewicz H, Laskowski W, Kulykovets O, Kudlińska-Chylak A, Czeczotko M, Rejman K. Food Products as Sources of Protein and Amino Acids-The Case of Poland. Nutrients. 2018;10(12):1977. Published 2018 Dec 13. doi:10.3390/nu10121977

[28] U.S. Department of Agriculture, Agricultural Research Service. 2019. USDA FoodData Central. Beef Top Sirloin Steak. Accessed January 2020.

[29] Russell Cross. Comment #571. Submitted to DGAC July 14, 2014.

[30] U.S. Department of Agriculture, Agricultural Research Service. 2019. USDA FoodData Central. Pork, fresh, loin, tenderloin, separable lean only, cooked, roasted. Accessed January 2020.

[31] Murphy MM, Spungen JH, Bi X, Barraj LM. Fresh and fresh lean pork are substantial sources of key nutrients when these products are consumed by adults in the United States. Nutrition Research. 2011; 31: 776-783.

[32] Carson, Jo Ann S., Hilton, G.G. and VanOverbeke. (2007) Lamb: It's place in the U.S. diet. http://leanonlamb.com/media/activity/lamb_in_US_Diet.pdf. Accessed May 7, 2015.

[33] Allen, L. H. (2009). "How common is vitamin B-12 deficiency?" Am J Clin Nutr 89(2): 693S-696S.

[34] Monma Y, Niu K, Iwasaki K, Tomita N, Nakaya N, Hozawa A, Kuriyama S, Takayama S, Seki T, Takeda T, Yaegashi N, Ebihara S, Arai H, Nagatomi R, Tsuji I. Dietary patterns associated with fall-related fracture in elderly Japanese: a population based prospective study. BMC Geriatr. 2010;10:31. PMID:20513246.

intake.[35] The preponderance of scientific evidence affirms the healthful role lean meat products, including minimally and further processed meats, play in dietary patterns. Moreover, numerous randomized, controlled trials illustrate that meat is a valuable component of a healthy dietary pattern. Other studies demonstrate that meat when consumed in combination with vegetables, helps the body absorb more nutrients from those vegetables.[36]

The high iron content in meat is particularly important to certain vulnerable populations, including the 1.2 million children in the U.S. with anemia. Meat's importance also holds true for teenage girls and pregnant women who are at a higher risk of anemia.[37] Although iron supplementation is an option, it is not as bioavailable as iron in meat. The heme iron present in meat is the most absorbable form of iron, and a prolonged deficiency could lead to negative long-term health outcomes, including decreased mood, shortness of breath, dizziness, headaches, and more. [38] The natural presence of heme iron also aids the absorption of non-heme iron.[39]

Throughout the life span, various subpopulations, such as children and pregnant women, have increased protein needs during growth and development, and meat is a logical choice. Per serving, meat provides more protein than most other foods. Protein is critical for developing, maintaining, and repairing strong muscles and vital for reducing the muscle loss that occurs with aging.[40] Finally, research shows that meat's high protein and low carbohydrate content translates into a low glycemic index, which offers benefits for both weight and diabetes control.[41] The high protein quality in MPM and FPM is vital in maintaining autonomy and musculoskeletal health in older adults by helping prevent frailty, disability, falls, and sarcopenia. A review in the journal *Applied Physiology,*

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[35] Institute of Medicine, National Academy of Sciences. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. National Academy Press., Washington, DC. 2001. http://www.nap.edu/openbook.php?isbn=0309072794

[36] Kris-Etherton PM, Yu S. Individual fatty acid effects on plasma lipids and lipoproteins: Human studies. Am J Clin Nutr 1997;65:1628S-44S.

Kris-Etherton PM, Pearson TA, Wan Y, Hargrove RL, Moriarty K, Fishell V, et al. High-monounsaturated fatty acid diets lower both plasma cholesterol and triacylglycerol concentrations. Am J Clin Nutr 1999;70:1009-15.

Gilmore LA, Walzem RL, Crouse SF, Smith DR, Adams TH, Vaidyanathan V, Cao X, Smith SB. Consumption of high-oleic acid ground beef increases HDL-cholesterol concentration but both high-and low-oleic acid ground beef decrease HDL particle diameter in normocholesterolemic men. J Nutr 2011;141:1188-1194.

Gilmore LA, Crouse SF, Carbuhn A, Klooster J, Calles JAE, Meade T, Smith SB. Exercise attenuates the increase in plasma monounsaturated fatty acids and high-density lipoprotein cholesterol, but not high-density lipoprotien 2b cholesterol caused by high-oleic ground beef in women. Nutr Res 2013;33:1003-1011.

[37] Accessed July 2, 2010: http://www.anemia.org/patients/feature-articles/content.php?contentid=000338.

[38] Iron and Iron Deficiency. http://www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html.

[39] National Academy of Sciences. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. National Academy Press. Washington, DC. 2001.

[40] Paddon-Jones, D., Campbell, W.W., Jacques, P.F., Kritchevsky, S.B., Moore, L.L., Rodriguez, N.R., and van Loon, L.J.C. Protein and healthy aging. American Journal of Clinical Nutrition (2015); 101(Suppl):1339S-1345S.

[41] Leidy, Mattes. Higher protein intake preserves lean mass and satiety with weight loss in pre-obese and obese women. Obesity. Obes Res. 2007; 15: 421-429.

Donald K. Layman, Ellen M. Evans, Donna Erickson, Jennifer Seyler, Judy Weber, Deborah Bagshaw, Amy Griel, Tricia Psota, and Penny Kris-Etherton. A Moderate-Protein Diet Produces Sustained Weight Loss and Long-Term Changes in Body Composition and Blood Lipids in Obese Adults. The Journal of Nutrition, March 2009

*Nutrition, and Metabolism* stated that the growing body of evidence indicates that protein intake well above the current Recommended Dietary Allowance helps promote healthy aging.[42]

### *6. Perceived Public Health Concerns*

Over the past decade, consumption of MPM and FPM has been at the center of many scientific studies and news stories. Evaluating and addressing potential public health concerns associated with meat consumption is necessary and must continue. Processing meat is one of the oldest forms of food preservation dating back to as early as 3,000 B.C.[43] The use of ingredients and different processes to preserve meat is thoroughly studied both for its effectiveness and, more importantly, for its impact on public health. These ingredients and processes are utilized to mitigate public health hazards. Regardless, some concerns associated with MPM and FPM consumption remain at the center of scientific evaluation, including nitrosamine formation, heterocyclic amines, and health outcomes.

#### *6.a. Nitrosamine Formation*

When exposed to specific conditions, a class of carcinogens known as nitrosamines can be formed in foods. Nitrosamines are formed by a reaction between nitric oxide and secondary or tertiary amines. Secondary and tertiary amines are present in all foods. These compounds are a part of all proteins as side chains of proline, hydroxyproline, histidine, arginine, and tryptophan. Nitrosamine formation occurs when nitric oxide and secondary or tertiary amines in foods are exposed to very high temperatures. Forms of nitric oxide are present in many foods. All cured FPMs, contain nitrates and nitrites which are precursors to nitric oxide and, therefore, have the potential to form nitrosamines. However, the levels of nitrates and nitrites are closely regulated by USDA and nitrosamines are rarely formed in many FPM.[44] Bacon is an item that has a higher risk of nitrosamine formation, because it is cured and cooked at very high temperatures, often in a frying pan. As a result of this increased risk, there is a lower level of nitrites allowed by USDA and cure accelerators must be used to mitigate risk. With the addition of cure accelerators such as ascorbate (a form of vitamin C ) and erythorbate (a similar compound to vitamin C), nitrosamine formation is prevented.

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[42]Phillips SM, Chevalier S, Leidy HJ. Protein "requirements" beyond the RDA: implications for optimizing health. Appl Physiol Nutr Metab. 2016 May;41(5):565-72. doi: 10.1139/apnm-2015-0550. Epub 2016 Feb 9.
[43]Romans, J. R., W. J. Costello, C. W. Carlson, M. L. Greaser, and K. W. Jones. 2001. The Meat We Eat. 14th ed. Interstate Publ., Danville, IL. pp. 779–887
[44] Table 3. Common ingredients used in meat processing.
Aberle, E. D., & Forrest, J. C. (2001). *Principles of meat science*. Kendall Hunt.

*6.b. Heterocyclic Amines*

Heterocyclic amines (HCA) are compounds that can form during high temperature cooking like grilling. Together, when amino acids and creatine are put under high heat, the Maillard reaction[45] occurs and can form HCAs. The formation of HCAs can be reduced or prevented by trimming away excess fat before grilling to reduce high heat flare-ups. Additionally, using lower temperatures when grilling, indirect heat, and turning meat frequently can reduce HCA formation. Additionally, using different marinades, spices, and seasonings can almost eliminate HCA formation. Research shows marinating or seasoning meat with rosemary, onion, garlic, lemon juice, and others can greatly reduce HCA formation.[46]

*6.c. The Effect of Meat Consumption on Cancer Outcomes*

The potential role that MPM and FPM may have on cancer outcomes is a widely debated topic. Scientific evaluations continue to explore high consumption of processed meat and any relation with colorectal cancer in both the general population and specific sub-groups. In 2018, the International Agency for Research on Cancer (IARC) released a Monograph addressing red and processed meat consumption and cancer. IARC concluded processed meat is a Group 1 carcinogen, meaning there was sufficient evidence in humans that intake causes colorectal cancer. IARC also concluded that red meat is a Group 2A carcinogen, meaning it is probably carcinogenic based on limited evidence that intake of red meat causes colorectal cancer in humans.[47] Many of the observed associations are weak in magnitude and may be due to methodological challenges and limitations. It has been shown repetitively across varying worldwide study populations that, on average, those who consume high levels of processed meat have demographic, lifestyle, other dietary, and clinical factors that are associated with an increased risk of chronic disease and cancer.[48] These other factors have demonstrated an increased cancer risk independently of processed

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[45] Maillard reaction – a form of non-enzymatic browning similar to caramelization; a chemical reaction between an amino acid and a reducing sugar, usually requiring heat

[46] Smith, J. S., Ameri, F., & Gadgil, P. (2008). Effect of marinades on the formation of heterocyclic amines in grilled beef steaks. *Journal of food science*, *73*(6), T100-T105.
Gibis, M. (2007). Effect of oil marinades with garlic, onion, and lemon juice on the formation of heterocyclic aromatic amines in fried beef patties. *Journal of agricultural and food chemistry*, *55*(25), 10240-10247.
Tsen, S. Y., Ameri, F., & Smith, J. S. (2006). Effects of rosemary extracts on the reduction of heterocyclic amines in beef patties. *Journal of food science*, *71*(8), C469-C473.

[47] IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. (2018). Red meat and processed meat. International Agency for Research on Cancer, World Health Organization.

[48] Bylsma, L. C., & Alexander, D. D. (2015). A review and meta-analysis of prospective studies of red and processed meat, meat cooking methods, heme iron, heterocyclic amines and prostate cancer. Nutrition journal, 14(1), 125.
Alexander, D. D., Weed, D. L., Miller, P. E., & Mohamed, M. A. (2015). Red meat and colorectal cancer: a quantitative update on the state of the epidemiologic science. Journal of the American College of Nutrition, 34(6), 521-543.
Alexander, D. D., Mink, P. J., Cushing, C. A., & Sceurman, B. (2010). A review and meta-analysis of prospective studies of red and processed meat intake and prostate cancer. Nutrition journal, 9(1), 50.
Alexander, D. D., Weed, D. L., Cushing, C. A., & Lowe, K. A. (2011). Meta-analysis of prospective studies of red meat consumption and colorectal cancer. European Journal of Cancer Prevention, 20(4), 293-307.
Klurfeld, D. M. (2018). What is the role of meat in a healthy diet?. Animal Frontiers, 8(3), 5-10.

meat consumption. In the Monograph, IARC noted that "Chance, bias, and confounding could not be ruled out with the same degree of confidence for the data on red meat consumption since no clear association was seen in several of the high-quality studies and residual confounding from other diet and lifestyle risk is difficult to exclude."[49] Cancer is complex. There are numerous known and suspected factors that contribute to cancer incidence, but separating one factor from another can be challenging. Research needs to continue to evaluate the effect of MPM and FPM on cancer outcomes, including mechanistic evaluations of exactly how meat may be linked to cancer.

*6.d. The Effect of Meat Consumption on Heart Health*

For adults over 65, heart disease is the leading cause of death.[50] Some studies determined a link between decreased heart health and meat consumption, but the evidence has not been consistent. Overall, the evidence implicating meat consumption in adverse cardiometabolic outcomes is of low quality. Therefore, the relationship between meat consumption and heart health is uncertain. Furthermore, evidence demonstrates if a causal relationship exists between meat consumption and heart health, the magnitude of association is very small.[51] Research needs to continue to evaluate the effect of MPM and FPM on heart health outcomes.

## *7. Conclusion*

Minimally and further processed meat products play a significant role in a healthy, well-balanced diet. Animal-derived proteins are the only sources of all essential amino acids. By including meat in the diet, consumers can more easily fulfill their macronutrient requirements. Meat packers and processors are committed to providing consumers with a wide array of products so consumers can choose the foods that best fit their personal lifestyle and family dietary needs. The industry is dedicated to providing safe, wholesome, and nutritionally diverse products to meet a variety of consumer needs.

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[49] IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. (2018). Red meat and processed meat. International Agency for Research on Cancer, World Health Organization.

[50] Heron, M. (2019). Deaths: Leading Causes for 2017. U.S. Department Of Health And Human Services. Centers for Disease Control and Prevention. National Center for Health Statistics. National Vital Statistics System. Volume 68, Number 6.

[51] Zeraatkar, D., Han, M. A., Guyatt, G. H., Vernooij, R. W., El Dib, R., Cheung, K., ... & Rabassa, M. (2019). Red and Processed Meat Consumption and Risk for All-Cause Mortality and Cardiometabolic Outcomes. Ann Intern Med, 171, 703-710.

Zeraatkar, D., Johnston, B. C., Bartoszko, J., Cheung, K., Bala, M. M., Agarwal, A., ... & Alonso-Coello, P. (2019). Effect of Lower Versus Higher Red Meat Intake on Cardiometabolic and Cancer Outcomes. Ann Intern Med, 171, 721-731.