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What is meat? A perspective from the American Meat Science Association

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Implications

- Meat is the edible tissues from an animal consumed as food.
- Meat analogs (plant, fungal, and bacterial) used to make imitation meat products are not considered meat.
- In vitro meats that originate from animal cells may be considered meat in the future.

Key words: meat, red meat, variety meat, white meat

Introduction

Ample anthropological evidence exists to show that meat has served as a food source for humans for thousands of years. Animals such as red deer (*Cervus elaphus*) and bison (commonly known as buffalo in North America) have served as sources of hide, bone, and meat for more than 500,000 yr. Humans have consumed meat throughout history because of meat's sustenance qualities and because it is recognized as an important source of essential amino acids (proteins), iron, B vitamins as well as other nutrients and minerals. Originally, humans hunted animals for meat and non-meat products, but today, animals used for food and sold into commerce are slaughtered under strict guidelines from various governing agencies. These agencies ensure the animals are put to death in a humane manner and also ensure the animals are free of disease at the time of death and the carcasses are kept clean throughout the dressing process to provide wholesome products for consumption. The portions of the animal consumed as food are collectively referred to as meat. Even so, other animal products such as milk and eggs are also derived from animals, but they are not considered meat. The definition of meat varies based on application. As an example, the Merriam Webster dictionary simply defines meat as "animal tissue especially as food" (Merriam Webster, 2017). The code of federal regulations goes a step further and specifically includes the tongue, diaphragm, heart, and esophagus as meat products, but lists lips, snouts, and ears as muscle typically not included as meat (9 CFR 301.2– Definitions). For the American Meat Science Association (**AMSA**), meat is skeletal muscle and its associated tissues derived from mammalian, avian, reptilian, amphibian, and aquatic species commonly harvested for human consumption. Edible offal consisting of organs and non-skeletal muscle tissues also are considered meat. Even though bones are not independently considered meat, when they are associated with a bone-in portion of meat such as a steak or chop, bones would be considered meat. Further, land dwelling and/or aquatic animals intended for human consumption are included in the definition of meat. This definition is broader than some used by regulatory agencies. For example, the USDA omits fish, poultry, and wild game from its definition of meat (USDA, 2017a). Likewise, ASTM International has defined meat as the flesh of animals used as food including the dressed flesh of cattle, swine, sheep, or goats and other edible animals, with the exception of fish, poultry, and wild game animals. On the other hand, AMSA does not consider meat analogs (plant, fungal, and bacterial) protein products as meat. Therefore, the objective of this article was to provide a justification for the definition of meat as outlined by AMSA.

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Carcass vs. Non-carcass Meat

During the slaughter process, an animal is converted into a carcass component and a non-carcass component. The carcass component of an animal consists of postmortem muscle, fat, and bone. These pieces are cut into portion sizes more acceptable to most consumers. Steaks, chops, roasts, sausages, and cured meats are derived from the carcass component of an animal. The non-carcass component, like the carcass component, can be further divided into edible and inedible portions, collectively referred to as offal. The term variety meat has been assigned by AMSA to represent the edible portion of the non-carcass component. Variety meats include organs and tissues such as the liver, hearts, kidneys, uteri, cheek meat, and other organs or tissues that can be inspected, deemed wholesome, and sold as food for human consumption. The edibility of offal is determined by consumer acceptability, cultural practices, regulatory requirements, hygiene, and religion.

The inedible portion of the non-carcass component of an animal can be referred to as by-products. By-products include offal items that are not inspected and therefore are not sold as food for human consumption (e.g., hides, toe nails, lungs, etc.). Products derived from the carcass component and edible offal are referred to as meat.

Composition of Meat (Skeletal Muscle)

Several biochemical reactions occur at the time of death as the carcass is attempting to maintain homeostasis. Homeostasis means the carcass is attempting to maintain equilibrium via physiological processes. However, exsanguination, removal of the blood, is the ultimate cause of death and prevents the carcass from achieving homeostasis. As a result, a by-product of anaerobic metabolism, lactate, is accumulated in the muscle and begins the conversion of muscle to meat. Lactate is converted from glycogen, a carbohydrate, which is stored in the muscle. Skeletal muscle meat is comprised of only approximately 1% carbohydrate (stored as glycogen). Carbohydrates are important for meat quality because when an animal is alive, respiration is

possible and the animal is capable of aerobic (meaning with oxygen) metabolism. However, when the animal is slaughtered, aerobic metabolism stops and anaerobic (meaning without oxygen) metabolism continues for a period of time. During anaerobic metabolism, glycogen is converted to lactate. Under normal (living) conditions, lactate would be transported to the liver through the circulatory system to be converted back to glycogen. However, the blood has been removed. Because the blood has been removed from the animal, there is no mechanism to remove this waste byproduct and it accumulates in the muscle. The accumulation of lactate in the muscle results in a decrease in pH and is associated with the conversion of muscle to meat.

When living muscle is converted to edible meat, the ability of the tissue to hold water is altered as a result of the decrease in pH. This is especially important because meat is approximately 75% water (Aberle et al., 2012). Water is held in muscle in three forms: bound, immobilized, or free water. Nearly 95% of the water associated with meat is in the free or immobilized form. This is also important because immobilized and free water are held by moderate to weak forces with the proteins associated with meat and are subject to removal by mechanical and physical forces such as freezing and thermal processing. Loss of water during these processes can negatively influence eating experiences such as juiciness and tenderness. Additionally, skeletal muscle, which is the most common form of meat, is approximately 20% protein, 4% fat, and 1% vitamins and minerals in addition to the 75% water. The composition of offal varies from the composition of skeletal muscle.

Among compositional parameters, fat is the most variable. Fat can be identified based on its anatomical location. In the case of lean meat, intramuscular fat (marbling) is often the most discussed in regard to eating quality. In general, marbling is the last fat to be deposited in a living animal and varies by species in terms of percentage of total fat (Gerrard and Grant, 2003). It is important to note that even very lean meat contains a nominal amount of fat that may be invisible. This fat source is referred to as phospholipids and differs from marbling. These phospholipids surround the muscle cells and serve structural and functional components of the muscle cell. Muscle contains between 0.5 and 1% phospholipids (Price and Schweigert, 1987). As stated before, the total percentage of fat varies based on anatomical location and animal maturity. Likewise, the proportion of phospholipids is also highly variable. As total lipid in the muscle decreases from approximately 5% to approximately 1%, the percentage of phospholipid as part of the total lipid increases from less than 10% to nearly 70% (Price and Schweigert, 1987).

Nutritional Value of Meat

People who choose to eat meat often cite three reasons. The first cited reason for consuming meat is that it tastes good and has a desirable flavor. Second, meat consumption is often associated with social status or is enjoyed during times of celebration or special occasions. Finally, meat is consumed because it has desirable nutritional benefits and supports human health (Murphy et al., 2011; McNeill, 2014; O'Connor et al., 2017). As a reasoning for consuming meat from a nutritional standpoint, meat advocates have historically used the acronym "ZIP," which stands for zinc, iron, and protein; three nutrients associated with meat. As noted previously, fresh uncooked meat is approximately 20% protein. According to the US Food and Drug administration, the percent daily value (**DV**) for protein based on a 2,000-calorie diet is 50 g. Assuming this DV, 100 g of cooked meat provides approximately 50% of the total DV (USDA, 2017b). Protein is often a key reason for meat consumers to choose to eat meat. Fortunately, meat protein is considered a high quality protein. A high quality protein is one that provides essential amino acids, which are those that must be consumed from a food source rather than being synthesized endogenously.

Meat proteins also have a high biological value. Biological value is a measure of the proportion of protein used from a food source to synthesize proteins in the animal's body. The greater the proportion of useable proteins, the greater the biological value. Most animal-derived food products like meat, milk, and eggs are considered to have a high biological value. The biological value of human breast milk is 100 (this means 100% of the

Table 1. Nutrient database standards for common meat items. Nutrients listed on a 100-g cooked basis.†

Item, cookery method	Protein, g	Lipid, g	Iron, mg	Sodium, mg	Zinc, mg	Vitamin A, IU
Beef	27.65	11.36	3.16	67	4.65	5
Porterhouse steak, grilled	28.88	9.01	1.98	60	5.49	0
Ribeye steak, broiled	30.93	7.7	3.02	54	3.66	22
Beef tenderloin, grilled	23.87	15.37	2.27	73	5.84	9
Ground beef 70% lean						
Pork	26.76	7.29	0.8	56	2.22	0
Grilled pork loin (chops), bone-in, lean, broiled	28.47	4.49	0.92	54	2.43	0
Broiled pork shoulder breast, boneless	26.69	20.04	1.1	89	2.57	0
Ground pork 84% lean, cooked	18.84	7.62	0.85	1155	2.23	0
Cured ham, boneless, cooked, heated						
Lamb	27.43	10.7	1.88	84	3.48	20
Lamb loin chop, cooked, fast fried	24.75	19.65	1.79	81	4.67	0
Ground lamb cooked, broiled	27.68	7.01	2.24	45	4.04	0
Lamb leg, lean only, cooked, roasted	26.16	13.31	1.77	81	4.47	0
Lamb rib cooked, roasted						
Poultry	30.54	3.17	0.45	52	0.9	32
Skinless chicken breast, cooked, grilled	28.62	8.08	1.32	96	3.22	61
Chicken drumsticks, cooked, fried						
Fish	60.62	11.43	1.06	51	1.14	103
Salmon filet with skin, smoked						
Beef liver, cooked, braised	29.08	5.26	6.54	79	5.30	31,714
Beef kidney cooked, simmered	27.27	4.65	5.8	94	2.84	0
Pork kidney cooked, braised	25.4	4.7	5.29	80	4.15	260
Pork tongue cooked, braised	24.1	18.6	4.99	109	4.53	0
Beef tongue, cooked, simmered	19.29	22.3	2.61	65	4.09	0
Lamb tongue cooked, braised	21.57	20.28	2.63	67	2.99	0

†Sourced from the USDA Food Composition Databases—https://ndb.nal.usda.gov/ndb/search/list (4 July 2017).

protein provided by the milk is available for use), whole eggs are 88–94, cow's milk is 88–90, and meat is 75– 85. In general, the percentage of essential amino acids as a percentage of crude protein differs little among beef, pork, and lamb (Lawrie and Ledward, 2006) although some may argue that beef has a greater percentage of leucine, lysine, valine and a lesser percentage of threonine than pork or lamb. In addition to providing nutritional protein, meat also provides valuable vitamins and minerals to a complete diet. Iron, specifically heme-iron, is often quoted as the most beneficial mineral provided through the consumption of meat. Iron is associated with the non-protein portion of myoglobin. A grilled beef steak may contain more than 3.0 mg/g of iron (Table 1). This represents a DV of 16% on a 100-g basis of meat for iron. A grilled lamb chop or pork chop contains approximately 2.4 mg/g of iron. Differences in iron content of foods derived from various species are likely related to myoglobin content where chicken has the least amount of myoglobin and beef has the most. Further, the iron associated with animal-derived proteins are more easily absorbed than iron associated with plant proteins (Layrisse et al., 1969).

In addition to protein and iron, meat is also a significant source of dietary zinc. A grilled porterhouse beef steak contains 4.65 mg per 100 g of meat (Table 1). Even ground pork contains 2.57 mg of zinc per 100 g of meat. This represents 17% DV based on a 2000 calorie diet.

Like meat products sourced from skeletal muscle, variety meats are also nutritious. As an example, braised beef liver contains more protein, iron, and zinc than a grilled porterhouse steak. Beef liver also contains over 100% DV for vitamin A. Likewise, a braised pork tongue (24.1 g) contains nearly as much protein as a grilled pork loin (26.76 g). Pork tongue also contains more iron and zinc than a grilled pork chop (USDA, 2017b).

Lab-Produced (In Vitro) Meat

Conventionally produced meat requires inputs such as water, land, and feed. Alternatives to livestock production for the purposes of meat are warranted because of concerns associated with sustainability, environmental impact, and animal welfare associated with conventional production of meat. Additionally, some believe human population growth and the derived

increase in demand for meat will outpace the meat industry's ability to produce enough meat. Therefore, alternatives to conventional meat production have been explored. Specifically, in vitro culturing of meat is one alternative to raising an animal intended for slaughter for the purpose of producing meat. The generation of bio-artificial meat from animal-derived satellite cells has been studied for more than 20 yr (Post, 2012). In 2013, a group of Dutch scientists cooked and consumed the first "lab-grown" hamburger (Hocquette, 2016). At that time, the cost of the 5-oz portion was more than $330,000 and was described to taste "almost" like a conventional burger by one of the three people provided the opportunity to taste the burger (Post, 2012). Since that time, the cost of production has decreased dramatically. Just a few years later, the price to manufacture a burger was quoted at just $11.36. Some project in vitro meat may be cost competitive and readily available to consumers in 20 or 30 yr (Crew, 2015). Several conditions are necessary to manufacture in vitro meat. First and foremost, a source of animal-based stem cells are required. Second, a three-dimensional environment is required to provide biological cues to the cells to proliferate and differentiate. Third, a system designed to deliver nutrients and remove waste products is necessary. Finally, a bioreactor to allow muscle fibers to mature is required (Langelaan et al., 2010). Because the origin of in vitro meat is animal-based protein, in vitro meat meets part of the definition for meat put forth by AMSA. However, because in vitro meat is not currently inspected by a governing body such as the FSIS and it is not naturally derived from an animal, it does not currently qualify as meat in accordance with AMSA's definition. Ultimately to be considered meat, in vitro meat must be originally sourced from an animal cell, be inspected and considered safe for consumption, and be comparable in composition and sensory characteristics to meat derived naturally from animals. In particular, the essential amino and fatty acid composition, macro- and micronutrient content and processing functionality should meet or exceed those of conventional meat.

Summary

Meat has historically held many definitions and has been used as a classification tool by government agencies, nutritional evaluation purposes, and marketing groups. Meat analog (plant, fungal, and bacterial) protein products are not considered meat by AMSA. Meat is defined by AMSA to be skeletal muscle and its associated tissues derived from mammalian, avian, reptilian, amphibian, and aquatic species commonly harvested for human consumption. Edible offal consisting of organs and non-skeletal muscle tissues also are considered meat. .

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