Published online September 21, 2017

‘Red’ and ‘white’ meats—terms that lead to confusion

Jimmy T. Keeton[†] and Michael E. Dikeman[‡]

[†]Professor Emeritus, Texas A&M University

[‡]Professor Emeritus, Kansas State University

Implications

- Terms describing meat and meat products have evolved over decades to identify products originating from food animals. In general, meat is defined as skeletal muscle and associated tissues derived from commonly farmed and/or harvested mammals and, more recently, from avian and aquatic species.
- However, the terms “red meat” and “white meat” are a continual source of confusion due to their broad and oversimplified use in scientific publications, popular press articles, and when communicating dietary recommendations, nutrition policy, and medical advice to reduce the risk of cardiovascular disease and cancer.
- Therefore, this article 1) examines the origin and use of the terms “red” and “white” meats; 2) presents examples of how misuse of these terms can potentially lead to flawed conclusions; and 3) supports the need for a meat science lexicon of standardized meat terms that accurately describe “meat” and “meat product” categories.

Key words: meat, meat science lexicon, red meat, white meat

Origin of ‘Red’ and “White” Meat Terms

A host of meat terms (some considered jargon) have been created for scientific, regulatory, day-to-day industry needs, and consumer communication. Jargon still exists in the meat industry because it is an “ancient craft” and some of these terms are still considered the most appropriate. The Federal Meat Inspection Act of 1906 was established to ensure the wholesomeness of what was considered “red” meat species (beef, swine, sheep, goat, and horse). As time passed, and as meat from other species—primarily poultry—became more popular, these were added to the inspection regulations (Poultry Products Inspection Act of 1957). The distinction between meat and poultry still exists in the United States Department of Agriculture (USDA) regulations, but over time, meat from lighter colored avian species has been referred to as “white” meat (primarily breast muscle) to distinguish it from the darker “red” meat species. Yet, meat from the thigh and leg of poultry often is referred to as poultry “dark meat.”

doi:10.2527/af.2017.0440

Meat Terminology that Leads to Confusion

Meat and food scientists may categorize individual muscles or muscle groups as “red” or “white” based on their myoglobin concentration, lipid profile, mitochondrial densities, muscle fiber physiology, and/or in response to physiological change during postmortem metabolism and/or proteolysis. Some physiological changes in meat color and texture are in response to an animal’s genetics, dietary regimen, and/or handling practices prior to slaughter that can alter the muscle pH endpoint and result in pale, soft, exudative (**PSE**) or dark, firm, dry (**DFD**) muscle. Thus, the use of the terms “red” and “white” and “light” and “dark” may have different meanings based on their context of use. Grouping certain products into “red” or “white” categories may not be sufficiently informative to precisely describe the actual parameter of interest when communicating scientific information. For example, in nutritional studies, the terms “red” and “white” meat are often used as “surrogate” descriptors for the unsaturated and saturated fat content differences between beef and poultry, respectively. Chicken and turkey breasts are traditionally considered “white” meat, but in some nutritional contexts, the dark meat from poultry and turkey legs are lumped together into the “white” category, even though they are compositionally quite different. Likewise, veal is sometimes considered a “white” meat due to its lower myoglobin concentration, but “beef,” on the other hand, is considered a “red” meat. Meat from turkey leg has essentially the same iron content as ground beef, but it may still be considered “white” meat due to its lipid profile difference. Thus, it would be more accurate to avoid the use of “red” and “white” terms altogether and actually identify meat derived from a specific species based on defined parameters such as myoglobin or heme iron content, lipid profile, fatty acid composition, cholesterol content, etc.

Reinagel (2013) stated that labeling “red” meat is not a reliable “proxy” for heme iron, total fat, or cholesterol. Figure 1 compares the compositional components of iron, total fat, saturated fat, and cholesterol of 13 meat cuts from 10 species. Ground lamb and ground turkey are essentially equal in iron, yet ground lamb has about 50% more total fat than ground turkey. Ground bison and ground turkey have almost equal contents of saturated fat, but ground turkey has about 30% more cholesterol than ground bison. Pork tenderloin and chicken breast meat are almost identical in heme iron and total and saturated fat composition, but pork actually has less cholesterol. Another comparison is that chicken nuggets have about five times more total fat than pork tenderloin, but nuggets are typically considered by consumers to be healthy “white” meat. Clearly, classifying beef as “red” and turkey as “white” meat is erroneous and misleading.

Additional confusion may occur because Wikipedia states that “white” meat is made up of fast-twitch fibers, whereas “red” or dark meat is made up of muscles with fibers that are slow-twitch. In this case, the terms “red” and

Iron	Total Fat	Saturated Fat	Cholesterol
Clams 28 mg	Ground lamb 19.7 g	Ground lamb 8.1 g	Shrimp 195 mg
Ground bison 3.2 mg	Chicken nuggets 18.8 g	Ground beef 5.5 g	Ground turkey 102 mg
Shrimp 3.1 mg	Ground beef 14.4 g	Chicken nuggets 4 g	Ground lamb 97 mg
Ground beef 2.7 mg	Ground turkey 13.1 g	Ground bison 3.5 g	Ground beef 91 mg
Turkey leg 2.6 mg	Salmon 12.3 g	Ground turkey 3.4 g	Chicken breast 85 mg
Ground turkey 1.9 mg	Ground bison 8.6 g	Flank steak 3.1 g	Pork tenderloin 73 mg
Chicken nuggets 1.8 mg	Flank steak 7.4 g	Salmon 2.5 g	Ground bison 71 mg
Ground lamb 1.8 mg	Turkey leg 5.4 g	Turkey leg 1.7 g	Turkey leg 70 mg
Flank steak 1.7 mg	Chicken breast 3.6 g	Pork tenderloin 1.2 g	Clams 67 mg
Tuna 1.5 mg	Pork tenderloin 3.5 g	Chicken breast 1 g	Salmon 63 mg
Pork tenderloin 1.2 mg	Clams 1.9 g	Shrimp 0.3 g	Chicken nuggets 55 mg
Chicken breast 1 mg	Shrimp 1.1 g	Clams 0.2 g	Flank steak 49 mg
Salmon 0.3 mg	Tuna 0.8 g	Tuna 0.2 g	Tuna 30 mg

Key: White meat; Red meat

Meat = 100g, cooked. Data reflects skinless chicken breast; 80% lean ground beef; turkey leg with skin; and canned tuna. Nutrient data provided by USDA Nutrient Data Laboratory SR-21.

Figure 1. The label of "red meat" as defined in *Nurses' Health Study II* and *Health Professionals Follow-up Study* is not a reliable proxy for heme iron, total fat, saturated fat or cholesterol (ranked above).

"white" are used in a physiological context, whereas in other instances, the terms are used to denote compositional differences. According to Carolyn McAnlis, RDN (in Reinagel 2013), red meats simply have more myoglobin, the heme protein that enables the exchange of oxygen and carbon dioxide between muscle cells and bloodstream (www.fitday.com). Muscles that are used much more often are darker than those used less frequently; domestic chicken or turkey breast meat is lighter than leg meat because leg muscles require more myoglobin to function effectively. In contrast, birds that use their breast muscles for sustained flight (such as wild ducks and geese) have dark breast meat. According to Wikipedia, dark meat also contains about 2.64 times more saturated fat than white meat per gram of protein, but also contains higher levels of B-vitamins and the minerals zinc and iron, which are more easily absorbed by the body compared with iron found in plant sources. There has been some association made between heme iron intake and colorectal cancer, with beef typically considered the culprit but without due consideration of dark meat from poultry or other foods in diets.

Pork, a traditional "red" meat, is pink to red when raw, but becomes lighter in color on cooking. The National Pork Board used the slogan "Pork, the Other White Meat" for a number of years to position pork as being competitive with "white" chicken and turkey breast muscle, which, based on Figure 1, was justified. In some cases, fish muscle is also generally referred to as "white" meat, but this is an oversimplification. "White" fish is white both before and after cooking, whereas fattier fish (e.g., salmon and tuna) are red before cooking and turn either white (tuna) or remain pink (salmon) after cooking. Although salmon is pink to red, it is not for the same reason that beef, pork, or lamb is red. Salmon consume tiny shrimp or krill that have a pigment in their exoskeleton, and over time, salmon absorb enough of this pigment to make their meat pink to red.

'Red' Meat vs. 'White' Meat– Health Controversies

The most recent meta-analysis by Wang et al. (2016) relating the risks of meat consumption to various causes of mortality included nine studies with 17 prospective cohorts from populations around the world. For the total population, the highest category of unprocessed "red" meat (beef, lamb, or pork) consumption was not associated with an increase in the risk of all-cause mortality relative risk (**RR**) = 1.05, and 95% confidence interval (**CI**) = 0.93–1.19), cardiovascular disease (**CVD**) mortality (RR = 1.06, 95% CI = 0.88–1.28), or cancer mortality (RR = 1.03, 95% CI = 0.89–1.18). However, for the US population, each serving per day of unprocessed "red" meat was positively associated with a risk of all-cause mortality (RR = 1.15, 95% CI = 1.12–1.19), CVD mortality (RR = 1.19, 95% CI = 1.13–1.26), and cancer mortality (RR = 1.12, 95% CI = 1.07–1.17). The difference among populations may be explained, in part, by the relatively higher consumption of beef, pork, and lamb in the US compared with other populations, whereas higher fish intake may have helped reduce disease progression among the Asian populations. Additionally, it has been suggested that food preparation techniques in the US, such as the frying and grilling of meats, are associated with increased disease risk (Wang et al., 2016). Clinical trials examining the relationship between beef/lean beef consumption and cardiovascular disease risk factors indicate that, within the context of a heart-healthy diet, there is no adverse effect on major CVD risk factors and, in fact, a heart-healthy diet with lean beef has been shown to decrease major CVD risk factors. A meta-analysis of 124 research clinical trials on lipid and lipoprotein changes comparing beef against poultry or fish consumption found no significant differences; both decreased LDL-C similarly (Maki et al., 2012).

While "red" meat consumption has been linked epidemiologically to diabetes, stroke, cancer, morbidity, and mortality, white meat (poultry) and fish have not shown the same degree of association with these health conditions. Most epidemiological studies that have linked "red" meat consumption to these health concerns were primarily surveys based on observational recall of foods consumed, meta-analyses of cohort studies, assessments of food disappearance from nutrient databases (i.e., NHANES, USDA-ARS), and few case-control studies. Correlations derived from these studies may show a statistical association or an estimation of health risk from certain types of meat consumption but cannot prove causation. Observational studies such as these are helpful in generating hypotheses but are not suited for testing the hypothesis. Generally, observational studies with large numbers of respondents show weak, inconsistent, or no association with "red" and "white" meat (both unprocessed) consumption and related health risks.

Some inherent limitations of epidemiologic studies for assessing the dietary effects of meat and meat product consumption are listed below.

- Accuracy and precision of recall surveys are difficult to document using the categorical terms "red" and "white" meat

- Survey groupings may be too broad or inaccurate to study specific meat effects
- Food disappearance does not always equate to consumption (does not take into consideration food waste).
- Nutrient composition within a category may be too diverse to draw specific conclusions
- Meat cooking method/preparation may not be available but could have a direct effect on the diet (grilling, broiling, pan frying, deep-fat frying, etc. can alter compositional characteristics and/or generate undesirable compounds)
- Correlations cannot demonstrate causation but only estimate the degree of association.

Randomized controlled studies using animal models physiologically close to humans and human intervention trials that examine the effects of meat consumption by species and/or specific meat products are lacking and are needed to assess any health risks of association with consumption. As noted by Avkan (2015), in a recent study to assess "red" meat and colorectal cancer, "Correlation does not mean causation of course, (since) many different international lifestyle factors (other) than red meat intake can contribute to this result, so there [is] a great need for prospective case-control or cohort studies to test the hypothesis of the link between 'red' meat consumption and colorectal cancer (CRC) risk after this correlation study."

Categorizing "red" and "white" meats in relation to health outcomes is quite often problematic. *At the heart of many studies correlating meat consumption with health-related conditions is the manner in which different meats are grouped on surveys into "red," "white," or "processed" categories.* The difficulty often comes when "red" and "white" meat items are grouped too broadly (grouping poultry and fish that differ compositionally) or categorized inappropriately (including further processed items containing approved ingredients only) with "red" muscle meats on a survey. This is further complicated when meta-analyses are used to assess meat consumption or disappearance data using broadly grouped categories that are not truly similar. Thus, results from these studies used to assess health risks or convey health recommendations (such as disease risk, morbidity, mortality, or dietary advice) may be too broad or generalized to accurately describe a specific meat or meat item's relationship to diet and health. As an example, Sinha et al. (2009) assessed "red" and "white" meat intake to the mortality of 617,119 individuals using 24-h recalls based on a 124-item food frequency questionnaire and applying a dietary assessment of the meat items categorized. The following excerpt describes how meats were grouped. These authors categorized "red" meat intake was calculated using "*all types of pork and beef - bacon, beef, cold cuts, ham, hamburger, hot dogs, liver, pork sausage, steak, and meats in foods such as pizza, chili, lasagna, and stew. "White" meat included chicken, turkey and fish and included poultry cold cuts, chicken mixtures, canned tuna, as well as low fat sausages and low-fat hot dogs made from poultry. Processed meat included bacon, red meat sausage, poultry sausage, luncheon meats (red and white meat), cold cuts (red and white meat), ham, regular hot dogs and low-fat hot dogs made from poultry. The components constituting red or white or processed meats overlap because both can include meats such as bacon, sausage, and ham, while processed meat also included smoked turkey and chicken. However, these meat groups are (were) not all used in the same models, thus they are not duplicated in any one analysis.*" A 10-yr cohort follow-up was conducted to assess mortality of the subjects, and the final conclusion of Sinha et al. (2009) based on model predictions and correlations was that "red" and "processed" meat intakes, especially as part of a high-risk meat diet, were "*associated with a modest increase in risk of total mortality, cancer, and CVD mortality in both men and women.*" In contrast, they reported that high "white" meat intake and a low-risk meat diet were associated with a small decrease in total and cancer mortality." A 10-yr cohort follow-up was conducted to assess mortality of the subjects, and the final conclusion of Sinha et al. (2009) based on model predictions and correlations was that "red" and "processed" meat intakes, especially as part of a high-risk meat diet, were *"associated with a modest increase in risk of total mortality, cancer, and CVD mortality in both men and women."* In contrast, they reported that high "white" meat intake and a low-risk meat diet were associated with a small decrease in total and cancer mortality."

Based on the somewhat confusing excerpt given above, it is apparent that the products grouped into "red" and "white" meat categories in this study were not the traditionally understood portioned cuts from beef and pork, and breast meat from chickens and turkey, but included further processed meats that varied dramatically in nutrient composition, addition of non-meat ingredients, and cooking method. It is also not known if the amounts consumed of each meat item in the 124-item food frequency were taken into account. Because multiple beef, pork, poultry, and fish meat items were included in the respective "red" and "white" groupings, attributing mortality outcomes to a traditional understanding of "red" or "white" categories may not be possible. This assessment of the research performed is not intended to be critical of the authors intent to identify dietary health risks; rather it is to show how inappropriate categorization or grouping of meat items can lead to difficulty in accurately assessing the true effects of portioned "red" (beef, pork, and lamb) and "white" (poultry and turkey breasts) meats on health outcomes.

In one of the largest meta-analyses of "red" (unprocessed), "processed", and total meat consumption in relation to the development of coronary heart disease (**CHD**), stroke, and diabetes mellitus, Micha et al. (2010) concluded that "processed" meats, but not "red" meats, were associated with a higher incidence of CHD and diabetes mellitus. However, what is not known is the accuracy of the categorizations and groupings of meat and meat products in the original 17 cohort and three case-control studies used for the meta-analysis. Additionally, in a systematic review of 40 studies using animal models or cell cultures to assess "red" and "processed" meat consumption in relation to colorectal cancer risk, Turner and Lloyd (2017) found insufficient evidence to confirm a mechanistic link between the intake of "red" meat as part of a healthy dietary pattern and colorectal cancer risk. Most of the studies reviewed used levels of meat or meat components well in excess

Table 1. Compositional differences in meats perceived as "red" and "white" (raw, 100g).

	Total lipid (g)	Saturated lipid (g)	Mono-unsaturated lipid (g)	Poly-unsaturated lipid (g)	Cholesterol (mg)	Protein (g)	Iron (mg)	Zinc (mg)	B_{12} (µg)	Energy (Kcal)
Red										
Ground beef, 10% fat	10.00	3.927	4.194	0.345	65	20	2.24	4.79	2.21	176
Ground beef, 5% fat	5.00	2.182	1.994	0.257	62	21.41	2.38	5.09	2.24	137
Beef top loin (select)	15.04	6.067	6.438	0.572	80	20.59	1.47	3.45	0.98	224
Pork loin chop	6.94	2.450	2.985	0.878	67	21.55	0.50	1.55	0.53	132
Ground lamb	12.41	4.848	2.077	0.483	63	20.33	1.04	2.75	1.62	193
Lamb chop	14.38	6.898	5.878	0.649	66	18.33	1.75	3.21	2.72	208
Ground bison	7.21	2.917	2.753	0.336	55	20.23	2.78	4.59	194	124
White										
Chicken breast	2.62	0.563	0.689	0.424	73	22.50	0.37	0.68	0.21	120
Chicken leg (w/o skin)	4.22	1.050	1.440	0.962	91	19.16	0.78	1.76	0.57	120
Ground turkey	7.66	2.024	2.635	2.205	69	19.66	1.09	2.35	1.00	148
Turkey leg (skin)	6.72	2.060	2.060	1.830	71	19.54	1.72	3.09	0.39	144
Salmon	6.34	0.981	2.103	2.539	55	19.84	0.80	0.64	3.18	142
Shrimp	1.01	0.261	0.181	0.295	126	13.61	0.21	0.97	1.11	71
Clams	0.96	0.187	0.120	0.192	30	14.76	1.62	0.51	11.28	86

Source: USDA-ARS, 2017.

of those found in human diets, and semi-purified diets were used without the benefit of the additional compounds found in whole foods. They concluded that it was essential that better-designed studies be conducted using relevant concentrations of meat in model diets representative of those consumed by humans. This conclusion supports the need for definitive randomized controlled studies to assess the dietary effects of meat consumption that, in turn, could lead to sound dietary and policy recommendations.

'Red' Meat (Beef) Consumption and Diabetes

Understanding potential differences in the associations of processed and unprocessed meats with other important disease outcomes (such as diabetes) is relevant for informing dietary guidance. According to Kris-Etherton, Etherton, and Fleming (2014), the research to date suggests that both processed and unprocessed "red" meat, regardless of fat, are linked to a higher incidence of diabetes; however, gram for gram, the risk is doubled for processed meats (Pan et al., 2011). While several potential mechanisms have been identified, they require further investigation. For example, there is evidence to show that the association may be mediated by the effects of heme iron, which may increase the risk for diabetes (Rajpathak et al., 2009). Heme iron acts as a pro-oxidant assisting in the production of reactive oxygen species and thereby inducing oxidative stress. Rajpathak et al. (2009) stated that this cascade of events can cause damage to tissues, in particular the pancreatic β cells, and interfere with insulin secretion. In the Pan et al. (2011) analysis, "red" meat consumption was highly correlated with heme iron intake (correlation coefficients ranged from 0.53 to 0.66), and as a result, the association between "red" meat and diabetes was further attenuated after adjustment for dietary heme-iron intake. However, Roussell et al. (2012) reported that there also is evidence to show that when lean beef is incorporated into a DASH-like diet, high in fruits and vegetables, significant improvements in cardiovascular risk factors are observed compared with an average American diet. Thus, it is possible that incorporating lean beef into a diet rich in antioxidants may negate any pro-oxidant effects of heme iron. Because chicken and turkey breast meat and fish have low heme iron content, a relationship with diabetes has not been observed and has not been of interest. It would be important to know if the similarly high heme iron content in chicken or turkey dark meat has been associated with a higher incidence of Type II diabetes.

Role of Lipids in Meat and Cardiovascular Disease

As cited by Kris-Etherton et al. (2014), Gilmore et al. (2011) conducted the only trial designed to test the hypothesis that ground beef high in MUFA would reduce cardiovascular risk factors, similar to plant-based MUFA, an effect that would not be seen with consumption of ground beef low in MUFA. Ground beef from both pasture- and grain-fed cattle was used, and total fat was matched at 24% of calories. Pasture-fed cattle contained higher concentrations of SFA, TFA, and α-linolenic acid [ALA, 18:3(n-3)] whereas the grain-fed cattle contained higher proportions of oleic acid [18:1(n-9)]. Their hypothesis was confirmed when the high-MUFA beef significantly increased HDL-C concentrations compared with the low-MUFA beef and significantly decreased the LDL-C:HDL-C ratio compared with the baseline. The authors note that the magnitude of the effect of high-MUFA ground beef in increasing HDL-C concentration (~0.08 mmol/L) is comparable to that reported in a review by Kris-Etherton and Yu (1997) of the effects of high-oleic acid vegetable oils on HDL-C levels in human studies.

Compositional Variation in Meats Often Categorized as 'Red' or 'White'

The need to definitively categorize meats is illustrated by the compositional variation that can be found in meats that might sometimes be categorized as "red" or "white" in some scientific studies (Table 1). As noted, meats or seafood categorized as "red" or "white" vary significantly in composition and may not be comparable due to nutrient profile differences. Thus, conclusions and recommendations emanating from a study using "red' and "white" categories may not be accurate. A second factor that might not be reflected in epidemiological studies is the compositional changes that have occurred in different meat species and meat products over the past 30 yr. For example:

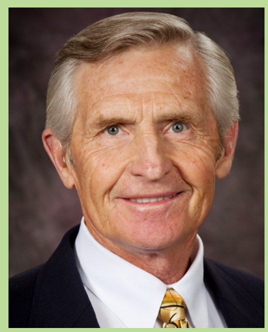
- Meat cuts from beef and pork carcasses have become leaner due to enhanced genetic selection and/or management practices
- Some changes in the fatty acid composition of beef cuts may be due to animal diet (grass vs. grain feeding) and/or Japanese genetics (Wagyu and Akaushi) and Korean (Hanwoo) genetics
- Human dietary studies by Smith and Smith (2014) have shown that male and female subjects consuming grain-fed beef (high in 18:1cis9) reduced circulating LDL and increased circulating HDL, whereas people consuming grass-fed beef had higher serum levels of trans FAs and LDL with concomitant reductions in HDL
- More meals and meat foods are prepared outside the home using a variety of preparation and cooking methods (batter-breading, cooking in oil, grilling, smoking, etc.), the effects of which are not fully known

Using Correct Meat Terminology

The use of precise terminology to categorize meat, meat products, and meat groupings is needed to improve the accuracy of scientific studies, ensure communication of sound dietary policy, and enable a more accurate assessment of meat's impact on nutrition and health. The intent of the Meat Science Lexicon (Seman et al., 2017) developed by the American Meat Science Association (**AMSA**) is to provide a standardized scientific classification of terms that accurately describe and categorize meat and meat products. Thus, the broad terms "red" and "white" meats do not appear in the lexicon as categories because they do not accurately describe the variations that can exist among species in terms of nutrient profile and product diversity. The Lexicon is not intended to do away with the traditional use of these terms from an inspection perspective that describe cuts from beef, pork, and lamb as "red" and those from poultry and turkey as "white" meats. It is intended to provide appropriate descriptions of meat categories and to avoid the misuse of meat terms.

About the Authors

Dr. Jimmy Keeton is Professor Emeritus at Texas A&M University, former Head of the Department of Nutrition and Food Science (2007–2013) and former Professor (Meat Chemistry) in the Department of Animal Science (1984–2007). He also served in the Department of Food Science faculty at North Carolina State University (1977–1983). He received his B.S., M.S., and Ph.D. degrees from the University of Tennessee–Knoxville and did post-doctoral work at North Carolina State University. Keeton's research has focused on enhancing the safety, nutritional value, and quality of meat products. He has authored or co-authored 81 refereed journal articles, 15 book chapters, secured two patents, and received more than $5.7 million in grant funding. **Correspondence:** jkeeton@tamu.edu



Dr. Michael E. Dikeman is Professor Emeritus of Animal Science and Industry at Kansas State University. His research has bridged the gap between basic meat science and efficient livestock production that consistently produces highly useable information. He attained national and international prominence through his cooperation on the Germplasm Evaluation and Utilization projects at the US Meat Animal Research Center. Dikeman's research has had significant impact, both economically and scientifically, on meat science and the livestock and meat industries, and in recognition of his achievements, he was recently inducted into the Meat Industry Hall of Fame.

Literature Cited

Avkan, N.F. 2015. Red meat and colorectal cancer. Oncol Rev. 9(1): 288. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4698595/. doi:10.4081/oncol.2015.288

Fleming, J., and P.M. Kris-Etherton. 2017. Controversies involving fat content of beef and human health. In: M.E. Dikeman, editor, Ensuring the safety and quality of beef: Volume 2. Quality. Burleigh Dodds Science Publishing, Cambridge, UK. p. 391–407.

Gilmore, L.A., R.L. Walzem, S.F. Crouse, D.R. Smith, T.H. Adams, V. Vaidyanathan, X. Cao, and S.B. Smith. 2011. 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. 141(6):1188–1194.

Kris-Etherton, P.M., and S. Yu. 1997. Individual fatty acid effects on plasma lipids and lipoproteins: Human studies. Am. J. Clin. Nutr. 65(5, Suppl)1628S–1644S.

Micha, R., S.K. Wallace, and D. Mozaffarian. 2010. Red and processed meat consumption and risk of incident coronary heart disease, stroke, and diabetes mellitus: A systematic review and meta-analysis. Circulation 121(21):2271–2283. doi:10.1161/CIRCULATIONAHA.109.924977

Pan, A., Q. Sun, A.M. Bernstein, M.B. Schulze, J.E. Manson, M.J. Sampfer, W.C. Willett, and F.B. Hu. 2012. Red meat consumption and mortality: results from 2 prospective cohort studies. Arch. Intern. Med. 172(7):555–563. doi:10.1001/archinternmed.2011.2287

Pan, A., Q. Sun, A.M. Bernstein, M.B. Schulze, J.E. Manson, W.C. Willett, and F.B. Hu. 2011. Red meat consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. Am. J. Clin. Nutr. 94:1088–1096.

Rajpathak S.N., J.P. Crandall, J. Wylie-Rosett, G.C. Kabat, T.E. Rohan, and F.B. Hu. 2009. The role of iron in type 2 diabetes in humans. Biochem. Biophys. Acta 1790:671–681.

Reinagel, M. 2013. Color confusion: Identifying red meat and white meat. Food & Nutrition, 2 Jan. 2013. https://foodandnutrition.org/january-february-2013/color-confusion-identifying-red-meat-white-meat/.

Roussell, M.A., A.M. Hill, T.L. Gaugler, S.G. West, J.P. Heuvel, P. Alaupovic, P.J. Gillies, and P.M. Kris-Etherton. 2012. Beef in an optimal lean diet study: Effects on lipids, lipoproteins, and apolipoproteins. Am. J. Clin. Nutr. 95(1):9–16.

Seman, D.L., D.D. Boler, C.C. Carr, M.E. Dikeman, C.M. Owens, J.T. Keeton, T.D. Pringle, J.J. Sindelar, D.R. Woerner, and T.H. Powell. 2017. Lexicon for meat science & technology allied fields. Meat Mus. Biol.

Sinha, R., A.J. Cross, B.I. Graubard, M.F. Leitzmann, and A. Arthur Schatzkin. 2009. Meat intake and mortality: A prospective study of over half million people. Arch. Intern. Med. 169(6):562–571. doi: 10.1001/archinternmed.2009.6

Smith, S.B., and D.R. Smith. 2014. Chemical and physical characteristics of meat: Adipose tissue. In: C. Devine and M. Dikeman, editors, Encyclopedia of meat sciences 2e. Vol. 1. Elsevier Science Publishers, Oxford. p. 222–234.

Turner, N.D., and S.K. Lloyd. 2017. Association between red meat consumption and colon cancer: A systematic review of experimental results. Exp. Biol. Med. 242(8):813–839. doi:10.1177/1535370217693117

USDA-ARS. 2017. National Nutrient Database for Standard Reference. Release 28. (https://ndb.nal.usda.gov/ndb/search/list; accessed 3 Apr. 2017).

Wang, X., X. Lin, Y.Y. Ouyyang, J. Liu, G. Zhao, A. Pan, and F.B. Hu. 2016. Red and processed meat consumption and mortality; dose–response meta-analysis of prospective cohort studies. Public Health Nutr. 19(5):893–905.