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Introductory Chapter: Meat Science and Human Nutrition

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1. Introduction

Meat holds a pivotal position among most of the communities. Meat is viewed as a sustenance of high nutritive incentive as its protein has 70% of biological availability in the body, and therefore it is frequently seen as the main food while planning meals. It is comparatively a good source of metabolically active iron and furthermore enhances its absorption from other food sources, its amino acid composition supplements the nutrition of many plant foods, and it is a concerted supply of vitamin B complex, including vitamin B₁₂, which is not present in plant foods. Therefore, meat and meat products are preferred to fulfill protein requirements [1].

2. Meat as a source of protein

Human prerequisites for protein have been altogether researched throughout the years and are assessed to be 55 g for each day for a grown-up male and 45 g for female. There is a higher need in different malady states and states of strain. These quantities allude to protein of what is named “good quality” and exceedingly palatable; generally, the sum ingested must be expanded proportionately to recompense for poor quality and lower palatability [2]. Generally, the muscle comprises of around 75% water, 20% protein, and 3% fat. Proteins are the real segment of the dry matter of lean meat. Nine of the amino acids in proteins are basic (or semi-fundamental) in light of the fact that the human body is unable to produce them and thus should be taken up in diet [1]. Consequently, the prerequisite for dietary protein comprises of two segments: (a) necessity for the nutritiously basic amino acids and (b) the need to meet the prerequisite for non-particular nitrogen keeping in mind the end goal to supply

the nitrogen fundamental for the supply of the healthy nonessential amino acids and other physiologically essential nitrogen-containing chemical compounds (nucleic acids, creatine, and porphyrins). Proteins are separated into their constituent amino acids in a process called digestion, which are then consumed and utilized for the biosynthesis of endogenous proteins [2]. These are fundamental for the human body in different capacities with respect to the development and repairing of the tissues, for the correct elements of the antibodies and for the control of catalysts and hormones [3]. There exists a tremendous variation in amino acid profile among different food sources, and it depends upon the unique mechanism of protein synthesis. The nutrition-delivering attribute of a protein depends upon the capacity of satisfying the human body needs [4]. Low-quality dietary proteins demonstrate an imbalanced proportion of fundamental amino acids; the most missing is known as the limiting amino acid [5]. The amino acid arrangement of meat protein is generally consistent paying little heed to the cut or organ from which the meat is procured. An outstanding exemption is for meats containing a lot of connective tissue, due to the unique amino acid profile of collagen and elastin. Meat contains mostly elevated amounts of the key essential amino acids, lysine, threonine, and tryptophan, and sulfur-containing amino acids (methionine, cysteine, homocysteine, and taurine) [6]. Protein quality is typically characterized by the amino acid profile of egg protein, which is viewed as a standard. It isn't amazing that animal proteins, for example, meat, milk, and cheese, have a tendency to be of a higher protein quality than plant proteins. Animal proteins have a superior palatability (95%) contrasted with plant proteins (80–90%) [7]. The lower digestibility of plant proteins is due to the fact that plant proteins are always present enclosed in a polysaccharide network that resists the proteolytic enzymes to interact with the food protein. A solid nourishment requires an adjusted blend of various sustenance proteins. By consolidating plant and animal sustenance, the dietary nature of the protein can be expanded on account of the supplementing impact [8].

3. Fat

Fat is the wealthiest dietary wellspring of vitality and supplies basic nutrients, for example, basic unsaturated fats, and in addition precursors of other nutrients that control various physiological processes (e.g., prostaglandins) and retain fat-based vitamins (A, D, E, and K) [9]. Additionally, fat has a conclusive significance as the most dense energy source for the body, as obsession and also a security of the organs and as wellspring of unsaturated fats which again go about as auxiliary component of cell films [10]. Fat additionally gives acceptability and flavor to nourishment. In the correct extents, it is subsequently a basic segment of any adjusted eating regimen, and consequently the level of fat decrease must not just consider tactile or mechanical factors yet it should likewise be, for example, to keep away from loss of wholesome advantages [11]. Meat is taken a gander at basically in light of its fat substance being for the most part included under the heading of fatty nourishments [12]. The fat in animals is principally found in their fatty tissue and is recognized as terminal fat (to a great extent, subcutaneous fatty tissue), intermuscular and intramuscular fat [13]. The remainder of these is called marbling. The measure of intermuscular and terminal fat present in a meat cut shifts, contingent upon the fat discharge of the animal and how the cut has been trimmed. As opposed to the far-reaching conviction that animal fat is for the most part made out of

saturated fatty acids (SFA), generally 50% of the fatty acids in meat are unsaturated. Meat lipids more often than not contain under 50% SFA and up to 70% (hamburger 50–52%, pork 55–57%, sheep 50–52%, and chicken 70%) unsaturated fats. Meat unsaturated fat synthesis is impacted by hereditary elements, in spite of the fact that to a lower degree than dietary components [14]. The level of leanness likewise affects the meat unsaturated fat synthesis. The substance of saturated and monounsaturated unsaturated fatty acids (MUFA) increments speedier with expanding largeness than does the substance of polyunsaturated unsaturated fatty acids (PUFA), bringing about a decline in the relative extent of PUFA and therefore in the polyunsaturated/saturated fatty acid (P/S) proportion [15]. The impact of largeness on the P/S proportion can be disclosed to a substantial degree by contrasts in the fatty acids arrangement of the real lipid portions and the relative commitment of these parts to add up to lipids [16]. Muscle lipids are made out of polar lipids, basically phospholipids situated in the phone layers, and impartial lipids comprising essentially of triacylglycerols in the adipocytes that are situated along the muscle filaments and in the interfascicular zone [17]. A little measure of triacylglycerols is additionally present as cytosolic beads in the muscle strands. The substance of phospholipids in the muscle is moderately autonomous of the aggregate fat substance and differs in the vicinity of 0.2 and 1% of muscle weight. Be that as it may, the substance of muscle triacylglycerols is emphatically identified with the aggregate fat substance and differs from 0.2 to more than 5% [18]. Phospholipids are especially rich in PUFA, though triacylglycerols contain bring-down measures of PUFA [8]. Since phospholipids are layer parts, their extent of SFA to unsaturated fats is entirely controlled so as to keep up film properties. Despite the fact that the PUFA substance of triacylglycerols can be impacted by dietary elements, especially in monogastrics, it is weakened once more by fatty acid union comprising of SFA and MUFA, accordingly, causing a decrease in the P/S proportion with expanding fat testimony [19]. The most omnipresent fatty acids in meat are oleic (C18:1), palmitic (C16:0), and stearic (C18:0) acid. Linoleic acid (C18:2n-6) is the transcendent PUFA (0.5–7%), trailed by alpha-linolenic acid (C18:3n-3). Trans-fatty acids involve beneath 0.5% of aggregate fatty acids over a wide range of meat from monogastric animals; in ruminant meats they speak to around 2–4% [20]. The biggest piece of soaked, monounsaturated, and polyunsaturated fatty acids are provided by the eating routine and however can likewise be incorporated in the body with exemption of the n-3 and n-6 fatty acids [21]. Thusly, these two gatherings of PUFAs are essential and must be provided by the sustenance. Meat can add to the supply with physiologically essential long-chain polyunsaturated n-3 fatty acids (LC n-3 PUFA), i.e., eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA), and docosahexaenoic acid (DHA), which appeared to apply different valuable well-being impacts, in light of the fact that meat is much more regularly devoured than fish [22]. Because of the extremely restricted in vivo combination of EPA and DHA from dietary alpha-linolenic acid in grown-up people, animals can be viewed as a transformer of alpha-linolenic acid to EPA and DHA through their amalgamation and following stockpiling in their muscles [23]. EPA and DHA are principally consolidated into muscle tissue phospholipids. In this way, lean meat should be considered when dietary LC n-3 PUFA admissions are resolved [24]. Fatty fish and fish are known to be a rich wellspring of the LC n-3 PUFA, bringing about general well-being proposals for consistent utilization of fatty fish [25]. Be that as it may, fatty fish has its negative perspectives too. Harmful mixes, for example, fat-dissolvable methyl mercury, dioxins, and polychlorinated biphenyls, are found in fatty fish. Moreover, the world's seas are intensively fished, abandoning a few species in peril of termination [26]. Hence elective nourishment sources are being

produced, empowered by the presentation of nutritious and well-being claims for utilitarian sustenance rich in LC n-3 PUFA [27]. These comprise of processed foods enriched with LC n-3 PUFA from microalgal and different sources and meat, milk and eggs from domesticated animals bolstered n-3-rich weight control plans. Advance improvement of meat with the LC n-3 PUFA might be a functional other option to expand the utilization of fish as a method for expanding populace admissions of LC n-3 PUFA [28].

4. Meat vitamins

Vitamins are a mind-boggling gathering of natural intensifiers that are by and large present in little amounts in foodstuffs [29]. Vitamins are critical as cofactors in enzymatic procedures and furthermore have hormonal role. Generally, vitamins have been characterized based on their dissolvability in either lipid or fluid solvents, and they are along these lines comprehensively isolated into fat- and water-dissolvable vitamin classifications [30]. Fat-solvent vitamins have a tendency for the most part to be reserved in the liver and fat tissues of animals, in relationship with reserved fat, and they are not promptly discharged [31]. Water-solvent vitamins, then again, have a tendency to be deposited to a far lesser degree in the body. The vitamins contained in animal and human eating methodologies are prevalently gotten from either plant or microbial source. Animal cells keep up the capacity for a new combination of a few vitamins, for example, vitamin D and, contingent upon the species included, niacin and ascorbate and additionally the capacity to change over forerunners (provitamins) to their dynamic frame. Moreover, commensal microorganisms in both the ruminant and nonruminant stomach-related tract can fill in as wellspring of vitamins, for example, vitamin K and the water-dissolvable B-complex vitamins [32]. Meat has for some time been perceived as a decent wellspring of B vitamins for human nourishment. Vitamin B6 exists in six structures: pyridoxal (PL), pyridoxine (PN), pyridoxamine (PM), and their phosphate subordinates: pyridoxal 5'-phosphate (PLP), pyridoxine 5'-phosphate (PNP), and pyridoxamine 5'-phosphate (PMP) [33]. PLP is the dynamic coenzyme shape and is the most essential frame in human digestion. It assumes a key part in the capacity of roughly 100 compounds that catalyze basic synthetic responses in the human body [34]. For instance, PLP works as a coenzyme for glycogen phosphorylase, a chemical that catalyzes the arrival of glucose put away in the muscle as glycogen [8]. A significant part of the PLP in the human body is found in the muscle bound to glycogen phosphorylase [35]. PLP is additionally a coenzyme for responses used to create glucose from amino acids, a procedure known as gluconeogenesis. Vitamin B1, otherwise called thiamine, is basic for ordinary cell capacities, development, and advancement. Thiamine in its coenzyme frame, thiamine diphosphate, assumes an urgent part in typical starch digestion, in which it takes part in the decarboxylation of pyruvic and α -ketoglutaric acids and in the usage of pentose in the hexose monophosphate pathway [36]. People and different well-evolved animals can't make thiamine and along these lines must acquire the vitamin from exogenous sources by means of intestinal retention [12]. Meat has been perceived as a decent wellspring of thiamine. Vitamin B2, generally named riboflavin, is an antecedent of flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD). FMN and FAD are coenzymes for various oxidases and dehydrogenases in eukaryotic cells. Vitamin B12 is the biggest and most complex of the considerable number of vitamins [37]. The structure of B12 depends on a corrin

ring, which is like the porphyrin ring found in heme, chlorophyll, and cytochrome. The focal metal particle is cobalt (Co^{2+}). Hence, cobalamin is the term used to allude to mixes having B12 action [38]. Methylcobalamin and 5-deoxyadenosyl cobalamin are the types of vitamin B12 utilized as a part of the human digestion. Vitamin B12 is particularly synthesized by microorganisms or by consolidation of some microbial constituents into nourishments. In ruminants, vitamin B12 is synthesized inside the rumen and consumed through the stomach-related tract preceding being transported by means of blood to body tissues. Ruminant items (meat and milk) constitute the significant normal wellspring of vitamin B12 for people [13]. Niacin is an essential component of coenzymes NAD and NADP, which act as a hydrogen donor or electron acceptor and required by approximately 200 enzymes primarily dehydrogenases. Pantothenic acid functions in the body as a component of CoA and 4'-phosphopantetheine [39]. Biotin functions in cells by covalently binding with enzymes and thus is considered as coenzyme. In addition, biotin functions in non-coenzyme roles including possible roles in cell proliferation and gene expression. Folate is involved in the metabolism of several amino acids, including histidine, serine, glycine, and methionine [11].

5. Minerals and trace elements

Meat also contains minerals and vitamins in addition to other nutrients like protein and fat. They are considered an essential part of diet as the body is unable to synthesize them, and they are involved in important life-sustaining metabolic pathways [1]. The most abundantly found minerals in meat are discussed below.

5.1. Iron

The quantity of iron consumed from the daily food intake relies upon an array of factors including its compound structure, the concurrent presence of other food components that can upregulate or downregulate its absorption, and different physiological variables of the individual including iron status. In general, while setting recommended daily intake of nutrients, the extent of iron ingested from a blended daily intake is normally taken as 10%. Half of the iron in meat is available as heme iron (in hemoglobin) [40]. Both heme iron and non-heme iron (inorganic iron) are abundantly found in meat; moreover, iron absorption-reducing factors (phytate, tannins, oxalate, and fibers) are also found missing in meat. The bioavailability of iron in the body is approximately 1–10% from non-heme, while heme iron contributes 20–25% in iron absorption. The iron absorbed from meat source does not only have increased absorption in the human body but also helps in the proper absorption of iron from other sources; therefore, the intake of meat is recommended along other sources to prevent the occurrence of anemia [7].

Besides, the admission of meat tissue is known to improve the retention of non-heme and heme iron, the supposed “meat factor.” The meat factor has not yet been distinguished but rather in a few examinations has been credited to cysteine or cysteine-containing peptides [41]. The possibility of cysteine and cysteine-containing peptides as the meat factor was additionally researched by others with the real discoveries that salt-dissolvable meat protein extricates containing for the most part myofibrillar proteins showed upgraded in vitro iron dialyzability [42]. Proposed, in the light of scientific explorations, it has been

observed that iron-binding peptides are created by pepsin processing and tie iron in a dissolvable frame in the stomach, anticipating connection with assimilation inhibitors, for example, phytic acid and polyphenols [14]. An eating regimen which is principally made out of vegetables, rice, beans, and corn is related with a poor iron bioavailability which in any event clarifies the high occurrence of weakness in under developed nations. Meat iron functions in the body as part of several proteins, including serving as a cofactor for dozens of enzymes. In many body proteins, iron is present as part of heme [43]. In other proteins, iron is found in a cluster with sulfur (2Fe-2S, 4Fe-4S, or 3Fe-4S), by itself as a single atom or as part of a bridge with oxygen. Heme proteins represent the largest group and include hemoglobin, myoglobin, and cytochromes involved in electron transport and enzymes such as monooxygenases, dioxygenases, and oxidases [44]. Iron-sulfur proteins also include several enzymes involved in electron transport, as well as a few non-redox enzymes such as aconitase and ferredoxin. Proteins that contain single iron atoms are mostly mono- and dioxygenase enzymes, and the one iron-oxygen bridge protein also is an enzyme, ribonucleotide reductase [15].

5.2. Copper

The essentiality of copper is due, in part, to its participation as an enzyme cofactor and as an allosteric component of enzymes. Superoxide dismutase (SOD) is copper- and zinc-dependent and is found in the cytosol of most cells of the body [45]. The phospholipid components of cells are extensively damaged by superoxide radicals. In other words, without SOD, superoxide radicals can form more destructive hydroxyl radicals that can damage unsaturated double bonds in cell membranes, fatty acids, and other molecules in cells. SOD therefore assumes a very important protective function. Cytochrome c oxidase contains three copper atoms per molecule [46]. One subunit of the enzyme contains two copper atoms and functions in electron transfer. Amine oxidases are also copper dependent. The oxidation of biogenic amines like tyramine, histamine, and dopamine into aldehydes and ammonium ions is catalyzed by amine oxidases, found both in the blood and in body tissues [47].

5.3. Zinc

Meat is the wealthiest wellspring of zinc in the eating routine and supplies 33% to one portion of the aggregate zinc admission of meat-eaters. It is notable that ingestion of dietary zinc from animal protein-based suppers is higher contrasted with whole grain-based dinners [48]. The fundamental reason is, as depicted for iron, the nonattendance of zinc ingestion hindering elements like phytate and filaments. It has been demonstrated that meat protein upgrades zinc retention from phytate-containing suppers because of its liking for zinc contrasted with phytate [49].

Zinc is present in all tissues of the body and is a component of more than 50 enzymes. Carbonic anhydrase, found primarily in the erythrocytes and in the renal tubule, is essential for respiration. Alkaline phosphatase contains four zinc atoms per enzyme molecule [50]. The enzyme, found mainly in the bone and in the liver (with small amounts in the plasma). *Alcohol dehydrogenase* also contains four zinc ions per enzyme molecule, with two of the four required

for catalytic activity and two required for structural purposes (protein conformation). This enzyme is important in the conversion of alcohols to aldehydes (e.g., retinol to retinal, which is needed for the visual cycle and night vision) [51]. Carboxypeptidase A, an exopeptidase secreted by the pancreas into the duodenum, is necessary to digest proteins. *Aminopeptidase* is also involved in protein digestion. Aminopeptidases contain one zinc atom, needed for catalytic activity. The enzyme cleaves amino acids from the amino terminal end of the protein or polypeptide that is being digested in the intestinal tract. Superoxide dismutase (SOD) found in the cell cytoplasm requires two atoms each of zinc and copper for function; zinc appears to have a structural role in the enzyme [52].

5.4. Manganese

Meat is a rich source of metabolically active manganese. At the molecular level, manganese, like other trace elements, can function both as an enzyme activator and as a constituent of metalloenzymes. Many transferases require manganese [53]. Two examples are xylosyl transferases and glycosyl (or called galactosyl) transferases. Glycosyl transferases catalyze the transfer of a sugar moiety such as galactose from uridine diphosphate (UDP) to an acceptor molecule. Manganese also activates prolidase, a dipeptidase with specificity for dipeptides [14]. The final step of collagen degradation is catalyzed by prolidase found in dermal fibroblasts. Arginase, which requires four manganese atoms per molecule, is a cytosolic enzyme responsible for urea formation and found in high concentrations in the liver [54]. The Mn^{2+} may allosterically activate arginase through a pH-mediated role. Low-manganese diets in animals have been shown to decrease arginase activity. Phosphoenolpyruvate carboxykinase (PEPCK), also activated by manganese, converts oxaloacetate to phosphoenolpyruvate and carbon dioxide. This reaction is important in gluconeogenesis [55]. The activity of phosphoenolpyruvate carboxykinase decreases in animals with manganese deficiency. Pyruvate carboxylase, which contains four manganese atoms, converts pyruvate to oxaloacetate, a TCA cycle intermediate [56].

5.5. Selenium

The trace component selenium (Se) is a significant supplement for human well-being. It is a part of various imperative selenoproteins including compounds required for such capacities as antioxidative guard, lessening of aggravation, thyroid hormone creation, DNA production, and proliferation [57]. It can likewise be changed over in the body to Se metabolites that are thought to decrease the blood supply to tumors and destroy malignancy cells [58]. The animals raised utilizing low-Se feedstuff store generally low centralizations of the mineral in their tissues and consumable items (e.g., milk, eggs), while animals nourished with a moderately high-Se eating routine yield sustenance items with substantially higher Se fixations. On account of the requirements of domesticated animals for Se to avoid crippling inadequacy disorders, Se (typically as Na_2SeO_3) is regularly utilized as a sustain supplement in animal nourishment in numerous parts of the world. This strategy has momentarily decreased the incidents of selenium deficiencies in North America and Europe during the last 25 years [59].

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References

- [1] McCance RA, Widdowson's EM. The Composition of Foods. 6th ed. Cambridge; UK: Royal Society of Chemistry; 2002
- [2] Abete I, Romaguera D, Vieira AR, Lopez de Munain A, Norat T. Association between total, processed, red and white meat consumption and all-cause, CVD and IHD mortality: A meta-analysis of cohort studies. *The British Journal of Nutrition*. 2014;**112**:762-775
- [3] Afshin A, Micha R, Khatibzadeh S, Mozaffarian D. Consumption of nuts and legumes and risk of incident ischemic heart disease, stroke, and diabetes: A systematic review and meta-analysis. *The American Journal of Clinical Nutrition*. 2014;**100**:278-288
- [4] Alexander DD, Weed DL, Miller PE, Mohamed MA. Red meat and colorectal cancer: A quantitative update on the state of the epidemiologic science. *Journal of the American College of Nutrition*. 2015;**34**(6):521-543. DOI: 10.1080/07315724.2014.992553
- [5] Aaslyng MD, Duedahl-Olesen L, Jensen K, Meinert L. Content of heterocyclic amines and polycyclic aromatic hydrocarbons in pork, beef and chicken barbecued at home by Danish consumers. *Meat Science*. 2013;**93**:85-91
- [6] Bellavia A, Larsson SC, Bottai M, Wolk A, Orsini N. Differences in survival associated with processed and with nonprocessed red meat consumption. *The American Journal of Clinical Nutrition*. 2014;**100**:924-929
- [7] Berger S, Raman G, Vishwanathan R, Jacques PF, Johnson EJ. Dietary cholesterol and cardiovascular disease: A systematic review and meta-analysis. *The American Journal of Clinical Nutrition*. 2015;**102**:276-294
- [8] Bouvard V, Loomis D, Guyton KZ, Grosse Y, Ghissassi FE, Benbrahim-Tallaa L, et al. Carcinogenicity of consumption of red and processed meat. *The Lancet Oncology*. Dec 2015;**16**(16):1599-1600. DOI: 10.1016/S1470-2045(15)00444-1
- [9] Elango R, Ball RO, Pencharz PB. Amino acid requirements in humans: With a special emphasis on the metabolic availability of amino acids. *Amino Acids*. 2009;**37**:19-27

- [10] Cassens RG, Briskey EJ, Hoekstra WG. Variation in zinc content and other properties of various porcine muscles. *Journal of the Science of Food and Agriculture*. 1963;**14**:427-432
- [11] Montagnese C, Santarpia L, Buonifacio M, Nardelli A, Caldara AR, Silvestri E, et al. European food-based dietary guidelines: A comparison and update. *Nutrition*. 2015;**31**:908-915
- [12] O'Sullivan TA, Hafekost K, Mitrou F, Lawrence D. Food sources of saturated fat and the association with mortality: A meta-analysis. *American Journal of Public Health*. 2013; **103**:e31-e42
- [13] Rouhani MH, Salehi-Abargouei A, Surkan PJ, Azadbakht L. Is there a relationship between red or processed meat intake and obesity? A systematic review and meta-analysis of observational studies. *Obesity Reviews*. 2014;**15**:740-748
- [14] Wyness L, Weichselbaum E, O'Connor A, Williams EB, Benelam B, Riley H, et al. Red meat in the diet: An update. *Nutrition Bulletin*. 2011;**36**:34-77
- [15] Wood JD, Richardson RI, Nute GR, Fisher AV, Campo MM, Kasapidou E, et al. Effects of fatty acids on meat quality: A review. *Meat Science*. 2003;**66**:21-32
- [16] Williamson CS, Foster RK, Stanner SA, Buttriss JL. Red meat in the diet. *Nutrition Bulletin*. 2005;**30**:323-355
- [17] Moeller A, MacNeil SD, Ambrose RF, Que Hee SS. Elements in fish of Malibu Creek and Malibu Lagoon near Los Angeles, California. *Marine Pollution Bulletin*. 2003;**46**:424-429
- [18] Piironen V, Toivo J, Lampi AM. New data for cholesterol contents in meat, fish, milk, eggs and their products consumed in Finland. *Journal of Food Composition and Analysis*. 2002;**15**:705-713
- [19] Li D, Siriamornpun S, Wahlqvist ML, Mann NJ, Sinclair AJ. Lean meat and heart health. *Asia Pacific Journal of Clinical Nutrition*. 2005;**14**:113-119
- [20] Lombardi-Boccia G, Aguzzi A, Cappelloni M, Di Lullo G, Lucarini M. Total-diet study: Dietary intakes of macro elements and trace elements in Italy. *British Journal of Nutrition*. 2003;**90**:1117-1121
- [21] Dunshea FR, D'Souza DN, Pethick DW, Harper GS, Warner RD. Effects of dietary factors and other metabolic modifiers on quality and nutritional value of meat. *Meat Science*. 2005;**71**:8-38
- [22] Klurfeld DM. Research gaps in evaluating the relationship of meat and health. *Meat Science*. 2015;**109**:86-95
- [23] Givens DI, Kliem KE, Gibbs RA. The role of meat as a source of n-3 polyunsaturated fatty acids in the human diet. *Meat Science*. 2006;**74**:209-218
- [24] Sahlin A, House JD. Enhancing the vitamin content of meat and eggs: Implications for the human diet. *Canadian Journal of Animal Science*. 2006;**86**:37-48

- [25] Lombardi-Boccia G, Lanzi S, Aguzzi A. Aspects of meat quality: Trace elements and B vitamins in raw and cooked meats. *Journal of Food Composition and Analysis*. 2005;**18**:39-46
- [26] LR MD. *Vitamins in Animal and Human Nutrition*. 2nd ed. Iowa: Iowa State University Press; 2000
- [27] Rivlin RS. Riboflavin. In: Bowman BA, Russell RM, editors. *Present Knowledge in Nutrition*. Washington: ILSI Press; 2001. pp. 191-198
- [28] Said HM, Ortiz A, Subramanian VS, Neufeld EJ, Moyer MP, Dudeja PK. Mechanism of thiamine uptake by human colonocytes: Studies with cultured colonic epithelial cell line NCM460. *American Journal of Physiology. Gastrointestinal and Liver Physiology*. 2001;**281**: G144-G150
- [29] Tilman D, Clark M. Global diets link environmental sustainability and human health. *Nature*. 2014;**515**:518-522
- [30] Calder PC, Yaqoob P. Omega-3 polyunsaturated fatty acids and human health outcomes. *BioFactors*. 2009;**35**:266-272
- [31] McEvoy CT, Temple N, Woodside JV. Vegetarian diets, low-meat diets and health: A review. *Public Health Nutrition*. 2012;**15**:2287-2294
- [32] Mozaffarian D, Appel LJ, Van Horn L. Components of a cardioprotective diet: New insights. *Circulation*. 2011;**123**:2870-2891
- [33] Williams P. Nutritional composition of red meat. *Nutrition and Dietetics*. 2007;**64**: S113-S119
- [34] Storcksdieck S, Bonsmann G, Hurrell RF. Iron-binding properties, amino acid composition, and structure of muscle tissue peptides from in vitro digestion of different meat sources. *Journal of Food Science*. 2007;**72**:19-28
- [35] Razminowicz RH, Kreuzer M, Scheeder MRL. Quality of retail beef from two grass-based production systems in comparison with conventional beef. *Meat Science*. 2006;**73**:351-361
- [36] Howe P, Meyer B, Record S, Baghurst K. Dietary intake of long-chain ω -3 polyunsaturated fatty acids: Contribution of meat sources. *Nutrition*. 2006;**22**:47-53
- [37] Given DI, Shingfield KJ. Food derived from animals: The impact of animal nutrition on their nutritive value and ability to sustain long-term health. *Nutrition Bulletin*. 2004;**29**:325-332
- [38] Rhee KS. Fatty acids in meats and meat products. In: Chow CK, editor. *Fatty Acids in Foods and their Health Implications*. 2nd ed. New York: Marcel Dekker; 2000. pp. 83-108
- [39] Fang X, An P, Wang H, Wang X, Shen X, Li X, et al. Dietary intake of heme iron and risk of cardiovascular disease: A dose-response meta-analysis of prospective cohort studies. *Nutrition, Metabolism, and Cardiovascular Diseases*. 2015;**25**:24-35

- [40] White DL, Collinson A. Red meat, dietary heme iron, and risk of type 2 diabetes: The involvement of advanced lipoxidation endproducts. *Advances in Nutrition*. 2013;**4**:403-411
- [41] Bastide NM, Chenni F, Audebert M, Santarelli RL, Tache S, Naud N, et al. A central role for heme iron in colon carcinogenesis associated with red meat intake. *Cancer Research*. 2015;**75**:870-879
- [42] Akiba S, Murata T, Kitatani K, Sato T. Involvement of lipoxygenase pathway in docosa-pentaenoic acid-induced inhibition of platelet aggregation. *Biological & Pharmaceutical Bulletin*. 2000;**23**:1293-1297
- [43] Pereira PMDCC, Vicente AFDRB. Meat nutritional composition and nutritive role in the human diet. *Meat Science*. 2013;**93**:586-592
- [44] McNeill S, Van Elswyk ME. Red meat in global nutrition. *Meat Science*. 2012;**92**:166-173
- [45] Baena Ruiz R, Salinas Hernández P. Diet and cancer: Risk factors and epidemiological evidence. *Maturitas*. 2014;**77**:202-208
- [46] Larsen CS. Animal source foods and human health during evolution. *The Journal of Nutrition*. 2013;**133**:3893-3897
- [47] Ulijaszek SJ, Mann N, Elton S. *Evolving Human Nutrition: Implications for Public Health*. Vol. 64. Cambridge University Press; 2012. ISBN: 9781139046794. <https://doi.org/10.1017/CBO9781139046794>
- [48] Leonard WR, Snodgrass JJ, Robertson ML. Effects of brain evolution on human nutrition and metabolism. *Annual Review of Nutrition*. 2007;**27**:311-327
- [49] McHenry HM, Coffing K. Australopithecus to homo: Transformations in body and mind. *Annual Review of Anthropology*. 2000;**29**:125-146
- [50] Leonard WR. Dietary change was a driving force in human evolution. *Scientific American*. 2002;**287**:106-116
- [51] Wang WJ, Crompton RH. The role of load-carrying in the evolution of modern body proportions. *Journal of Anatomy*. 2004;**204**:417-430
- [52] Speth JD. Early hominid hunting and scavenging: The role of meat as an energy source. *Journal of Human Evolution*. 1989;**18**:329-343
- [53] Leroy F, Praet I. Meat traditions. The co-evolution of humans and meat. *Appetite*. 2015;**90**:200-211
- [54] Food and Agriculture Organization of the United Nations (FAO). *World Livestock 2011: Livestock in Food Security*. Rome: FAO; 2011
- [55] Higgs JD. The changing nature of red meat: 20 years of improving nutritional quality. *Trends in Food Science and Technology*. 2011;**11**:85-95
- [56] McAfee AJ, McSorley EM, Cuskelly GJ, Moss BW, Wallace JM, Bonham MP, et al. Red meat consumption: An overview of the risks and benefits. *Meat Science*. 2010;**84**:1-13

- [57] Chanson A, Brachet P, Grolie P, Rock E. Micronutrient intakes from meat. *Sciences des Aliments*. 2003;**23**:47-55
- [58] Bou R, Guardiola F, Padró A, Pelfort E, Codony R. Validation of mineralization procedures for the determination of selenium, zinc, iron and copper in chicken meat and feed samples by ICP-AES and ICP-MS. *Journal of Analytical Atomic Spectrometry*. 2004;**19**:1361-1369
- [59] Raymann MP. The importance of selenium in human health. *Lancet*. 2000;**356**:233-241