REVIEW ARTICLE

Risky Benefits and Beneficial Risks of Animal Protein

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Abstract

The importance of protein as a source of essential macronutrients cannot be overstressed. Adequate amounts of protein in diets have been shown to reduce weight, improve cardiometabolic risk factors, attenuating fat-free mass and waist circumference and markers of blood glucose. Unfortunately, higher animal protein has been indicted with increased mortality as well as disease risks such as cancer development and cardiovascular diseases. However, the results have always remained unduplicated, creating suspicion about the authenticity of the claims. This review aims to explore established differences between plant and animal proteins and unravel the risks and benefits associated with animal proteins to provide insights into future research activities involving animal protein and its potential limitations.

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1. Introduction

Animal proteins are rich in nutrients. They supply high-quality protein and are a good source of several vitamins, minerals, long fatty acids, bioactive compounds and trace elements, including B vitamins, Fe, Zn, Se, haem, eicosapentaenoic acid, docosahexaenoic acid, choline, carnitine, carnosine and anserine[1][2]. Moderate consumption of animal product has been reported to reduce the risk of micronutrient deficiency and the need for supplementation, owing to their amino acid profile, high protein digestibility, micronutrient bioavailability and density, thereby contributing to dietary ‘robustness’[3][4].

The importance of protein as a source of essential macronutrient cannot be overstressed. Adequate amount of protein in diets has been shown to reduce weight, improve cardiometabolic risk factors, attenuating fat free mass and waist circumference and markers of blood glucose[5][6]. Unfortunately, higher animal protein has been indicted with increased mortality as well as disease risks such as cancer development and cardiovascular diseases[7][8][9], although the results have always remained unduplicated, creating suspicion about the authenticity of the claims. It has been established that there is no an independent link between animal-sourced protein intake and elevated cancer risk and there is no distinct clear association to elevated cardiovascular disease risks[10][11].

Disease risks and protein intake often involve other factors such as other nutrients consumed alongside the protein sources[12]. It is a complex relationship that has not been fully explored. For instance, men and women differ not only in their protein intake but also in the distribution between animal and plant protein intake. It has been noted that ladies consume about 61 % of their proteins from animal proteins and dairy products while men consume about 76 % of their protein from animal and dairy sources[13][14]

A relatively recent study on the relationship between animal and plant protein intake and overall diet quality in young adults concluded that young female and male adults consuming less than 70% of their protein from animal sources had higher scores on a modified Healthy Eating Index (HEI) compared to those consuming more than 70% of their protein from animal sources[14]. However, irrespective of protein intake sources, young male adults scored lower than female adults on the modified HEI, indicating that a lot remains to be explored about disease risks and protein sources (plant or animal). This review aims to explore established differences between plant and animal proteins as well as to unravel the risks and benefits associated with animal proteins in order to provide insights into future directions for research activities involving animal protein and its limitations.

2. Discussion

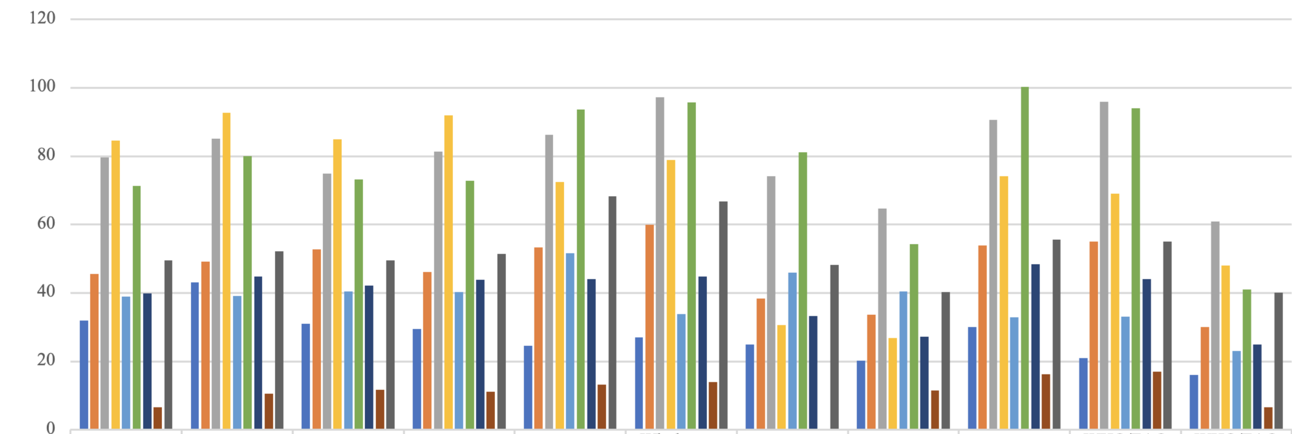
2.1. Health benefits of animal proteins

Proteins in animal and human nutrition are irreplaceable. They play essential roles in all physiological functions[15][16], and an adequate dietary intake of protein, providing nitrogen and amino acids is needed for regular tissue turnover and functional body proteins[17]. Of a particular importance in human nutrition are the essential amino acids, which the body cannot synthesize or in adequate amount, underscoring the importance of essential amino acids in determining the quality of a protein. The quality of a protein is also determined by its ability to meet the body's requirements, expressed as amino acid score. Amino acid score is the ratio of the content of essential or indispensable amino acids to the quantity required[15]. However, non-essential amino acids also play important roles in the body, such as being precursors for the synthesis of other amino acids.

Animal proteins are superior to plant proteins in terms of essential amino acid profile and in addition are more easily digestible than plant proteins, making them easily available for essential body functions. For instance, chicken eggs have always been used as reference for measuring the quality (biological value) of other proteins. On the other hand, the presence of antinutritive factors (tannins, trypsin inhibitor, lectins etc.) in plant proteins limit their bioavailability. Antinutritive factors require extensive processing of the food to reduce their impacts[18]. Plant cell walls also limit accessibility of plant proteins, being partially digested in the gastrointestinal tract of man, owing to the lack of the enzymes required for the breaking of fibers and cellulose[19][20].

Intake of animal protein has been shown to improve cognitive performance in school children average age 7.5 years than for total protein[21]. Animal protein intake has also been reported to be associated with higher lean body mass in women, whereas no such relationship existed for plant protein[22]. A comparison study conducted to investigate the effect of protein in combating sarcopenia and preserving muscle mass in ovariectomized rats showed that only a diet supplemented with animal protein slowed muscle decline and improved muscle structure in sedentary animals[23]. In another comparison study between soy protein and beef in middle-aged men at rest and after physical exercise, it was revealed that beef significantly induced higher response[24].

Moderate consumption of animal products has been shown to support physical and cognitive development in children as well as reducing the risk of micronutrient deficiencies in susceptible populations (adolescents and reproductive age women[25]. About two billion people across the globe have been reported to suffer from micronutrient deficiencies, which reduction has been linked to consumption of animal proteins, resulting in improved birth weight, reduced stunted growth and cognitive development[26][27][28], indicating the key roles animal proteins play in alleviating protein and micronutrient deficiencies[25]. Animal proteins are richer in essential amino acids than plant proteins. Figure 1 shows the comparison of the selected animal and plant protein dietary sources in terms of amino acid pattern, mg/g protein compared to the FAO/WHO reference protein[15][16][29], indicating that animal proteins have amino acid patterns closer to the requirements for human body, providing the essential amino acids in approximately adequate amount.



	Beef	Pork	Chicken	Cod	Chicken egg	Whole cow milk	Wheat	Wheat flour	Soybean	WHO/FAO ref.*	WHO/FAO ref.**
His	31,9	43,2	31	29,4	24,5	27	24,9	20,3	30,1	21	16
Ile	45,5	49,2	52,8	46,1	53,3	60	38,4	33,7	54	55	30
Leu	79,6	85,1	75	81,3	86,3	97,3	74,1	64,6	90,7	96	61
Lys	84,5	92,7	84,9	91,9	72,5	78,8	30,6	26,8	74,1	69	48
SAA	39	39,1	40,5	40,3	51,7	33,9	46	40,5	32,9	33	23
AAA	71,4	80	73,3	72,8	93,7	95,8	81,1	54,2	100,3	94	41
Thr	39,9	44,9	42,2	43,9	44,1	44,8	33,2	27,2	48,4	44	25
Trp	6,6	10,5	11,7	11,2	13,3	13,9		11,6	16,2	17	6,6
Val	49,6	52,2	49,6	51,5	68,2	66,7	48,3	40,2	55,6	55	40

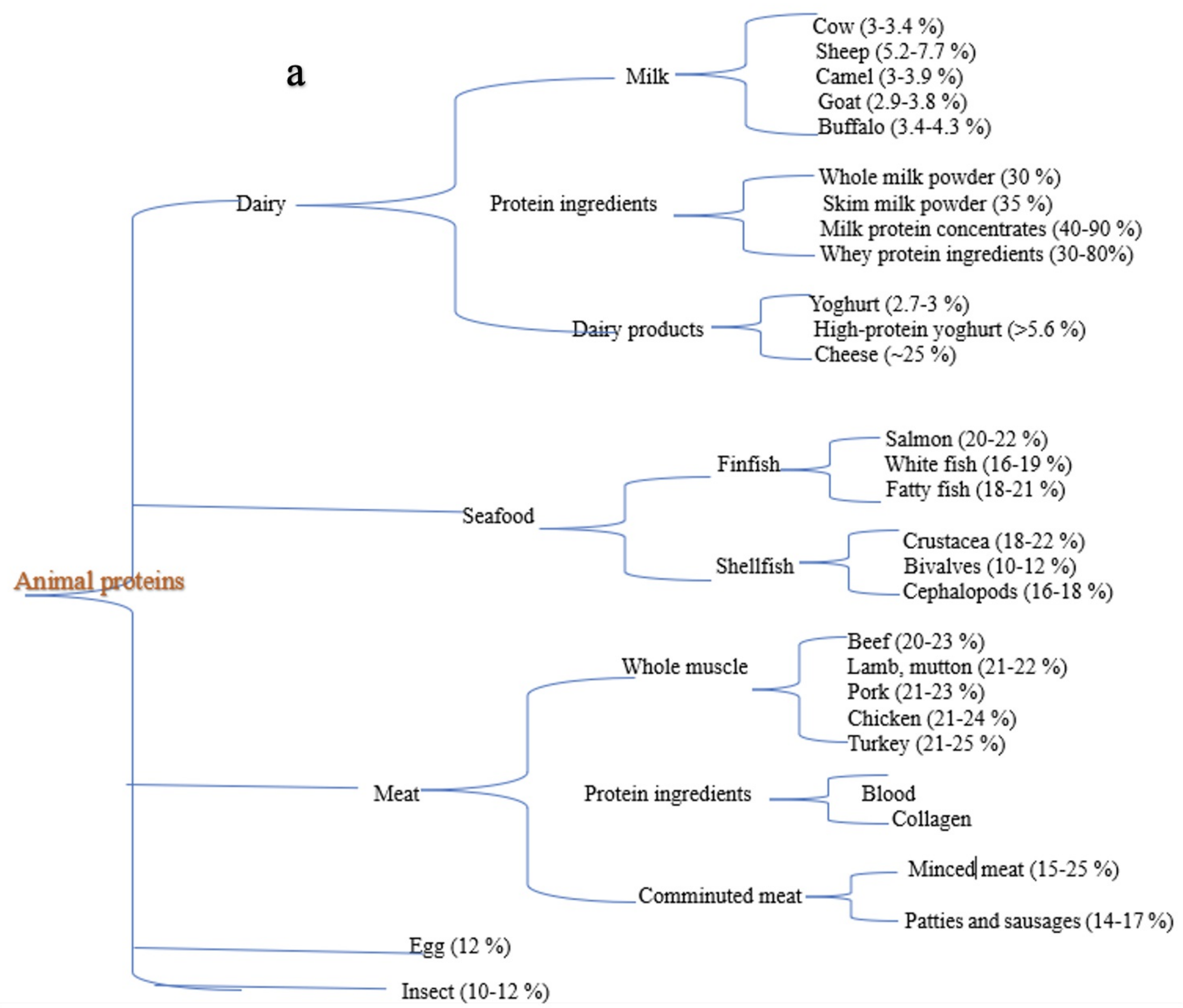
Figure 1. Amino acid pattern, mg/g protein of dietary animal and plant proteins compared to the FAO/WHO [16]reference protein; Raw animal products were used. Beef (tenderloin, 1/8 fat, all grades); pork (tenderloin, lean); chicken (breast meat only); for cod (Atlantic, fillet); wheat (soft red winter whole grain); wheat flour (white, unenriched); soybean (mature seeds, raw); *WHO/FAO reference infant; **WHO/FAO reference child 3+ years, adults; AAA = aromatic amino acids (i.e., phenylalanine and tyrosine); His = histidine; Ile = isoleucine; Leu = leucine; Lys = lysine; SAA = sulfur amino acids (i.e., methionine and cysteine); Thr = threonine; Trp = tryptophan; Val = valine[15][16][29]

2.2. Animal and plant proteins

Protein in human and animal diets can be broadly classified into plant and animal protein, depending on their sources. Proteins obtained from animal products are regarded as animal proteins or animal-sourced proteins, while those from plants or crops are regarded as plant proteins or plant-sourced proteins. Both animal and plant proteins are important sources of dietary protein for human and animals. However, they are different in some instances. Proteins may differ in their biological, chemical, functional, and nutritional characteristics depending on their source, molecular make-up and structures[30].

Plant-sourced proteins have attracted increased consumers' interest, based on concerns for ethical, sustainability or health issues, explaining why food industry keeps responding with many plant-sourced alternatives. Similar flavour and textual features were observed in early plant and animal proteins. However, plant proteins are inferior to animal proteins because they lack some essential amino acids such as lysine, which thus must be supplied through other means when fed, thereby making them of lower nutritional values than animal proteins. Digestibility is also slowed or reduced for plant proteins owing to their molecular structures. Notwithstanding, they are still known to be a good protein source for human and animals and can contribute to a balanced diet[30].

Animal proteins are considered as complete proteins because they contain all the essential amino acids which are absent or deficient in plant proteins. Animal-sourced proteins have higher nutritional quality than plant-based proteins, based on their amino acid profile, digestibility and ability to transport other important nutrients (such as iron and calcium). Animal-sourced proteins provide adequate nutrition for human and are essential for infants' physical and cognitive development, making animal proteins recommended sources in food and products[31]. The technological functionality such as foaming, gelling and emulsification, which gives food its appealing texture and sensory attributes, possessed by animal protein is superior to plant-sourced protein[32]. Commonly available and most widely used animal and plant proteins as well as emerging proteins such as insects, pseudocereals are presented in Figure 2. Most commonly used animal-sourced proteins in human nutrition include egg, meat, dairy and milk, with recent interest in insects.


a
Animal proteins
Dairy
Milk
Cow (3-3.4 %)
Sheep (5.2-7.7 %)
Camel (3-3.9 %)
Goat (2.9-3.8 %)
Buffalo (3.4-4.3 %)
Protein ingredients
Whole milk powder (30 %)
Skim milk powder (35 %)
Milk protein concentrates (40-90 %)
Whey protein ingredients (30-80%)
Dairy products
Yoghurt (2.7-3 %)
High-protein yoghurt (>5.6 %)
Cheese (~25 %)
Seafood
Finfish
Salmon (20-22 %)
White fish (16-19 %)
Fatty fish (18-21 %)
Shellfish
Crustacea (18-22 %)
Bivalves (10-12 %)
Cephalopods (16-18 %)
Meat
Whole muscle
Beef (20-23 %)
Lamb, mutton (21-22 %)
Pork (21-23 %)
Chicken (21-24 %)
Turkey (21-25 %)
Protein ingredients
Blood
Collagen
Comminuted meat
Minced meat (15-25 %)
Patties and sausages (14-17 %)
Egg (12 %)
Insect (10-12 %)

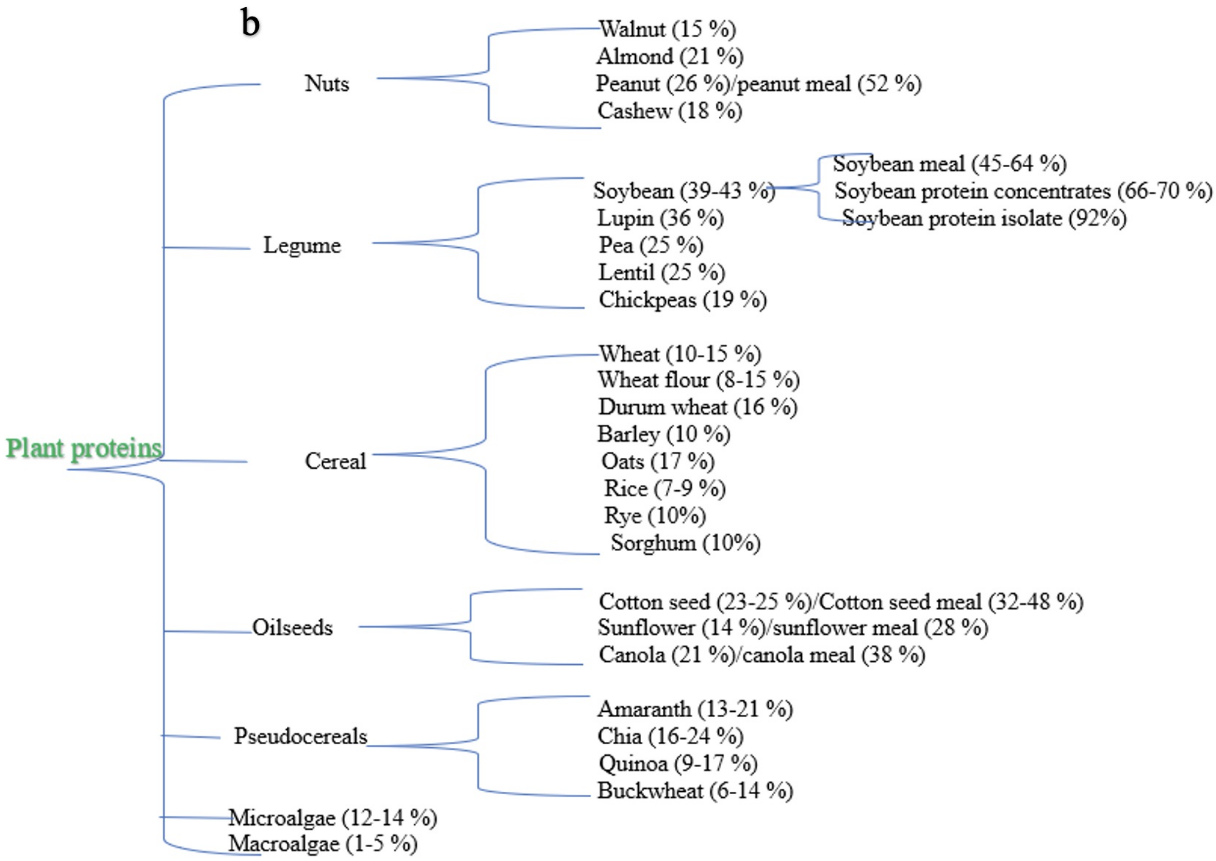


Figure 2. Animal and plant proteins contents: (a) animal proteins; (b) plant proteins. The values presented as percentages are protein concentrations in natural biological resources, per wet weight, except for the protein powder ingredients in per dry weight[30][33][34][35][36][37]

2.2.1. Dairy

The data presented in Figure 2 clearly shows that milk may contain between 3-8 % protein, depending on the species of animals from which it is obtained, underscoring the influence of genetical variation, farming systems, seasonality and feeding, which in turn may be responsible for variation in their amino acid composition. Dairy protein ingredients are extensively used in bakery products, foods for elderly, beverages, fish products, confectionary, meat, infant dietary products and dietetic foods. They are used in specialty products aimed at slimming, clinical and medical support and sports nutrition[38]. Dairy proteins can be grouped into whey proteins (approximately 20 % of the total proteins from cow) and casein (80 %,), phosphoproteins.

Bovine milk is the most consumed globally although non-bovine sources are also contributing significant amount and increasing in production and consumption[39]. Caseins provide micelles in milk, which supply calcium, phosphate and proteins in high concentrations that would otherwise be insoluble in water, thereby providing adequate nutrients for neonates. The relationship between protein and mineral components, responsible for their functional properties have been broadly utilized for producing dairy products such as cheeses, yogurts and cheeses. It has been noted that these unique technological and nutritional characteristics of caseins are difficult to replace with plant proteins[30]. Skim powder milk (about 30 % protein) and whole milk powder (about 24 % protein) are produced from dried skim and whole milk respectively.

2.2.2. Seafoods and eggs

The importance of seafood as a diverse and valuable protein source in human diet cannot be over-emphasized. Fish provides about 16 % of the global animal proteins[30]. Fish, a high-protein, low energy and total fat, especially saturated fat protein is rich in vitamins and minerals, required for growth and development. The qualities of avian eggs include complete supply of essential amino acids, outstanding digestibility and high nutritional value. Over 90 % of egg white dry matter is made of protein. Eggs generally are made up of about 75 % water and 12 % protein. Albumen (egg white) makes up about 50 % of the protein in egg. The egg yolk makes up about two-fifth of the protein, while eggshell and eggshell membrane share the remaining protein[30]. Processed egg powder ingredient and products are utilized in bakery, confectionery, and condiment products, bakeries being the largest user of whole eggs and separated yolks and whites. Egg products are used for forming abilities, for instance, egg white remains the reference for foaming properties when compared with other plant and animal protein products.

2.2.3. Meat

Muscle meat contains between 20 and 25 % protein, and its importance in human nutrition cannot be overstressed, consisting of relatively consistent protein content across species. Comminuted and reformed foods consisting of organs, muscle, or co-products, such as burgers, minced meat and sausages can be potentially substituted with plant-sourced protein products, where their functional properties such as fat and water binding capacity and meat emulsion formation can match that of plant-sourced protein products. However, their protein content is generally lower than the muscle meat cuts[30]. Also, aside possessing a complete nutritional quality based on complete essential amino acid profile, required for growth and development, meat contains additional benefits such as having essential minerals and vitamins including selenium, calcium, iron, vitamins B6, B12, and vitamin D. In meat, iron is usually present in the form of haem, which is easily and efficiently absorbed. Little wonder why moderate intake of lean meat is key to ensuring a healthy balanced diet[40], by the way, moderation is key in life, not just in protein consumption. Collagen, abundantly present in animals plays important roles in connective and structural functions in blood vessels, tendon, skin, cartilage and bone. Partial hydrolyzation or heat denaturation of collagen results in the production of gelatin, a versatile meat protein ingredient commonly used in food additives, used as thickener and stabilizer as well as in soup, sauce, frozen products, coating and edible film[30].

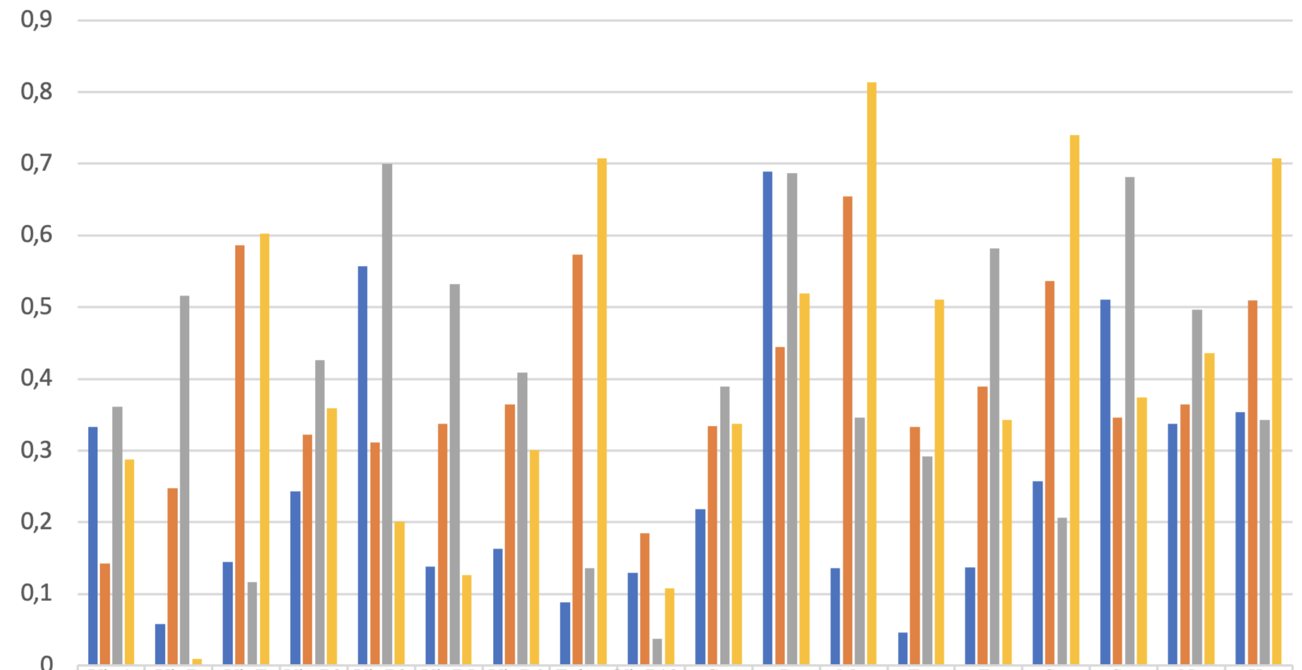
2.2.4. Insects

Insects may contain protein content ranging between 19 and 24 %, depending on the species in question, their feeding source, processing method and maturity age[30][41], concentrated in the cuticle layers (covering the epidermis) and the muscles. Insect-based proteins are used in human and animal nutrition although the interest is just growing globally. Insect consumption may be a common practice in some regions, global interest is just growing and processed protein ingredients may be a greater potential of insects[42].

Animal-sourced and plant-sourced proteins also have different physicochemical properties/functionalities. High hydrophobicity is usually associated with plant-sourced proteins. They are less-soluble and flexible than animal-sourced proteins, limiting their effective use in various food products. The limitation may be improved upon but it may induce amino acid sidechain modifications or structural amendments which may further reduce the bioavailability of amino acid in plant-sourced proteins[43][44]. Despite sophisticated technologies, processing techniques and creative formulations now available, there is not an effective replacement in terms of texture and mouthfeel to muscle foods, suggesting that a combination of both animal and plant proteins may be necessary as an immediate remedy to their respective limitations[45].

Proteins possess tertiary structures as a result of attractive and opposing molecular forces such as hydrogen bonding, electrostatic forces, conformational entropy, ion-pairing, van der Waals interactions and the hydrophobic effect. Protein folding is mainly brought about by the hydrophobic effect, resulting in the compactness of globular proteins. However, animal and plant proteins are structurally different because they have different polypeptide sequences and are within different native environments[46]. They have different secondary structural characteristics and hence, different tertiary structures, influencing their performance, functional and nutritional characteristics such as forming properties, gelation, emulsification, availability of essential amino acids, accessibility to the digestive system and fragmentation into peptides. Each protein source has several structural different classes of proteins. For instance, caseins and whey are classes of milk proteins, while caseins are disordered protein owing to low number or lack of disulphide bonds, their flexible and open structures with its constituents (β-, α S1-, α S2- and κ-caseins) forming casein micelle in milk, while whey protein (β-lactoglobulin) is a globular protein, existing as a dimer at neutral pH and as tetramers and octamers at acidic or basic pHs. Meat having three stromal, myofibrilla and sarcoplasmic muscle proteins, which are structurally different[30][47].

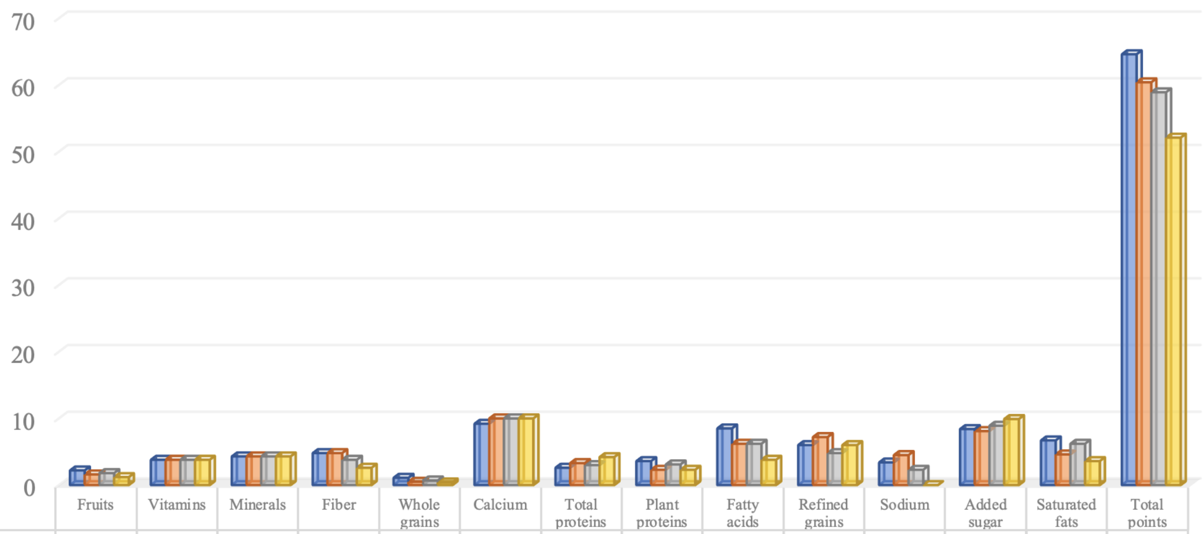
The relationship between source of dietary protein intake and micronutrient intake in young female and young male adults is shown in Figure 3. The data presented shows that plant protein intake is positively associated with vitamin E, B2, B6, folate, calcium, phosphorus, magnesium, iron, zinc, copper, selenium, sodium, and potassium intake in both sexes, while animal protein intake is positively associated with vitamins A, B2, B3, phosphorus, selenium, sodium, and potassium intake[14].



	Vit A (mcg/d)	Vit D (mcg/d)	Vit E (mg/d)	Vit B2 (mg/d)	Vit B3 (mg/d)	Vit B5 (mg/d)	Vit B6 (mg/d)	Folate (mcg/d)	Vit B12 (mcg/d)	Ca (mg/d)	P (mg/d)	Mg (mg/d)	Fe (mg/d)	Zn (mg/d)	Cu (mg/d)	Se (mcg/d)	Na (mg/d)	K (mg/d)
APIF	0,333	0,058	0,145	0,243	0,557	0,138	0,163	0,088	0,129	0,218	0,689	0,136	0,046	0,137	0,257	0,51	0,337	0,354
PPIF	0,142	0,248	0,586	0,322	0,311	0,337	0,364	0,573	0,185	0,334	0,445	0,655	0,333	0,389	0,537	0,346	0,364	0,509
APIM	0,361	0,516	0,117	0,426	0,7	0,532	0,409	0,136	0,037	0,389	0,687	0,346	0,292	0,582	0,206	0,682	0,496	0,343
PPIM	0,288	0,009	0,602	0,359	0,201	0,126	0,3	0,708	0,108	0,337	0,519	0,814	0,511	0,343	0,74	0,374	0,436	0,707

Figure 3. Bivariate correlations among dietary protein intake and micronutrients for young female and male adults; APIF = Animal protein intake (g/d) for female; PPIF= Plant protein intake (g/d) for female; APIM= Animal protein intake (g/d) for male; PPIM= Plant protein intake (g/d) for male[14]

Plant proteins are limited when compared with animal proteins in terms of essential amino profile and digestibility, which may negatively impact health and development, especially for neonates and children, necessitating recommendations for improvement through processing approaches, breeding and genetic modifications and fortification with essential amino acids[48][49][50]. Figure 4 shows modified healthy eating index for young female and male adults eating less than or more than 70% of proteins from animal sources[14].



	Fruits	Vitamins	Minerals	Fiber	Whole grains	Calcium	Total proteins	Plant proteins	Fatty acids	Refined grains	Sodium	Added sugar	Saturated fats	Total points
FE<70%AP	2,2	3,8	4,3	4,8	1,1	9,2	2,6	3,6	8,5	6	3,4	8,4	6,7	64,6
FE>70%AP	1,6	3,8	4,3	4,8	0,5	10	3,3	2,3	6,2	7,2	4,5	8,1	4,6	60,4
ME<70%AP	1,8	3,8	4,3	3,8	0,7	10	3	3,1	6,2	4,8	2,3	8,9	6,2	58,9
ME>70%AP	1,2	3,8	4,3	2,6	0,4	10	4,2	2,3	3,8	6	0	9,9	3,6	52,1

Figure 4. Modified healthy eating index for female and male; FE<70%AP = Young female adults eating less than 70% of proteins from animal sources; FE>70%AP = Young female adults eating more than 70% of proteins from animal sources; ME<70%AP = Young male adults eating less than 70% of proteins from animal sources; ME>70%AP = Young male adults eating less than 70% of proteins from animal sources[14].

2.3. Health and disease risks of animal proteins

It may be safe to assume that the dietary benefits of animal-sourced proteins are well-known. However, consumption of animal-sourced proteins and animal agriculture are currently indicted with issues, especially in developed high-income countries. Factors fueling such issues include concerns about their impacts on the climate change and environmental health, animal welfare and human health[51][52][53].

2.3.1. Disease risks

Among animal proteins red and processed meat have been specifically indicted with non-communicable diseases, including colorectal cancer, type 2 diabetes mellitus and cardiovascular disease[53][54][55]. On the other hand, white meat is regarded as being protective. The association of red meat and disease risks had led many global organisations to advocate for avoidance or reduction of red meat consumption[53][56]. Interestingly, the debate is not won yet, scientific literature debate is ongoing, calling for the evidence base for such recommendations, with a strong attention on the methodology used and the sources of information as well as their weighting. It is opined that food-based dietary guidelines should be based on comprehensive and methodologically sound analyses of health benefits and harms of these classes of proteins, not leaving behind the issues of food culture, accessibility, affordability, food traditions and other factors of sustainable diets[25][57][58][59], until then does it seem that this issue can be effectively laid to rest. Processed meat may have been condemned too early, arising perhaps from over-dependence on observational epidemiology and risk avoidance in food policy-making[59], undermining the importance of adequate consideration for the heterogenic nature of the type and intensity of processing of such products, which would have required wholistic and multidimensional approaches[60].

The Guidance for Cardiovascular Health Related to Animal-Based Protein Foods, Based on US Dietary Guidelines can be summarized under the subcategories: balance, variety, plant inclusion, fish and seafood inclusion, choice of lean meat and poultry cuts, and avoidance of processed meats and fried meats. It is recommended that the daily total protein food intake should be sufficient to support nutrient adequacy without compromising intake from other food groups, the protein foods should be mixed to include different subgroups and foods to support nutrient adequacy, and accommodate personal preferences, plant-based protein foods such as nuts, seeds and legumes should be included, between 2-3 servings of fish or seafood per week should be consumed, lean cuts of meat and poultry should be chosen, processed and high-temperature cooking meat and fish should be avoided[61][62][63].

People have often been advised when choosing animal protein foods, that they should avoid processed and/or fried animal products such as sausages and chicken nuggets[64] in order to avoid disease risks such as cardiovascular diseases. The risk of cardiovascular disease has been associated with animal proteins than with plant proteins. However, the functional mechanisms through which animal protein might be more toxic than plant proteins have not been fully explained and explored, and thus not yet fully understood[65][66]. It has been established that study of diet and disease risk (cardiovascular disease risks) is difficult, owing to the complex nature of cardiovascular diseases, linked with main causal components formed over years[67][68], coupled with diets being complex as well, containing several bioactive substances that may contribute to or inhibit cardiovascular diseases which are unevenly distributed across food groups and subgroups, as well as being often influenced by food production, processing and consumption patterns.

Figure 5 shows cancer development-associated agents in meat products, in raw meat products, formed during meat product processing, by contamination, modulating factors, use of processing spices or formed during digestion as reported in literature[59][69]. Substances or agents involved in meat processing linked with cancer development and cardiovascular diseases have been documented[69][70][71]. However, some of the substances reported are not peculiar to animal products, even though some of them are shown to be mutagenic, genotoxic or carcinogenic, it is not logical to singly hold them responsible for an effect of processed meat dietary intake on non-communicable diseases or cancer in general[59][72]. A lot remain to be understood about the effects of different substances in processed meat on human health[69][71].

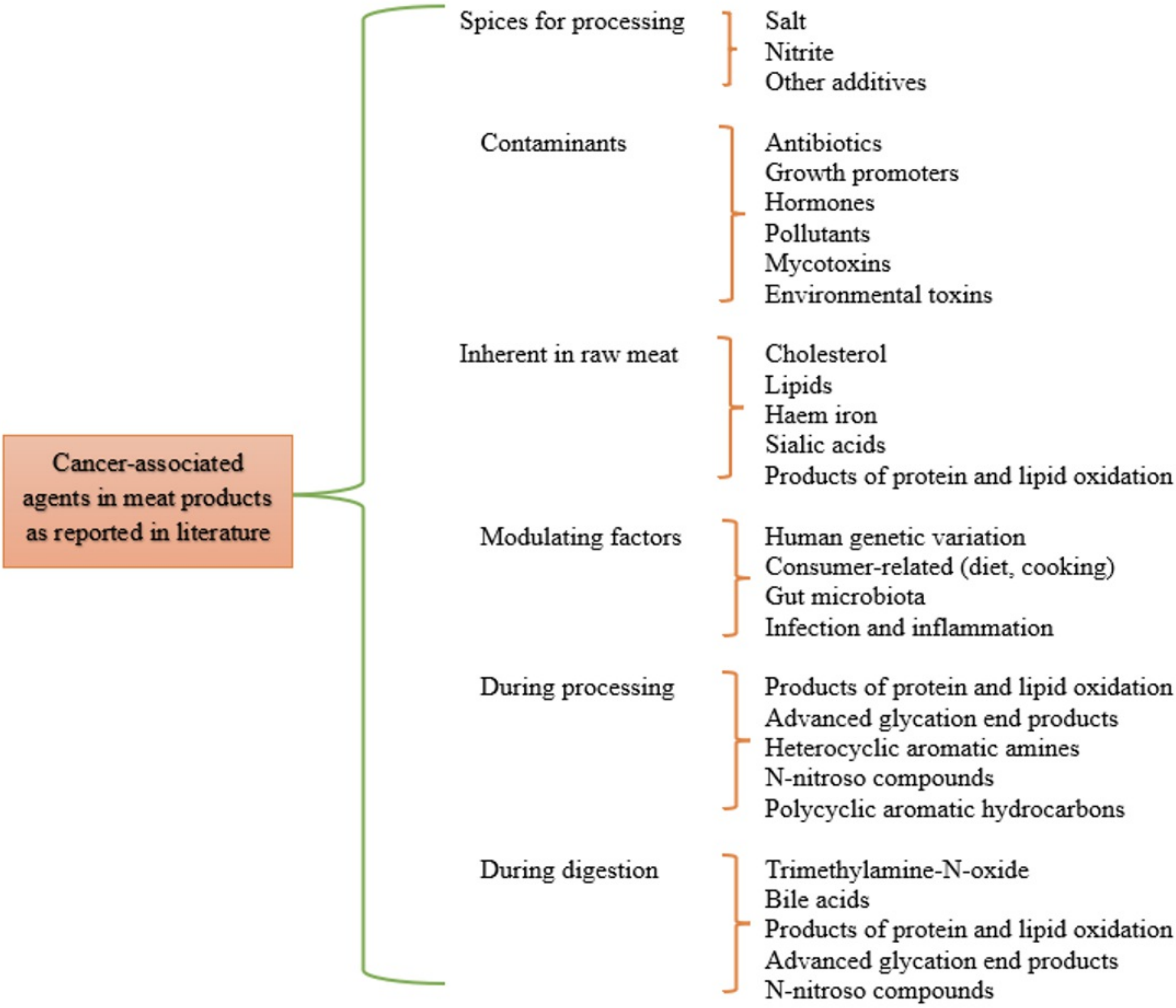


Figure 5. Cancer development-associated agents in raw meat products, formed during meat product processing, formed by contamination, modulating factors, use of processing spices or formed during digestion as reported in literature[59][69]

The heterogenous nature and inconsistent definition of meat processing contribute to the doubts cast against the results of disease-risks association of animal foods reported in literature. Most studies which associated animal products to disease risks do not adopt unform definition of animal product terminologies, which may be misleading. Also, the heterogenous nature of animal products more often than not are not taken into consideration. Lack of uniform classification of animal products[73] is a big problem to accepting the findings attributing animal products to disease risks. Processed meat has been described as further processing, which implies that the cooking of fresh meat prior to consumption is not regarded as processing but minimal processing. Hence, the products of such cooking are regarded as unprocessed meat products[59][73], corroborating the terms (processed and unprocessed meats) mostly used in nutritional epidemiological studies and dietary advice[55]. Unfortunately, lack of uniform definitions of animal food terminologies and the heterogenous nature of animal foods and their products cast a big question mark on accurate assessment of their intake and relationship with disease-risks, which is regarded as one of the limitations of nutritional epidemiology, on which most of the findings associating disease-risks with animal proteins are based[59][74]. Processing techniques and processing methods, involving physical and chemical treatments and a combination of both as well as inclusion of additives[60][75][76] are other factors that may contribute to disease-risks associated with animal proteins, which are less or inadequately considered in studies making attempts to unravel the relationships between animal proteins and disease risks.

Regarding the association of animal proteins and disease risks, particularly regarding processing of meat and meat products, it has been noted for instance, using the effect of cooking on meat protein digestion and the use of nitrite in meat processing, that meat can lead to beneficial and detrimental changes in nutritional value, and may be linked with the formation of potentially harmful compounds, the nature and concentrations which are not easily investigated, owing to complex interactions among additives, ingredients, adherence to good manufacturing practices and processing techniques[59]. In agreement with previous authors animal proteins and the effects of their processing on human health cannot and should not be generalized, and may not be as detrimental as widely perceived, that is not to deny the possibility of the claimed risks. In addition, it should be noted that in order to ensure animal food safety, a minimal processing of meat and meat products is required.

Several observational epidemiological studies have linked animal proteins (high consumption of red meat) with disease risks (non-communicable diseases). Low versus high dietary intake of processed or red meat was linked with decreased risk of al-cause mortality, coronary heart disease, type 2 diabetes and colorectal cancer[77][78][79]. It has been observed that the increased relative risk per unit change in dietary intake, or for the lowest versus highest dietary intake group is lower for unprocessed meat than for processed meat intake.

Several studies (meta-analyses) have also reported non-significant associations with dietary intake of unprocessed red meat, and it is worth noting that the largest effect sizes are reported for processed meat consumption and type 2 diabetes incidence, with most relative risk estimates greater than1.2, uncommon in nutritional epidemiology[54]. How much risk a person in a group bears when compared with another person in another group is revealed by a relative risk. Of note, however, is that relative risks should not be interpreted in isolation but together with absolute risks of the event(s) in question[80]. Despite the availability of findings suggesting disease risks of animal proteins, there has not been any negative association with white meat, especially from poultry, rather, their protective potentials have been reported[81]. Interestingly, a comprehensive study (meta-analysis) reported consistent favourable relationships between dietary intake of animal proteins versus non-consumption (vegetarians and vegans) and better mental adult health[82]. The authors indicated that the more rigorous their analysis the more the findings revealed positive and consistent results although other meta-analyses[83][84] reported otherwise.

Several studies have linked high consumption of animal food, particularly processed and red meat to disease risks such as obesity, diabetes mellitus, cardiovascular diseases, inflammation and cancer development[77][85][86][87][88][89]. Unfortunately, the specific contribution of animal protein to the effects has not been established[90][91], as only total proteins are analyzed in many studies while some others only differentiate between protein-rich foods without considering protein itself[17].

It is opined that nutritional epidemiology in its current form relies mainly on relatively weak methods, which requires significant improvements in scientific analysis, reporting, design and measurement[92], in addition to the potential bias in relative risk estimates limiting nutritional epidemiology, necessitating the need for more sophisticated approaches and models, since foods are not consumed in isolation[93]. Scientific literature questions the extent to which the relationship between the consumption of processed and red meat and colorectal cancer is confounded by dietary patterns[59]. A recent study which assessed the relationship between estimated dietary protein intake and cardiovascular disease, stroke and ischemic heart disease study, published by The American Journal of Clinical Nutrition revealed that neither plant nor animal protein consumption was linked with overall cardiovascular disease, ischemic heart disease or stroke incidence[94].

2.3.2. *Agricultural waste and animal food contamination*

Animal food contamination and generation of potential waste from animal agriculture are other concerns limiting animal protein intake, with implications on the environment and public health. Agricultural production generates large quantities of potential waste materials which contribute to climate change and environmental pollution. Animal agriculture has been implicated with significant contributions to climate change and environmental pollution.

The agricultural sector no doubt is one of the main sectors generating the largest quantities of solid wastes. Animal production solid wastes described as solid wastes generated from the production of livestock for whatever purposes, such as bedding/litter, animal carcasses; and food and meat processing solid wastes described as wastes produced from the processing of crop or animal products for human consumption, such as abattoir or slaughterhouses including hoofs, bones, feathers, banana peels, etc. are examples of broad classification of agricultural solid wastes. Interestingly, agricultural waste materials are generated from all aspects of agriculture, but not peculiar to animal agriculture. Table 1 shows the broad classifications of agricultural solid waste[95]. The problem of waste generated from animal agriculture becoming a nuisance is largely dependent on lack of proper awareness, improper orientation and governmental lackadaisical attitude in some parts of the world to effectively manage such wastes. The animal producers who strive to ensure animal food security and their safety are not always to blame. In some parts of the world, agricultural practices are left in the hands of uneducated farmers with no access to adequate extension services[96][97][98][99].

Table 1. Classification and causes or sources of agricultural solid wastes

Waste classification	Examples
Animal production	Bedding, carcasses, damaged feeders, damaged water-trough
Food and meat processing	Hoofs, bones, feathers, banana peels
Crop production	Husks, crop residues
On-farm medical	Syringes, disposable needles, vaccine containers or wrapper
Horticultural production	Grass cuttings, pruning wastes
Industrial agricultural	Cuttings
Chemical	Pesticide containers

In some parts of the world the generated waste accumulates indiscriminately in open places while they are burnt indiscriminately in some other places thereby constituting nuisance to global health. However, researchers including animal scientists are advocating for recycling of the potential agricultural wastes in order to reduce the cost of production, as well as to effectively manage the waste that otherwise would have endangered the environment and public health. Among the on-going efforts and recommendations is the bioconversion of such wastes into non-conventional feed ingredients including bioconversion adopting mushroom biotechnology [100][101][102]; bioconversion of feather meal [103][104][105]; bioconversion of poultry offal and crayfish fish wastes into poultry feed ingredients[106][107][108]; and bioconversion of fruit wastes, oil sludge and crop residues for feeding livestock [109][110][111][112][113][114]. Agricultural solid wastes could have negative impacts on food security, environment and human health. However, animal agriculture is not the only sector generating solid wastes. Hence, all hands must be on deck to ensure their effective management without leading to negative impacts on animal protein intake, which has tremendous benefits for human, significantly contributing to help human beings overcome protein deficiencies among other aforementioned benefits. However, animal scientists and producers should adopt sustainable approach and be environmental health conscious in their practices.

The fear of synthetic antibiotics or chemical residues in animal foods has limited the consumption of animal foods. Some potential consumers have avoided animal proteins solely for this reason. Interestingly, deliberate and extensive research efforts have been focused on addressing chemical residues and contaminants in animal foods. Researchers have investigated the effect of plant-derived antibiotics as a replacement for synthetic antibiotics in order to minimize chemical and antibiotic contamination in animal foods[115][116][117][118][119]. Also, efforts are ongoing to fully understand the functional mechanism of probiotics, which are one of the current alternatives used in place of synthetic antibiotics in animal nutrition, for sustainability purposes[120]. Animal food safety is a concern for all and animal scientists are also making concerted efforts to ensure safety of animal foods they produce. Studies by animal scientists have reported the beneficial effects of some feed additives such as garlic, ginger, turmeric and their mixture in lowering low-density lipoprotein cholesterol, regarded as a risk factor for cardiovascular diseases, in animal production[121][122][123][124].

3. Conclusion

Plant proteins are inferior to animal proteins in terms of nutritional qualities, owing to their lack of essential amino acids required for growth and development, which are on the other hand, adequately and effectively supplied by animal proteins, in addition to their high digestibility. The limitation of essential amino acids in plant proteins may be overcome by feeding two or more plant proteins. However, the problem of low digestibility with accompanying impacts on health and development, especially for neonates and children, remains a key issue. Animal proteins, on the other hand, have adequate amino acid profiles, and high nutritional properties including digestibility. However, ethical concerns for animal welfare and the association with disease risks, sustainability and environmental health remain key issues, although efforts are ongoing to sensitize people about moderate consumption of animal products as well as animal scientists and related fields working assiduously to improve the quality of animal foods as well as ensuring sustainability and animal foods safety at all levels.

The problems are not all solved, but with more efforts in the right direction, the risky benefits and beneficial risks of animal proteins can be overcome and the world will be presented with animal proteins that are free of potential risks and contamination. There has not been an effective replacement (texture and mouthfeel) for real muscle foods (meat) despite the advancement in technology and creative formulations. Hence, rather than condemning animal proteins for their potential limitations, which have not been adequately verified, all hands must be on deck to change their narratives from being risk carriers to improving their benefits. In the meantime, a combination of animal and plant proteins may help address their respective and probable limitations.

Red and processed meat have been especially associated with the risk of non-communicable diseases, compelling many people to avoid animal proteins in entirety, not because they do not enjoy the mouthfeel' experience, but because they are concerned for their health. However, the methodology and sources of information from which some decisions regarding reducing or avoiding red meat are obtained from are currently debatable issues in scientific literature. There are calls for wholistic and all-inclusive approaches, accommodating a comprehensive and technically sound methods of analysis, a deep consideration into food culture and traditions, as well as food accessibility, sustainability and affordability issues. There seems to be a urgent need for a comprehensive and multi-dimensional and multi-disciplinary approach to solving the riddle at hand, to leave both the eaters and the farmers on the same page. A recent study concluded that neither plant nor animal protein was associated with overall cardiovascular disease, ischemic heart disease and stroke, indicating that animal protein may be associated with disease risks too early.

Statements and Declarations

Conflicts of Interest

We declare that we have no conflicts of interest regarding this article.

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Data Availability

There are no original data generated in this article.

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