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Review

Bioactive peptides from meat muscle and by-products: generation, functionality and application as functional ingredients

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ABSTRACT

Bioactive peptides are sequences of between 2–30 amino acids in length that impart a positive health effect to the consumer when ingested. They have been identified from a range of foods, including milk and muscle sources including beef, chicken, pork and marine muscles. The myriad of peptides identified from these sources have known antihypertensive, opioid, antioxidant, antithrombotic and other bioactivities. Indeed, bioactive peptides could play a role in the prevention of diseases associated with the development of metabolic syndrome and mental health diseases.

The aim of this work is to present an overview of the bioactive peptides identified in muscle proteins and by-products generated during the processing of meat. The paper looks at the isolation, enrichment and characterisation strategies that have been employed to date to generate bioactive peptides and the potential future applications of these peptides in functional foods for the prevention of heart and mental health problems and obesity.

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Abbreviations: EC, European Commission; MW, molecular weight; MAED, microwave assisted enzymatic digestion; BSE, bovine spongiform encephalopathy; EU, European Union; DPP-IV, dipeptidyl peptidase-IV; UF, ultrafiltration; RPC, reversed-phase chromatography; IEC, ion exchange chromatography; GFC, Gel Filtration Chromatography; SEC, size exclusion chromatography; RP, reversed phase; HPLC, high-performance liquid chromatography; LC, liquid chromatography; MS, mass spectrometry; ESI, electrospray ionization; MALDI, matrix-assisted laser desorption/ionization; TOF, time of flight; WHO, World Health Organization; CVDs, cardiovascular diseases; BP, arterial blood pressure; RAAS, renin-angiotensin-aldosterone system; ACE-I, angiotensin-I converting enzyme; Ang-II, Angiotensin-II; Ang-I, Angiotensin-I; NO, nitric oxide; eNOS, endothelial nitric oxide synthase; CaM, calmodulin; PAF-AH, platelet activation factor acetylhydrolase; LPC, lysophosphatidylcholine; oxNEFAs, oxidized non-esterified fatty acids; T2D, type-2 diabetes; BACE-1, beta-site amyloid precursor protein-cleaving enzyme-1; SHR, spontaneously hypertensive rats; VTE, venous thromboembolism; PEP, prolyl endopeptidase; CNS, central nervous system; HAT, hydrogen atom transfer; ET, electron transfer; TRAP, total radical-trapping antioxidant parameter; ORAC, oxygen radical absorbance capacity assay; HORAC, hydroxyl radical absorbance capacity assay; NORAC, peroxynitrite radical absorbance capacity assay; ZORAC, superoxide radical absorbance capacity assay; DPPH, 2,2-diphenyl-1-picrylhydrazyl; FRAP, ferric ion-reducing antioxidant power; CUPRAC, cupric ion-reducing antioxidant capacity; FCR, Folin-Ciocalteu assay; TEAC, trolox equivalent antioxidant capacity assay; MTT, methylthiazol tetrazolium; AMPs, antimicrobial peptides; Ang-III, angiotensin-III; Ang-IV, angiotensin-IV; AT1, angiotensin-II type I receptor; cGMP, 3′,5′-cyclic guanosine monophosphate; HBP, high blood pressure; LDH, lactate dehydrogenase; NADPH, nicotinamide adenine dinucleotide phosphate; PKG, protein kinase G; ROS, reactive oxygen species; sGC, guanylyn cyclase.

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1. Introduction

According to the European Commission (EC), the term meat refers to the edible parts removed from the carcass of domestic animals including bovine, porcine, ovine and caprine animals, poultry and wild game (Regulation EC 835/2004). Meat is a valuable livestock product and is the first choice source of animal protein for many consumers. The meat industry involves the slaughter of animals and the generation of end- and by-products. By-products represent environmental and economic problems for meat processors if they are not correctly treated. Animal by-products may be defined as entire bodies or parts of animals, products of animal origin or other products obtained from animals, which can, but are not intended for direct human consumption (Regulation (EC) No 1069/2009). The definition of by-products depends on several factors including traditions, culture and religion, but they are generally accepted as carcasses, skins, bones, meat trimmings, blood, fatty tissues, horns, feet, hoofs or internal organs (Di Bernardini et al., 2011; Toldrá, Aristoy, Mora, & Reig, 2012). Different industrial processes are used in the meat industry in order to treat and to reduce by-product generation, but in the majority of cases, these by-products are discarded as waste or used for low-value purposes. However, meat by-products can be used as raw materials to obtain high value-added ingredients for the functional foods market, which is one of the top trends in the food industry and is estimated to be worth $130 billion by the year 2015 (Crowe & Francis, 2013). Meat by-products are rich in lipids, carbohydrates and proteins which can be used in a wide range of applications as shown in Fig. 1. Certain meat proteins have important physiological activities. For example, collagen has a positive influence on the delivery and bioactivity of bone morphogenic protein-2 and ectopic bone formation enhancing bone healing (Bhakta et al., 2013). Furthermore, bioactive peptides can be generated from meat proteins using hydrolysis, cooking or fermentation. These bioactive peptides may also exert beneficial physiological benefits. Bioactive peptides are short sequences of approximately 2–30 amino acids in length with a low molecular weight (MW) that may be generated from food sources such as milk, egg, fish, soy, meat or blood (Di Bernardini et al., 2011). Such peptides are inactive within the sequence of the parent protein but have a positive impact on systems of the body once released. There is a variety of bioactive peptides that are generated by endogenous enzymes in *post-mortem* meat products (Sentandreu, Coulis, & Ouali, 2002) or that are naturally present in animals including antimicrobial peptides in animal skin. Bioactive peptides can be generated during food processing or from precursor meat by-products by microbial fermentation or by chemical/enzymatic hydrolysis using proteolytic enzymes derived from animals, microorganisms or plants (Korhonen & Pihlanto, 2006; Mora et al., 2009). Other methods of peptide generation such as

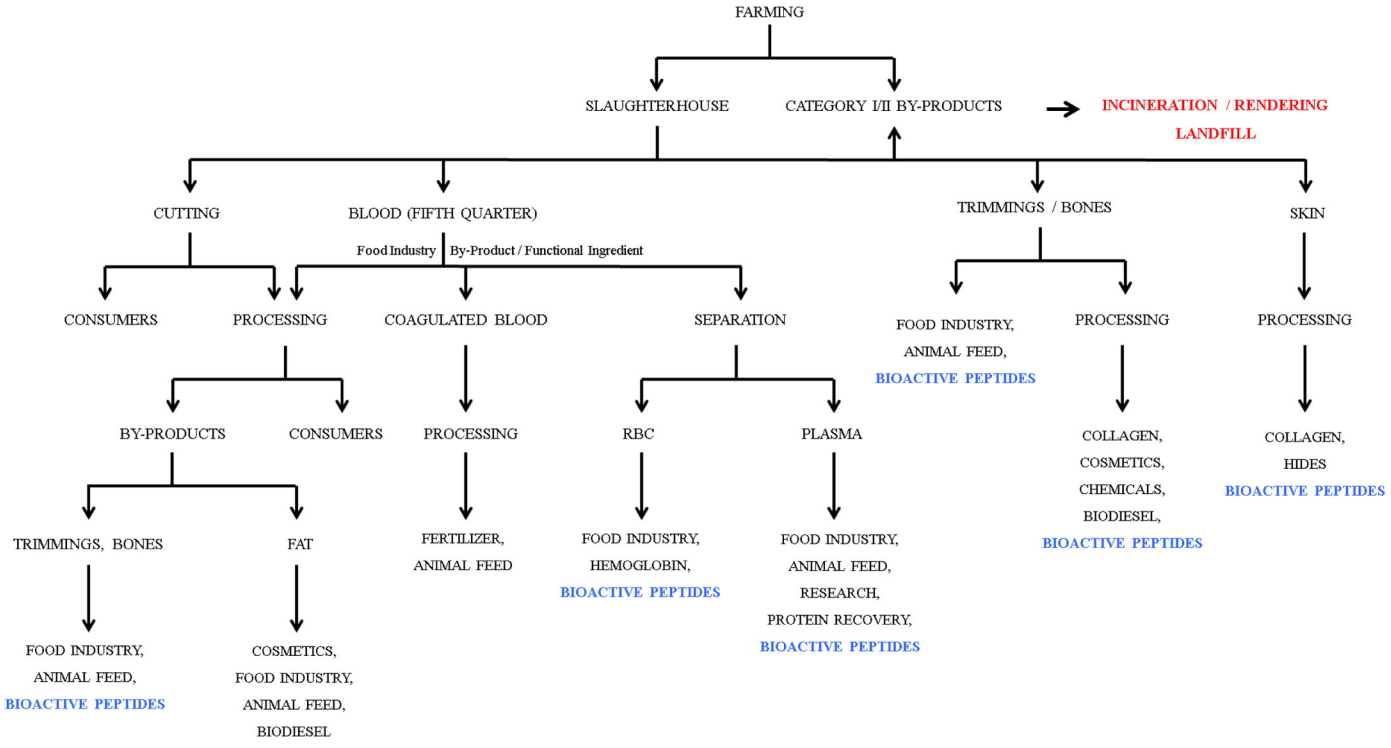

Fig. 1. Main uses of meat muscle and by products. During farming and slaughter, a number of type I and II by-products may be generated. According to EU regulations, these by-products should be directly disposed of as waste by incineration or used as landfill in certain circumstances. The most interesting parts of an animal, from a bioactive peptide generation point of view, include blood, trimmings, bones, internal organs and skin. Blood is used as a food ingredient in some countries such as Spain (Morcilla sausages), Germany (Thuringian sausage), Ireland and the UK (Black pudding) and may be directly processed to a food product. After cutting, meat products can be either sold directly to the consumer or, like blood, processed into by-product ingredients. These by-products are rich in fat, meat proteins and bone and can be used for the generation of bioactive peptides, for animal feed, food and cosmetic use. Coagulated blood is usually processed and used as animal feed or fertilizer. Non-coagulated blood can be separated into its constituent proteins and plasma, and used in microbiology, the food industry, as animal feed or for the generation of bioactive peptides. Meat trimmings and bones generated during slaughter can be used directly for the generation of bioactive peptides. Animal skins are used in the hides Industry, and for the generation of valuable bioactive peptides and proteins such as collagen.