

MEAT AND FERMENTED MEAT PRODUCTS AS A SOURCE OF BIOACTIVE PEPTIDES

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ABSTRACT

Bioactive peptides are short amino acid sequences, that upon release from the parent protein may play different physiological roles, including antioxidant, antihypertensive, antimicrobial, and other bioactivities. They have been identified from a range of foods, including those of animal origin, e.g., milk and muscle sources (with pork, beef, or chicken and various species of fish and marine organism). Bioactive peptides are encrypted within the sequence of the parent protein molecule and latent until released and activated by enzymatic proteolysis, e.g. during gastrointestinal digestion or food processing. Bioactive peptides derived from food sources have the potential for incorporation into functional foods and nutraceuticals. The aim of this paper is to present an overview of the muscle-derived bioactive peptides, especially those of fermented meats and the potential benefits of these bioactive compounds to human health.

Key words: bioactive peptides, muscle proteins, fermented meat products, functional food

INTRODUCTION

In the food guide pyramid, meat is classified as a protein food group along with poultry, fish, and eggs (Lachance and Fisher, 2005). Undoubtedly, meat is an excellence source of well balanced essential amino acids, particularly sulphated ones, since it contains an abundance of proteins with high biological value. Meat is also an exceptional source of such valuable nutrients as minerals and vitamins (Biesalski, 2005; Chan, 2004; Mulvihill, 2004). Some of these key nutrients (e.g., iron, vitamin B12, and folic acid) are either absent or have deficient bioavailability in other foods. Regrettably, meat has a negative health image mainly due to its content of fat, saturated fatty acids and cholesterol (Ovesen, 2004; Valsta et al., 2005). Also, intake of sodium chloride, which is added to most meat products for several purposes, has been linked to hypertension (Ruusunen and Puolanne, 2005).

For the above mentioned reasons, many consumers associate consumption of meat and meat products with increased risk of cancer, obesity and other chronic lifestyle-related diseases (CLSRDs). However, such an approach ignores the fact that meat plays a crucial role in maintenance of human health.

Nowadays, due to increasing concerns about health, nutrition research focuses on the link between diet components and their physiological effects. Numerous food constituents have been determined to be beneficial to the human body in preventing or treating one or more diseases or improving physiological performance (Hasler, 1998). In addition to a variety of biologically active phytochemicals found in plants (e.g. vegetables), several attractive meat-based bioactive compounds, such as carnosine, anserine, L-carnitine, conjugated linoleic acid, glutathione, taurine and

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creatine, have already been studied for their physiological properties (Arihara, 2004). In addition to these components, meat protein-derived peptides are another group of promising functional compounds of meat. Although the activities of these peptides are latent in the sequence of proteins, they are released and activated during gastrointestinal (GI) digestion or food processing. Therefore, meat proteins have possible bioactivities beyond a nutritional source of amino acids alone (Arihara, 2006).

The food-derived bioactive peptides were first reported in 1950 when Mellander suggested that casein-derived phosphorylated peptides enhanced bone calcification in rachitic infants (Mellander, 1950). FitzGerald and Murray (2006) defined bioactive peptides as “peptides with hormone- or drug-like activity that eventually modulate physiological function through binding interactions to specific receptors on target cells leading to induction of physiological responses”. The majority of the known bioactive peptides are not absorbed from the GI tract into the blood circulation. Hence their effect is probably mediated directly in the gut lumen or via receptors on the intestinal cell wall (Korhonen and Pihlanto, 2006; Möller et al., 2008). Most known bioactive peptides usually contain 2–20 amino acid residues (in some cases this range can be extended) linked in specific sequences (Bhat et al., 2015; Ryan et al., 2011).

The activities of bioactive peptides depend on their structures, such as the amino acid composition, the type of amino acid in *N*- and *C*-terminal, the weight and length of the peptide chain, charge character of amino acid, the hydrophobic/hydrophilic property, spatial structure, and so on. For example, peptides with higher ACE-inhibitory activity usually have aromatic or alkaline amino acids in *N*-terminal, higher quantity of hydrophobic and positively charged amino acids in *C*-terminal (Li and Yu, 2015). However the relationship between activity and structure of peptide is still in the explanatory stage.

These peptides are inactive within the sequence of parent protein and can be released by enzyme-catalyzed protein hydrolysis. This process can occur naturally within the GI tract during normal metabolism of dietary proteins. The same happens during fermentation or ageing in food processing (Möller et al., 2008; Udenigwe and Howard, 2013).

Depending on the amino acid sequence, these peptides may exert a number of different activities *in vivo*, affecting, e.g., the cardiovascular, endocrine, digestive, immune and nervous systems. To date, immunomodulatory, antimicrobial, antithrombotic, opiate-like, mineral binding, antioxidative, antihypertensive, hypocholesterolemic and other effects have been discovered in a range of foods. In addition, many of the known bioactive peptides possess multifunctional properties, at least *in vitro* (Dziuba and Dziuba, 2014; FitzGerald and Murray, 2006; Korhonen and Pihlanto, 2006).

This paper reviews the current knowledge about bioactive peptides derived from meat, with emphasis on their production and occurrence in fermented meat products and the potential benefits of these bioactive compounds to human health. While most of physiologically active peptides derived from animal sources are generated from milk, meat being a major source of high quality proteins, offer huge potential as novel source of bioactive peptides (Bhat et al., 2015; Lafarga and Hayes, 2014; Ryan et al., 2011; Udenigwe and Howard, 2013). Because among various bioactive peptides, the ACE-inhibitory and antioxidative are the most widely studied, this two groups of bioactive peptides have been characterised in this work.

ANTIHYPERTENSIVE PROPERTIES

The most widely studied meat protein-derived bioactive peptides are angiotensin I-converting enzyme (ACE) inhibitory peptides (Iwaniak et al., 2014; Korhonen and Pihlanto, 2006). These peptides have attracted much attention because of their ability to prevent hypertension, the risk factors for the development of cardiovascular diseases, one of the most common CLSRDs nowadays. ACE-inhibitory peptides could be used as potent functional food additives and would constitute a natural and healthier alternative to hypertension drugs.

Angiotensin I-converting enzyme (EC 3.4.15.1) is a carboxyl-terminal dipeptidyl exopeptidase that converts an inactive form of angiotensin I, a decapeptide, to a potent vasoconstrictor angiotensin II, an octapeptide. As a multifunctional enzyme, ACE also inactivates bradykinin, which is a known vasodilator. Therefore, inhibition of ACE's catalytic action can

exert an antihypertensive effect (Iwaniak et al., 2014). A great number of ACE-inhibitory peptides have been found in the enzymatic hydrolysates of food proteins (Arihara, 2006; Vercruyse et al., 2005;). Their inhibitory potency is evaluated *in vitro* and expressed by the IC_{50} value, the peptide concentration that inhibits 50% of ACE activity. In order to reduce increased blood pressure levels after oral administration, peptides must be resistant to further degradation by GI enzymes as to reach an appropriate target site in an active form. Therefore, the *in vitro* bioavailability and bioactivity of the peptides needs to be evaluated under simulated GI conditions. Antihypertensive effect of peptides derived from different food matrices is usually assessed by *in vivo* experiments using spontaneously hypertensive rats (SHR) that constitute an accepted animal model to study human essential hypertension (Iwaniak et al., 2014; Katayama et al., 2008; Saiga et al., 2003a).

The first report of ACE-inhibitory peptides derived from muscle proteins of domestic animals was made by Arihara et al. (2001). They identified two ACE-inhibitory pentapeptides (MNPPK and ITTNP) from the thermolysin (EC 3.4.24.27) digestion of porcine skeletal muscle proteins. These peptides, named myopentapeptide A and B corresponded to position 79–83 and 306–310 on the myosin heavy chain, respectively. *In vivo* studies by Nakashima et al. (2002) demonstrated antihypertensive activities of these myopentapeptides in SHR when administrated in single oral doses. Also, six tripeptides (MNP, NPP, PPK, ITT, TTN, and TNP) containing sequence parts of the myopentapeptides, demonstrated activity. Tripeptide MNP (f79–81) exhibited enhanced ACE-inhibitory activity, compared to the parent myopentapeptide A, with IC_{50} value of 66.6 μ M (Arihara et al., 2001). Myosin as a source of bioactive peptides has also been used by Katayama et al. (2007). By digestion of crude myosin light chain with pepsin, ACE-inhibitory octapeptide (VKKV-LGNP, f47–54, the IC_{50} value of 28.5 μ M) has been generated. On the basis of antihypertensive activity assessment, this peptide was estimated as a temporally effective hypotensor. Another myosine-derived peptide with IC_{50} values of 6.1 μ M (KRVIQY, M6) was identified in a pepsin hydrolysate of porcine myosin B (Muguruma et al., 2009). The fact that this peptide retained his ACE-inhibitory activity after heating the myosin B at 98°C for 10 min prior to hydrolysis

by pepsin indicates that meat may have antihypertensive properties even after cooking.

Katayama et al. (2003) suggested that ACE-inhibitory peptides were generated not only from porcine myofibrillar but also from regulatory proteins such as troponin and tropomyosin. They isolated a corresponding peptide RMLGQTPTK from porcine troponin C hydrolyzed with pepsin. This peptide showed relatively high resistance to digestive proteases and therefore, might be expected to work well *in vivo* as an antihypertensive agent. These same researchers in another experiment (Katayama et al., 2008) identified two novel ACE-I-inhibiting peptides from porcine skeletal troponin by treatment with pepsin. These peptides were sequenced as EKERERQ and KRQKYDI and presented IC_{50} values of 552.5 and 26.2 μ M, respectively. KRQKYDI showed the strongest ACE-inhibitory activity among previously reported troponin-originated peptides.

Simulated digestion of pork meat (*longissimus dorsi*) by sequential action of pepsin and pancreatin yielded 22 peptides, including those not described before in the literature, i.e. MYPGIA and VIPEL (Escudero et al., 2010). A titin-derived pentapeptides KAPVA (f 4784–4788) and PTPVP (f4216–4220) showed the highest ACE-inhibitory activity with IC_{50} values of 46.56 μ M and 256.41 μ M, respectively. They represent probably the first identified ACE-I peptides coming from this protein. Their antihypertensive action, as well as nebuline-derived tripeptide RPR, has been investigated *in vivo* by Escudero et al. (2012b). It is worth noting that the RPR was 8-fold less effective than KAPVA exhibiting low *in vitro* ACE-inhibitory activity, but in the *in vivo* test both peptides gave a comparable effect. According to authors cited by Iwaniak et al. (2014), higher antihypertensive activities of peptides *in vivo* despite weaker *in vitro* ACE-inhibitory effects might be explained by their higher affinity to tissues or by a possible antihypertensive mechanism, other than ACE inhibition, involved in the blood pressure-lowering effect exerted by food-derived peptides.

Next to porcine, also chicken muscle was hydrolyzed in order to search for ACE-inhibitory peptides. Fujita et al. (2000) isolated seven ACE-inhibitory peptides (LKA, LKP, LAP, IKW, FQKPKR, FKGRYYP, and IVGRPRHQG) generated from chicken muscle

proteins by thermolysin treatment. The *in vitro* ACE-inhibitory activity of these peptides showed IC_{50} values ranging from 0.21 to 14 μM . However, the heptapeptide FKGRYYP (IC_{50} value of 0.55 μM) failed to show antihypertensive activity after administration to SHR thus confirming that inhibitory activity of the peptides against ACE does not always correlate with their *in vivo* antihypertensive effects. It has been elucidated that the potent ACE-inhibitory activities of this peptide may be eroded by its degradation due to the action of intracellular peptidases or enzymes existing in the digestive tract or blood serum. Another reason for the loss of activity by peptides is their modification in the liver (Iwaniak et al., 2014). Saiga et al. (2003a) have also shown that poultry can be a source of peptides with biological activity. They reported inhibitory activity against angiotensin I-converting enzyme of *Aspergillus* protease and gastric proteases (trypsin, chymotrypsin, and intestinal juice) treated chicken muscle extract. Of the four ACE-inhibitory peptides isolated from the hydrolysate, three possessed a common sequence, which is homologous with that of collagen. The peptide GFHypGTHypGLHypGF, showed the strongest inhibitory activity with IC_{50} value of 42.4 μM . This peptide was found to possess a high affinity toward ACE and inhibited the enzyme in a noncompetitive manner. The presence of an aromatic amino acid at the antepenultimate position and Phe at the C-terminus was reported to play an important role in the observed inhibitory activity (Saiga et al., 2006). This supports the theory that presence of hydrophobic (aromatic or branched-chain) amino acid residues located at the three C-terminal positions is responsible for the ACE-inhibitory activity of the peptide. This is explained by interaction of these residues with the three hydrophobic subunits located on the active site of ACE (Ryan et al., 2011). Generation of ACE-inhibitory peptides from chicken meat by artificial gastric juice digestion has been studied by Terashima et al. (2010). Among the four separated peptides, two (MNVKHWPWMK and VTVNPKWLP) were identified as the novel ACE-inhibitory peptides encrypted in the sequence of myosin heavy chain. The latter peptide with a relatively low IC_{50} value of 5.5 μM , may serve a good starting substance for designing food supplements for hypertensive people.

Four peptides with ACE-inhibitory activity were identified in chicken collagen hydrolysate treated with proteases. Long-term administration studies indicated that the low fraction of this hydrolysate showed a significant suppression of increased blood pressure in SHR (Saiga et al., 2008). As regards connective tissue, apart from chicken collagen hydrolysate, bioactive peptides with strong ACE-inhibitory effects were also identified in bovine skin gelatin hydrolysates. Kim et al. (2001) isolated two peptides, GPL and GPV with calculated IC_{50} values of 2.55 and 4.67 μM , respectively.

Beef proteins have also been examined as a source of ACE-inhibitory peptides. Jang and Lee (2005) assayed ACE-inhibitory activities of several enzymatic hydrolysates of sarcoplasmic protein extracts from beef rump (*biceps femoris*). A hexapeptide (VLAQYK) with an IC_{50} value of 32.06 μM was purified from the hydrolysate with the highest ACE-inhibition activity. Feeding this peptide to SHR resulted in a significant suppression of systolic blood pressure (SBP) in addition to lower total and LDL-cholesterol blood concentrations (Jang et al., 2004). In another study, the same research group separated four peptides with high ACE-inhibitory effect from beef sarcoplasmic protein hydrolysates. They were identified as GFHI, DFHING, FHG, and GLSDGEWQ and have both antimicrobial and cancer cell cytotoxic effects (Jang et al., 2008). Several other ACE-inhibiting peptides derived from muscle proteins have been previously reviewed by Vercurysse et al. (2005) and Ahmmed and Muguruma (2010).

ANTIOXIDANT PROPERTIES

The literature does not sufficiently explain the exact mechanism of antioxidant activity of peptides. Based on current knowledge, it is supposed that they may exert their antioxidant effect through the scavenging of free radicals and reactive oxygen species (ROS), inhibiting of lipid peroxidation and chelating of transition metal ions. Their action may be determined by many factors (position of the peptide in the protein structure, hydrophobicity, protein isolation method, degree of hydrolysis, type of enzymes used, concentration of peptide and amino acid configuration). It has been shown that certain amino acids may have higher antioxidant properties, when they are included

in dipeptides (Di Bernardini et al., 2011; Sarmadi and Ismail, 2010).

The best-known antioxidants found only in meat, poultry and some fish are histidine-containing dipeptides, carnosine (β -alanyl-L-histidine) and anserine (N- β -alanyl-1-methyl-L-histidine) (Nagasawa et al., 2001; Sarmadi and Ismail, 2010; Young et al., 2013). The concentration of carnosine in meat ranges from 500 mg/kg in chicken thigh to 2700 mg/kg in pork shoulder, while anserine is especially abundant in chicken muscle. Antioxidant activity of these peptides is mainly attributed to their ability to chelate transition metals such as cobalt, zinc and copper (Arihara, 2006; Young et al., 2013).

Apart from the above mentioned dipeptides, there are many antioxidant peptides isolated from meat sources. As evidenced by studies of Wu et al. (2005) extract of chicken essence, a traditional Chinese product possessed various antioxidant activities. Two peptides with amino acid sequences HVTEE and PVPVEGV were isolated and identified. They displayed inhibition of the autooxidation of linoleic acid in a model system.

Saiga et al. (2003b) tested porcine myofibrillar protein hydrolysates (obtained by treatment with papain and actinase E) as a source of antioxidant peptides. These hydrolysates inhibited peroxidation of linoleic acid and possessed 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity and metal ion chelating activity. Five antioxidant peptides with the sequences DSGVT, IEAEGE, DAQEKLE, EELD-NALN and VPSIDDQEELM were separated from the papain hydrolysate. Among them, DAQEKLE, corresponding to a part of the protein actin, showed the highest activity. Park and Chin (2011) in their work assessed the antioxidant activity of pepsin-digested water-soluble protein and salt-soluble protein extracted from pork ham. Obtained results pointed out that low molecular weight peptides (<7 kDa) have antioxidant activities, such as radical scavenging ability and reducing power, resulting in function as inhibitors of lipid peroxidation developing in linoleic acid emulsion system. Pork as a source of antioxidant peptides, has also been evidenced by Arihara et al. (2011) who found that peptides ALTA, SLTA and VT, obtained by papain-treated hydrolyzate of pork actomyosin exhibited antioxidant activity *in vitro*, as well as *in vivo*.

Di Bernardini et al. (2012) investigated the antioxidant activity of sarcoplasmic proteins isolated from bovine brisket muscle (*Pectoralis profundus*) by enzymatic hydrolysis with papain. The 10-kDa and the 3-kDa peptidic fractions demonstrated antioxidant activities using *in vitro* assays (DPPH free radical scavenging activity, the ferric ion reducing antioxidant power (FRAP) and the Fe²⁺ metal chelating ability). Hydrolysis of porcine skin collagen with a cocktail mixture of proteases resulted in the release of four peptides (QGAR, LQGM, LQGMH and HC) showing strong antioxidant activity (Li et al., 2007). The antioxidant peptide QGAR, which has high antioxidant activity without strong proton-donating amino acid residues in the sequence, is of special interest. Kim et al. (2009) obtained two antioxidative peptides from venison protein hydrolysates, APVPH I (MQIFVK-TLTG) and APVPH II (DLSDGEQGVV), respectively. Their free radical scavenging activity was higher than that of vitamin C.

Other studies on the generation of antioxidant peptides derived from meat muscle and by-products have been reviewed by Di Bernardini et al. (2011) and Lafarga and Hayes (2014).

BIOACTIVE PEPTIDES FROM FERMENTED MEAT PRODUCTS

Meat fermentation has been used since thousands of years to preserve them for prolonged storage. Since proteolytic degradation of meat proteins is one of the most important processes occurring in these products, bioactive peptides would be generated during the processing of meat into cured ham or fermented sausages (Arihara, 2006). In particular, meat proteins appear to encrypt ACE-I inhibitors and antioxidant peptides that are released during process-induced proteolysis (dry-curing, ageing, fermentation) (Ferranti et al., 2014).

To date, a few studies on the final products of proteolysis have described various low and medium weight peptides, oligopeptides and free amino acids with *in vitro* antioxidant and antihypertensive effect in protein extracts from cured meats and fermented sausages (Broncano et al., 2012; Castellano et al., 2013; Escudero et al., 2012a, 2013a, 2013b, 2014; Sentandreu and Tolodr a, 2007; Sun et al., 2009; Vařtag et al., 2010). The bioactive peptides identified in recent years

Table 1. Bioactive peptides generated from dry-cured meat products (Spanish dry-cured ham)

Bioactivity	Sequence*	MW Da**	Reference
Antioxidative	SAGNPN	558.55	Escudero et al. (2013b)
Antioxidative	GLAGA	387.44	Escudero et al. (2013b)
Antihypertensive	AAATP	429.47	Escudero et al. (2013a)
Antihypertensive	KAAAAP	527.62	Escudero et al. (2014)
Antihypertensive	AAPLAP	538.64	Escudero et al. (2014)
Antihypertensive	KPVAAP	581.71	Escudero et al. (2014)
Antihypertensive	IAGRP	512.61	Escudero et al. (2014)
Antihypertensive	KAAAATP	628.72	Escudero et al. (2014)

*Source – porcine muscle.

**Search was carried out by interrogation of the Pepstats informatics database.

in dry-cured meat products are summarized in Table 1. Dry-cured meat products as a natural source of antihypertensive and antioxidant peptides are of particular interest because these peptides could help to counteract the adverse action of NaCl in this product, thus helping to maintain a satisfactory blood pressure and good health. However, information on bioactive peptides generated from fermented meats is still limited.

Sentandreu and Toldrá (2007) obtained seven dipeptides (RP, KA, AA, GP, AR, GR and RR) with ACE-inhibitory activity by the action of dipeptidyl peptidases (DPP) purified from porcine skeletal muscle. Among the assayed dipeptides, Arg-Pro was the most effective (suppress more than 60% of the initial enzyme activity at a concentration of 25 μ M). Also the dipeptides KA (IC_{50} value of 31.5 μ M), AA (IC_{50} value of 51.4 μ M) and GP (IC_{50} value of 66.0 μ M) are effective ACE inhibitors, although to a lesser extent. As DPP remain active during either a great part or the whole processing period of dry-cured meat products, their proteolytic action could contribute to the generation of antihypertensive peptides. Castellano et al. (2013) derived ACE-inhibitory peptides from the hydrolysis of sarcoplasmic porcine proteins by the action of meat-borne *Lactobacillus sakei* CRL1862 and *Lactobacillus curvatus* CRL705. Both lactobacilli species were able to generate peptides with ACE-inhibitory

activity, of which the most effective was peptide FISNHAY. Ability of lactic acid bacteria to generate ACE-inhibitory peptides highlights their potential to be used in the development of functional fermented products.

Spanish dry-cured ham as a natural source of antihypertensive and antioxidant peptides has been extensively investigated by Escudero et al. (2012a, 2013a, 2013b). *In vitro* research confirmed that some of the peptide fractions exhibited DPPH radical-scavenging activity (ranging from 39% to 92%) and superoxide ion extinguishing ability (41.67% to 50.27% of the antioxidant activity). Pooled fractions corresponding to peptides of less than 1.7 kDa exhibited marked *in vitro* ACE-inhibitory activity and were the most antihypertensive with a decrease of 38.38 mm Hg in SBP in spontaneously hypertensive rats (SHR) after oral administration (Escudero et al., 2012a). In the course of further studies 27 antioxidant (Escudero et al., 2013b) and 73 antihypertensive peptides (Escudero et al., 2013a) were identified from Spanish dry-cured ham. The highest radical scavenging activity was observed for the peptide SAGNPN (IC_{50} value of 1.5 mg/ml). Considering the reducing power analysis, the most effective proved to be peptide GLAGA. The most potent antihypertensive peptide was AAATP (IC_{50} value of 100 mM) which also showed good activity in the

in vivo test (Escudero et al., 2013a). These indicate the potential of Spanish dry-cured ham as a source of natural peptides with possible benefits to human health. In the most recent studies, a Spanish dry-cured ham extract rich in bioactive peptides showing ACE-inhibitory activity have been examined for their stability during heat treatment and *in vitro* GI digestion (Escudero et al., 2014). Obtained results indicate that peptides present in processed Spanish dry-cured ham extract maintained almost the same ACE-inhibitory activity, before and after application of differential heating (from 50°C to 117°C), at different times (from 3 to 60 minutes) and during simulated *in vitro* digestion. Peptides KAAAAP, AAPLAP, KPVAAP, IAGRP, and KAAAATP were the most active presenting IC₅₀ values in the range from 12.37 µM to 25.94 µM.

Ferranti et al. (2014) identified more than 170 potential bioactive peptides liberated from the myofibrillar and sarcoplasmic protein fractions of bovine muscle proteins from simulated *in vitro* digestion of a dry-cured meat product Bresaola. Antioxidant and ACE-inhibitory activities in fermented sausages has also been studied by Vaštag et al. (2010) who found that the DPPH radical scavenging activity and the reducing power in protein extracts from Petrovac Sausage (*Petrovska Kolbasa*) were 2 or 3 fold greater in the final product than in the initial sausage mixture. The examined protein extracts also exhibited *in vitro* ACE-inhibitory activity, which increased with the progress of ripening time. The antioxidant activity of low molecular weight compounds isolated from Iberian fermented sausages was tested by Broncano et al. (2012). Due to extensive degradation during the ripening of chorizo, the extracts did not contain many peptides in a concentration that allowed identification. However, naturally occurring β-alanyl-peptides, many free amino acids and other metabolites has been identified. Compounds included in the most hydrophilic fractions were expected to be primarily responsible for the antioxidant activity of the chorizo extract. In other study the antioxidant activity of peptides extracted from semi-dry sausage (Cantonese) was related to small peptides including histidine amino acid (Sun et al., 2009).

Application of probiotic microorganisms is another possible direction for introducing physiological functions for fermented meat products. Probiotics,

such as bifidobacteria and lactic acid bacteria (LAB) may contribute to microbial safety and offer organoleptic, technological and nutritional advantages, but more importantly confer a health benefit on the host (Kołozyn-Krajewska and Dolatowski, 2015). Combination of probiotics and biopeptides from meat proteins could provide the possibility of developing novel functional fermented meat products. To date, there are no studies about isolation and purification of bioactive peptides present on dry meat products fermented by probiotics as starter cultures.

CONCLUSION

Bioactive peptides derived from meat and fermented meat products exhibit various biological activities potentially beneficial for human health. Peptides derived from meat proteins offer a promising approach to prevent, control and even treat lifestyle-related diseases through a regulated diet. Taking into account the fact that consumers consider food not only to satisfy the basic nutritional needs but also as a means of supporting the work of the body production of meat products containing active components, e.g. bioactive peptides fits into the trends in the development of innovative functional products and nutraceuticals. However, the majority of the beneficial bioactivities described for meat-derived peptides were assessed *in vitro* which is not enough to evaluate their activity in the human body after digestion. It is necessary to assess their efficacy, dose response and safety *in vivo* before use as a functional ingredient. The challenge for meat technologists will also be development of functional meat products without the undesired side effects of added peptides (e.g. the bitter taste), and to retain the stability of peptides within the shelf life of the product. Possible generation of bioactive peptides in dry meat products fermented by probiotics as starter cultures seems the most promising way for designing novel functional foods.

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MIĘSO I FERMENTOWANE PRODUKTY MIĘSNE JAKO ŹRÓDŁO BIOAKTYWNYCH PEPTYDÓW

STRESZCZENIE

Bioaktywne peptydy to krótkie sekwencje aminokwasowe, które po uwolnieniu z białka prekursorowego mogą wpływać na fizjologiczne funkcje organizmu, m.in. poprzez aktywność przeciwnadciśnieniową, antyoksydacyjną i przeciwbakteryjną. Peptydy o właściwościach fizjologicznych wyizolowano z wielu produktów żywnościowych, w tym pochodzenia zwierzęcego takich, jak mleko i mięso (wieprzowina, wołowina, drób, ryby i organizmy morskie). Związki te pozostają nieaktywne w sekwencjach białka prekursorowego do momentu uwolnienia przez enzymy proteolityczne podczas trawienia w przewodzie pokarmowym lub przetwarzania żywności. Dzięki swoim właściwościom biologicznie aktywne peptydy mogą być składnikami żywności funkcjonalnej i nutraceutyków. Celem pracy była charakterystyka bioaktywnych peptydów uzyskanych z białek mięsa, w szczególności z fermentowanych produktów mięsnych, i ich potencjalnych korzyści dla zdrowia człowieka.

Słowa kluczowe: bioaktywne peptydy, białka mięśniowe, fermentowane produkty mięsne, żywność funkcjonalna

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