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Food protein-originating peptides as tastants - Physiological, technological, sensory, and bioinformatic approaches

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ABSTRACT

Taste is one of the factors based on which the organism makes the selection of what to ingest. It also protects humans from ingesting toxic compounds and is one of the main attributes when thinking about food quality. Five basic taste sensations are recognized by humans: bitter, salty, sour, sweet, and umami. The taste of foods is affected by some molecules of some specific chemical nature. One of them are peptides derived from food proteins. Although they are not the major natural compounds originating from food sources that are responsible for the taste, they are in the area of scientific research due to the specific composition of amino acids which are well-known for their sensory properties. Literature data implicate that sweet, bitter, and umami are the tastes attributable to peptides. Moreover, the bitter peptide tastants are the dominant among the other tastes. Additionally, other biological activities like, e.g., inhibiting enzymes that regulate the body functions and acting as preventive food agents of civilization diseases, are also associated with the taste of peptides.

The advance in information technologies has contributed to the elaboration of internet archives (databases) as well as in silico tools for the analysis of biological compounds. It also concerns peptides – namely taste carriers originating from foods. Thus, our paper provides a summary of knowledge about peptides as tastants with special attention paid to the following aspects: a) basis of taste perception, b) taste peptides detected in food protein sequences with special emphasis put on the role of bitter peptides, c) peptides that may enhance/suppress the taste of foods, d) databases as well as bioinformatic approaches suitable to study the taste of peptides, e) taste-taste interactions, f) basis of sensory analysis in the evaluation of the taste of molecules, including peptides, and g) the methodology applied to reduce/eliminate the undesired taste of peptides. The list of taste peptides serving some biological functions is presented in the Supplement file. The information provided includes database resources, whereas peptide sequences are given with InChiKeys, which is aimed at facilitating the Google® search. Our collection of data regarding taste peptides may be supportive for the scientists working with the set of peptide data in the context of structure-function activity of peptides.

Contents

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1. Introduction

The sense of taste in the mammals is one of the key factors allowing the inter-individual evaluation of the ingested foods (Born, Levit, Niv, Meyerhof, & Behrens, 2013). The human gustatory system can distinguish five basic tastes: bitter, salty, sour, sweet, and umami (Kim, Son, Kim, Misaka, & Rhyu, 2015). Studies have, however, indicated some additional taste sensations that should be considered, e.g., "fatty" and "metallic" taste (Bartoshuk & Klee, 2013). In brief, the sense of taste is perceived by an organism when nutrients or chemical compounds activate some special receptor cells within the taste buds. Thus, the sense of taste helps humans to protect themselves from toxic foods by choosing "what to ingest" as well as prepares the organism to metabolize the ingested food components. It can be said that taste is one of the factors considered when deciding whether to accept or not accept a food product (Breslin, 2013). According to Fisher and Scott (1997), most of the taste stimulants are non-volatile and well soluble in water. The most well-recognized taste substances that can be found in food are salts, sugars, amino acids, and proteins (Fisher & Scott, 1997). Sequence fragments of proteins, i.e., peptides, possess a variety of bioactivities that affect body functions like blood pressure reduction, antioxidant, antibacterial, immunomodulatory, lipid-lowering effects etc. (Udenigwe & Aluko, 2012). So far, the taste of peptides has not been considered primarily in the context of the biological activity and/or functionality of peptides. Data from scientific reports show that peptides derived from food can exhibit all 5 taste sensations, however three of them, i.e., sweet, bitter, and umami are the major ones attributable to peptides. Salty and sour taste of peptides is related to their zwitterionic or amino acid side chains nature (Temussi, 2012).

Recently, sensory peptides have become the subject of scientific interests that can be generally grouped into the following categories: a) the knowledge about the physiology of taste and taste-taste interactions, b) the taste of peptides derived from foods including aspects concerning sensory evaluation of taste and methodology involved to reduce/remove undesired tastes, c) the databases as the catalogues of information about peptide tastants and bioinformatic approach used to study sensory peptides, and d) the issues concerning the taste of peptides in relation to their bioactivities.

Thus, the aim of this article was to discuss the taste peptides paying special attention to their bitter, sweet, and umami tastes.

2. Basis of taste perception

Tongue is a body organ which has the first contact with food we consume and then allows distinguishing its taste. It is possible via taste buds which are anatomical structures containing receptor cells responsible for the sense of taste mediation (Nelson, 1998). Taste buds are located on the upper side of a tongue and possess projections called papillae. Taste sensations are detected by taste buds located in different regions of the tongue, i.e., papillae of the taste buds located at the back of the tongue detect bitter molecules, sides of the tongue are sensitive to sour taste, and taste buds found in the front of the tongue recognize sweet molecules. Taste buds located in the front and at sides of the tongue are sensitive to salty compounds. Each taste bud consists of 50 to several hundred cells and, according to literature, they may represent cells, support cells, and taste receptor cells. The latter possess nerve endings that send impulses to the central nervous system (Jackson, 2002).

Taste receptor cells (TRCs) are classified into four categories named I, II, III, and IV. The TRCs of the first category are similar to glial cells and are involved in the expression of ecto-ATPase, which leads to the restriction of the ATP spread inside the taste bud, thereby limiting this process to a smaller number of cells. The second group of TRCs is called sensory receptor cells and is responsible for the expression of GPRC (G protein coupled receptor cells, a group of receptors involved in the functions of sense organs). In the group of GPRCs, two receptors called T1R and T2R are responsible for taste sensing and signal transduction of sweet, bitter, and umami tastants. The third category of TRCs is involved in the formation of sensory nerves as well as releasing serotonin and norepinephrine, whereas the fourth one is found as the precursor of other TRCs and is positioned at the bottom of the taste buds (Cygankiewicz, Masłowska, & Krajewska, 2013). T1R can be divided into the following subunits: T1R1, T1R2, and T1R3. The T2R is responsible for binding bitter tastants, whereas T1R2 and T1R3 detect sweet compounds (Kim et al., 2015; Zhang & Hoon, 2003). Moreover, T1R1 and T1R3 are regarded as L-amino acid sensors (Zhang & Hoon, 2003).

It has been reported that human receptors T1R2 and T1R3 recognized natural and synthetic sweeteners, whereas T1R1 and T1R3 receptors were responsible for the recognition of L-glutamate enhanced by 5′-ribonucleotides – the compounds known as umami tastants. Based on this fact, it was concluded that T1R receptors are involved in umami taste perception and that sweet taste recognition by T1Rs may result from sharing the common subunit by umami and sweet receptors (Li et al., 2002).

When discussing about taste buds, taste perception, and taste receptors, the role of saliva cannot be neglected. Saliva is a body fluid aimed at transporting the tastant and protecting the taste receptor. The initial task of saliva is to dissolve a tastant and then to diffuse it to the functional site of the receptor. Saliva can stimulate the TRCs and affect taste perception. The impact of saliva on taste perception is dependent on the anatomical relation between the taste buds and oral openings of the salivary gland tubes (Matsuo, 2000). Thus, Matsuo (2000) postulated that research focused on the analysis of the relationships between saliva and taste sensitivity may lead to the development of new therapies helping in the treatment of taste dysfunctions (e.g., an artificial saliva).

As food consumers, we realize that taste perception is a derivative of few factors like e.g.: masking of unpleasant taste by the addition of sugar, olfaction, appearance, and our physiological state (satiety/hunger). Also psychological and physiological aspects are taken into consideration when discussing the final brain taste perception (Chandrashekar, Hoon, Ryba, & Zuker, 2006).

3. Bitter peptides – Protein sources, structural requirements, and indicators of bitterness

Bitter and bitterish taste of some foods are perceived as typical by humans. It concerns, e.g., beer, coffee, and tea. Moreover, the bitterness of protein-based foods intensifies during the fermentation processes and/or enzymatic proteolysis aimed at producing hydrolysates. The taste of hydrolysates may vary depending on protein, proteolysis conditions, and proteolytic enzyme applied (Maehashi & Huang, 2009). According to Maehashi and Huang (2009), the first observations concerning the bitter taste of peptides were made in the early 1950s. It was demonstrated that hydrolysates of casein and gelatin were bitter and this bitterness could be reduced by the use of spent carbon. Moreover, it was noticed that the bitterness of hydrolysates was attributed rather to the presence of peptides than of free amino acid residues (Maehashi & Huang, 2009). Noteworthy is that, in contrast to infants aged 4 months and younger who accept the bitter taste of milk food, the adults as well as older children rather avoid fermented milk products with bitter taste. It is probably due to the fact that in the early