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Review

Formation of taste-active amino acids, amino acid derivatives and peptides in food fermentations – A review

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ABSTRACT

Fermented foods are valued for their rich and complex odour and taste. The metabolic activity of food-fermenting microorganisms determines food quality and generates odour and taste compounds. This communication reviews the formation of taste-active amino acids, amino acid derivatives and peptides in food fermentations. Pathways of the generation of taste compounds are presented for soy sauce, cheese, fermented meats, and bread. Proteolysis or autolysis during food fermentations generates taste-active amino acids and peptides; peptides derived from proteolysis particularly impart umami taste (e.g. α-glutamyl peptides) or bitter taste (e.g. hydrophobic peptides containing proline). Taste active peptide derivatives include pyroglutamyl peptides, γ-glutamyl peptides, and succinyl- or lactoyl amino acids. The influence of fermentation microbiota on proteolysis, and peptide hydrolysis, and the metabolism of glutamate and arginine is well understood, however, the understanding of microbial metabolic activities related to the formation of taste-active peptide derivatives is incomplete. Improved knowledge of the interactions between taste-active compounds will enable the development of novel fermentation strategies to develop tastier, less bitter, and low-salt food products, and may provide novel and "clean label" ingredients to improve the taste of other food products.

Contents

1. Introduction

Taste determines food selection, intake, absorption, and digestion, and thus contributes to the nutritional status as well as to decisions on food purchase (Barylko-Pikielna & Kostyra, 2007; Beksan et al., 2003). Six basic tastes, salt, sweet, and umami, sour, bitter, and oleogustus,

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are detected by taste receptors in taste buds on the tongue and palate epithelium (Running, Craig, & Mattes, 2015). Sweet, umami and bitter tastes are particularly related to food acceptance or rejection (Barylko-Pikielna & Kostyra, 2007). Sweet taste allows to identify carbohydrate-rich foods as a source of energy (Behrens, Meyerhof, Hellfritsch, & Hofmann, 2011); sweet taste receptors are absent in carnivores (Jiang et al., 2012). Umami molecules impart savory taste and increase other taste intensities (Jinap & Hajeb, 2010). Umami taste is linked to meat intake and umami taste receptors are typically absent in herbivores (Zhao, Yang, Xu, & Zhang, 2010). L-Glu and 5′-ribonucleotides elicit umami taste (Jinap & Hajeb, 2010). Humans reject bitter tasting foods, however, a limited level of bitterness in food may be desirable. Moreover, bitter taste reception in humans is highly variable (Meyerhof et al., 2010). Saltiness often determines the sensory acceptance of savory foods, such as soups, sauces, snacks, and bakery products (Schindler et al., 2011). However, salt intake in industrialized nations exceeds by 80–100% the amount recommended by WHO. Sodium reduction, achieved through partial replacement of sodium chloride with potassium chloride, a combination of different taste enhancers, such as glutamate, peptides or modified physical properties of food, has been investigated (Blesa et al., 2008; Schindler et al., 2011; Zhao, Kinner, Wismer, & Gänzle, 2015). Kokumi-active compounds are not taste active but enhance the taste intensity of other compounds by modulation of the signal transduction from the taste receptors to the brain (Kuroda & Naohiro, 2015; Maruyama, Yasuda, Kuroda, & Eto, 2012). The kokumi taste activity imparts mouthfulness, complexity, and long lasting taste (Ueda, Yonemitsu, Tsubuku, Sakaguchi, & Miyajima, 1997; Toelstede & Hofmann, 2008b; Toelstede, Dunkel, & Hofmann, 2009).

Food fermentation is one of the oldest methods for food processing and traditional fermented foods are highly valued for their rich and complex taste and odour (Hutkins, 2006). The metabolic activity of food-fermenting microorganisms determines food quality, generates flavour, and enhances palatability. This communication aims to review the current knowledge related to taste active compounds in fermented foods, focussing on taste-active amino acids, amino acid derivatives, and peptides. The established or putative pathways of the generation of taste-active compounds are discussed for soy sauce, cheese, fermented meats, and bread. While these foods do not represent the diversity of fermented foods, they provide a cross-section of the different fermentation procedures, raw materials, and fermentation organisms that are employed in food fermentations (Hutkins, 2006; Gänzle, 2015). The conversion of sugars to organic acids is common to all food fermentations with lactic acid bacteria and is therefore not considered.

2. Generation of taste-active amino acids and peptides during food fermentation

Taste compounds are generated through primary proteolysis of the raw material by proteases from endogenous enzymes or microorganisms (Fig. 1 and Table 1), followed by secondary proteolysis, and enzymatic or chemical conversion of amino acids into derivatives. An overview on enzymes with putative or known contribution to the formation of taste active peptides or amino acids in fermented foods is provided in Table 2. Taste active peptides, amino acids, and amino acid derivatives are the predominant tastants in many fermented foods and impart bitter, umami, or kokumi taste (Toldra & Flores, 1998; Hillmann & Hofmann, 2016; see below).

Proteolysis in food fermentations has comprehensively been reviewed (Table 1; Gänzle et al., 2008; Hughes et al., 2002; Savijoki, Ingmer, & Varmanen, 2006; Toldra et al., 1993; Toldra & Flores, 1998). In cheese and soy sauce, microorganisms are the major or sole contributor of protease and peptidase. During cheese ripening, casein is hydrolyzed by cell wall-bound proteinases from LAB and peptides are subsequently hydrolyzed by intracellular peptidases of LAB (Broadbent et al., 2002; Khalid & Marth, 1990). An imbalance of proteolysis and peptide hydrolysis, especially proteolysis of β-casein, accumulates bitter peptides and imparts a bitter taste defect (Fallico et al., 2005). In soy sauce, extracellular enzymes produced by koji starter cultures carry out primary proteolysis. At the moromi stage, growth and metabolism of *Tetragenococcus halophilus* and yeasts contribute to taste and flavour generation (Kaneko, Kumazawa, & Nishimura, 2011; Kaneko et al., 1994).

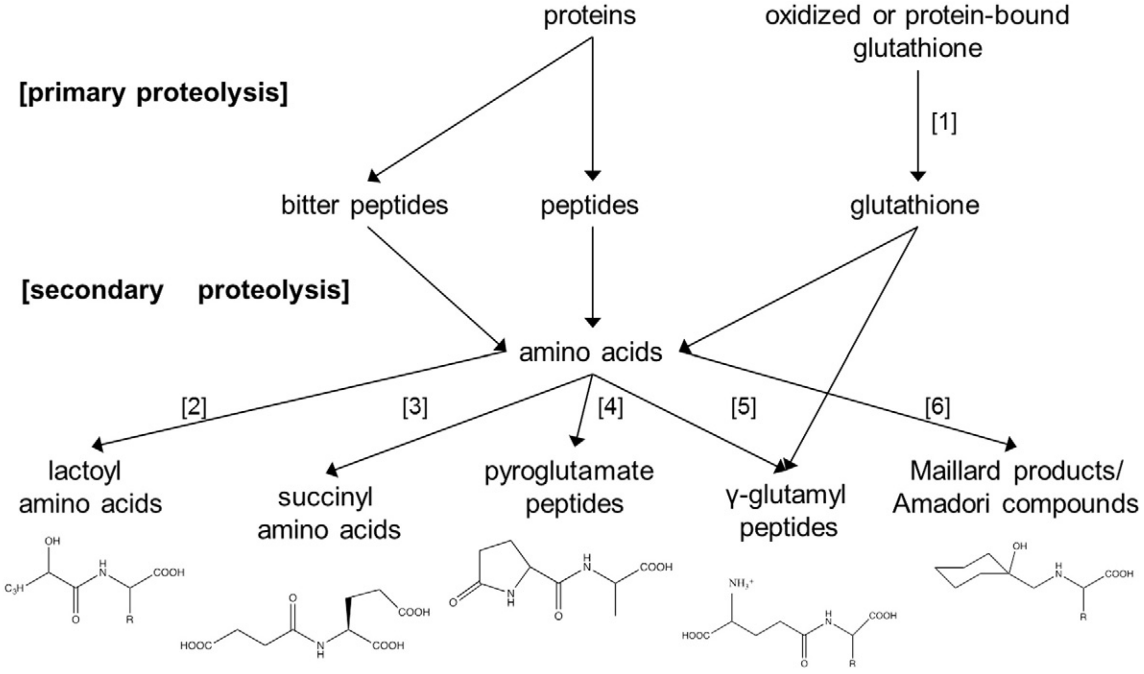

Fig. 1. Overview on the generation of taste compounds from proteins during food fermentation. Proteolysis generates taste active peptides and amino acids; glutathione reductase generates the kokum-active glutathione. Further conversion of peptides or amino acids to taste active compounds proceeds by enzymatic reactions. Enzymatic conversions were proposed to be catalysed by lactoyl-transferase [2], succinyl transferase [3], pyroglutamyl cyclase [4], or by γ-glutamyl-transferase [5]. Maillard/Amadori products [6] are formed by chemical conversion during heating.