運用同位素標記探討梅納反應風味化合物生成機制

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摘要

梅納反應是食品風味發展的關鍵過程，但許多重要香氣化合物的生成路徑仍未完全釐清。本研討會整合多篇運用同位素標記的研究，以闡明其生成機制。首先，利用茶葉原位同位素標記模型（$[^{15}N]$-丙胺酸與 $[U\text{-}^{13}C_6]$-葡萄糖）顯示，烘焙武夷岩茶中的烷基吡嗪主要由丙胺酸提供氮原子，而呋喃類化合物的碳原子則主要源自葡萄糖，並揭示茶葉不溶性基質在風味化合物形成中的貢獻。其次，藉由 *D*-葡萄糖與 *L*-半胱胺酸的碳模組標記實驗，釐清 2-乙醯噻唑的形成路徑，顯示其 C-4 與 C-5 來源於葡萄糖，並首次提出糖降解產生的乙二醛與甲基乙二醛在半胱胺酸釋放的 H_2S 與 NH_3 作用下生成 2-乙醯噻唑的新途徑。最後，研究外加木糖與丙胺酸–木糖 Amadori 產物共加熱過程，透過 $[^{13}C_5]$-木糖追蹤發現，外加木糖可競爭性促進 2-糠醛生成並抑制吡嗪生成，原因在於改變加熱過程中的 pH 與 α-二羰基中間體的去向。整體而言，這些研究成果深化了對梅納反應風味化合物生成機制之理解，並為食品與茶葉加工風味調控提供了理論依據。

Isotopic Labeling Approach to Elucidate Flavor Compound Formation in the Maillard Reaction

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Outline

Abstract

The Maillard reaction is a key process in the development of food flavors, yet the formation pathways of many important aroma compounds remain incompletely understood. This seminar integrates multiple studies employing isotopic labeling to elucidate these mechanisms. First, an in-leaf isotopic labeling model using [^{15}N]-alanine and [U-$^{13}C_6$]-glucose demonstrated that, during the roasting of Wuyi rock tea, alkyl pyrazines predominantly derive their nitrogen atoms from alanine, whereas the carbon skeleton of furan compounds mainly originates from glucose, highlighting the contribution of the insoluble tea leaf matrix to flavor compound formation.

Second, a carbon-module labeling experiment with D-glucose and L-cysteine clarified the formation pathway of 2-acetylthiazole, showing that its C-4 and C-5 carbons are derived from glucose and, for the first time, proposing a novel route in which glyoxal and methylglyoxal—produced from sugar degradation—react with H_2S and NH_3 released from L-cysteine to form 2-acetylthiazole. Finally, in a model system co-heating exogenous xylose with alanine–xylose Amadori products, tracing with [$^{13}C_5$]-xylose revealed that added xylose competitively promotes 2-furfural formation while inhibiting pyrazine generation, likely due to alterations in pH and the fate of α-dicarbonyls intermediates during heating. Collectively, these findings advance our understanding of flavor compound formation mechanisms in the Maillard reaction and provide a theoretical basis for flavor modulation in food and tea processing.