

魚類幹細胞脂質代謝形成機制並應用於細胞培養魚肉

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大綱

一、前言

二、大黃魚肌肉與脂質幹細胞脂質代謝與揮發性化合物分析

三、鯖魚肌肉細胞系之脂質累積與脂肪酸組成分析

四、虹鱒肌肉與脂肪幹細胞及細胞培養魚肉之建立與品質評估

五、結論

摘要

目前細胞培養肉以哺乳動物為主，海洋物種相對研究較少，由於過度捕撈以及重金屬、塑膠污染對海洋生物產生負面影響，故以細胞培養魚肉(cultured fish meat, CFM)作為永續食品來源之一，避免糧食危機。本文整合不同魚種幹細胞建立與脂質代謝研究成果，探討脂肪生成與風味形成之差異，比較不同分化途徑之脂質組成與揮發性化合物特徵，解析其對細胞培養魚肉風味調控影響。結果顯示大黃魚脂肪幹細胞(adipose stem cells, ASCs)與肌肉幹細胞(muscle stem cells, MSCs)於脂肪生成與轉分化過程中呈現顯著脂質體差異，ASCs 分化後三酸甘油酯與鞘磷脂含量提升，並與醛、酮與酯類等揮發性化合物呈正相關，顯示富含不飽和脂肪酸之磷脂為關鍵風味前驅物。鯖魚自發性永生細胞系具脂質累積與成脂分化能力，與天然鯖魚相比單元不飽和脂肪酸含量較高。虹鱒肌肉幹細胞系(muscle stem cell line, RTMS)和脂肪幹細胞系(adipose-derived stem cell line, RTADS)分別於 10%與 15%胎牛血清(fetal bovine serum, FBS)、18°C 條件下具最佳生長速率，最終製備出含 57%細胞比例之大理石紋 CFM，且抗生素殘留低於法規限值，具安全性與可行性，然而 CFM 之多元不飽和脂肪酸與 ω -3 脂肪酸含量低於天然魚肉，顯示脂質代謝調控為關鍵技術。綜上所述，細胞培養魚肉之品質提升需結合具高分化潛力之細胞來源，並增加功能性脂質合成途徑，以兼顧風味、營養與產業化發展需求。

Mechanisms of Lipid Metabolism in Fish Stem Cells and Their Applications in Cultivated Fish Meat Production

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Outline

1. Introduction
2. Lipid Metabolism and Volatile Compound Analysis in Large Yellow Croaker Muscle and Adipose Stem Cells
3. Lipid Accumulation and Fatty Acid Composition in Atlantic Mackerel Muscle Cell Lines
4. Establishment of Rainbow Trout Muscle and Adipose Stem Cells and Evaluation of Cultured Fish Meat Quality
5. Conclusion

Abstract

Cultured meat research has predominantly focused on mammalian species, whereas marine organisms remain comparatively underexplored. In response to overfishing and contamination by heavy metals and plastic pollutants, cultured fish meat (CFM) has emerged as a promising sustainable protein source to alleviate food security concerns. This study integrates findings on the establishment of stem cell lines from multiple fish species and their lipid metabolic characteristics, with emphasis on adipogenesis and flavor formation. Lipidomic profiles and volatile compound signatures were compared across differentiation pathways to elucidate their roles in flavor modulation of CFM. Significant lipidomic differences were observed between adipose stem cells (ASCs) and muscle stem cells (MSCs) from large yellow croaker during adipogenic differentiation and transdifferentiation. Differentiated ASCs exhibited increased triacylglycerol and sphingomyelin levels, positively correlated with aldehydes, ketones, and esters, suggesting that phospholipids enriched in unsaturated fatty acids act as key flavor precursors. Spontaneously immortalized mackerel cell lines demonstrated lipid accumulation and adipogenic capacity, with higher monounsaturated fatty acid content than native tissue. Rainbow trout muscle (RTMS) and adipose-derived (RTADS) stem cell lines achieved optimal proliferation at 10% and 15% fetal bovine serum (FBS) at 18°C, enabling production of marbled CFM containing 57% cellular content. However, reduced polyunsaturated and ω -3 fatty acid levels compared with conventional fish highlight lipid metabolic regulation as a critical challenge.

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