高脂飲食對大鼠生殖功能障礙的機制與微營養素干擾

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大綱

I. 前言

II. 高脂肪飲食會干擾大鼠附睾精子成熟

III. 短期高脂肪飲食透過 SIRT1 / NRF2 / MAPK 傳遞路徑改變大鼠睪丸活動

IV. 微量營養素的抗氧化介入改善高脂肪飲食誘導大鼠精子和睪丸氧化損傷

V. 結論

摘要

高脂飲食 (High Fat Diet；HFD) 誘發的肥胖已成為全球性健康危機，與男性生殖功能障礙密切相關。臨床證據顯示，肥胖男性普遍存在精子品質下降、生育力減退等問題，但其分子機制仍未完全闡明。本報告系統性探討 HFD 對雄性大鼠生殖系統的多層面影響。研究發現 HFD 透過以下機制損害生殖功能 : (1) 荷爾蒙失衡:睪固酮表現量顯著下降，破壞下視丘-腦垂體-性腺軸；(2) 精子成熟障礙:副睪環境改變導致精子活化異常、膜穩定性受損 (3) 氧化壓力升高 : 活性氧過度累積，SIRT1/NRF2/MAPK 抗氧化路徑受抑制，導致 DNA 與脂質過氧化損傷；(4) 粒線體功能障礙 : 融合 / 分裂動態失衡，能量代謝受阻。研究證實補充葉酸、維生素 B_6、鋅、膽鹼、甜菜鹼等抗氧化微量營養素，可活化 NRF2 路徑、恢復抗氧化酶活性，進而改善精子活力與睪丸組織學指標。HFD 誘導的雄性生殖障礙涉及複雜的氧化 - 代謝 - 內分泌系統失調。抗氧化微量營養素補充提供了可行且安全的預防 / 治療策略，對臨床改善肥胖相關男性不孕症具有重要應用潛力。

Mechanisms of Reproduction Dysfunction Induced by HFD In Rats and Micronutrient Interventions

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Outline

Abstract

High-fat diet (HFD)-induced obesity has emerged as a global health crisis, closely associated with male reproductive dysfunction. Clinical evidence shows that obese men generally have problems such as decreased sperm quality and reduced fertility, but the molecular mechanisms are still not fully elucidated. This report systematically explores the multifaceted effects of HFD on the reproductive system of male rats. The study found that HFD impairs reproductive function through the following mechanisms:(1)Hormonal imbalance: testosterone levels are significantly reduced, disrupting the hypothalamus-pituitary-gonadal axis;(2)Sperm maturation disorder: changes in the epididymal environment lead to abnormal sperm capacitation and impaired membrane stability;(3)Increased oxidative stress: excessive accumulation of reactive oxygen species and inhibition of the SIRT1/NRF2/MAPK antioxidant pathway, leading to DNA and lipid peroxidation damage;(4)Mitochondrial dysfunction: imbalance in fusion/fission dynamics and impaired energy metabolism. Studies have demonstrated that supplementation with antioxidant micronutrients such as folic acid, vitamin B6, zinc, choline, and betaine can activate the NRF2 pathway and restore antioxidant enzyme activity, thereby improving sperm motility and testicular histological parameters. HFD-induced male reproductive impairment involves a complex network of dysregulation of oxidation, metabolism, and endocrine function. Antioxidant micronutrient supplementation offers a feasible and safe preventive/therapeutic strategy with significant potential for clinical improvement of obesity-related male infertility.

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