Plasma Bioavailability of Vitamin D_3 Following Dietary Intake of OTM-2403-13 Insect Oil in Rats: A Controlled 14-Day Intervention Study

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Abstract

Background: The metabolic fate and systemic bioavailability of vitamin D_3 are profoundly shaped by the lipid matrix through which it is delivered, influencing micellar solubilization, enterocyte uptake, chylomicron secretion, and subsequent hepatic bioconversion. Insect-derived oils—rich in bioactive mono- and polyunsaturated fatty acids—have recently emerged as unconventional yet promising vectors capable of enhancing nutrient-lipid interactions and facilitating absorption.

Objective: This study sought to characterize, under controlled dietary conditions, the capacity of the vitamin-D_3–enriched insect oil OTM-2403-13 to restore and potentiate circulating 25(OH)D_3 concentrations in rats following nutritional depletion, compared with a vitamin D_3-deficient homologous lipid matrix.

Methods: Male Wistar rats were subjected to a 28-day depletion phase before receiving either: (1) a deficient control diet containing MO-2403-13 oil devoid of vitamin D_3, or (2) an intervention diet incorporating OTM-2403-13 delivering 22 µg/day/rat of vitamin D_3 for 14 days. Plasma 25(OH)D_3 was quantified using HPLC-DAD following standardized extraction and calibration.

Results: Animals receiving OTM-2403-13 exhibited a striking restoration of vitamin D status, with mean plasma 25(OH)D_3 rising from 6.9 ng/mL in deficient controls to 40.3 ng/mL ($p = 4.4\times10^{-11}$). Inter-individual variability was minimal within groups, indicating consistent absorption and metabolic handling.

Conclusion: OTM-2403-13 demonstrated substantial bioavailability, suggesting that insect-derived lipid matrices constitute a promising modality for dietary vitamin D_3 delivery and may provide translational applications for functional foods aimed at correcting insufficiency.

Keywords: Vitamin D3, bioavailability, insect oil, Tenebrio molitor, 25(OH)D_3, lipid matrix, nutrition, rodent model

1. Introduction

Vitamin D_3 remains a cornerstone of endocrine and immunometabolic physiology, with well-established roles in calcium homeostasis, bone remodeling, neuromuscular function, and innate immunity. Despite its biological centrality, vitamin D insufficiency is highly prevalent worldwide, driven by inadequate dietary intake, restricted sunlight exposure, and impaired metabolic activation. A substantial body of work has highlighted that the bioavailability of vitamin D_3 is strongly modulated by the surrounding lipid matrix, wherein fatty acid composition, emulsification behavior, micelle formation, and chylomicron assembly collectively influence its absorption efficiency.

Insect-derived oils have gained traction as sustainable lipid vectors exhibiting unique physicochemical properties, including favorable ratios of MUFA and PUFA, structured lipid configurations, and natural oxidative stability. These attributes may facilitate improved solubilization and transport of lipophilic micronutrients. OTM-2403-13, a Tenebrio-molitor–derived oil enriched in vitamin D_3, represents a novel candidate for enhancing dietary vitamin D delivery.

This study therefore examined the capacity of OTM-2403-13 to raise circulating 25(OH)D_3 levels under controlled nutritional conditions, following a standardized depletion protocol designed to mimic dietary insufficiency.

2. Materials and Methods

2.1 Animal Model

Eight-week-old male Wistar rats underwent a 28-day vitamin D_3 depletion period using a semi-purified diet containing 480 ng/100 g vitamin D_3 and 6.8% fat. Animals were randomized into two experimental groups (n = 8/group) under controlled environmental and lighting conditions.

2.2 Diets and Vitamin D_3 Exposure

The control group received pellets containing 7% MO-2403-13 oil, naturally devoid of vitamin D_3. The intervention group consumed pellets incorporating 7% OTM-2403-13, providing 1,652±149.5 µg vitamin D_3/100 g, equivalent to 22 µg/day/rat. All diets were offered ad libitum.

2.3 Plasma Collection and HPLC Analysis

Blood samples were collected at day 14 via terminal puncture. Plasma was analyzed for 25(OH)D_3 concentrations using high-performance liquid chromatography with diode-array detection (HPLC-DAD). Quantification employed external calibration curves constructed with certified standards. Statistical significance was assessed using Student's t-test with $\alpha = 0.05$.

3. Results

3.1 Plasma Vitamin D_3 Status Restoration

Following the intervention, plasma 25(OH)D_3 differed markedly between groups. Animals maintained on the vitamin-D_3–deficient MO-2403-13 oil remained severely depleted (mean 6.9 ng/mL).

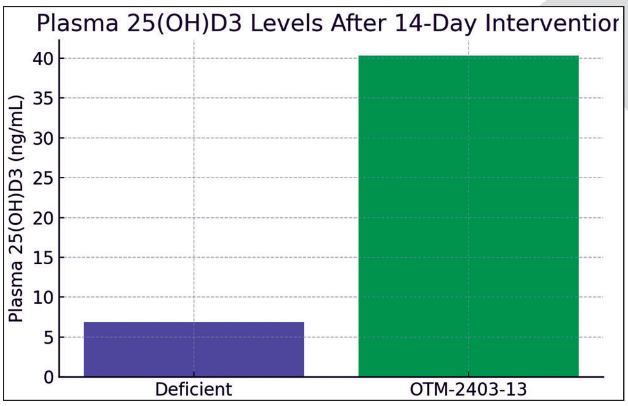

Figure 1. Plasma 25(OH)D_3 Levels After 14 Days

In contrast, rats receiving OTM-2403-13 exhibited a dramatic six-fold elevation (mean 40.3 ng/mL), with exceptional statistical support ($p = 4.4\times10^{-11}$).

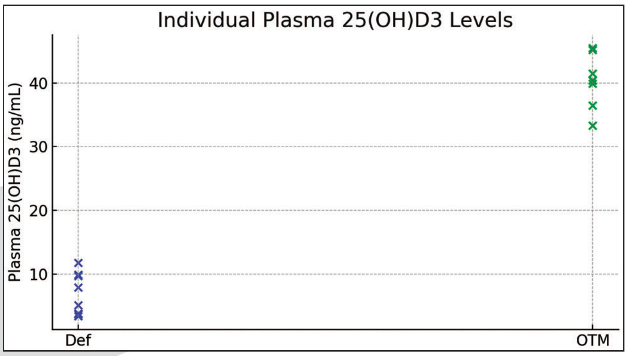

Figure 2. Individual Animal 25(OH)D_3 Values

Table 1. Individual Plasma 25(OH)D_3 Levels (ng/mL)

Animal	Deficient Control	OTM-2403-13
1	11.8	36.5
2	9.7	40.4
3	7.9	40.4
4	9.9	41.5
5	3.7	45.5
6	5.1	39.9
7	3.8	33.3
8	3.4	45.2

4. Discussion

The present investigation demonstrates, with high statistical robustness, that OTM-2403-13 is a highly bioavailable dietary source of vitamin D_3. The magnitude of the elevation in plasma 25(OH)D_3 is consistent with lipid-assisted enhancement of intestinal uptake, aligning with mechanistic literature that emphasizes the importance of micellar solubilization, enterocyte lipid trafficking, and hepatic hydroxylation kinetics.

Several factors may underpin the superior absorptive performance of OTM-2403-13:

(1) favorable MUFA-rich fatty acid composition enhancing micelle fluidity;
(2) potential synergistic interactions between insect lipids and intestinal lipid transporters;
(3) optimized partitioning into chylomicrons facilitating lymphatic entry; and
(4) the absence of inhibitory components commonly found in certain vegetable oils.

These findings resonate with recent nutritional science exploring alternative lipid matrices capable of improving the metabolic handling of fat-soluble vitamins.

Translationally, the results suggest that insect-derived oils may serve as viable fortification agents in food systems aiming to correct widespread vitamin D insufficiency. Further research - particularly long-term human studies - is warranted to elucidate dose-response dynamics, safety profiles, and matrix interactions in complex dietary environments.

5. Conclusion

Daily intake of 22 μg vitamin D_3 delivered through OTM-2403-13 insect oil produced a substantial restoration of circulating $25(OH)D_3$ following depletion. The bioavailability observed here underscores the translational potential of insect oils as functional lipid carriers for micronutrient fortification.

6. References

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