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Homemade oral nutritional supplements with reduced long-chain triglycerides: bromatological and sensory evaluation

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Abstract

Introduction: Restricting long-chain triglycerides (LCTs) and replacing them with medium-chain triglycerides (MCTs) may improve the nutritional status of patients with lipid malabsorption. Homemade oral nutritional supplements (ONS) containing MCTs aim to increase energy intake and prevent weight loss. **Objective:** To develop an accessible, nutritionally adequate, and palatable homemade ONS with restricted LCTs and added MCTs, targeted at patients with diseases affecting lipid absorption. **Methods:** This prospective observational study adhered to the STROBE guidelines. Three formulations of energy-dense homemade ONS with low LCT content and added MCTs were developed, considering nutritional value, cost, and ingredient availability. Proximate composition was assessed through bromatological analysis. Sensory acceptability was evaluated in 30 assessors (19 healthy individuals and 11 patients with malabsorption syndromes) using a 0-10 hedonic scale. Data were analyzed using one-way ANOVA. As no significant differences were detected, post-hoc testing was not performed ($p < 0.05$ considered significant). **Results:** Energy density ranged from 1.56 to 1.74 kcal/mL, and protein content ranged from 5.1 to 5.9 g/100 mL. No significant differences were found between formulations regarding color ($p=0.765$), aroma ($p=0.459$), flavor ($p=0.721$), or overall impression ($p=0.146$). **Conclusion:** Homemade ONS are feasible alternatives that are affordable, palatable, and nutritionally appropriate for patients requiring LCT restriction, with potential to improve therapeutic adherence and nutritional status.

Keywords: Intestinal absorption. Oral Nutritional Supplements. Medium-chain triglycerides. Chylothorax. Intestinal Lymphangiectasia.

Introduction

Fats are the primary energy source in the human diet and are predominantly present as triglycerides, classified according to the length of their carbon chains [1]. Long-chain triglycerides (LCTs), containing 14 or more carbon atoms, are found in vegetable oils, animal fats, and fish oils, whereas medium-chain triglycerides (MCTs), with 6–12 carbon atoms, can serve as an alternative energy source [2]. Differences in carbon chain length influence the physicochemical properties of lipids, as well as their biological and metabolic functions [3].

Conditions characterized by lipid malabsorption, such as celiac disease [4], short bowel syndrome [5], and primary intestinal lymphangiectasia [6,7], have estimated prevalences of approximately 1% in the general population, 1–3 per 100,000 inhabitants, and 1.5–2.5 per 100,000 inhabitants, respectively. These

conditions may lead to protein-energy malnutrition and micronutrient deficiencies, highlighting the need for tailored dietary strategies. Lipid digestion occurs mainly in the duodenum and is mediated by pancreatic lipase and colipase, with emulsification by bile salts **[8]**. LCTs are re-esterified within enterocytes and transported as chylomicrons via the lymphatic system, whereas MCTs are absorbed directly and transported through the portal circulation bound to albumin **[1]**.

Replacing LCTs with MCTs in food preparations has been associated with clinical benefits in patients with lipid malabsorption, including improved nutritional status, better dietary adherence, and enhanced quality of life **[3,9]**. However, access to affordable and palatable homemade oral nutritional supplements (ONS) with low LCT content remains limited. Sensory attributes such as flavor, aroma, and texture are key determinants of supplement acceptance and adherence to nutritional therapy **[10]**.

Therefore, this study aimed to develop three accessible, nutritionally adequate, and palatable homemade ONS formulations for individuals requiring dietary LCT restriction.

Material and Methods

Location and Study Design

This prospective observational study was conducted at a tertiary-care university hospital (Hospital das Clínicas of Ribeirão Preto Medical School, University of São Paulo – HCFMRP-USP), in collaboration with the Laboratory of Food Analysis and Technology, University of Ribeirão Preto (UNAERP), and followed the STROBE guidelines **[11]**. The study was carried out between June and November 2023.

Ethical Approval

It was approved by the institutional ethics committee (Approval No. 4.347.249). All volunteers participating in the sensory evaluation provided written informed consent.

Development of the Formulations

Three homemade ONS formulations were developed using minimally processed foods **[12]**, prioritizing nutritional value, availability, cost, and palatability. Nutritional composition was calculated using DietWinPlus, setting the following targets: energy density ≥1.5 kcal/mL, protein ≥5.5 g/100 mL, LCTs <0.8 g/100 mL, and MCT supplementation of 5.0-7.0 g/100 mL. Cost was calculated per 100 kcal of ready-to-consume product, including the MCT module but excluding labor and energy costs, and expressed in U.S. dollars (US$).

Bromatological Analysis

Proximate composition was determined in triplicate, including moisture, ash, protein, lipids, and carbohydrates, prior to MCT addition. Moisture was measured by oven-drying at 105°C; ash by incineration **[13]**; protein by Micro-Kjeldahl (conversion factor 6.25); and lipids by Soxhlet extraction. Carbohydrate content was calculated by difference **[14]**. Total energy value was calculated as 4 kcal/g for carbohydrates and protein, and 9 kcal/g for lipids, expressed per 100 mL. After adding the MCTs module, energy values and energy density were recalculated per 150-mL portion.

Sensory Evaluation

Sensory testing was conducted with 30 participants (15 females, 15 males; mean age 38.5 ± 12.8 years). Nineteen were healthy and eleven were hospitalized with severe malabsorption disorders, including one case of intestinal lymphangiectasia and ten with short bowel syndrome resulting from mesenteric thrombosis (n=3), Crohn's disease (n=3), or postoperative complications (n=4). ONS were prepared by trained staff under dietitian supervision. A structured hedonic scale was used to evaluate color, aroma, flavor, and overall impression. A score of 10 indicated "liked extremely," whereas 0 indicated "disliked extremely" **[10]**. Samples (50 mL each) were served at room temperature in plain disposable cups. Mineral water was provided between samples.

Evaluations were conducted under controlled lighting, temperature, and noise conditions, with assessors seated at least 5 meters apart to avoid communication. Participants were instructed not to compare the samples or express personal opinions aloud.

Statistical Analysis

Sensory data were expressed as minimum, maximum, mean, and standard deviation. Differences between formulations were evaluated using one-way ANOVA ($p < 0.05$ considered significant). As no significant differences were detected, post-hoc testing was not performed. Statistical analyses were performed using SAS® (SAS Institute Inc., Cary, NC, USA), and the sensory profiles were displayed using radar charts.

Results

Composition and Cost

Table 1 presents the ingredients used, with corresponding quantities and household measures. Main components included skim milk powder,

industrialized rice flour (commonly marketed as infant rice cereal), and commercial MCT module. The cost per serving ranged from US$1.19 to US$1.36.

Table 1. Ingredients, household measures, and cost of three oral nutritional supplements (ONS) with restricted long-chain triglycerides (LCTs).

Ingredients	ONS1	ONS2	ONS3	Household measures
Skim milk powder (g)	30	30	30	3 tablespoons
Industrialized rice flour (g)	14	14	14	2 tablespoons
Commercial MCT oil (g)	11	11	11	1 tablespoon
Banana (g)	40	40	-	1 small unit
Canned peach (g)	38	-	-	½ unit
Guava paste (g)	-	10	-	½ tablespoon
Peeled apple (g)	-	-	60	½ medium unit
Papaya (g)	-	-	50	½ medium slice
Filtered water (mL)	150	150	150	1 glass
Cost per serving (≈US$)	1.36	1.19	1.36	-

Source: Own authorship.

Bromatological Analysis

Before MCTs addition, lipid concentrations ranged from 0.03±0.00 g/100 mL in ONS2 to 0.11±0.03 g/100 mL in ONS3, while protein levels were high across formulations (Table 2). After MCT enrichment, energy density increased to 1.56-1.74 kcal/mL, supplying 234.31-261.79 kcal per 150-mL portion.

Table 2. Proximate composition, energy value per serving, and energy density of three oral nutritional supplements (ONS) with restricted long-chain triglycerides (LCTs).

Proximate analysis before MCTs addition (Mean ± SD)			
Moisture (g/100 mL)	70.36 ± 0.06	74.29 ± 0.04	75.36 ± 0.22
Ash (g/100 mL)	1.37 ± 0.00	1.16 ± 0.00	1.09 ± 0.05
Proteins (g/100 mL)	5.94 ± 0.12	5.10 ± 0.12	5.75 ± 0.05
Lipids (g/100 mL)	0.07 ± 0.02	0.03 ± 0.00	0.11 ± 0.03
Carbohydrates (g/100 mL)	21.22 ± 0.29	17.87 ± 0.25	16.74 ± 0.13
Energy value (kcal/100 mL)	109.26 ± 0.79	92.12 ± 0.82	90.94 ± 0.44
After MCTs addition (per 150 mL serving)			
Energy value (kcal/150 mL)	261.79	236.08	234.31
Energy density (kcal/mL)	1.74	1.57	1.56

Source: Own authorship.

Sensory Evaluation

Table 3 presents the mean sensory scores, while Figure 1 provides a visual overview of the sensory profile. No significant differences were found for color ($p = 0.765$), aroma ($p = 0.459$), flavor ($p = 0.721$), or overall impression ($p = 0.146$). Likewise, no significant differences were observed between men and women or between healthy and hospitalized participants ($p > 0.05$). The radar plots show that ONS1 scored highest for aroma and overall impression, ONS2 for flavor and color, whereas ONS3 received lower scores for flavor and overall impression. The center of the radar chart represents the lowest score (0), with increasing intensity toward the periphery (Figure 1).

Table 3. Sensory evaluation scores of the three oral nutritional supplements (ONS), expressed as mean ± standard deviation, and minimum-maximum values.

	ONS1	ONS2	ONS3	p-value
Color	6.0 ± 1.9 (1 to 10)	6.7 ± 1.6 (3 to 10)	7.1 ± 2.5 (2 to 10)	0.765
Aroma	6.8 ± 2.5 (1 to 10)	6.3 ± 2.2 (3 to 10)	6.2 ± 2.2 (2 to 10)	0.459
Flavor	7.2 ± 2.4 (2 to 10)	7.3 ± 2.4 (3 to 10)	5.6 ± 2.7 (1 to 10)	0.721
Overall impression	7.5 ± 1.9 (3 to 10)	7.3 ± 2.2 (2 to 10)	6.0 ± 2.5 (2 to 10)	0.146

Source: Own authorship.

Figure 1. Sensory profile of the oral nutritional supplements (ONS) based on color, aroma, flavor, and overall impression scores. Source: Own authorship.

Discussion

In the present study, the three developed oral nutritional supplements (ONS) exhibited low long-chain triglyceride (LCT) content, adequate protein levels, and energy densities consistent with predefined targets **[3]**. A descriptive study of homemade ONS designed for oncology patients reported energy densities ranging from 1.35 to 2.17 kcal/mL, with acceptability rates between 78% and 85%. Although acceptability in the present study was slightly lower than that reported by Garófolo et al. **[15]**, it remained within an acceptable range, supporting the potential applicability of these formulations in clinical practice.

Regarding sensory acceptability, minor variations were observed among the formulations. ONS1 achieved higher scores for aroma and overall impression, ONS2 for flavor and color, whereas ONS3

received slightly lower ratings. However, no statistically significant differences were identified. These findings suggest that, even with low-cost ingredients and homemade preparation, comparable sensory acceptability can be achieved across different formulations [10].

In comparison with recent evidence, systematic reviews indicate that MCT-enriched diets may promote favorable metabolic effects, such as reduced serum triglyceride levels and improved insulin sensitivity, although most studies have focused on populations with overweight or obesity [3,16]. Although the present study addressed a different clinical context—patients with malabsorption disorders—these findings reinforce the physiological relevance of lipid modification. In this setting, it is important to emphasize that fat malabsorption presents specific therapeutic challenges. The risk of deficiencies in essential fatty acids and fat-soluble vitamins, along with the higher osmolality of MCT-based formulations, requires careful monitoring and continuous clinical supervision.

A notable limitation of this study was the variability in sensory ratings among evaluators, which may reflect individual differences in perception or the clinical condition of hospitalized patients [17]. Symptoms such as xerostomia may negatively affect palatability [18], as may serving temperature [19]. Furthermore, the study did not include anthropometric parameters (e.g., body weight and body composition) or markers of intestinal function, such as transit time and fecal fat excretion, which could provide additional evidence regarding the functional impact of the formulations beyond acceptability and bromatological composition.

Conclusion

The development of homemade ONS formulations represents a promising nutritional strategy for meeting dietary requirements involving LCT restriction. The proposed recipes were more cost-effective than commercial ONS and aligned with the principles of a balanced diet. Sensory evaluation proved essential for predicting therapeutic adherence, particularly in populations with specific clinical conditions. Future studies with longitudinal follow-up, conducted in well-defined populations (e.g., lymphangiectasia, chylothorax, and short bowel syndrome), are needed to determine whether homemade formulations with LCT restriction and MCT enrichment can effectively improve nutritional status, reduce complications associated with malabsorption, and ensure long-term safety.

CRediT

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Ethical Approval

It was approved by the institutional ethics committee (Approval No. 4.347.249). All volunteers participating in the sensory evaluation provided written informed consent.

Informed Consent

Written informed consent was obtained from all participants.

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Data Sharing Statement

All data are published in this article.

Conflict of Interest

The authors declare no competing interests.

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Application of Artificial Intelligence (AI)

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