UNIVERSITY OF COPENHAGEN
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Group 1 - Hemp Protein Bar
NFOK24004U

This report is a theoretical project for the production of a hemp protein bar as a dairy substitute.

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Link to Git repo.: https://github.com/DanishUnicorn/dnf_dpa_project

Preface and abstract

Preface

This written assignment has been prepared as part of the course NFOK24004U - Dairy and Plant-based Alternatives at the University of Copenhagen. The course addresses the challenges of developing sustainable and healthy diets by examining processing effects on nutrients in dairy products, hybrid products and their alternatives.

The project is a theoretical study on the development of a hemp seed protein bar as a dairy substitute. Through this work, we aimed to apply the knowledge and competences obtained during the course, including nutritional evaluation, processing considerations, sustainability aspects, and consumer perspectives. The assignment was carried out by Sofie Karoline Thue Hansen (FVC568), Nils Hugo Nilsson (XQK212), Niclas Hauerberg Hyldahl (JNC117), and Lucas Daniel Paz Zuleta (TZS159), all MSc students at the University of Copenhagen.

Abstract

This project explores the development of a hemp seed protein bar as a sustainable alternative to dairy-based protein products. The aim was to design a nutrient-rich product with a favourable environmental profile, while addressing consumer demand for plant-based, convenient, and health-oriented snacks. The nutritional composition was assessed through literature-based data on macronutrients, dietary fibres, and fatty acids, with focus on protein quality and digestibility. Comparisons were made to existing market products (ROO'bar hemp protein bar), highlighting the bar's potential for high protein and high fibre claims under EU regulations. The lipid fraction showed a desirable omega-6 to omega-3 ratio, although thresholds for authorised health claims were not met. Environmental perspectives further emphasised the advantages of hemp cultivation, including low carbon footprint, soil health benefits, and potential use of side streams. Together, these findings demonstrate the relevance of hemp seeds in developing innovative plant-based products that align with both nutritional and sustainability goals.

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Chapter 1
Introduction

1 Problem Description

Protein is one of the macronutrients which primarily makes up tissue building in the human body. Furthermore, the macronutrient is indispensable in many other physiological functions, such as hormones, immune system, and other regulatory mechanisms (Ferrari et al., 2022). The recommended daily allowance of protein varies between 0.8 - 1.6 g/kg body weight, depending on factors such as physical activity, age, gender etc. (Philips et al., 2016).

With an increasing population and an estimate of almost 10 billion by 2050. The future protein demand is projected to increase as a correlated factor to the population increase (Henchion et al., 2016). Proportionally, Makkar et al. 2014 predicts an increase in animal consumption of 60-70%. The increasing demand for animal protein risks further extending planetary boundaries and resulting in conflicts related to sustainability. The planetary boundaries framework by the Potsdam Institute for Climate Impact Research defines “a safe operating space for humanity”. It maps out nine Earth system processes critical for maintaining the planet’s stability and resilience, processes which are all affected by the Anthropocene (Figure 1) (Richardson et al. 2023).

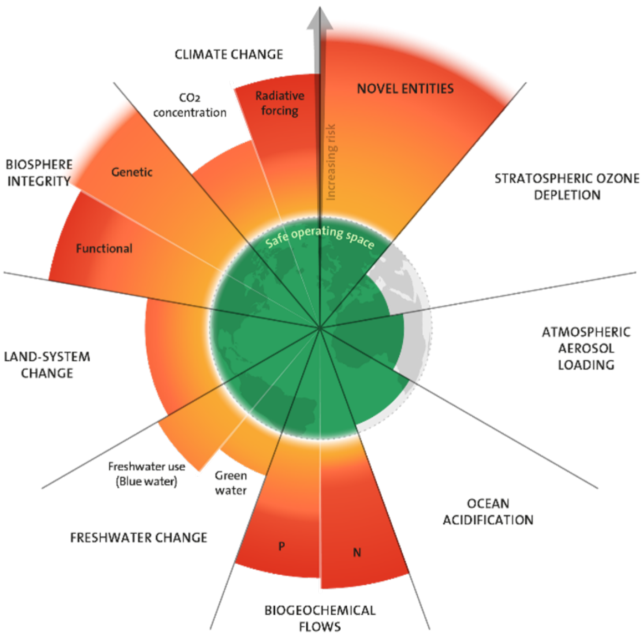

Figure 1.1: *Schematic of the nine Plantary Boundries. (Richardson et al. 2023).*

Thus, humanity stands in front of a challenge in sustaining the supply of animal proteins. Meanwhile, the EAT-Lancet commission declares numerous arguments for a protein shift towards plant-based alternatives. Where human health and environment are two pillar arguments of the diet recommendations (Willett et al., 2019).

1.1 Aim and Objectives

The scope of this report narrows down to a nutrient-rich product with low water impact and low CO2 footprint. The formulation targets two of the nine planetary boundaries, freshwater change and CO2-concentration. This report aims to present a hemp protein bar, which served as an alternative to animal-source protein bars, which could help in mitigating the transgression of these planetary boundaries.

2 Market Trends & Target Consumer Group

With animal sourced protein risking straining the planets' resources, a shift in the traditional diet of the Nordic countries has been studied. On the very subject, Geirsdóttir et al. 2023 provided a thorough scoping-review on Nordic Nutrition Recommendations. They concluded that a shift towards a more plant-based protein diet would benefit both health and the environment. Hence, given the need for a shift, the demand for plant-based protein is expected to increase, while the European meat consumption is expected to decline, the consumption still exceeds that of the respective countries' national recommendations (typically 300-500 g/week). (OECD/FAO, 2023) The Smart Protein Project collects data which helps understanding the status and attitude towards a plant-based diet in various European Countries. Among many surveys, it is stated that "Plant-based sweets, meat alternatives, and milk substitutes emerge as the most sought-after categories for expanding plant-based options." This accounts for 27% of the cohorts "express for desire" of such product. Among the top 6 drivers for choosing these products, "health" and "environmentally friendly" are mentioned (45% and 21% respectively) (ProVeg, 2023). Looking at market predictions and current trends, the global growth of plant-based protein supplements is currently outpacing the growth of that animal source. Which yet again correlates with the future need for sustainable plant-based protein (Market.us, 2024). The consumption of such is seen in either ready-to-eat products or supplements as concentrates or isolates. It is shown that nutritious / functional protein bars are an emerging market as in 2023, it was worth 0,92 billion $ in Europe. Offering a convenient, ready-to-eat alternative to reach fitness goals. The main consumers of such products are found to be Millennials and Generation Z, with enthusiasm over high protein bars (PW, 2024). Hence, targeting younger consumers is of interest. Furthermore, a plant-based protein bar would target any consumer interested in reducing animal consumption, complementing their daily protein intake, and supplementing regular meals.

2.1 Existing Market

As development of plant-based fitness supplements and ready to eat products are increasingly popular, a wide range of products are available. Below is a showcase of an Estonian and Finnish producer, which specialize in hemp-based products and/or raw material. A showcase of a current hemp bar product is also presented.

Nordic Hemp, Estonia

Specializes in organic industrial hemp growing and processing of raw material. Production of 6000 ha / year. (Nordic Hemp, 2025)

- Sorting

- Dehulling
- Processing
- Protein isolation

Impolan Kasvitila, Finland

Impola plant farm is a family-owned company in its fourth generation. (Impolan Lasvitila, 2025) They grow and produce product for end-consumers.

- Pet and Feed products
- Pressing
- Dehulling
- Hemp chocolate
- Hemp muesli
- Hemp meal

Figure 1.2: *Hemp protein bar by Nordic Hemp. Selection of products from Impolan Kasvitila, Finland.*

ROO'bar by Smart Organic, Bulgaria

Roobar is the flagship brand by Smart Organic AD. They are the largest producer of "minimalistic plant-based bars." They focus on "... 4-5 ingredients… organic, vegan, raw, and gluten-free". The production is estimated to 1 million bars per month, and they are accessible in around 50 countries. (Smart Organic, 2025)

- Broad range of different bar products
- Owner of a wide range of ready to eat brands

Figure 1.3: *ROO'bar Hemp protein bar*

Roobar Hemp protein bar

Table 1.1: *Ingredients: Dates, almonds, hemp protein (18%). Nutrient declaration per 100 g.*

Energy	1582 kJ/377kcal
Fat	11 g
- Fatty acids	1.9 g
Carbohydrates	49 g
- Sugars	33 g
- Dietary Fibers	11 g
Protein	14 g
Salt	0 g

Chapter 2
Literature résumés

This section of the course notes is designed to streamline access to the key findings from each reading material (RM), providing a concise and accessible overview of essential information. Created through experimentation with various AI platforms, this chapter also serves to enhance prompt engineering skills, exploring diverse methods of note-taking for maximum efficiency and clarity. The procedures for creating these summaries have varied, but all methods share a common approach: each RM has been fully read, with summaries and notes prepared after completing each respective subsection. By using these AI-co-op'ed approaches, these notes aim to be both a reliable reference and a resource for continuous improvement in capturing complex microbiology concepts.

1 1st Reading Material from the Curriculum

1.1 Milk for Liquid Consumption

Liquid milk is treated by pasteurization or sterilization to ensure safety, extend shelf life, and retain flavour. Raw milk is considered unsafe and is restricted in many countries. Pasteurized milk retains better flavour, while sterilized milk offers longer shelf life, especially valued in cooking. Fat content is usually standardized, but low-fat and skim milks are also common. Some products are fortified or processed via ultrafiltration for consistent protein content, although this may be legally restricted. Quality attributes vary by use, and packaging is essential for hygiene [**curr_rm_01_dairy_science_technology**].

Manufacture

Thermalization reduces lipase activity and psychrotrophic growth, aiding shelf life. Homogenization prevents creaming but increases lipolysis risk, requiring higher heat (e.g., 20 s at 75 °C). Low pasteurization (15 s at 72 °C) kills pathogens while preserving natural inhibitors, though heat-sensitive compounds like agglutinins and immunoglobulins are degraded in high-pasteurized milk. Packaging hygiene is crucial to prevent recontamination and preserve shelf life [**curr_rm_01_dairy_science_technology**].

Shel Life

Shelf life is influenced by bacterial growth, enzymatic activity, and chemical/physical changes. Key factors include storage temperature, recontamination, and Bacillus cereus spore levels. Below 7 °C, psychrotrophs dominate spoilage. Hygiene in packaging is essential; rapid tests help detect recontamination [**curr_rm_01_dairy_science_technology**].

Extended-Shelf-Life Milk

ESL milk combines long shelf life with near-fresh flavour. One method applies short-time direct UHT treatment (e.g., 2 s at 140 °C) with aseptic packaging; enzymes like plasmin may still affect taste after weeks. The second method involves microbial removal via microfiltration or bactofugation, often followed by partial UHT sterilization of retentate and cream. Aseptic packaging is essential. Cooked flavour is minimized by limiting heat to fat-rich fractions [**curr_rm_01_dairy_science_technology**].

1.2 Sterilized Milk

1.2.1 Description

Sterilized milk must be microbe-free, shelf-stable at ambient temperature, and retain acceptable flavour and nutritional value. UHT sterilization (e.g., 1 s at 145 °C) minimizes browning, off-flavours, and vitamin loss. To prevent spoilage, packaging must be aseptic, and milk free from heat-resistant enzymes. Homogenization avoids creaming and coalescence. Lactulose content is used to identify UHT-treated milk [**curr_rm_01_dairy_science_technology**].

Manufacture

Sterilized milk is made via in-bottle, mild in-bottle, or flow-through UHT processes. Psychrotroph enzymes (esp. from *Pseudomonas*) are heat-resistant, so raw milk must be fresh. UHT heating (>140 °C) ensures safety but risks casein aggregation, off-flavors, and vitamin loss. Aseptic homogenization and deaeration are crucial to prevent oxidized flavor. Oxygen- and light-tight packaging prolongs shelf life [**curr_rm_01_dairy_science_technology**].

Shelf Life

Spoilage of in-bottle sterilized milk may result from surviving spores (e.g., *B. subtilis*, *B. stearothermophilus*) or leaky packaging. UHT milk mainly deteriorates via recontamination or residual heat-resistant enzymes, causing gelation, off-flavors, or plasmin-induced bitterness. Nonenzymatic spoilage includes oxidation, Maillard reactions, and light effects. Shelf life is tested via incubation, oxygen pressure, or ATP bioluminescence [**curr_rm_01_dairy_science_te**

1.3 Reconstituted Milk

Reconstituted milk is made by dissolving milk powder in water; recombined milk adds anhydrous milk fat to reconstituted skim milk. It mimics whole milk but lacks natural fat globule membrane components. Filled milk uses vegetable oil instead of milk fat. Toned milk blends buffalo milk with skim milk to reduce fat content [**curr_rm_01_dairy_science_technology**].

1.4 Flavour

Good flavour means a bland taste without off-flavours. Sources include microbial growth (e.g., *B. cereus*, *P. fragii*), plasmin, lipoprotein lipase, and oxidation by Cu or light. Heat causes cooked, UHT ketone, or sterilized-milk flavour, depending on thermal load. Sunlight flavour arises from methionine oxidation with riboflavin present [**curr_rm_01_dairy_science_technology**].

1.5 Nutritive Value

This section addresses changes in nutritive value due to deliberate changes in composition, processing, and storage. For details on the nutritive aspects of milk components, see Subsections 2.1.2, 2.2.4, 2.3.3, 2.4.5, and Table 2.18 in the book [**curr_rm_01_dairy_science_technology**].

Modification of Composition

Milk of modified composition includes low-fat, skim, or vitamin-fortified types. Filled milk uses vegetable oils, often rich in vitamins D and E, with added antioxidants. Calcium may be added as lactate or whey permeate. Lactose-free milk, produced by adding lactase after UHT treatment, has limited success due to cost and sweet taste. Functional foods and specialised products are also being developed [**curr_rm_01_dairy_science_technology**].

Loss of Nutrients

Pasteurized and UHT-sterilized milk lose few nutrients, while in-bottle sterilized milk shows greater loss, especially of lysine and vitamins due to Maillard reactions. Losses mainly affect vitamin C and B vitamins (B_1, B_2, B_6, B_9, B_12). Oxygen and light accelerate degradation, with riboflavin acting as a catalyst. Packaging permeability is crucial to prevent losses [**curr_rm_01_dairy_science_technology**].

1.6 Infant Formulas

Breast feeding is preferable, but when not possible, infant formulas based on cows' milk fractions are used. Unmodified cows' milk is unsuitable. Due to higher risk of microbial contamination, strict hygiene is essential during preparation and storage. Liquid formulas should be refrigerated [**curr_rm_01_dairy_science_technology**].

Human Milk

Human milk differs from cows' milk in composition and varies by individual and lactation stage. It contains more essential fatty acids, cholesterol, and oligosaccharides, but less protein, casein, and minerals. It includes immunoglobulin A, lysozyme, and lactoferrin, and lacks β-lactoglobulin. Infant formulas require significant adjustment to mimic its properties [**curr_rm_01_dairy_science_technology**].

Formula Composition and Manufacture

Infant formulas use skim milk and sweet whey (e.g., 1:5 ratio), often with added lactose, vegetable oils, vitamins, Fe, and Cu. Whey is partly desalted. Oligosaccharides or lactulose may be added. Manufacture involves wet mixing, pre-emulsification, pasteurization, and homogenization. Products may be UHT-sterilized, canned, or spray-dried [**curr_rm_01_dairy_science_technology**].