Solubility and Functionality of a Novel Fava Bean Milk Powder

- Effects of pH, Processing, and Dispersion Medium

Jonathan Terneborg

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Department of Molecular Sciences
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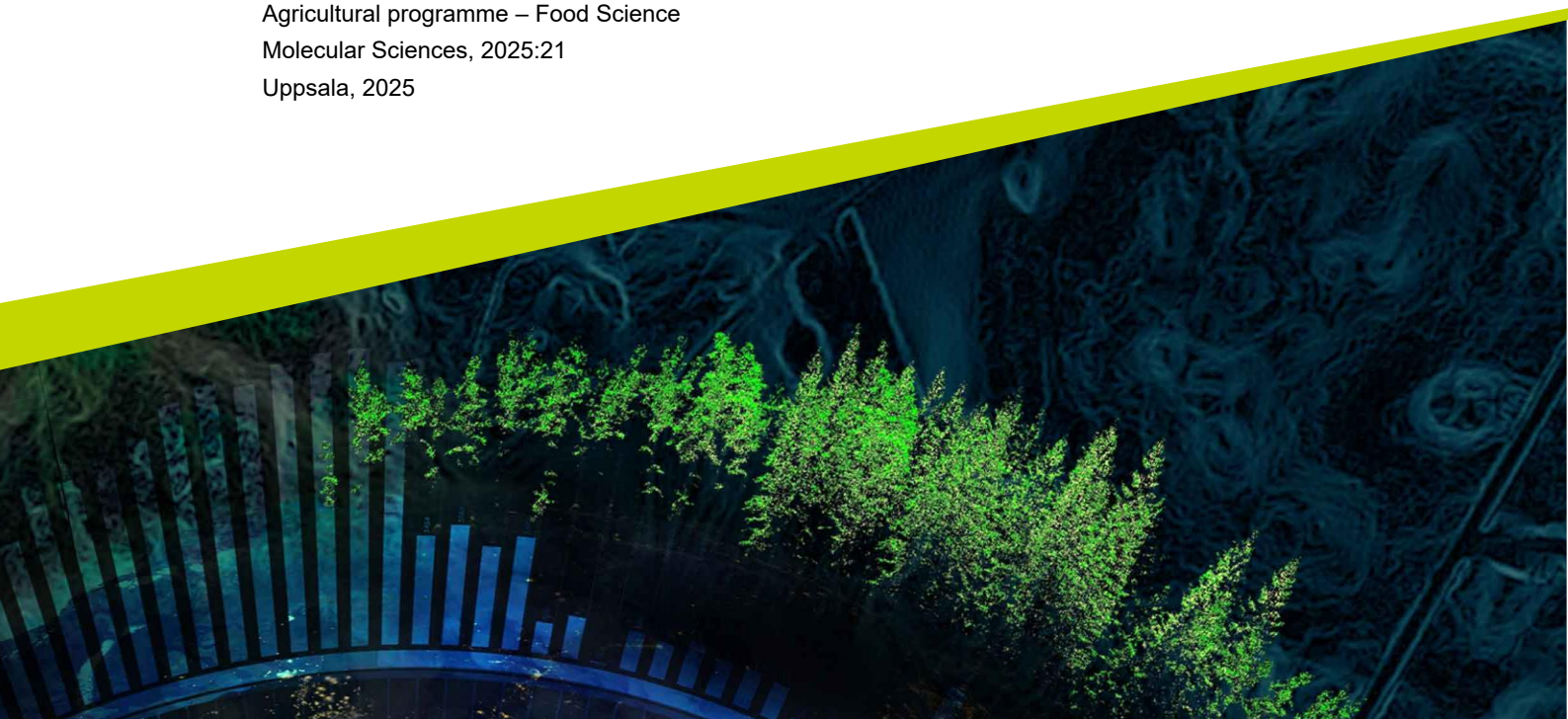

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Supervisor:	**Anja Herneke, SLU, Department of Molecular Sciences**
Assistant supervisor:	Fredrik Fogelberg, Research Institute of Sweden (RISE)
Examiner:	Jing Lu, SLU, Department of Molecular Sciences

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Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Molecular Sciences

Abstract

As interest in sustainable and plant-based alternatives to dairy products grows, legume-derived powders are being increasingly investigated for their functional properties in food systems. This study evaluates the solubility and emulsifying functionality of a novel fava bean milk powder (FBMP), produced from the *Vicia faba* cultivar Tiffany through enzymatic processing, UHT treatment, and spray drying. The solubility of reconstituted FBMP was tested under varying pH conditions (3–7) and physical treatments, including heating, high-shear mixing, ultrasonication, and soaking. Gravimetric analysis showed that solubility increased with pH and was highest after ultrasonic treatment, reaching 46 % at pH 7. Comparisons with cow's milk powder indicated that FBMP reached approximately 57 % of the solubility of the reference dairy powder. Emulsions were prepared using FBMP at 10 % and 20 % concentrations, combined with varying oil-to-water ratios. Stability observations over 24 hours revealed that higher FBMP concentration and lower oil content (30:70 and 50:50) yielded more stable emulsions. These findings suggest that FBMP has potential as a functional ingredient in plant-based formulations but also highlight the need for processing optimization to improve its solubility and emulsifying performance.

Keywords: fava bean, fava bean powder, fava bean milk powder, legume-based powder, Vicia faba, plant-based milk alternative, spray-dried legume, powder solubility, legume emulsifier

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Abbreviations

Abbreviation	Description
FBMP	Fava Bean Milk Powder
FBP	Fava Bean Protein
pI	Isoelectric Point
HCl	Hydrochloric Acid
NaOH	Sodium Hydroxide
rpm	Revolutions Per Minute
s	Seconds
x g	Gravitational force
g	Grams

1. Introduction

As interest in sustainable and plant-based alternatives to animal-derived dairy products continues to grow, legumes have emerged as promising raw materials due to their nutritional composition and functional potential (Sethi et al. 2016). Among these, the fava bean (*Vicia faba*) is particularly notable for its high protein content and essential micronutrients, combined with beneficial agronomic traits such as nitrogen fixation and adaptability to a wide range of growing conditions (Mínguez & Rubiales 2021).

Traditionally used for both animal feed and staple food products, fava beans are now gaining attention as ingredients in more refined applications, including dairy analogues, where functionality such as solubility and emulsification is essential (Sethi et al. 2016). These properties are well established in animal-based milk powders, such as cow's milk powder, where proteins like casein and whey provide excellent dispersion and interfacial behaviour. However, most plant-based powders, especially those derived from legumes, face challenges due to the structural rigidity of their storage proteins and the presence of antinutritional compounds, which can impair solubility and limit functionality (Mayer Labba et al. 2021; Day et al. 2022).

Today, soy is a popular legume-based milk alternative, valued for its high protein quality and well-characterised functional behaviour (Paul et al. 2020). However, soybean cultivation is geographically restricted and has been associated with large-scale deforestation and the clearance of natural vegetation. In addition, intensive farming practices can lead to water pollution, contributing to broader environmental degradation that may ultimately impact both ecosystem integrity and human well-being (Dreoni et al. 2022).

In contrast, fava bean can be cultivated across a broader range of temperate regions, including northern Europe, and offers comparable nutritional qualities, particularly in terms of protein content and amino acid composition (Dhull et al. 2022). These features make fava bean an increasingly relevant candidate for the development of sustainable and regionally produced plant-bas alternatives to animal-derived dairy products.

2. Background

2.1 Fava bean

Vicia faba, also known as fava bean, faba bean, broad bean, horse bean and field bean, is a legume seed cultivated all around the globe (Mínguez & Rubiales 2021). It is well adapted to grow in a variety of climates and conditions and is used for both feed and food.

Fava beans are a valuable source of plant-based protein, containing approximately 20–40 %, alongside substantial amounts of carbohydrates (50–68 %), dietary fibre (15-30 % of carbohydrates), and lipids (1–2 %). They are also rich in essential minerals such as iron, magnesium, and potassium, and contain bioactive compounds like l-3,4-dihydroxyphenylalanine (L-DOPA), a precursor of dopamine (Dhull et al. 2022).

However, fava beans also contain various antinutritional factors, including phytic acid, phenolic compounds, saponins, vicine and convicine, which can affect protein digestibility and functionality (Mayer Labba et al. 2021).
Different processing methods are used to reduce these antinutritional factors, common methods utilized include thermal treatments, soaking, germination, fermentation, enzymatic treatments etc. (Badjona et al. 2023).
The nutritional and antinutritional composition of legume crops can vary considerably between cultivars. Consequently, systematic screening is essential to identify genotypes best suited for specific applications, e.g. *Vicia faba* minor L., var. 'Tiffany' is a variety of fava bean that is low in antinutrients, but rich in protein, dietary fibre and other nutrients (Mayer Labba et al. 2021)

Furthermore, the combination of proteins, polysaccharides, fibres, and phenolic compounds contributes to the complex matrix of fava bean-based ingredients, influencing their solubility and functional properties in food systems (Sharan et al. 2021).
To explore the functional properties of fava bean-derived ingredients, this study focuses on a spray-dried powder made from the Tiffany variety of Vicia faba.

2.1.1 Composition and characteristics of fava bean powder

The fava bean powder used in this project is a novel plant-based alternative to traditional dairy powders. The production process of making the powder involves dehulling, soaking, grinding, and filtering fava beans to obtain a liquid extract, which could be referred to as a "milk". The milk is then subjected to a technique known as spray drying, a process that transforms liquids or slurries into dry powders

by atomizing them into fine droplets and rapidly drying them with hot gas, a process widely used in the food industry for heat-sensitive materials (Paniwnyk 2014). From this process, a powder is produced that will be referred to as Fava Bean Milk Powder (FBMP) throughout this study.

The FBMP used in this project was produced in 2021 and has since been stored in a cool and dark room, in a sealed, airtight, light-protected plastic bag. An analysis made on the powder the same year shows the composition of the powder. The raw protein content (acc. to Kjeldahl) is 33.2 %. The calculated carbohydrate content is 41.9 %, including 2.7 % dietary fibre and a total sugar content of 9.3 %. It also contains 3.53 % water, 3.14 % ash and 15.5 % crude fat. The full analysis report can be seen in Appendix 1.
As protein and carbohydrates constitute the major components of the fava bean milk powder, the primary focus of this study will be directed towards these constituents. Accordingly, the literature review and analytical considerations will emphasize their composition, functionality, and relevance in potential applications.

Fava bean protein (FBP) consists predominantly of globulin storage proteins, which represent approximately 70–85 % of the total protein content (Nivala et al. 2021). This poses a challenge, as these proteins are generally large and structurally rigid, unlike many dairy and animal proteins commonly used in industrial applications (Day et al. 2022). The globulins are classified according to their sedimentation coefficients into legumin (11S), vicilin (7S), and convicilin (regarded as a 7S protein-subunit of vicilin) (Warsame et al. 2022).
Legumin proteins exhibit a hexameric structure composed of two trimeric subunits linked via disulfide bonds. These subunits are commonly referred to as legumin A (~38–40 kDa) and legumin B (~23 kDa), also known as legumin α and β. Vicilin is a trimeric protein with subunits of approximately 48–55 kDa and >60 kDa, the latter often designated as convicilin. (Warsame et al. 2018).

Among carbohydrates present in pulse seeds, starch is the most prevalent, typically making up 22–45 %.(Ambigaipalan et al. 2011).
Starch is a glucose-based polymer consisting of two main polysaccharide components: the nearly linear amylose and the highly branched amylopectin (Stoddard 2004). In fava bean starch, the amylose content typically ranges between 29 % and 40 % (Ambigaipalan et al. 2011). This relatively high amylose concentration imparts distinct thermal characteristics to legume starches, including limited swelling capacity, elevated gelatinisation temperatures, increased molecular aggregation, and high final gel viscosities (Nilsson et al. 2022).

2.2 Powdered milk

Powdered milk, also known as dried milk, is a manufactured dairy product created by removing almost all moisture from liquid milk through drying processes such as spray drying or freeze drying. This dehydration process results in a stable, shelf-stable powder that can be stored for extended periods without refrigeration. Powdered milk retains much of the nutritional content of fresh milk, including proteins, carbohydrates, and minerals, and can be reconstituted with water for use in various food applications (Walstra et al. 2006).

Animal-based milk powders, such as those derived from cow's milk, have long been utilized in the food industry due to their high nutritional value and functional properties, including its good solubility and emulsification (Sharma et al. 2012). In contrast, plant-based milk powders, including those made from legumes, seeds, cereals, nuts, and vegetables, have gained popularity due to increasing consumer demand for dairy-free alternatives. While these plant-based options offer benefits such as lactose-free composition and lower environmental impact, they often face challenges related to solubility, taste, and nutritional completeness (Sethi et al. 2016).

Milk powder, whether derived from animal or plant sources, is widely used in the food industry due to its long shelf life, ease of storage and transport, and versatility in formulation. It is used in applications such as infant formulas, bakery and confectionery products, dairy analogues (e.g., yogurt and ice cream), ready-to-drink beverages, and nutritional supplements. In addition, milk powders are used as emulsifiers, stabilizers, and sources of protein and carbohydrates in processed foods. The functionality of milk powder in these applications depends largely on its solubility, dispersibility, and emulsifying capacity (Walstra et al. 2006).

2.3 Powder solubility

The solubility of plant-based powders in water, oil and other solvents, is a key functional attribute that influences food stability and texture. The solubility of the powder’s functional ingredients (i.e. proteins and polysaccharides) in water will affect its thickening, gelling and emulsifying abilities, making solubility essential for their functionality in many food systems (Phillips & Williams 2009).

2.3.1 Protein-related factors

The protein content and composition greatly influence the powder solubility (Grossmann & McClements 2023).
Solubility is a key functional property of proteins in food systems, given the role solubility plays in enabling other functionalities such as emulsification and foaming. It is governed by multiple factors, including the protein's amino acid composition, surface hydrophobicity, and molecular weight (Akharume et al. 2021; Gao et al. 2024). These structural differences cause proteins to behave differently during food processing, but also during storage and consumption (Grossmann & McClements 2023).

The solubility of proteins in powders is strongly influenced by the processing steps used to obtain them. Extraction, purification, and drying methods affect both the protein's molecular structure (e.g., native vs. denatured) and aggregation state (e.g., monomers, oligomers, aggregates) (McClements & Grossmann 2021). Spray drying methods performed on pea protein isolates have shown a significant increase in solubility when the pH at the time of spray drying is moved away from the isoelectric point of pea protein (Burger et al. 2022).

Parameters such as pH, solvent type, ionic strength, temperature, and applied mechanical forces all shape the final solubility profile. In addition, non-protein components commonly present in plant-based powders—such as polysaccharides, lipids, and minerals—can further impact solubility (Grossmann & McClements 2023).

2.3.2 pH and isoelectric point

Protein solubility is influenced by pH in relation to the protein's isoelectric point (pI) (Thomsen et al. 2025). Protein solubility is generally lowest at its pI, where electrostatic interactions are minimal and protein–protein aggregation and precipitation are favoured due to zero net charge (Vogelsang-O'Dwyer et al. 2020). At pH values above or below the pI, proteins carry a net charge, increasing repulsion and water–protein interactions, which promotes solubility (Pelegrine & Gasparetto 2005).
Far above or below the pI, electrostatic repulsion between charged groups promotes unfolding, which can lead to aggregation (Kishore et al. 2012). However, even when proteins unfold at extreme pH values, strong electrostatic repulsion can limit aggregation. Most proteins show highest solubility in pH far away from their isoelectric point (Mercadé-Prieto et al. 2007).

Some proteins, such as native whey, remain soluble across a wide pH range due to surface-exposed hydrophilic residues (LaClair & Etzel 2010).
Fava bean proteins have their isoelectric point at approximately pH 4, with their lowest solubility at this point (Żmudziński et al. 2021).

2.3.3 Ionic strength and thermal effects

The protein solubility is also influenced by ionic strength, as demonstrated by Kimura et al. (2008), who studied the behaviour of fava bean 7S and 11S globulins under varying salt concentrations. In their study, low ionic strength referred to a NaCl concentration of 0.03 M, while intermediate ionic strength corresponded to 0.25 M NaCl. At low ionic strength (0.03 M), the 7S proteins showed minimal solubility between pH 5 and 6.5, indicating pronounced isoelectric precipitation. However, at intermediate ionic strength (0.25 M), the solubility of 7S proteins improved markedly, with precipitation suppressed across all tested pH values, and solubility exceeding 80 % above pH 4.0. The 11S globulins, which were more prone to precipitation across a broader pH range under low salt conditions, also displayed significantly improved solubility at neutral pH (above 80 % for pH >6) when salt levels were raised to 0.25 M.

Protein solubility is also affected by temperature, as both excessive heating and cooling can lead to denaturation. Heat-induced unfolding exposes hydrophobic regions and thiol groups. This promotes intermolecular interactions and aggregation, leading to reduced solubility (Damodaran & Parkin 2017). The balance between molecular interactions and conformational entropy determines a protein's structure at a given temperature, with unfolding typically occurring at the thermal denaturation temperature (Grossmann & McClements 2023). The amino acid sequence and the extraction method of the proteins affects the temperature at which the protein denatures. Fava bean concentrate proteins typically denatures at a temperature between 89-94 °C (Badjona et al. 2024). If heated below the denaturation temperature, protein solubility tends to remain stable or slightly increase. This has been shown in soy protein where protein solubility is constant or slightly increases when heated up to 80 °C, and can be attributed to the main soy protein denaturation temperature being around 80-93 °C (Grossmann & McClements 2023).

2.3.4 Mechanical treatment

Physical processing, like ultrasonication, can also affect solubility. Ultrasonication uses high-intensity sound waves to improve protein solubility by altering protein conformation and aggregation (Jambrak et al. 2008). Cavitation generated by ultrasonic waves creates localized shear, heat, and pressure, which can disrupt protein aggregates without affecting the primary structure (Zhu et al. 2018). Ultrasonication may increase or decrease protein solubility depending on protein type and processing conditions. Increased solubility is typically linked to disruption of aggregates and partial unfolding that exposes hydrophilic groups in the protein to the surface (Nikbakht Nasrabadi et al. 2021).

2.3.5 Starch-related solubility

The solubility of starch is closely linked to the leaching of molecular components during heating, primarily amylose. Heating starch in excess water disrupts its crystalline structure, allowing water to bind to hydroxyl groups on amylose and amylopectin, which increases swelling and solubility (Singh 2021). According to Tester and Morrison (1990), the amount of leached amylose is highly correlated with the extent of starch swelling between 60 and 80 °C, suggesting a strong relationship between solubility and amylose content. In their study, amylose represented the majority of the solubilized fraction at elevated temperatures, highlighting its contribution to increased starch solubility in aqueous systems. While these findings are specific to cereal starches, they provide a useful model for understanding starch behaviour in legumes, particularly given that fava bean starch also contains a relatively high amylose content (Ambigaipalan et al. 2011). However, amylose can also inhibit swelling under certain conditions by interacting with lipids and stabilizing the granular structure, which may reduce solubility at lower temperatures or in less hydrated systems. Thus, amylose can both promote and restrict starch solubility depending on the structural and thermal context.

2.4 Emulsification

Emulsifiers are functional ingredients capable of adsorbing at oil–water interfaces to stabilize dispersed droplets by forming a protective interfacial layer. This layer contributes to emulsion stability by introducing mechanical rigidity and generating repulsive forces, primarily electrostatic or steric, that inhibit droplets from merging. Plant-based emulsifiers typically include amphiphilic molecules or colloidal particles with surface characteristics that allow partial wetting by both oil and

water. Among molecular emulsifiers, certain plant proteins—such as those derived from soy, pea, lentil, and fava bean—exhibit surface activity due to their hydrophilic and hydrophobic amino acid regions, enabling them to function as natural emulsifiers in food systems (McClements & Grossmann 2021)

2.4.1 Emulsion instability mechanisms

Once formed, oil-in-water emulsions must remain stable under various conditions during processing, storage, and consumption. One of the most common forms of destabilization is gravitational separation, which includes creaming and sedimentation. This occurs due to the density difference between the dispersed oil droplets and the continuous aqueous phase. Another key instability mechanism is droplet aggregation, which includes flocculation, coalescence, and partial coalescence. Flocculation results in loose clusters of droplets, while coalescence causes droplets to merge, forming larger droplets and potentially leading to oiling-off. Partial coalescence occurs in emulsions containing crystallized fat droplets, where solid fat crystals bridge between droplets without full merging due to internal crystal structures. Effective protein-based emulsifiers must therefore not only reduce droplet size but also prevent aggregation and maintain interfacial stability under varying environmental stresses (McClements et al. 2022).

2.4.2 Fava bean protein as an emulsifier

Findings on faba bean protein (FBP) demonstrate its ability to function as a molecular emulsifier due to its amphiphilic character (Thomsen et al. 2025). While native FBP exhibits limited flexibility and solubility compared to dairy proteins (Day et al. 2022), studies have shown that its interfacial activity can be enhanced through physical, chemical, or enzymatic modification (Krause et al. 1997; Martinez et al. 2016; Eckert et al. 2019). Modified FBP has been found to adsorb effectively at oil–water interfaces and, under the right conditions, improve emulsion stability by reducing droplet size and preventing coalescence and creaming (Tsoukala et al. 2006; Hall & Moraru 2021).

3. Aim

The aim of this study was to investigate the solubility and functional behaviour of a novel fava bean milk powder (FBMP) under varying conditions relevant to food processing. The research focused on evaluating the impact of pH, thermal treatment, mechanical processing (including high-shear mixing and ultrasonication), and storage-like conditions (soaking) on the solubility of reconstituted FBMP. Furthermore, the solubility performance of FBMP was benchmarked against a conventional cow's milk powder to assess its relative functionality. In addition, the emulsifying capacity and physical stability of FBMP-based oil-in-water emulsions were explored to provide initial insights into its potential applications as a plant-based milk powder in complex food systems.

4. Materials and Methods

4.1 Literature review

Scientific literature was gathered using databases such as Web of Science, Scopus, and Google Scholar. Keywords included “fava bean”, “fava bean powder”, "fava bean protein", “legume-based powder”, “Vicia faba”, “plant-based milk alternative”, “spray-dried legume”, “powder solubility”, “legume emulsifier”. Relevant articles were selected based on their focus on composition, functionality, solubility, and emulsifying properties of legume-based powders.

4.2 Materials

4.2.1 FBMP

The fava bean-based powder used in this study was kindly provided by Research Institutes of Sweden (RISE).
According to the information available and communicated about the production process of the powder, the following steps have been carried out:

Dehulled fava beans of the Tiffany variety were soaked in cold water for 8–10 hours in refrigerated conditions. After soaking, the beans were rinsed and ground with water to produce a slurry. The slurry was then heated and enzymatically treated with Ceremix Flex, to break down starch into simple sugars. The resulting liquid base was separated from the fibrous residue through decantation. To ensure microbiological stability, the liquid base was ultra-high temperature (UHT) treated at 143 °C and subsequently cooled and transferred into intermediate bulk containers (IBC).
The liquid fava bean base was spray-dried at Food Industry PROcessing Services (FIPROS) in March 2021. The process was performed using a rotary atomizer at a speed of 11,700 rpm. The inlet air temperature during drying was approximately 177 °C, and the outlet temperature was 88 °C. The product feed rate was set to ensure a final powder moisture content of approximately 3.5 %. From a total of 3,000 kg of liquid base, 360 kg of dry matter was obtained. The finished powder was stored in sealed bags with a measured moisture content of 3.5 % and a bulk density of 0.6 kg/l. The full spray-drying statement can be seen in Appendix 2.

4.2.2 Cow’s milk powder

A commercial instant full cream cow’s milk powder (NIDO, 400g, produced by Nestlé) was purchased from a local supermarket and used as a reference material for comparative purposes.

4.3 Sample preparation

All samples were prepared by reconstituting powder in distilled water at a concentration of 10 % powder to water, i.e. 10 g powder per 100 g water. The powder was dispersed under continuous stirring on a magnetic stirrer for approximately 20 min to ensure complete hydration. All samples were prepared fresh before each treatment and stored in Falcon tubes until further analysis. All tests were done in duplicates.

To evaluate pH-related effects, the reconstituted FBMP and cow's milk powder solutions were divided into five aliquots. The pH of each aliquot was adjusted to 3, 4, 5, 6, or 7 using 1M and 0.1M, HCl or NaOH.

4.4 Heat treatment

Samples adjusted to pH 3–7 were heated on a magnetic stirrer at 50 °C for 60 min with continuous stirring.

4.5 Soaking

A pH-unmodified sample was left under continuous stirring at room temperature (~22 °C) for 24 h. The beaker was covered with aluminium foil to limit evaporation and contamination.

4.6 High-shear mixing

Samples at pH 3–7 were treated with an Ultra-Turrax homogenizer at 11,000 rpm for 1 min.

4.7 Ultrasonic treatment

Samples at pH 3–7 were processed using a Vibra-Cell VCX 750 ultrasonic homogenizer for 3 min at 60 % amplitude (pulse mode: 10 s. on / 10 s. off). Beakers were surrounded with ice to minimize heating.

4.8 Gravimetric determination of solubility

Treated samples were centrifuged at 4,500 × g for 10 min at 20 °C. From each supernatant, 1 ml was pipetted (in duplicate) into pre-weighed aluminium dishes and dried at 105 °C for 24 h. Dishes were cooled in a desiccator before final weighing. Solubility was calculated as the mass of dry residue per ml supernatant.

4.9 Emulsification test

FBMP was reconstituted at two concentrations: 10 % and 20 % (w/v). For each concentration, emulsions were prepared by mixing 200 ml of FBMP solution with rapeseed oil at oil-to-water ratios of 50:50, 70:30, and 30:70.

Mixing was performed in a Wilfa kitchen blender for 30 s. The emulsions were then poured into glass jars and stored at room temperature. Visual observations of phase separation were recorded at 15 min, 30 min, 45 min, 1 h, 3 h, and 24 h. Photos were taken to document emulsion stability.

Additionally, a small amount of each emulsion was placed on a flat surface to observe initial appearance and spreading behaviour.

4.10 Overview of experimental workflow

A schematic flowchart summarizing all sample treatments and analyses is presented in Figure 1.

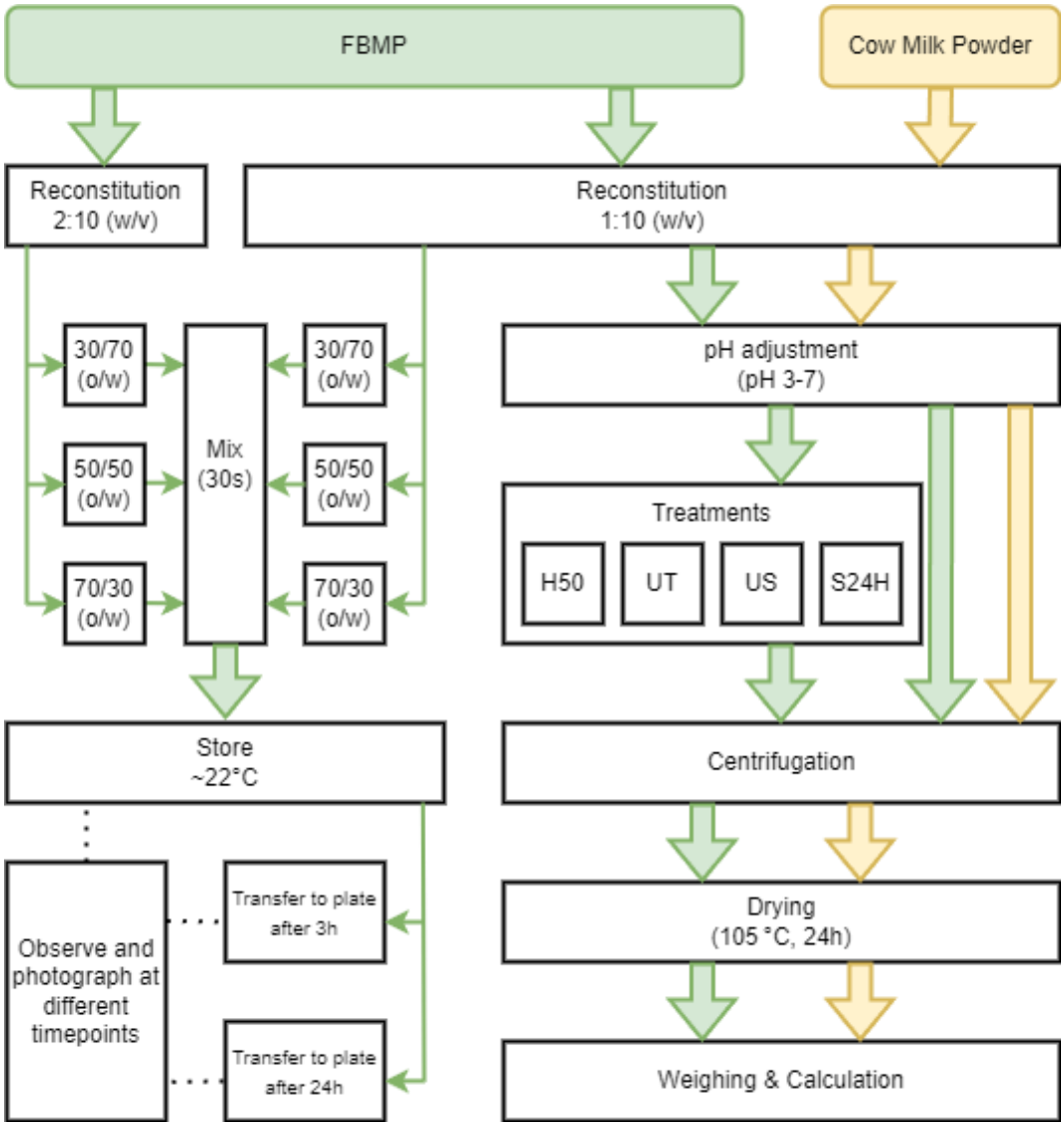

Figure 1. Flowchart illustrating methods for solubility and emulsification tests. Yellow arrows represent treatments on cow's milk powder, green arrows represent treatments on FBMP. Solubility treatments include heat (H50), high-shear mixing (UT), ultrasonication (US), and soaking for 24 h (S24H). o/w = oil-to-water ratio.

5. Results

5.1 Solubility measurement overview

The gravimetric solubility of reconstituted FBMP was evaluated under different pH conditions (3-7) and across four treatments: simple stirring, heating at 50 °C, high-shear mixing (Ultra-Turrax), and ultrasonic processing. For comparison, cow's milk powder was analysed under identical pH conditions. The full table summarizing the measured solubility values, from the duplicate measurements, is found in Table 1 and Table 2, in Appendix 3.

Across all treatments, solubility generally increased with higher pH, with the lowest values observed at pH 4–5, around the pI of FBP, and the highest at pH 7. Figure 2 shows the solubility profiles for each treatment across the pH range, clearly illustrating the positive effect of increase in pH on powder solubility.

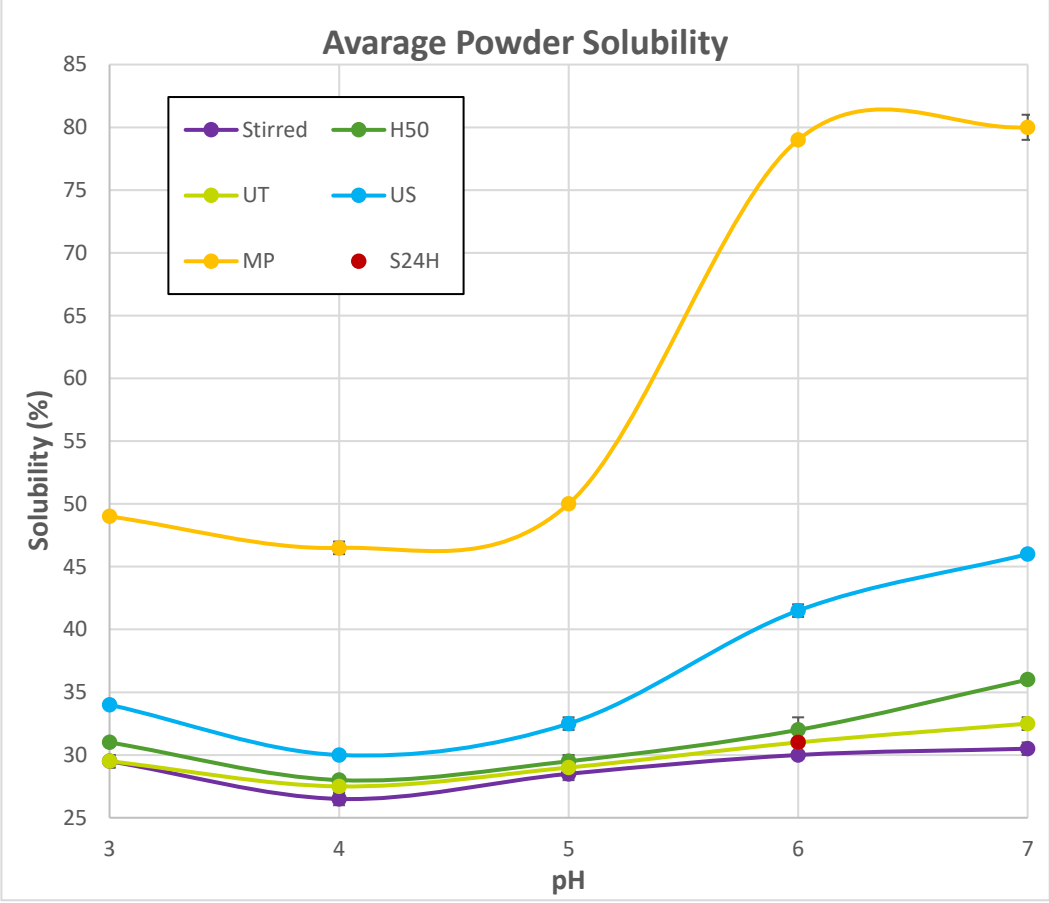

Figure 2. Graph of average solubility for FBMP and cow's milk powder across pH 3–7 under different treatments. Stirred for 20min (Stirred), Stirred in 50 °C (H50), Ultra-Turrax (UT), Ultrasonic processing (US), Stirred and soaked for 24 hours (S24H), Cow's milk powder (MP).

Among the FBMP treatments, ultrasonic processing consistently produced the highest solubility, reaching approximately 46 % at pH 7. In contrast, simpler methods such as stirring, heating, or high-shear mixing resulted in maximum solubility values between ~30–36 %.

A visual inspection, as seen in Figure 3, confirms the results of the gravimetric calculations, where noticeably higher turbidity can be seen in the samples treated with ultrasonication, especially at pH 7 and 6, and when compared to samples treated with heat or high shear mixing.

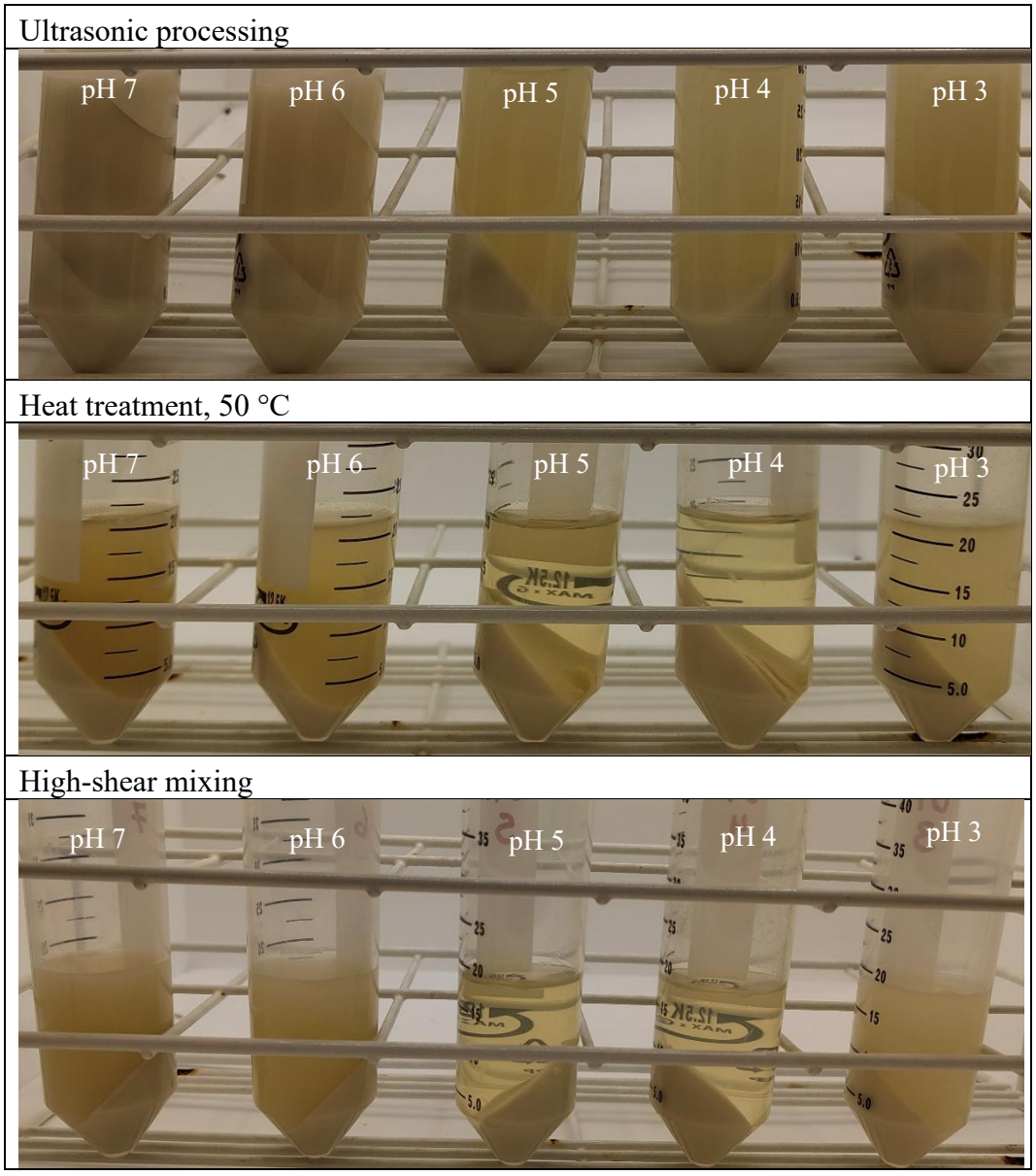

Figure 3. Photo of centrifuged samples. Samples treated with ultrasonic processing (top picture), 50 °C (middle picture) and high shear mixing (bottom picture). pH in samples ranging from 7 (left) to 3 (right).

High turbidity can be linked to better solubility, as turbidity indicates that a greater amount of material is dissolved in the liquid and blocks light transmission through the sample. This can be compared to the samples at pH 4 and 5, with lower solubility, where the supernatant is much clearer in all samples.

5.1.1 Benchmarking against cow's milk powder

Cow's milk powder displayed significantly higher solubility across all pH levels, as seen in Figure 2, with values peaking at ~80 % at pH 6–7. Ultrasonic-treated FBMP reached ~57 % of the cow's milk powder solubility, while the other FBMP treatments remained below 50 %. This comparison underscores the limitations of the FBMP solubility when subjected to current treatments.

5.2 Emulsion stability over time

The visual appearance of oil-in-water emulsions prepared with 10 % and 20 % FBMP was documented after 3 and 24 hours of storage at room temperature. Emulsions were formulated at oil-to-water ratios of 30:70, 50:50, and 70:30.

In the 10 % FBMP emulsions (Figure 4), slight phase separation was visible after 3 hours, especially in the 50:50 and 30:70 samples, where diffuse phase boundaries and light surface foaming were observed. After 24 hours, all 10 % emulsions showed clear sedimentation, with distinct separation layers becoming prominent, particularly in the 50:50 and 30:70 formulations and signs of flocculation in the 70:30 formulation.

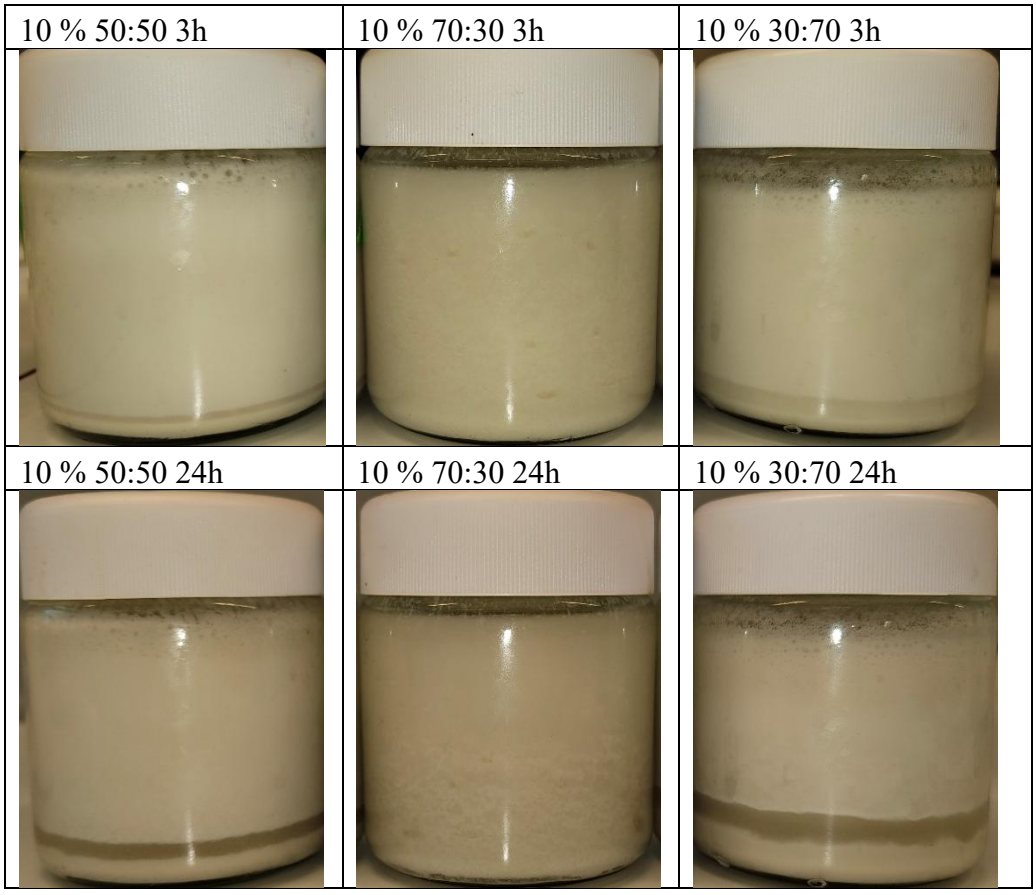

Figure 4. Photos of emulsions in jars, made with 10 % FBMP. Pictures taken after 3h (top row), pictures taken after 24h (*bottom row). *Samples made with o/w ratio of 50:50 (left); 70:30 (middle); 30:70 (right).*

In contrast, emulsions with 20 % FBMP (Figure 5) appeared more stable at both time points. After 3 hours, the 50:50 emulsion displayed a thick, viscous consistency; the 70:30 was dense but showed signs of flocculation, while the 30:70

was evenly dispersed and homogeneous. At 24 hours, the 30:70 and 50:50 emulsions remained visually stable with minimal phase separation. Only the 70:30 sample exhibited slight surface instability and minor creaming.

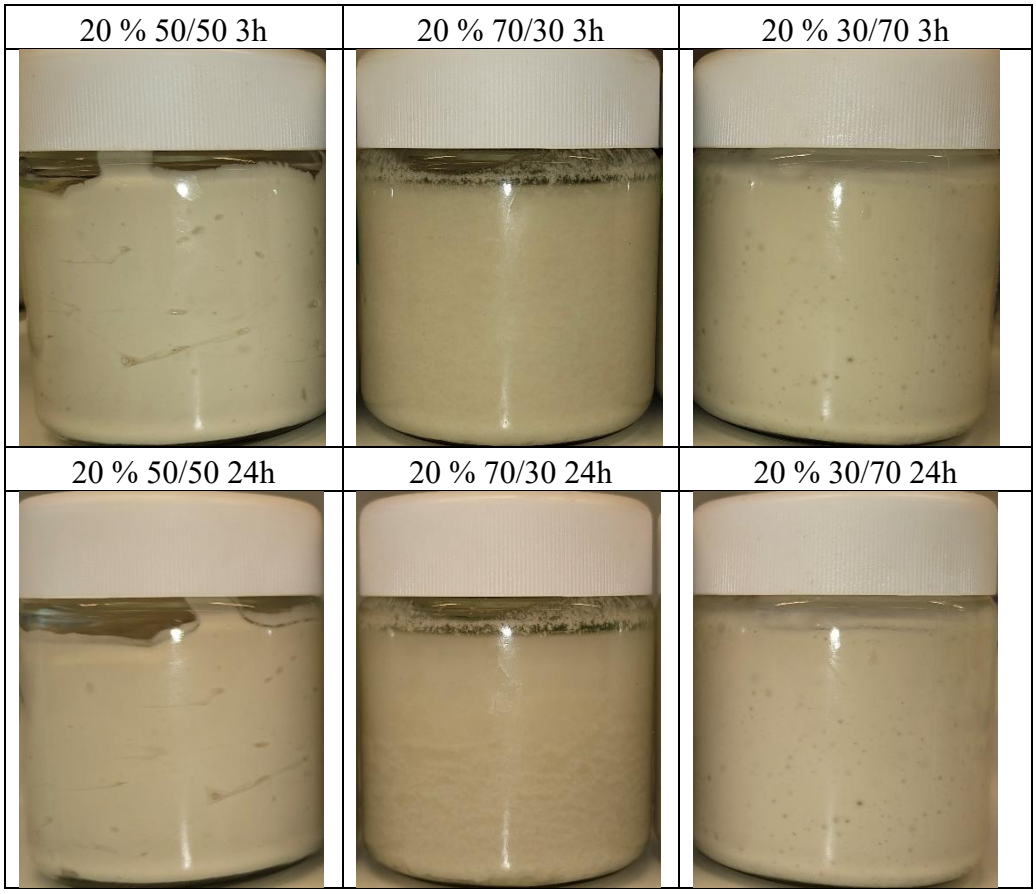

Figure 5. Photos of emulsions in jars, made with 20 % FBMP. Pictures taken after 3h (top row), pictures taken after 24h (bottom row). Samples made with o/w ratio of 50:50 (left); 70:30 (middle); 30:70 (right).

5.2.1 Spreadability test (flat surface evaluation)

A teaspoon-sized portion of each emulsion was placed on a flat surface and photographed at 3- and 24-hours post-preparation. These tests were used to assess relative spreadability and visual structure.

In addition to the observations of the 10 % FBMP emulsions in the jar, the spread test (Figure 6) confirms what has been observed and provides some additional information. At 3h phase separation in the 50:50 and 30:70 samples is not as distinctive, and looks homogeneous, with some foaming in the 30:70 sample. In the 70:30 sample, separation and graininess are visible.

After 24 hours, no significant differences are seen in the 50:50 and 30:70 samples, except that they both flow more across the plate, and that some separation and oiliness are seen around the edges of the 30:70 sample. However, an apparent change is visible in the 70:30 sample. There has been a clear separation with oily edges and obvious big clumps formed, creating an uneven surface.

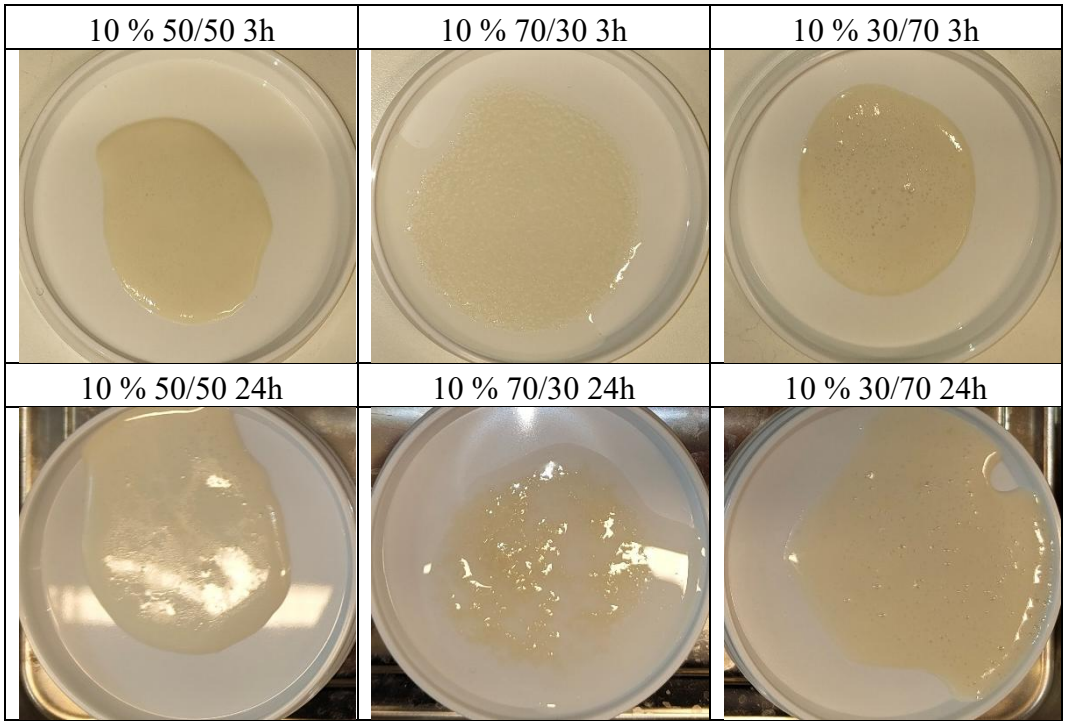

Figure 6. Photos of emulsion spread tests in plates, made with 10 % FBMP. Pictures taken after 3h (top row), pictures taken after 24h (bottom row). Samples made with o/w ratio of 50:50 (left); 70:30 (middle); 30:70 (right).

At 3 hours (Figure 7), 20 % FBMP emulsions demonstrated limited spread. The 50:50 sample remained thick and compact, the 70:30 sample showed visible oil dispersion and spotty texture, and the 30:70 emulsion was more uniform but slightly bubbly. After 24 hours (Figure 7), the 20 % 50:50 sample was highly viscous with nearly no spread. The 70:30 sample displayed oil separation, while the 30:70 retained a smooth and slightly bubbly surface.

For the emulsions with 20 % FBMP it becomes clearer that no significant visual differences have emerged between the different time points. However, something that becomes clear with the spread test is the substantially higher viscosity in these samples, compared to the 10 % FBMP emulsions. Especially in the 50:50 sample which has a mayonnaise-like consistency, and the 30:70 sample which is thick and slow-flowing. Both also appear to be homogeneous at both time points. The 70:30 sample is grainy and lumpy, with an uneven surface at both timepoints.

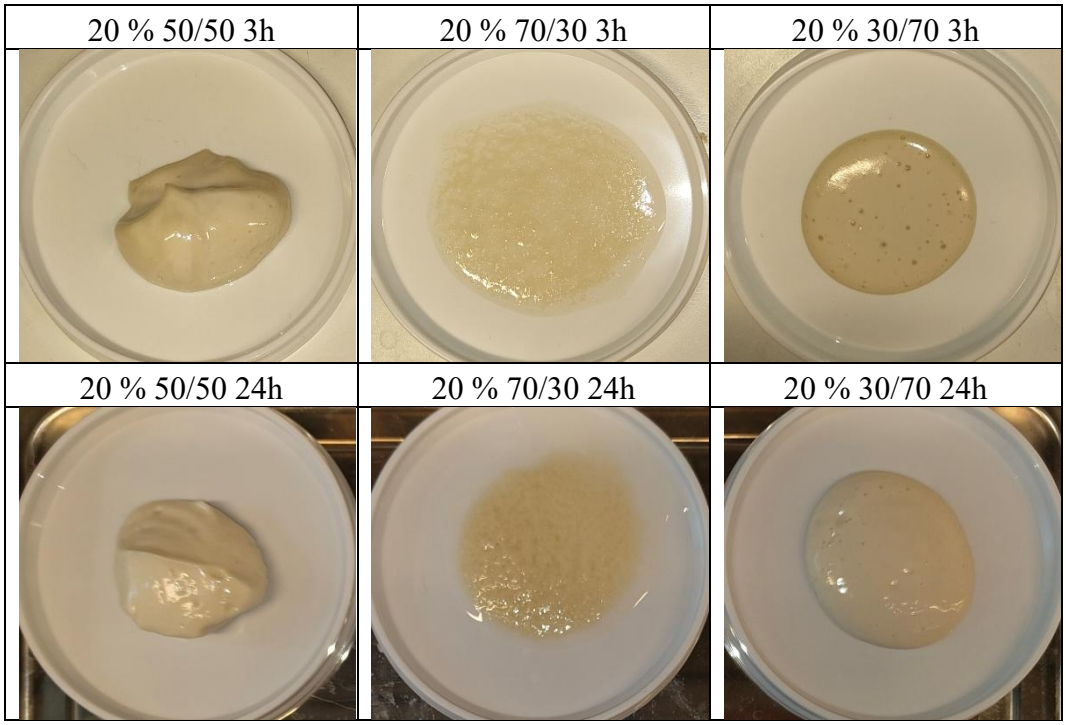

Figure 7. Photos of emulsion spread tests in plates, made with 20 % FBMP. Pictures taken after 3h (top row), pictures taken after 24h (bottom row). Samples made with o/w ratio of 50:50 (left); 70:30 (middle); 30:70 (right).

Emulsion performance varied noticeably with oil content. The 50:50 formulations appear to create the most stable emulsions, with the least visible phase separation The 70:30 formulations showed the highest degree of separation already at 3h and a dense sediment layer after 24h. The 30:70 formulations showed similar stability with the 50:50 formulations but with a bit higher degree of phase separation and lower viscosity.

The samples made with 20 % FBMP appear to have overall created better emulsions, compared to 10 % FBMP.

6. Discussion

The solubility results demonstrate that FBMP exhibits moderate solubility under standard aqueous conditions, with performance heavily influenced by pH, treatment method, and the inherent structural properties of the powder's protein and carbohydrate matrix. As highlighted before, FBMP is predominantly composed of globulin storage proteins, particularly legumin (11S) and vicilin (7S), which are relatively large and rigid in structure. These molecular features contribute to their limited water solubility, especially in their native form (Nivala et al. 2021; Day et al. 2022).

Across all tested treatments, solubility of FBMP increased progressively with pH, reaching maximum values at pH 7. This trend aligns with literature findings that fava bean proteins have their pI near pH 4, where solubility is minimal due to the lack of net surface charge and increased protein–protein aggregation (Pelegrine & Gasparetto 2005; Żmudziński et al. 2021). At pH levels above the pI, electrostatic repulsion increases, enhancing protein–water interactions and improving solubility (Mercadé-Prieto et al. 2007).

Among the tested processing methods, ultrasonic treatment yielded the highest solubility, reaching ~46 % at pH 7. This enhancement can be attributed to the ability of high-intensity ultrasound to disrupt protein aggregates and partially unfold molecules, exposing hydrophilic regions and increasing water-binding capacity (Nikbakht Nasrabadi et al. 2021). In contrast, heat treatment at 50 °C and high-shear mixing via Ultra-Turrax offered only marginal improvements over simple stirring, suggesting that these methods alone are insufficient to overcome the structural rigidity of native FBMP proteins. Soaking for 24 hours provided a slight increase, likely due to prolonged hydration, but was also less effective than sonication.

The relatively low overall solubility of FBMP could perhaps be partially explained by its high content of insoluble or semi-soluble components, including starch, dietary fibre, and native protein aggregates. The starch component, particularly its high amylose content (29–40 %), may also limit solubility due to restricted swelling and lower leaching at moderate temperatures (Tester & Morrison 1990; Nilsson et al. 2022). While heating promotes amylose release, the moderate temperature (50 °C) used here may have been insufficient to significantly disrupt starch crystallinity and improve solubility.

In comparison, cow’s milk powder showed markedly higher solubility (~80 % at pH 6–7), likely due to the superior solubility and dispersion of casein micelles and whey proteins, which are evolutionarily adapted to function efficiently in aqueous

environments (Walstra et al. 2006). When benchmarking FBMP against cow's milk powder, even the most effective FBMP treatment (ultrasound) achieved only ~57 % of the solubility of cow's milk. This gap highlights the structural and compositional constraints of FBMP, underscoring the challenges associated with formulating it into high-solubility applications without further modification.

Taken together, these findings suggest that while FBMP holds potential as a plant-based ingredient, its application in systems requiring high solubility may require processing optimisation or formulation with solubility-enhancing agents. The results also emphasize the importance of controlling pH and employing advanced processing techniques, such as ultrasonication, to improve the functional performance of legume-based powders.

In addition to the solubility tests, an emulsification experiment was conducted to evaluate the powder's ability to form and stabilize oil-in-water emulsions.
The emulsification results demonstrate that both the concentration of fava bean milk powder (FBMP) and the oil-to-water ratio significantly influence emulsion stability, physical appearance, and spreading behaviour over time. As earlier suggested, FBMP contains predominantly globulin storage proteins, legumin and vicilin, which are structurally rigid and less surface-active in their native form compared to animal-derived proteins such as casein or whey (Nivala et al. 2021; Day et al. 2022). These properties can hinder the ability of unmodified FBMP to form and stabilize emulsions effectively, particularly at low concentrations.

It should also be noted that the reconstituted FBMP used for the emulsification tests had its native unaffected pH and had not been subjected to any other treatment. Had the pH of the reconstituted bean-milk been adjusted to 7 and then ultrasonicated, as was the case with the best results in the solubility tests, it is likely that more stable emulsions would have been created.

At 10 % FBMP concentration, all emulsions exhibited signs of phase separation after 24 hours, with clearly visible sediment layers. This supports previous observations that low protein concentration limits the formation of a stable interfacial layer, which is necessary to prevent gravitational separation, flocculation, and coalescence (McClements & Grossmann 2021). In contrast, emulsions prepared with 20 % FBMP showed markedly improved stability, with minimal visual separation after 24 hours in the 30:70 and 50:50 formulations.

The improved stability at higher concentration may be explained by the increased availability of surface-active protein molecules, which allows more complete coverage of oil droplets. Despite the inherent limitations of faba bean globulins

(e.g., low flexibility and solubility), the presence of both hydrophilic and hydrophobic amino acid regions allows them to adsorb at oil–water interfaces and function as emulsifiers under favourable conditions (Thomsen et al. 2025). As mentioned by Grossmann & McClements (2023), protein concentration plays a central role in determining interfacial coverage and thus droplet stability.
The spreading tests further illustrate the role of protein concentration in defining emulsion structure and viscosity. At 20 % FBMP and 50:50 oil-to-water ratio, emulsions displayed extremely limited spreadability, forming dense and pasty textures. This suggests that at high concentrations, FBMP may form a partially gelled or highly viscous protein network, which increases resistance to flow—aligning with known behaviours of legume proteins at elevated concentrations (Nilsson et al. 2022).

Taken together, the results support findings from the literature that plant proteins, although structurally limited compared to dairy proteins, can be functional emulsifiers when used at sufficient concentrations and under optimized conditions. The observations in this study align with previous conclusions that faba bean protein functionality is concentration-dependent, and that modifying the protein or combining it with other stabilizers may be necessary to further improve emulsification performance in high-oil systems.

7. Conclusion

This study examined the solubility and emulsification capacity of a novel fava bean milk powder (FBMP), with the goal of evaluating its potential as a plant-based dairy alternative. The findings demonstrate that FBMP exhibits moderate solubility in aqueous systems, with clear improvement at higher pH levels and when subjected to ultrasonic treatment. However, even under optimized conditions, FBMP did not reach the solubility performance of conventional cow's milk powder, highlighting the structural limitations associated with native legume proteins and starch components.

The emulsification tests further underscored the functional challenges of FBMP. At low concentrations (10 %), emulsions exhibited pronounced phase separation over time, whereas 20 % FBMP produced more stable emulsions, particularly at 30:70 and 50:50 oil-to-water ratios. These results support previous literature suggesting that legume-based emulsifiers require relatively high concentrations or pre-treatment to match the functionality of animal-derived proteins.

Together, the results show that FBMP holds promise for application in plant-based food systems, particularly where full solubility is not critical, such as creamy sauces, spreads, dressings, or bakery fillings. However, further refinement of the production and formulation methods is necessary to improve its functional performance and fully realise its potential as a sustainable milk powder alternative.

7.1 Recommendations for future research

Since fava bean milk powder (FBMP) is a novel and relatively unexplored ingredient, its behaviour under various processing and formulation conditions remains insufficiently characterised. Future research is needed not only to better understand its solubility and emulsification properties, but also to optimise processing strategies that can unlock its full functional potential in food systems.

Based on the findings of this study and reflections throughout the experimental process, several ideas have emerged that would be valuable to explore if the project were to be repeated or expanded.
The following suggestions are based on observations and limitations encountered during this study, and are intended to guide future experimentation on FBMP:

- Broader pH testing: In this study, solubility was measured only within pH 3–7. Expanding the range to cover the entire pH spectrum could help better characterize solubility dynamics around and far from the isoelectric point.

- Thermal variation: Only one temperature (50 °C) was used in the heating treatment. Future studies should explore a broader range of temperatures, including sub-denaturation and near-denaturation levels, to assess their effect on protein and starch solubility.

- Powder ageing effects: The FBMP used in this study was produced in 2021 and has been stored for over four years. It would be valuable to assess how storage time and conditions affect solubility and emulsification performance, especially regarding protein aggregation and oxidation.

- Enzymatic treatment variables: The FBMP was subjected to an enzymatic step during its production. Future studies should investigate the use of targeted enzymatic treatments to enhance solubility or reduce antinutritional compounds more effectively.

- Spray-drying parameters: A better-controlled investigation into how drying conditions (e.g., inlet/outlet temperature, feed rate, atomization speed) affect powder structure and solubility would be valuable. This would require access to new batches of powder produced under varied and documented drying protocols.

- Instrumental analysis of emulsions: The emulsification stability assessment in this study was based on visual observations and spreadability tests, providing qualitative rather than quantitative data. For a more

comprehensive evaluation, future studies could apply instrumental analyses such as droplet size distribution, zeta-potential measurements, or rheological characterization to obtain more objective and detailed insights into emulsion stability.

- Sensory evaluation: Although not addressed within the scope of this study, sensory attributes such as taste, odour, and colour will be important considerations for the commercial application of FBMP in consumer products. These aspects will require dedicated assessment in further product development stages.

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Appendix 1

Full analysis report of the FBMP.

Analysrapport

Provnummer:	525-2021-05030099
Provmärkning:	Torkad FAVA, bas 210430
Provet ankom:	2021-05-03
Analysrapport klar:	2021-05-18
Analyserna påbörjades:	2021-05-03

Testkod		Parameter	Resultat	Enhet	Mäto.	Metod/ref.	Lab
LP06U	[a]	Vattenhalt	**3.53**	g/100 g	± 10%	NMKL 23	EUSELI
LP06V	[a]	Aska	**3.14**	g/100 g	± 10%	NMKL 173	EUSELI
LP021	[a]	Råprotein enl. Kjeldahl (Nx6.25)	**33.2**	g/100 g	± 10%	NMKL 6:2003	EUSELI
LW1RG	[a]	Råfett	**15.5**	g/100 g	± 10%	NMKL 160 mod.	EUSELI
LP06Z	[a]	Kolhydrater (beräknade)	**41.9**	g/100 g		(EU) nr 1169/2011	EUSELI
LP072	[a]	Energivärde kJ (beräknad)	**1872**	kJ/100 g		(EU) nr 1169/2011	EUSELI
LP072	[a]	Energivärde kcal (beräknad)	**447**	kcal/100 g		(EU) nr 1169/2011	EUSELI
LP05C	[a]	Kostfiber	**2.7**	g/100 g	± 15%	AOAC 991.43 mod.	EUSELI
LP00D	[a]	Fruktos	**<0.04**	g/100 g	± 25%	AOAC 982.14, mod.	EUSELI
LP00F	[a]	Glukos	**0.33**	g/100 g	± 25%	AOAC 982.14, mod.	EUSELI
LP00J	[a]	Laktos	**<0.04**	g/100 g	± 25%	AOAC 982.14, mod.	EUSELI
LP00L	[a]	Maltos	**6.32**	g/100 g	± 15%	AOAC 982.14, mod.	EUSELI
LP00Q	[a]	Sackaros	**2.21**	g/100 g	± 15%	AOAC 982.14, mod.	EUSELI
LP00E	[a]	Galaktos	**0.44**	g/100 g	± 15%	AOAC 982.14, mod.	EUSELI
LW0U5		Socker totalhalt (beräknad)	**9.30**	g/100 g			EUSELI
LP056	[a]	C 6:0 (Kapronsyra)	**<0.1**	% av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 8:0 (Kaprylsyra)	**<0.1**	% av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 10:0 (Kaprinsyra)	**<0.1**	% av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 12:0 (Laurinsyra)	**<0.1**	% av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 14:0 (Myristinsyra)	**<0.1**	% av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 14:1 n-5 (Myristoleinsyra)	**<0.1**	% av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 15:0 (Pentadekansyra)	**<0.1**	% av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 15:1 n-5	**<0.1**	% av fettsyror	± 20%	Internal Method - GC-FID	EUSELI

LP056	[a]	C 16:0 (Palmitinsyra)	**5.3** % av fettsyror	± 10%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 16:1 n-7 (Palmitoleinsyra)	**0.2** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 17:0 (Margarinsyra)	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 17:1 n-7 (Heptadecensyra)	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 18:0 (Stearinsyra)	**1.7** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 18:1 (Oljesyra)	**59.8** % av fettsyror	± 10%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 18:2 n-6 (Linolsyra)	**21.8** % av fettsyror	± 10%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 18:3 n-3 (α-Linolensyra)	**7.7** % av fettsyror	± 10%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 18:3 n-6 (γ-Linolensyra)	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 18:4 n-3 (Oktadekatetraensyra)	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 20:0 (Arachinsyra)	**0.6** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 20:1 n-9 (Gadoljesyra)	**1.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 20:2 n-6 (Eikosadiensyra)	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 20:3 n-6	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 20:3 n-3	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 20:4 n-6 (Arakidonsyra)	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 20:4 n-3	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 20:5 n-3 (EPA)	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 22:0 (Behensyra)	**0.3** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 22:1	**0.2** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 22:2 n-6 (Dokosadien syra)	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 22:4 n-6	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 22:5 n-6	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 22:5 n-3 (Dokosapentaensyra)	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 22:6 n-3 (DHA)	**<0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 24:0 (Lignoserinsyra)	**0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	C 24:1 n-9 (Tetracosensyra)	**0.1** % av fettsyror	± 20%	Internal Method - GC-FID	EUSELI
LP056	[a]	Summa mättade fettsyror	**8.2** % av fettsyror		Internal Method - GC-FID	EUSELI
LP056	[a]	Summa enkelomättade fettsyror	**61.5** % av fettsyror		Internal Method - GC-FID	EUSELI
LP056	[a]	Summa fleromättade fettsyror	**29.5** % av fettsyror		Internal Method - GC-FID	EUSELI
LP056	[a]	Totalsumma fettsyror	**99.3** % av fettsyror		Internal Method - GC-FID	EUSELI
LP056	[a]	Oidentifierade komponenter	**0.7** % av fettsyror		Internal Method - GC-FID	EUSELI
LP056	[a]	Summa av omega 6 fettsyror	**21.8** % av fettsyror		Internal Method - GC-FID	EUSELI
LP056	[a]	Summa av omega 3 fettsyror	**7.7** % av fettsyror		Internal Method - GC-FID	EUSELI
LP056	[a]	Kvot omega6/omega3 fettsyror	**2.84**		Internal Method - GC-FID	EUSELI
LW0U4		Beräkningsfaktor fettsyra	**0.955**			EUSELI
LW0U4		Summa mättade fettsyror (beräknad)	**1.22** g/100 g			EUSELI
LW0U4		Summa enkelomättade fettsyror (beräknad)	**9.11** g/100 g			EUSELI
LW0U4		Summa fleromättade fettsyror (beräknad)	**4.37** g/100 g			EUSELI
LW0U4		Totalsumma fettsyror (beräknad)	**14.71** g/100 g			EUSELI
LW0U4		Oidentifierat (beräknad)	**0.10** g/100 g			EUSELI
LW0U4		Summa av omega 6 fettsyror (beräknad)	**3.23** g/100 g			EUSELI
LW0U4		Summa av omega 3 fettsyror (beräknad)	**1.14** g/100 g			EUSELI
LW04E		NaCl ber. ur Natrium halt	**0.04** g/100 g			EUSELI
SL0AC	[a]	Natrium Na	**17** mg/100 g	± 25%	SS-EN ISO 17294-2:2016 /SS- EN 13805:2014	EUSELI2

Appendix 2

Drying statement of the fava bean milk.

Drying statement of Faba Bean
PO108157

FIPROS

	Drying period	From	24-03-2021	to	24-03-2021		
		batch nr.	batch nr.	batch nr.	batch nr.	SUM	Remarks
		16					
	Liquid weight from AAK (kg)	3.000				3.000	
	Dry matter content from AAK (%)	12					
	Dry matter quantity from AAK (kg)	360	0	0	0	360	
	Weighed liquid quantity at Fipros (kg)	3.000				3.000	
	Dry matter content at Fipros (%)	12					
	Dry matter quantity at Fipros (kg)	360	0	0	0	360	
	Difference between AAK and Fipros dry matter (kg)	0	0	0	0	0	
						0	
	Total amount of powder in BB from the tower (kg)	333				333	
	Swept out from tower (kg)	0				0	
	Loss from sieving in tower (kg)	0				0	
	Dry matter swept out from tower (kg)	0	0	0	0	0	
	Dry matter loss from sieving in tower (kg)	0	0	0	0	0	

DATE:

	BAGGING SUMMARY						Remarks
	Packed volume (kg)	333				333	
	Amount of received dry matter (kg)	360	0	0	0	360	
	Loss from sieving during bagging (kg)	0				0	
	Calculated weight loss of bagging (kg) (overfilling)					1	0,1 kg pr. sæk
	Water content of the finished product (kg)					10	ved 3 % vand i pulver
	Verified dry matter quantity after bagging (kg)					324	Rent TS.
	Difference between AAK delivery and Fipros outcome (dry matter) kg					-36	

DATE: 25.03.2021 BL

Forbrugt 8 timer

Faba bean **LOT.NR.** **PO108157** AAK

Operatør	Dato	Tidspunkt	Sæk no	A. kg	Tom mellem BB / pulje	KOH	Forstøver FW 15 RPM	Primær temp	Primær luftmængde m/s	Sekundær temp.	Sekundær luftmængde m/s	Top temperatur	Bundtemperatur	Trykventilator	Tørmusler	Pasteuriseringstemp	Tørstof feed	Vandindhold pulver	Gram vand / kg luft	%	Noterer operatør
							11700	250	18,5	125	13,5	175	88	75		80	12%	3,5%			
TH	24.03.21	17.00	1	10			v	v	19	135	12	177	v	v	92	v	10	2,98	2,61	608	
	24.03.21		2	10																	
	24.03.21		3	10																	
	24.03.21		4	10																	
	24.03.21		5	10																	
	24.03.21		6	10																	
	24.03.21		7	10																	
	24.03.21		8	10																	
	24.03.21		9	10																	
	24.03.21		10	10																	
	24.03.21		11	10																	
	24.03.21		12	10																	
	24.03.21		13	10																	
	24.03.21		14	10																	
	24.03.21		15	10																	
	24.03.21		16	10																	
	24.03.21		17	10																	
	24.03.21		18	10																	
	24.03.21		19	10																	
	24.03.21		20	10																	
	24.03.21		21	10																	
	24.03.21		22	10																	
	24.03.21		23	10																	
	24.03.21		24	10																	
	24.03.21		25	10																	
	24.03.21		26	10																	
	24.03.21		27	10																	
	24.03.21		28	10																	
	24.03.21		29	10																	
	24.03.21		30	10																	
	24.03.21		31	10																	
	24.03.21		32	10																	
	24.03.21		33	10																	
	24.03.21		34	2,5																	
			Sum :	332,5																	

Bemærkninger:

Appendix 3

Table 1. Table of solubility (%) of reconstituted fava bean milk powder and cow's milk powder under different treatments and pH conditions, made in duplicates (Rep A & B). Stirred for 20min (Stirred), Stirred in 50 °C (H50), Ultra-Turrax (UT), Ultrasonic processing (US), Stirred and soaked for 24 hours (S24H), Cow's milk powder stirred for 20 min (Stirred MP).

pH	Stirred Rep A	Stirred Rep B	H50 Rep A	H50 Rep B	UT Rep A	UT Rep B	US Rep A	US Rep B	MP Rep A	MP Rep B	S24H Rep A	S24H Rep B
3	29	30	31	31	29	30	34	34	49	49	N/A	N/A
4	27	26	28	28	27	28	30	30	46	47	N/A	N/A
5	28	29	29	30	29	29	32	33	50	50	N/A	N/A
6	30	30	33	31	31	31	42	41	79	79	31	31
7	31	30	36	36	33	32	46	46	79	81	N/A	N/A

Table 2. Table of average solubility (%) of reconstituted fava bean milk powder and cow's milk powder under different treatments and pH conditions. Stirred for 20min (Stirred), Stirred in 50 °C (H50), Ultra-Turrax (UT), Ultrasonic processing (US), Stirred and soaked for 24 hours (S24H), Cow's milk powder stirred for 20 min (Stirred MP).

pH	Stirred	H50	UT	US	MP	S24H
3	29,5	31	29,5	34	49	N/A
4	26,5	28	27,5	30	46,5	N/A
5	28,5	29,5	29	32,5	50	N/A
6	30	32	31	41,5	79	31
7	30,5	36	32,5	46	80	N/A

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