Happy Goat Goodness

Case Studies Product Quality (FQD 24306) - 2025/2026

Group 4

Supervisors: Qing Ren, Etske Bijl

Commissioner: Victor Boone

Authors:

Nabila Agatha (1097504)
Marije Oostenveld (1223143)
Lakshmipriya Bhaskaran (1051766)
Aleksia Toprakchyoglu (1204920)
Willemijn Bleichrodt (1251910)
Eline Verhoef (1140841)

Management Summary

Introduction

Cow’s milk is a common source of protein and calcium but can cause allergies, intolerance, or digestion issues for some people. Goat milk is a traditional alternative in many parts of the world and is believed to have health benefits, like easier digestion and fewer allergic reactions. However, much of this is based on anecdotal evidence. This study examines whether goat milk ice cream from the company ‘Happy Goat Goodness’, can be a good substitute for people who cannot tolerate ice cream made from cow's milk. The study will look at the nutritional composition of goat milk ice cream, digestibility, allergenicity, and how processing affects the potential health benefits of goat milk. The goal is to provide clear, science-based insights for consumers and the company on whether goat milk ice cream is a healthy and practical alternative for people who cannot easily digest cow's milk ice cream.

Problem statement and objectives

The problem statement: How do the underlying compositional properties, physiological mechanisms, and digestibility of goat’s milk compare to cow’s milk, and to what extent can it contribute as a viable and nutritionally beneficial alternative for individuals with lactose intolerance and/or cow’s milk allergy?

Objectives:

- Summarize the Stages and Physiological Mechanisms of Lactose Intolerance and Cow's Milk Allergy.
- Review the Health Benefits and Underlying Nutritional Composition of Goat’s Milk and Goat’s Milk Ice Cream Compared to Cow’s Milk.
- Assess the Digestibility of Goat’s Milk and Goat’s Milk Ice Cream Compared to Cow’s Milk and Cow's Milk Ice Cream.
- Identify the Suitability of Goat’s Milk Ice Cream as an Alternative for Individuals with Cow’s Milk Allergy and Lactose Intolerance
- Determine the Impact of Potential Degradation of Components During Production Processes in Goat’s Milk Ice Cream.
- Synthesize All Findings into Concise and Evidence-based Conclusions.

Methodology

Research was conducted through literature review, expert interviews, and lactose content analysis using the MilcoScan machine, although there were some limitations in measuring melted ice cream accuracy. Various communication platforms and weekly supervisor meetings facilitated collaboration, while expert insights supplemented the study. The research focused on health-related aspects of goat milk ice cream, excluding sensory analysis, market trends, and environmental impact. Findings aimed to provide evidence-based recommendations to the company ‘Happy Goat Goodness', regarding the validity of their product claims and its viability as a cow’s milk alternative.

Results

Lactose intolerance occurs in 10% of northern white Europeans, they lack the enzyme lactase, which breaks down the sugar called lactose. Due to lactase deficiency, lactose is fermented in the colon by bacteria, producing gases and acids, resulting in loose stool and flatulence. According to some studies, 12 grams of lactose should not result in any discomfort for lactose intolerant people, however, there are some individual differences, thus a cup of Happy Good Goodness with 3.38g of lactose, should be symptom-free.

A Cow's milk allergy (CMA) is an allergic reaction by the immune system to milk proteins. CMA commonly develops in infants, who often outgrow the allergy before the age of 6. About 2% of children aged 0-3 years and 0.3% of the rest of the population of the Netherlands have CMA. For people with CMA, it does not matter how large the dose of milk proteins is, because already small amounts can cause symptoms. Goat's milk proteins and cow's milk proteins are very similar thus there is cross-reactivity, which means that an allergic reaction like in CMA often also occurs within consumption of goat's milk.

In addition, people could also have trouble digesting dairy products, due to other factors such as Irritated Bowel Syndrome, trouble with the digestive system, or sensitivity to components in milk. For them, it depends on their body how much goat's milk ice cream they can consume.

Goat's milk may be easier to digest than cow's milk. This is because it has smaller fat molecules, does not contain a component (agglutinin) that makes fat cluster together, and has a different type of protein. An important difference is in the protein called β-casein, goat's milk has different types of β-casein that do not contain a part (BCM-7) that can cause adverse symptoms in the abdomen. That part, however, is present in milk with the label A1 milk, but not in goat milk.

'Happy Goats Goodness' heats the milk to 80°C for 5 minutes, which is different from the usual pasteurization methods. This process doesn't change the lactose much, so it stays about the same as in raw goat milk (4.33%). The fat in the milk is mostly unchanged, though the size of the fat droplets may change a little. About 20% of the protein group called "whey" is broken down, which makes digestion easier, but the casein proteins stay mostly the same.

Conclusion/Recommendation

The report concludes that goat's milk is not a suitable alternative for people with cow's milk allergies due to protein cross-reactivity. Nutritionally, goat milk is thought to be easier to digest and may have more beneficial compounds, which could help people with digestive sensitivities, but further research is needed to confirm these effects.

The report also concludes that one serving of 'Happy Goat Goodness 'ice cream, containing approximately 3.38 grams of lactose, should be safe for lactose-intolerant individuals, as they typically tolerate up to 12 grams of lactose, although the tolerance levels strongly differ per individual. Happy Goats Goodness can promote its goat milk ice cream as a healthier, easier-to-digest option for those who struggle with cow's milk. Adding lactase would make it more suitable for lactose-intolerant individuals, while fortification could enhance its nutritional benefits. Clear packaging and educating consumers about goat milk's advantages could help attract more customers.

Table Of Contents

Introduction

Cow's milk and its derived dairy products are key dietary staples, they are a rich and cheap source of protein and calcium and a valuable food for bone health (Turck, 2013). However, many people experience adverse effects from cow's milk due to allergy, intolerance, or digestion issues, substantially impacting their health and quality of life. This emphasizes the importance of investigating alternatives for these individuals.

Dairy goats have been traditionally used for milk production across the globe, in particular in Asia, Africa, and Europe, producing 58.4%, 24.1% and 14.2% of the world's goat milk, respectively. However, only a small portion is commoditized dairy products, the majority is self-consumed milk (Stergiadis et al., 2019).

The potential health benefits from the consumption of goat milk have been reviewed, this included information about hypo-allergenicity, improvements in gastro-intestinal disorders, absorption of Iron (Fe) and Coper (Cu), growth rates, bone density, and blood levels of vitamin A, cholesterol, thiamine, niacin, riboflavin and calcium, however, claims around human health still mostly rely on anecdotal evidence, which is also used in industry promotional material and within the media (Haenlein, 2004; Stergiadis et al., 2019).

The following research paper aims to investigate the potential of goat milk, specifically goat milk ice cream, as an alternative for individuals with cow's milk allergy, lactose intolerance and digestion issues. This is done by examining the nutritional and functional properties of goat's milk ice cream, from the company 'Happy Goat Goodness', compared to cow's milk, with a focus on assessing its potential health effects and market acceptability through a series of targeted research questions.

The main research question (MRQ) which acted as a baseline for the literature is: How do the underlying compositional properties, physiological mechanisms, and digestibility of goat's milk compare to cow's milk, and to what extent can it contribute as a viable and nutritionally beneficial alternative for individuals with lactose intolerance and/or cow's milk allergy?

The main research question (MRQ) for this research was divided into five objectives to answer the MRQ, including:

1. Summarize the stages and physiological mechanisms of lactose intolerance and cow's milk allergy
2. Review the health benefits through the nutritional composition of goat milk (and ice cream) and cow milk (and ice cream)
3. Assess the digestibility of goat milk (and ice cream) and cow milk (and ice cream)
4. Identify the potential cross-reactivity of goat milk ice cream
5. Determine the impact of potential degradation of components during production processes in goat milk ice cream

By addressing these objectives, this study aims to contribute to the growing body of knowledge on dairy alternatives and provide valuable insights for the consumers and the company 'Happy Goat Goodness' regarding the viability of goat's milk ice cream as a nutritious and functional alternative to traditional cow's milk-based products.

Materials and Methods

Materials

This study was conducted by adapting a literature-based approach to gain scientifically backed-up evidence and insights while evaluating goat milk and goat milk ice cream, particularly their suitability for individuals with lactose intolerance and cow milk allergy. The research predominantly focused on analysing the nutritional composition, functional properties, digestibility, allergenicity, potential cross-reactivity, and the impact of processing methods of lactose, lipid, and fat levels in *Happy Goat Goodness Goat Milk Ice Cream*. Additionally, the study assessed the possibility of whether all individuals within the lactose intolerant and cow milk allergic spectrum can consume the product based on available published research. This research aimed to compile findings from various available studies and provide evidence-based recommendations to give to the company, Happy Goat Goodness, and their consumers about the suitability of claims used by Happy Goat Ice Cream, as well as to determine whether goat milk ice cream is a viable substitute for cow milk ice cream.

To conduct the research, the primary materials used for all objectives mentioned in the introduction were scientific and statistical information derived from scholarly peer-reviewed articles and theoretical frameworks such as Elsevier, ScienceDirect, NCBI, UniProt, etc. Access to these articles was permitted through databases such as Google Scholar, Scopus, WUR library, PubMed, etc. There was no specific year criteria set for the research as all background information is important to be accounted for. Additionally, interviews with experts were conducted to provide specialized insights and supplementary information for the report.

Several communication platforms including WhatsApp, MS Teams, and Email were utilized throughout the research to facilitate effective and efficient communication within and across all stakeholders.

Methods

At the beginning of the research, a work plan was developed to establish the timeline, hypotheses, research questions, and objectives. This approach was done to provide a framework that can be used as a 'guideline' throughout conducting the research, ensuring that all objectives and questions were addressed, while still aligning with the needs of the commissioner.

In order to delve further into the research questions, tasks were divided among all group members, and each member was assigned a specific objective. Extensive literature research was carried out to investigate the aim of the study.

Excluded Aspects for Literature Review

The case study **will not** include the following:

- Baseline protein source for infants: The benefits of using goat milk as a first protein source compared to cow milk in infants after breastfeeding due to its positive effects in terms of digestibility and nutritional composition.
- Sensory analysis: The perceived sensory evaluation and consumer acceptance of HGG Goat's Milk Ice Cream as a product in the consumer's perspective will not be assessed in this research.
- Market analysis: The emphasis of this research is based on giving evidence-based advice for the health benefits of the product through its ingredients to the company. An extensive market analysis beyond what is needed will not be done.

- Environmental impact analysis: This study will not include the impacts of the production line on the environment. Detailed LCA (life cycle assessments) will not be done.

Excluding aspects which are not the main scope of the study allows more time to allocate resources such as time and focus spent to work more effectively and efficiently. The demarcation of included and excluded aspects of the research is made to maintain a clear focus and understanding on achieving the primary objective of answering the main research question.

Approach to Research

Weekly supervisor meetings were conducted to ensure that the research progressed as planned and to address challenges encountered during the study and report writing process. The supervisors provided insights, suggested strategies on how to progress with the research, and introduced experts who could give specific information. The commissioner also provided needed information and responded to questions whenever asked.

Two experts, namely Ir. Swantje Breunig and Prof. Dr. Ir. Kasper Hettinga, were brought in for an interview to ask questions tailored to their respective areas of expertise. Ir. Swantje Breunig is a PhD candidate specializing in dairy chemistry and dairy science, with a particular focus on emulsions and milk products. Her research primarily explores goat milk, dairy goats, caseins, and related topics. Given her expertise on caseins, she was interviewed for this study to provide relevant insights. Prof. Dr. Ir. Kasper Hettinga is a professor of dairy processing and functionality, specializing in dairy science. His expertise includes protein detection, protein expression analysis, milk quality assessment, and the development and testing of milk products. Additionally, he has conducted multiple studies on lactose intolerance and cross-reactivity, making his insights valuable for this section of the report. A transcript of both interviews are included in the Appendix.

Furthermore, to gain a deeper understanding of the production process of goat milk ice cream and its potential implications for lactose-intolerant and cow milk-allergic individuals, lactose content analysis was conducted on goat milk sourced from the farm, supplied by the commissioner, prior to processing. The analysis was performed by the supervisor using the MilcoScan machine in the Axis Building. Additionally, the lactose content of the goat milk ice cream product was also analysed using the same machine. However, the results were inconclusive since the MilcoScan does not have a specific setting for (melted) ice cream, which limited the accuracy of the measurements and thus was not used in the report.

Results and Discussions

Dairy Sensitivity

The human diet starts with milk; directly after birth, infants are fed maternal milk. Dairy products are beneficial for adults as well because they contain a high source of proteins, fatty acids, minerals, and vitamins (Corgneau et al., 2017). Unfortunately, milk is also related to a lot of gastrointestinal disorders because milk contains many ingredients that can induce gastrointestinal disorders or discomfort (Al-Beltagi et al., 2022). Some diagnoses and their mechanisms are known, such as lactose intolerance and cow's milk allergy, however, a lot is still unknown. For example, people with Irritated Bowel Syndrome (IBS) experience gastrointestinal symptoms from consuming milk, according to a study up to 49% of people with IBS have trouble with dairy due to incomplete absorption of carbohydrates, however, the exact mechanism is unknown (Böhn et al., 2013; Sebastián Domingo, 2022). According to the Dutch Fund of the GI (Maag Darm Lever fonds), 5-10% of the Dutch population has IBS (Prikkelbare Darm Syndroom (PDS), 2025). Other causes can be carbohydrate malabsorption, where bacteria break down carbohydrates, producing gases and fatty stool, fat malabsorption, which causes fatty stool, and protein malabsorption due to a protein intolerance (Montoro-Huguet et al., 2021).

Lactose Intolerance

Lactose is a carbohydrate made out of the two sugar molecules glucose and galactose as is shown in Figure 1. Glucose provides energy, and galactose is used for multiple purposes such as energy, communication between cells, immune functions, epithelial stabilization, and neurological development. In the human body, lactose is digested by the enzyme lactase phlorizin hydrolase (LPH) which cuts the lactose into glucose and galactose, the sugar molecules can be absorbed through the intestinal wall (Szilagyi & Ishayek, 2018; Toca et al., 2022).

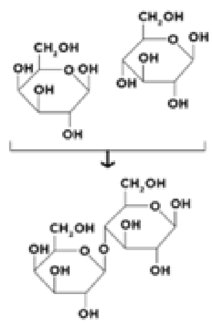

Figure 1 – A lactose molecule made up of glucose and galactose

Note. Szilagyi, A., & Ishayek, N. (2018). Lactose Intolerance, Dairy Avoidance, and Treatment Options. *Nutrients*, *10*(12), 1994. https://doi.org/10.3390/nu10121994

The LPH activity is high during birth to break down maternal milk, because the main energy source in mammal milk is lactose. After weaning the activity of LPH reduces, resulting in 35% of the people having the ability to break down lactose (lactose persistence) (Toca et al., 2022). The level and time course over which the lactase activity decreases varies with ethnic groups. “Chinese and Japanese lose 80%–90% within three to four years after weaning, whereas Asians and Jews can retain some 20%–30%, taking several years to reach the lowest level. The 10% of white northern Europeans who lose lactase after weaning can take 18–20 years to reach their nadir (lowest expression)” (Matthews et al., 2005).

The clinical syndrome lactose intolerance (LI) has been assigned to the phenomenon of developing gastrointestinal symptoms after eating lactose-containing foods such as flatus, gas, bloating, cramps, and diarrhoea (Lawrence, 2013; Szilagyi & Ishayek, 2018). Factors influencing the LI are “dose of lactose in diet, intestinal transit time, lactase expression, distribution and fermentation ability of gut microbiota, sensitivity towards chemicals and mechanical stimulation of the gut and psychological factors”. There are three types of lactose intolerance: 1. Congenital lactase deficiency: meaning there is a reduced or absent lactase activity from birth. 2. Primary lactose intolerance: results from change of lactase gene expression after weaning. 3. Secondary lactase deficiency: intestinal damage due to diseases such as infections, food allergies, celiac disease, small bowel bacterial overgrowth Crohn’s disease or chemotherapy-induced enteritis (Di Costanzo & Berni Canani, 2018).

Lactose Maldigestion is a result of lactase deficiency. If lactose is not degraded by lactase in the small intestine, the lactose travels to the colon. In the colon, lactose is metabolized by colonic bacteria, particularly bifidobacteria, lactobacilli and *E.coli*. They have an enzyme that causes the same chemical reaction as lactase, however, it differs in structure, enzymatic properties and regulation, called β-galactosidases that cleave glucose and galactose, which are converted by intestinal bacteria into products such as short-chain fatty acids, and hydrogen gas (Corgneau et al., 2017). Those fermentation products increase the osmotic pressure in the colon, so water enters the colon to compensate for the isotonic content (see Figure 2). Water inflow in the colon can result in loose stool and appreciable diarrhoea depending on the amount of lactose that is consumed (Levitt et al., 2013).

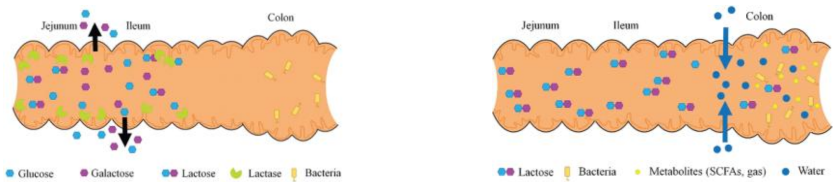

Figure 2 – Normal lactose digestion vs lactose deficiency

Note. Corgneau, M., Scher, J., Ritie-Pertusa, L., Le, D. t. l., Petit, J., Nikolova, Y., Banon, S., & Gaiani, C. (2017). Recent advances on lactose intolerance: Tolerance thresholds and currently available answers. *Critical Reviews in Food Science and Nutrition*, *57*(15), 3344–3356. https://doi.org/10.1080/10408398.2015.1123671

For lactose intolerant people the dietary advice is to keep consuming lactose-containing food (Catanzaro et al., 2021). By consumption of daily levels of lactose, increasing levels of Bifidobacterium indicate an adaptation of the gut microflora. Bifidobacteria break down lactose without producing gasses, thus reducing intestinal gas formation and bloating (Lonneke Janssen-Duijghuijsen et al., 2023, Wilt et al., 2010). It differs per person how much lactose they can consume before experiencing symptoms, according to Wilt et al (2010) it depends on psychological factors, the form of lactose, timing of the ingestion, other compounds in the meal, routine doses of lactose, and sensitivity of the colon. In a study done by Hertzler et al. (1996), it was shown that lactose maldigester showed no difference between the consumption of 0 gr and 6 gr of lactose, however at 12 gr of lactose one-third of the subjects experienced abdominal pain, other studies suggest that lactose intolerant people can consume up to 12 g of lactose (1 cup of milk), and the majority of the population of maldigester experience symptoms near the 25 g of lactose (Suarez et al., 1995, Savaiano et al., 2006).

In conclusion, 10% of northern Europeans have a lactose intolerance, thus they lose lactase activity before turning 20 years old. When lactase is not present, in the colon it will be fermented by bacteria, resulting in gas production and water absorption, leading to loose stool and flatulence. Lactose intolerant individuals can consume 12 gr of lactose because that will result in no symptoms of the majority, and it aids in keeping the colon microbiome ready for lactose.

Cow’s Milk Allergy

Cow's milk allergy is an allergic reaction to the protein found in cow’s milk, diagnosis of cow’s milk allergy can be difficult due to a lack of precise criteria for diagnosis. It manifests as a variety of symptoms and signs which commonly develop in infants (younger than 6 months old) and can regress by the age of six. Cow milk allergy in children can cause parental and family stress due to a milk-free diet and can lead to a subsequent nutritional deficiency if not treated appropriately

(Edwards & Younus, 2024). Development of the sensitisation to the cow's milk proteins depends on the interaction between genetic susceptibility and factors of exposure to cow's milk proteins (for example, antigen dose, the transmission of cow's milk proteins through the mother's milk and the mother's dietary exposure during pregnancy) (Martorell et al., 2006).

Cow milk allergy is not particularly common in the Netherlands, although a bit more prevalent among young children. According to a study conducted by the National Institute for Public Health and the Environment (RIVM), the prevalence of cow's milk allergy in the Netherlands was assumed to be about 2% in children aged 0-3 years and 0.3% in the rest of the population (Dutch Ministery of economic affairs, 2016). In Europe, a recent meta-analysis found the overall pooled estimate of self-reported lifetime prevalence of cow's milk allergy across all age groups to be 5.7%, while the point prevalence of food challenge-verified cow's milk allergy was much lower at 0.3% (Spolidoro et al., 2023). For the United States, these percentages were much higher. Analyzing survey responses estimated that 4.7% of the US population reported current CMA, whereas 1.9% symptom-report criteria for convincing IgE-mediated allergy. An estimated 0.9% had CMA that met convincing symptom-report criteria and was physician-diagnosed (Warren et al., 2022).

Food allergies stem from the body's immune system. The body's immune system of an individual with an allergy to milk responds to a specific milk protein, this triggers an immune response, and the immune system attempts to neutralize the triggering protein. The next time that the body comes into contact with a specific milk protein, the immune response recognizes the protein. This triggers the immune system to mount a response, including the release of histamine and other immune mediators. This release of chemicals causes the signs and symptoms of cow's milk allergy (CMA). (Hicks et al., 2024)

Cow's milk contains more than 20 protein fractions, but the significant allergens belong to casein protein (alpha-s1-, alpha-s2-, beta-, and kappa-casein) and whey proteins (alpha-lactalbumin and beta-lactoglobulin). Most people with a cow's milk allergy have a sensitivity to both whey proteins and caseins. Immune-mediated adverse food reactions are classified into two primary categories: IgE-mediated and non-IgE-mediated. The non-IgE mediated mechanism most frequently causes cow's milk allergy.(Edwards & Younus, 2024)

IgE-mediated CMA:

With IgE-mediated CMA, the immune system reacts to cow's milk protein by producing IgE antibodies. The first stage, 'Sensitization', occurs when milk proteins enter the body and are processed by antigen-presenting cells (APCs). APCs present the milk protein fragments to T cells. This initial exposure to cow's milk proteins leads to the production of Immunoglobulin E (IgE) antibodies specific to these proteins. This process often occurs in the first year of life. The second phase, the 're-exposure' phase, occurs upon subsequent exposure to cow's milk. The bound IgE on mast cells and basophils triggers an immediate sensitivity reaction (Giovanna et al., 2012).

During the activation phase, IgE associated with mast cells binds to allergenic epitopes on milk proteins, leading to a rapid release of inflammatory mediators, such as histamines, which are responsible for the allergic reaction. This type I hypersensitivity reaction, also known as immediate CMA, typically manifests within minutes to 2 hours after milk ingestion (M. Lin & Yanjun, 2024).

During re-exposure, cow's milk proteins cross-link the IgE on sensitized cells, leading to degranulation and release of mediators such as histamine, leukotrienes, and prostaglandins. This results in symptoms such as urticaria, angioedema, gastrointestinal distress, and potentially anaphylaxis within minutes to hours after ingestion (Edwards & Younus, 2024; Hicks et al., 2024; Martorell et al., 2006)

Non-IgE-mediated CMA:

Non-IgE-mediated reactions can arise from other cellular processes involving eosinophils or T-cells. In the first stage, the 'Initial Reaction', symptoms may take longer to manifest, often appearing hours or even days after exposure. After that, there will be a diagnosis. This typically involves an elimination diet followed by a controlled reintroduction of cow's milk protein (Giannetti et al., 2021).

Non-IgE-mediated reactions involve different immune pathways, including T-cell-mediated responses. These reactions can lead to gastrointestinal symptoms like diarrhoea and vomiting, as well as skin manifestations such as eczema. The underlying mechanisms may include delayed-type hypersensitivity (type IV) or other immune-mediated processes that do not involve IgE (Giannetti et al., 2021; X. Lin et al., 2025).

Mixed CMA:

Some babies may experience mixed allergic reactions with symptoms of both IgE-mediated and non-IgE-mediated CMA. This means symptoms can appear quickly or after a few days of consuming cow's milk protein. Combined CMA may be related to the cross-inhibitory response of Th1 and Th2 in the immune system of newborn infants. It may present with conditions such as atopic dermatitis, allergic eosinophilic esophagitis, and eosinophilic gastritis

Substitutes such as sheep's and goat's milk generally are not acceptable, because of a high degree of cross-reactivity with cow's milk protein. (Edwards & Younus, 2024)

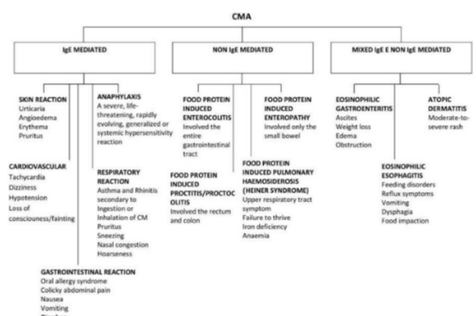

Figure 3 – Overview symptoms Cow's Milk Allergy (CMA)

Note. Giannetti, A., Toschi Vespasiani, G., Ricci, G., Miniaci, A., di Palmo, E., & Pession, A. (2021). Cow's Milk Protein Allergy as a Model of Food Allergies. *Nutrients*, *13*(5). https://doi.org/10.3390/nu13051525

Cross Reactivity

Goat's milk ice cream has been thought of as an alternative to cow's milk ice cream for individuals with lactose intolerance and cow's milk allergy due to the difference in the protein composition present in their milk counterparts and also due to the slightly lower levels of lactose present in goat's milk compared to cow's milk. However, this might not be the case. On the one hand, the cross-reactivity between the proteins present in goat's milk and cow's milk makes goat's milk as well as goat's milk ice cream unsuitable for lactose intolerant and cow's milk allergic individuals. On the other hand, the allergic potential of goat's milk is found to be less than that of cow's milk because of the difference in their respective protein composition (Figure 4).

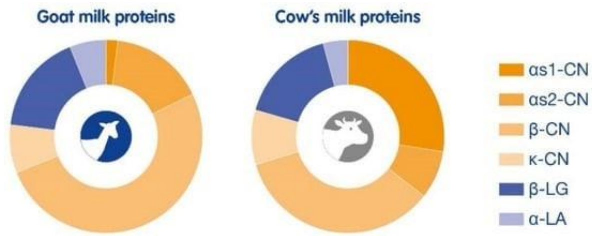

Figure 4 - Composition of goat milk proteins compared to cow's milk proteins.

Note. Olga Benjamin-van Aalst, Dupont, C., Lucie, Johan Garssen, & Knipping, K. (2024). Goat Milk Allergy and a Potential Role for Goat Milk in Cow's Milk Allergy. *Nutrients*, *16*(15), 2402–2402. https://doi.org/10.3390/nu16152402

The major allergen present in both goat milk and cow milk is casein (Olga Benjamin-van Aalst et al., 2024; Umpiérrez et al., 1999), making up about 80% of the total proteins found (Prosser, 2021). αS1-casein, αS2-casein, β-casein, and κ-casein are the four different casein classes present in goat milk and cow milk (Olga Benjamin-van Aalst et al., 2024; Goh et al., 2019; Rahmatalla et al., 2022), but the proportion in which they are present in the milk differs. Out of these four classes, αS1-casein is of the most importance when it comes to the allergic potential of milk.

The level of αS1-casein present in goat milk usually depends on the goat breed and can vary from approximately high (3.6 g/L), medium (1.1–1.6 g/L), low (0.45–0.6 g/L), or absent levels (Grosclaude et al., 1987; Moatsou et al., 2004; Küpper et al., 2009). The level of αS1-casein present in cow milk is almost always higher (~12 g/L). According to the literature, the lower αS1-casein content of goat milk is typically associated with having hypoallergenic characteristics (Rahmatalla et al., 2022) but a proper dose-response curve has not been made yet to better support the argument (Olga Benjamin-van Aalst et al., 2024). However, this is only true when there are no αS1-caseins present in the milk since lower levels of the caseins can still trigger allergic reactions.

An Immunoglobulin E (IgE)- mediated allergic reaction occurs when the immune system recognizes a protein in the milk as a foreign substance causing the plasma cell to produce IgE (Mansor et al., 2023; Sampson et al., 2018). The mast cells release histamine when this IgE binds to the protein causing an allergic reaction. Due to the presence of similar proteins in both goat as well as cow milk, the immune system of an individual recognizes the similar proteins in the different kinds of milk which then leads to an allergic reaction in both cases. For cross-reactivity to occur, there should be at least a 70% amino acid sequence homology in the proteins (Francis et al., 2020; Cox et al., 2021). According to (Bellioni-Businco et al., 1999), it has been found that there is a similarity of 87% to 98% between the αS1 and αS2 caseins present in cow and goat milk. More than 90% of individuals who are allergic to cow milk are also allergic to goat milk (Levy et al., 2014; Francis et al., 2020).

According to a study conducted by (BEVILACQUA et al., 2001), an IgE-dependent guinea pig model for cow's milk allergy was made to understand the effect of different levels of αS1-casein on the allergic potential of goat milk. In this study, the guinea pigs received cow milk, goat milk with a high concentration of αS1-casein (7 g/L) and goat milk with a low concentration of αS1-casein (0.7 g/L). High IgG1 antibodies to cow β-lactoglobulin (which is one of the primary milk allergens) were produced in the guinea pigs that were given cow milk. The guinea pigs that were given goat milk with a high level of αS1-casein also produced high IgG1 antibodies to goat β-lactoglobulin and these antibodies also reacted with cow β-lactoglobulin implying that cross-reactivity occurs. However, the animals that were fed the goat milk with a low level of αS1-casein did not have such a strong response to goat β-lactoglobulin which indicates that goat milk with lower αS1-casein content could be less allergic.

Nutritional Composition

This section of the report aims to evaluate the health benefits of goat milk (and ice cream) and cow milk (and ice cream) by analyzing their nutritional composition. Various components of the milk (and ice cream) will be assessed to evaluate the potential benefits they may carry.

The main ingredient in Happy Goat Goodness Ice Cream, which is further investigated in this research, is milk sourced from Dutch White Goats (Saanen geit) straight from the farm. Milk, and other dairy products, play a crucial role in human diets due to their high nutritional content which has positive effects and influences on health. Composition levels and their characteristics are crucial factors that significantly affect the quality of dairy products, such as ice cream.

According to National Research Council (US) (2016), it is essential to consider that the nutritional composition of milk is significantly influenced by multiple intrinsic and extrinsic factors, including breed, genetic variations, diet, lactation stage, health status, milking practices, and environmental conditions, as seen in Table 6 in the Appendix. Environmental factors, such as temperature fluctuations at the time of milking, can induce physiological stress responses, potentially leading to a decrease in milk protein synthesis and overall compositional changes. The lactation stage and age of the animal also significantly influence the biochemical profile of milk, with protein composition and yield fluctuating throughout the lactation cycle (Kalscheur et al., 1999). Specific dietary interventions that the livestock undergo may modify the fatty acid profiles, micronutrient content, and other components in the milk that is produced (Cui et al., 2023), and thus can be an effective way to increase the health-promoting fatty acid content of milk (Verruck et al., 2019).

To compare the potential health benefits between goat's milk (and goat's milk ice cream) and cow's milk (and cow's milk ice cream) through the nutritional composition, two different types of ice cream will be analyzed, including *Happy Goat Goodness Cookie Dough* and *Happy Mrs Jersey Chilla Vanilla*. Table 7 in the Appendix demonstrates the nutrition facts of both ice creams.

The cookie dough flavor is chosen as it primarily consists of vanilla ice cream with pieces of cookie dough and brownie in it, making it a suitable comparison for a standard vanilla ice cream. Happy Mrs. Jersey is included in this study due to both companies use the same production process type, focusing on organic production practices and using fresh milk directly from the farm to ensure the best quality in terms of sensory properties. However, limited information is available regarding the specific breed that is used for the Happy Goat Goodness Ice Cream, hence standard goat milk is analyzed instead.

Goat milk has a high nutritional value, and a large number of bioactive compounds including oligosaccharides, and medium-chain fatty acids (MCFAs). It is also more easily digestible compared to cow milk due to the higher β-casein fraction, smaller diameter of fat globules, and the absence of agglutinins, which prevents fat globules from clumping (Jenness, 1980) (Park, 2009) (Yadav et al., 2016). Nutritionally, goat milk contains higher levels of protein, calcium, and potassium compared to conventional cow milk, as shown in Table 6 in the Appendix. Additionally, goat milk is high in ash content (Saikia et al., 2022) and non-protein nitrogen (NPN) content (Delger, 2021), enhancing the digestibility and absorption.

These qualities are mainly due to the physical and chemical properties of goat milk fat, especially the melting point, lactose content, protein content, fatty acid composition and chain length variation. As stated by Bhattacharya (1980), goat milk has a lower melting point and a more diverse fatty acid profile, including differences in fatty acid number and chain length variations in comparison to cow milk. All these different qualities in terms of its nutritional content impact the potential health benefits that can be achieved from consuming the product.

Protein

This section of the report aims to evaluate the proteins in goat milk (and ice cream) and cow milk (and ice cream), by analyzing their protein structure, processing effects, and digestibility. Various factors, including casein and whey proteins, as well as pasteurization methods, will be examined to determine how they impact protein digestion, allergenicity, and overall gastrointestinal comfort.

Composition

Milk features various kinds of protein impacting its digestibility, allergenicity, etc. Milk proteins can be divided into two groups, casein the most predominant protein in ruminant milk which constitutes approximately 80% of the total protein content, and whey which constitutes around 20% (Davoodi et al., 2016). Different livestock breeds have variations in the total milk protein content which directly affects the proportional ratio of casein and whey proteins. In Dutch goats, this ratio is reported as 86.9:13.1 (Breunig et al., 2024).

Table 1 - *Comparative Protein Composition of different types of Milk (% of total protein)*

Component	*Cow Milk*	*Goat Milk*	*Dutch Goat Milk*
αS1-Casein	8	16	17.29
αS2-Casein	27	Not determined	13.92
β-Casein	34	51	55.27
κ-Casein	9	8	13.52
β-Lactoglobulin	16	17	8.2
α-Lactalbumin	4	6	6
Serum albumin	1	1	0.6

Note. Data adapted from Breunig et al. (2024), Ruprichová et al. (2014), Wang et al. (2020), Selvaggi et al. (2014), (Gaynor, 2016), and Prosser (2021).

Casein has various types of isoforms, such αS1-casein, αS2-casein, β-casein, and κ-casein. The content of casein and whey in milk differs greatly both across and within species, as seen in Table 1. β-Casein, which can be present in amounts as high as 30-50% in cow milk products, can be present in several distinct forms of genetic variants and genotypes (or as a combination) which are: A1, A2, A3, B, C, D, E, F, G, H1, H2, and I (Giribaldi et al., 2022). αS1-casein, αS2-casein, and β-casein are responsible for binding calcium and phosphorus, whilst κ-casein is responsible for stabilizing the structure (Müller-Buschbaum et al., 2007).

It is essential to note that while many proteins in cow and goat milk exhibit high sequence similarity, in some cases up to 90%, the remaining differences in their amino acid composition can significantly alter their structural and functional properties (Olga Benjamin-van Aalst et al., 2024). Goat milk is predominantly composed of β-casein (55%), followed by κ-casein (20%), αS2-casein (19%), and αS1-casein (6%) (Breunig et al., 2024) (Jenness, 1980) (Selvaggi et al., 2014) (Park, 2017).

A comparative analysis of the four casein protein sequences in cow and goat milk is presented to highlight structural variations that may influence their functional and nutritional properties. For each casein variant, a table provides detailed information in both species, including the associated gene that produces the protein, the total number of amino acids, and the complete protein sequence. Additionally, differences in the amino acid sequences are highlighted in bold to illustrate the differences between the two species.

β-casein

In dairy livestock breeds, there are different variants of β-casein, where A1 and A2 are the most common, and B, C, A3, and others are uncommon and rare (Farrell et al., 2004). Originally, only the

A2 variant was produced in cow milk; however, due to a genetic mutation where a single nucleotide polymorph-orphism (SNP) occurred, the A1 variant also emerged from a substitution of histidine for proline at the 80 position of the β-Casein protein. The result is a histidine in A1 β-Casein and a proline in A2 β-Casein. It is important to consider that since UniProt is used to check for the protein sequence, the numbering might differ with other sources as UniProt includes the full precursor protein sequence, including the signal peptides and pro-peptides. In most literature, the H to P substitution is referenced at position 67, as the cleavage of signal peptides is accounted for (Cieślińska et al., 2022).

Table 2 - *A2 β-Casein Protein Sequence in Cows*

CASB_BOVIN	
Cow (Bos taurus)	
Protein	β-casein
Gene	CSN2
Amino acids	224
Variant	Sequence of A2 Allele
Sequence	MKVLILACLV **ALALARELEE** L**NVPGEIVES** LSSSEESIT**R** INKKIEKFQS EEQQQTEDEL QDKIHPFAQ**T** QSLVYPF**PGP** IPNSLPQN**IP** PLTQTPVVVP PFLQPEV**MGV** S**KVKEAMAPK** HKEMPFPKYP VEPFTESQSL TLTDVENLHL PLP**LLQSWMH** Q**PHQPLPPTV** MFPPQSVLSL **SQSKVLPVPQ** KAVPYPQRDM PIQAFLLYQE PVLGPVRGPF PI**IV**

Note. Data from *UniProt Knowledgebase: P02666 (A2 β-Casein, Cow)*, by UniProt Consortium, 2024, *UniProt*. Retrieved from https://www.uniprot.org/uniprotkb/P02666/entry

The sequence spanning positions 75-81, highlighted in red in Table 2, plays a crucial role in protein function. A specific change at position 80 from proline (P) to histidine (H), marked in yellow, directly leads to the production of β-casomorphin-7 (BCM-7) in cow milk (Noni et al., 2009). It is commonly reflected in the literature that the A1 β-Casein containing histidine, which is present in different amounts in cow's milk, can lead to harmful side effects such as contributing to digestive problems in sensitive individuals, including constipation, diarrhoea, bowel inflammation, and possesses higher allergenic potential. Upon ingestion, the histidine in the A1 β-Casein can release opioid peptides known as BCM-7, which can bind to opiate receptors in the gut and slow down gastrointestinal transit. Longer transit times allow for increased fermentation in the gut, hence causing various symptoms stated above (Giribaldi et al., 2022) (Brooke-Taylor et al., 2017) (Defilippi et al., 1995).

Proline is a rigid amino acid with a cyclic side chain bonded to the backbone, forming a tertiary amine that restricts peptide backbone rotation (Théoneste Umumararungu et al., 2024). In β-casein, the presence of proline prevents proteases from cleaving the protein at the 80th position due to its cut-resistant bond, thereby inhibiting the release of BCM-7 during digestion (Giribaldi et al., 2022).

Table 3 - *β-Casein Protein Sequence in Goats*

CASB_CAPHI	
Saanen Goat (Capra hircus)	
Protein	β-casein
Gene	CSN2
Amino acids	222
Variant	Sequence of A Allele
Sequence	MKVLILACLV **ALAIAREQEE** L**NVVGETVES** LSSSEESIT**H** INKKIEKFQS EEQQQTEDEL QDKIHPFAQ**A** QSLVYPF**TGP** IPNSLPQN**IL** PLTQTPVVVP

PFLQPEI**MGV** P**KVKETMVPK** HKEMPFPKYP VEPFTESQSL TLTDVE**KLHL** PLP**LVQSWMH** Q**PPQPLSPTV** MFPPQSVLSL **SQPKVLPVPQ** KAVP**QRDMPI** QAFLLYQEPV LGPVRGPFPI **LV**

Note. Data from *UniProt Knowledgebase: P11839 (β-Casein, Goat)*, by UniProt Consortium, 2024, *UniProt*. Retrieved from https://www.uniprot.org/uniprotkb/P11839/entry

*The amino acids highlighted in red indicate the potential site for BCM-7 production. The underlined amino acid represents a substitution that prevents BCM-7 formation.

Goat milk β-casein is structurally different and has different functionalities from cow A1 and cow A2 β-casein. Specifically, goat β-casein contains a T (threonine) instead of a P (proline) at position 78, as underlined in the sequence. This substitution prevents the formation of (BCM-7) in goat milk, confirming that BCM-7 is absent from its amino acid sequence.

According to the commissioner (V. Boone, personal communication, February 24, 2025), the dairy factory supplying goat milk for Happy Goat Goodness Ice Cream states that it contains A2 β-casein, which is why it is classified as 100% A2 milk in the front packaging. BCM-7 is a peptide fragment which is derived from the β-casein during digestion through proteolysis. The most effective method for detecting peptides is LC-MS/MS (Liquid Chromatography-Tandem Mass Spectrometry), particularly UHPLC-MS/MS (Ultra-High-Performance Liquid Chromatography-Tandem Mass Spectrometry) and UHPLC-HRMS (Ultra-High-Performance High-Resolution Mass Spectrometry, Orbitrap MS). These techniques provide high accuracy and sensitivity to detect low concentrations or trace amounts, specificity to distinguish the BCM-7 peptide, and reliable confirmation (Liliane et al., 2023). Tandem MS/MS determines the mass-to-charge ratio (m/z) of peptides by fragmenting BCM-7 into smaller parts, enabling detailed confirmation through peptide sequencing (Neagu et al., 2022).

If the lab tested specifically for BCM-7 as an indicator of A1 β-casein, no BCM-7 would be detected, as goat β-casein differs sequentially from cow β-casein and does not produce BCM-7 upon digestion. Additionally, the presence of proline in goat β-casein does not indicate that it is identical to A2 β-casein in cow milk, as their overall protein sequences differ in multiple amino acid positions (as bolded in position 78). These differences emphasize that goat and cow β-casein are different from each other and are therefore not directly comparable.

The predominance of β-casein and the casein micelle structure in goat milk, as seen in Table 1, contributes to reduced digestive discomfort compared to cow milk. As stated by Almaas et al. (2006) human proteolytic enzymes can degrade goat milk proteins more rapidly. The presence of proline in the amino acid sequence of goat milk makes the protein more susceptible to enzymatic breakdown, because it disrupts the rigid secondary structure of the proteins, making them more flexible, and loosely structed. This ability allows for faster digestion and lowers the chance of long gastrointestinal transit time (Li et al., 1996). However, it is important to take into account where the proline is located in the sequence, as many proteases, including trypsin, elastase, chymotrypsin, etc. struggle to cleave peptide bonds which are adjacent to proline (Gasteiger et al., 2005, Manea et al., 2007). Furthermore, the presence of other enzymes such as dipeptidyl peptidase-IV and brush-border proteases specialized in cleaving proline in peptides, potentially facilitates the breakdown of the protein and thus a faster digestion process (Olivares et al., 2018).

The effect is linked to the different coagulation properties of goat milk, as it forms a softer curd structure in the stomach (Prosser, 2021). Moreover, it reduces the release of BCM-7, thereby lowering the antigenic burden and potentially reducing allergenicity (Benjamin-van Aalst et al., 2024).

In addition to differences in BCM-7 production, the lower levels of αS1-casein content in goat milk leads to hypo-allergenic properties (Benjamin-van Aalst et al., 2024).

αS1-Casein

αS1-casein constitutes up to 40% of the casein fraction, and can exist in multiple phosphorylated forms (Grosclaude et al., 1973) and exhibits structural and sequence variations across species. A complete information of αS1-Casein in both cow and goat milk can be seen in Tables 8 and 9 in the Appendix.

Different breeds of goats can produce different amounts of αS1-Casein, ranging from 0% to 25%. The variability in milk protein composition among different goat breeds is primarily due to genetic differences in the CSN1S1 gene. Polymorphisms in this gene influence αS1-casein expression in milk, resulting in different levels, as discussed in the Cross Reactivity section of the report. Expression levels correspond to specific alleles: A, A3, B1, B2, B3, B4, C, H, L, and M (high); E and I (medium); D, F, and G (low); and N, O1, and O2 (null) (Brignon et al., 1990; Martin et al., 1999; Bevilacqua et al., 2002; Ramunno et al., 2005; Mestawet et al., 2013).

The E allele is particularly prevalent in Saanen goats globally (Maga et al., 2009), further supporting the evidence that there is reduced expression of αS1-casein while having higher levels of β-casein and αS2-casein. This composition influences the milk's allergenicity and digestibility, making it potentially more suitable for individuals with sensitivities (Rahmatalla et al., 2022).

As indicated by Ng-Kwai-Hang and F. Grosclaude (2003), some phenotypes have been proven to have higher protein yield, whilst some others have been associated with lower protein concentration in the milk. By altering the genetic variants of the αS1-Casein in livestock, attempts to correlate milk characteristics or production with the genotype have been made.

αS2-Casein

αS2-Casein consists of two major and several minor components which exhibit varying levels of post-translational phosphorylation and minor degrees of intermolecular disulfide bonding (Swaisgood, 1993) (RASMUSSEN et al., 1992), which differs structurally and sequentially between species. A complete information of αS2-Casein in both cow and goat milk can be seen on Table 10 and 11 in the Appendix.

As mentioned by Prosser (2021) and Rahmatalla (2022), goat milk naturally contains higher proportions of αs2-casein and lower fractions of αs1-casein, allowing for thinner and softer coagulates (curds) when exposed to stomach acid, making it less dense.

κ-Casein

κ-Casein, the only casein which is highly glycosylated, is a calcium insensitive protein which forms a protective layer around the other types of caseins (α-S1, α-S2, and β), resulting in stable casein micelles (Caballero et al., 2003). Different species possesses different amino acid composition and structure, which can be seen in Table 12 and 13 in the Appendix.

In goat milk, κ-casein constitutes approximately 20% of the total casein content, contributing to its nutritional properties. Additionally, digestion of κ-Casein can generate an antimicrobial peptide, known as caseinomacropeptide (CMP) (Malkoski et al., 2001). CMP has been reported to serve beneficial health effects to the human body, including suppression of gastric secretions (Yvon et al., 2025), immunomodulating activities (Meisel, 1997), depression of platelet aggregation (Boman, 1991), etc. According to Catota-Gómez et al. (2017), Saanen goats worldwide predominantly carry the CSN3*C variant of the CSN3 gene.

Digestion

Cow's milk is predominantly rich in αs1-casein, a protein that forms firm curds during digestion. This characteristic leads to slower digestion and is often linked to allergic responses and gastrointestinal discomfort in sensitive individuals.

Goat milk β-casein is structurally different from cow A1 and A2 β-casein, with a key amino acid substitution at position 78 (threonine instead of proline), which prevents the formation of β-casomorphin-7 (BCM-7). As discussed in the nutritional chapter, BCM-7 is a peptide fragment released during the digestion of A1 β-casein, contributing to slower gastrointestinal transit and increased gut inflammation. Since goat milk does not produce BCM-7, its consumption is associated with improved digestive comfort and reduced inflammatory responses (Pal et al., 2015).

Cow's milk contains a higher concentration of β-lactoglobulin, a protein that is a major allergen for some individuals. Goat's milk, however, has lower levels of β-lactoglobulin, which may contribute to better tolerance among individuals with cow's milk protein allergies. Furthermore, goat's milk contains a higher proportion of α-lactalbumin, a protein that is structurally similar to human milk, making it easier to digest. α-Lactalbumin is rich in essential amino acids and bioactive peptides that support immune function and gut health (Park, 2017).

Additionally, whey proteins in goat's milk are more sensitive to heat compared to those in cow's milk. Research indicates that goat whey proteins denature more extensively upon heating, with nearly no denaturation observed at 65°C for 30 minutes but complete denaturation occurring at 85°C for 30 minutes (Zhao et al., 2020). Furthermore, goat whey proteins more readily interact with casein micelles during heating, which can lead to aggregation. While heat-induced denaturation can expose protein structures to digestive enzymes, excessive aggregation may hinder digestion rather than improve it. This suggests that the impact of heat treatment on goat milk's digestibility depends on the balance between protein unfolding and aggregation (Dupont & Tomé, 2020).

Processing

According to Fox et al., 2015, pp. 345–376, there are different time-temperature combinations to treat milk as seen in table 4. The main processing step that will be discussed will be about pasteurization of the fresh goat's milk.

Table 4 - Showing the time-temperature combinations used in the treatment of milk

Thermization	*65°C for 15 seconds*
Pasteurization	
Low temperature, long time (LTLT)	63°C for 30 minutes
High temperature, short time (HTST)	72°C for 15 seconds
Forewarming for sterilization	90°C for 2 – 10 minutes, 120°C for 2 minutes
Sterilization	
Ultra-high temperature (UHT)	130°C – 140°C for 3 – 5 seconds
In-container	110°C – 115°C for 10 – 20 minutes

Note. Fox, P. F., T Uniacke-Lowe, Mcsweeney, P. L. H., & O'mahony, J. A. (2015a). Dairy Chemistry and Biochemistry (Second, pp. 345–376). Cham Springer International Publishing. https://link.springer.com/book/10.1007/978-3-319-14892-2

According to the company, Happy Goats Goodness, the pasteurization process takes place at 80°C for 5 minutes (V. Boone, personal communication, February 15, 2025). As seen in table 4, the mentioned time-temperature combination for the pasteurization process does not fall under LTLT or HTST, however, in order to determine how the lactose content, proteins, and fats in milk is affected, HTST will be used, as the temperature is the most similar to the one used in the production for Happy Goats Goodness, however, the process takes longer, which the overall effects could be quite different.

The heat treatment of milk has the biggest impact on proteins (Fox et al., 2015, pp. 345–376).

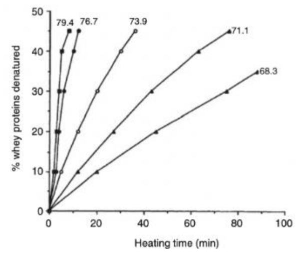

Figure 5 – A graph showcasing the % of denatured whey proteins depending on heating time and temperature of bovine skim milk.

Note. Fox, P. F., T Uniacke-Lowe, Mcsweeney, P. L. H., & O'mahony, J. A. (2015a). Dairy Chemistry and Biochemistry (Second, pp. 345–376). Cham Springer International Publishing. https://link.springer.com/book/10.1007/978-3-319-14892-2

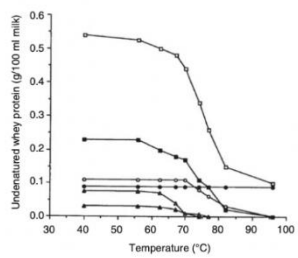

Figure 6 – Denaturation of different whey proteins with 30 minutes of heat treatment, with open squares – total whey proteins, filled square - β-lactoglobulin, open circle – a-lactalbumin, filled circle – proteose peptone, open triangle – immunoglobulins and filled triangle – serum albumin.

Note. Fox, P. F., T Uniacke-Lowe, Mcsweeney, P. L. H., & O'mahony, J. A. (2015a). Dairy Chemistry and Biochemistry (Second, pp. 345–376). Cham Springer International Publishing. https://link.springer.com/book/10.1007/978-3-319-14892-2

In bovine milk, 20% of the protein is whey protein which are sensitive to denaturation caused by heat as whey proteins consists of secondary and tertiary structures. A saturated solution of NaCl at pH 4.6 is used to determine the amount of denatured whey proteins by examining the loss in solubility (Fox et al., 2015, pp. 345–376). As seen in Figure 5, from Fox et al., 2016, pp. 122–390, around 20% of the whey proteins found in goat's milk would denature, as the pasteurization condition for Happy Goats Goodness is 5 minutes at 80°C. As shown in Figure 6, from Fox et al., 2015, pp. 345–376, a majority of the whey proteins start to denature once the temperature surpasses 70°C. Heat treatments that exceed 70°C led to irreversible denaturation of β-lactoglobulin (β-lg) and resulted in aggregation. Aggregation type I begins with intermolecular disulphide bonds and is followed by type II with hydrophobic and electrostatic bonding (non-specific interactions), and type III takes place with non-specific interactions and when there is a block on the sulphydryl groups (Fox et al., 2015, pp. 345–376). In addition to this, pH impacts the thermal stability, as when milk is heated for 5 minutes at 85°C, the heat stability decreased as the pH increased (Rafiee Tari et al., 2021; Zhang et al., 2021).

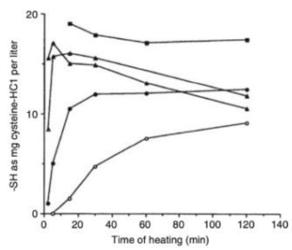

Figure 7 – Graph showing how heating at different temperatures impacts the exposure of sulphydryl groups, open circle – heating at 75°C, filled circle – heating at 80°C, open triangle – heating at 85°C, filled triangle – heating at 95°C and filled square – heating of de-aerated milk at 85°C

Note. Fox, P. F., T Uniacke-Lowe, Mcsweeney, P. L. H., & O'mahony, J. A. (2015a). Dairy Chemistry and Biochemistry (Second, pp. 345–376). Cham Springer International Publishing. https://link.springer.com/book/10.1007/978-3-319-14892-2

As seen in Figure 7, from Fox et al., 2015, pp. 345–376, the time-temperature combination used by Happy Goats Goodness will result in 1-SH as mg cysteine-HC1 per litre. Heating results in the exposure of sulphydydryl/disulphide residues due to the protein denaturation, which leads to many interactions in milk. When the temperature exceeds 75°C, the whey proteins can interact due to the sulphydryl-disulphide interchange resulting in the forming of β-lg with k-casein established by the disulphide links in the natural pH of milk. (Fox et al., 2015, pp. 345–376). Aggregation can occur between whey proteins, but also between casein micelles and whey protein and when the pH of milk is neutral, most of the aggregation of whey proteins occurs on the surface of the casein micelle (van Lieshout et al., 2019); (Vasbinder & de Kruif, 2003). B-lactoglobulin contains SH-group which can form disulfide bridges between whey proteins or whey proteins and casein micelles resulting in aggregation (van Lieshout et al., 2019); (Loveday et al., 2014).

According to Prof. Dr. Ir. Kasper Hettinga, the whey proteins that are denatured are easier to digest, however, it is not clear if the denaturation causes a change in allergenicity (K. A. Hettinga et al., personal communication, February 20, 2026). Overall digestibility is not impacted by the denaturation of proteins, however, denatured β-lactoglobulin can promote gastric hydrolysis. Furthermore, alterations in the protein structure could influence the digestion rate and digestive process. Changes in the structure of the protein can impact the accessibility of the proteolytic enzymes towards the amino acids, where unfolding results in amino acids being more available for the enzymes, however, aggregation could lead to a decrease of amino acids to proteolytic enzymes depending on the modification on the amino acid sequence (van Lieshout et al., 2019). β-lactoglobulin that is denatured when the milk that is heated above 75°C is unfolded which becomes more digestible by pepsin as there is more access to cleavage sites of proteins (van Lieshout et al., 2019); (Guo et al., 1995); (Kitabatake & Kinekawa, 1998); (Sánchez-Rivera et al., 2015); (Wang et al., 2018). A study done on rats resulted that β-lactoglobulin which was heated showed signs of damage compared to untreated β-lactoglobulin (van Lieshout et al., 2019); (Kitabatake & Kinekawa, 1998).

Pepsin cannot digest the dimers of β-lactoglobulin, as the undenatured conformation can be present in the dimer, hindering the accessibility when milk is heated at 90°C for 5 minutes. In addition to this, the digestion of bounded compounds by pepsin would take place slower, such as β-lactoglobulin monomers interacting with peptides through disulfide bonding forming intermediates compared to the free β-lactoglobulin (van Lieshout et al., 2019); (Loveday et al., 2014); (Peram et al., 2013).

Casein in bovine milk is found in casein micelles and includes different casein molecules; as1, as2, β and k-casein (van Lieshout et al., 2019); (Pellegrino et al., 2011). Caseins differ from whey proteins, as caseins are smaller in size (20-25 kDa), hydrophobic and do not have sulfhydryl groups, however, only k-casein and as2 contain a small amount of disulphide bonds. Caseins are not sensitive to denaturation caused by heat treatment, as caseins are phosphorylated, leading to aggregation and precipitation due to their ability to bind to calcium (Fox et al., 2015, pp. 345–376). Caseins are stable against denaturation of heat, as they do not have a secondary and tertiary structure, and there are no alterations in the solubility of caseins when milk is heated at 100°C at the neutral pH of milk (Pellegrino et al., 2016). The temperature that Happy Goat Goodness uses to pasteurise the goat milk is not intense enough to alter the casein structure.

Whey protein, especially β-lactoglobulin, is more susceptible to denaturation caused by the heat treatment compared to caseins because of the difference in structure. A temperature above 70°C results in alterations that are not reversible, which makes it easier for protein digestion by pepsin. Furthermore, aggregation starts occurring, however, there could still be problems with digestion by pepsin. Mild heat treatments are necessary for complete hydrolysis of β-lactoglobulin; however, intense heat treatments can hinder digestion due to whey aggregation.

Digestion of Ice Cream

Proteins in this ice cream come mainly from goat milk and egg yolk. Goat milk proteins are generally easier to digest than cow milk proteins due to their lower content of αs1-casein, which makes them form softer curds in the stomach. This allows digestive enzymes like pepsin to break down more efficiently (Rahmatalla et al., 2022).

The heat treatment of milk during pasteurization partially denatures whey proteins, which make up about 20% of goat milk protein. Denaturation unfolds the protein structure, exposing amino acid sites that make enzymatic digestion easier (Felipe et al., 1997).

Casein proteins, which form the bulk of milk protein, are digested more slowly. They create a soft curd in the stomach that is gradually broken down, allowing for a steady release of amino acids into the bloodstream. Egg yolk proteins, which remain largely unaffected by processing, also contribute to protein intake and are efficiently digested (Rahmatalla et al., 2022).

In conclusion, the digestibility and nutritional value of proteins can vary greatly depending on their source and how they are processed. Goat milk's lower αs1-casein content, unique protein structure, and higher levels of digestible components like taurine contribute to smoother digestion and better absorption. Additionally, heat treatment processes like pasteurization can alter the structure of whey proteins, enhancing digestibility but potentially affecting their allergenicity. While further research is needed to fully understand the benefits, goat milk-based products may offer a more comfortable and tolerable option for those who struggle with cow milk, promoting better gastrointestinal comfort and reduced discomfort.

Lipids

This section of the report examines the role of lipids in goat milk (and ice cream) compared to cow milk (and ice cream). Specifically, it explores the differences in fat composition, including the size of fat globules and the presence of medium- and short-chain fatty acids, as well as the impact of processing on lipid structure and digestion. By understanding these factors, we aim to assess how lipid composition influences fat absorption and overall digestive comfort.

Composition

Table 5 - *Comparative Composition of Different Types of Milk (g/100 mL milk)*

Component	*Cow*	*Jersey Cow*	*Goat*
Total protein	3.4	4.85	3.3
Casein (% of total protein)	83	82	83
Whey (% of total protein)	17	18	17
Lactose	4.5	4.285	4.25
Oligosaccharides	0.06	0.05-0.07	0.3
Total fat	3	4.91	3.5
Saturated fatty acids	62.8	59.27	66.9
Medium chain fatty acids	12.8	14.2	18.6
Mono-unsaturated fatty acids	2-25.2	36.975	19-36
Poly-unsaturated fatty acids	12	3.755	9.4
Short chain fatty acids	55-73	10.9	59-74
Calcium	87	140-160	121
Phosphorus	76	90-110	104

Note. Data adapted from Prosser (2021), Shkolnik et al. (1980), Mollica et al. (2021), Lim et al. (2020), and Lindmark Månsson (2008).

*Values for total protein, casein, whey, lactose, oligosaccharides, and total fat are expressed in g/100 mL, while fatty acid composition is reported as % of total fatty acids. Calcium and phosphorus concentrations are given in mg/100 mL.

The content of medium-chain fatty acids (MCFAs) is relatively higher in goat milk compared to cow milk (Jenness, 1980) (Liao et al., 2024), providing health benefits such as altering the gut microbiota, which in turn affects bodily functions and the immune system (Roopashree et al., 2021). At least 20% of the fatty acids in goat milk are short-chain fatty acids (SCFA), have a shorter molecular structure and higher water solubility (Barman et al., 2024) (MacDonald & Reitmeier, 2017). Goat milk contains high levels of butyric (C4:0), caproic (C6:0), caprylic (C8:0), capric (C10:0), lauric (C12:0), myristic (C14:0), palmitic (C16:0), and linoleic (C18:2) acids, making it more digestible (Mollica et al., 2021).

Additionally, as stated by Schönfeld and Wojtczak (2016), both SCFAs and MCFAs require less bile and enzymatic activity for absorption and are directly transported into the bloodstream via the hepatic portal system. Furthermore, these fatty acids are easily converted into energy and are less prone to fat storage (Jane, 2016). The variations of the melting point of the fat in goat milk, which is approximately 33.9-38.0°C for its solid fraction and 23.8-26.2°C for the liquid fraction (M.P. Bindal & Wadhwa, 1993), play a role in the digestibility of goat milk for people who are sensitive with dairy products.

Factors such as changes in composition, size, lipid interaction, and structure of fat globules/droplets significantly affect the digestion, absorption, as well as sensory properties of the ice cream. The individual globules of fat in goat milk range from 0.73 to 8.58 μm in diameter, making them smaller than those in cow milk, which range from 1-15 μm (Attaie & Richter, 2000).

Digestion

Fat composition and absorption are crucial factors in determining the digestibility of milk and its derivatives. Goat milk differs from cow milk in several fundamental ways that contribute to its superior digestibility, particularly in individuals with lactose intolerance or sensitivity to dairy fat. One of the primary distinctions lies in the size and structure of fat globules. Goat milk features smaller fat globules compared to cow milk (Attaie & Richter, 2000). The increased surface area exposed by the smaller fat globules promotes better digestibility, allowing lipase enzymes in the human stomach to break down and disintegrate fats more efficiently. Additionally, raw goat milk contains little to no agglutinin, a component found in raw cow milk that binds to sugars and proteins, causing fat globules to cluster. Without agglutinin, raw goat milk maintains a naturally homogenized structure, preventing the formation of large fat clusters that can be harder to digest (Gashaw Getaneh Dagnaw et al., 2016).

Another significant difference between goat and cow milk is the fatty acid composition. Goat milk is rich in medium-chain triglycerides (MCTs) and also contains a high proportion of short-chain fatty acids (SCFAs). These MCTs are more rapidly absorbed in the digestive system than the long-chain fatty acids found in cow milk, as they do not require pancreatic lipase or bile salts for digestion. Similarly, SCFAs are easily absorbed through passive diffusion due to their shorter molecular structure and higher water solubility, making them a quick and efficient energy source (Barman et al., 2024) (MacDonald & Reitmeier, 2017). Instead of undergoing extensive digestion, MCTs are directly absorbed into the portal vein and transported to the liver for rapid metabolism as an energy source. Similarly, SCFAs, which are primarily produced by colonic bacteria, are absorbed by colonocytes and partially metabolized locally, with the remainder entering the portal circulation and being transported to the liver for further metabolism (Schönfeld & Wojtczak, 2016).

The amino acid profile of goat milk further contributes to its digestibility. It is particularly rich in essential amino acids and contains higher levels of taurine, an amino acid that plays a critical role in bile salt formation (Yang et al., 2024). During digestion, taurine is released as proteins are broken down and may immediately aid in the synthesis of bile salts, promoting more efficient fat emulsification and absorption (Maldonado-Valderrama et al., 2011). This is especially beneficial given goat milk's high MCT and SCFA content, as enhanced bile salt availability further facilitates fat metabolism. Taurine is also involved in regulating osmotic balance and antioxidant activity, helping maintain gut integrity and reduce inflammation linked to digestive disorders (Duszka, 2022).

Processing

When milk is heated, lipids are the least affected compared to lactose and proteins, however, lipids physical properties are altered (Fox et al., 2015, pp. 345–376). According to Zhang et al., 2022, pasteurization caused less lipid hydrolysis and oxidation than ultra-hight temperature. In most animal species, around 97 – 98% of the lipids are triacylglycerols (triglycerides). In addition to this, phospholipids make up around 1% and are found in the milk fat globule membrane (MFGM). The membrane of the fat globule is not altered by high temperature, or short time (HTST) and does not have an impact on characteristics of the milk fat (Fox et al., 2015b, pp. 69–144). As mentioned by Fox et al., 2015, pp. 345–376, when milk is processed under normal conditions, fatty acids and some inter-esterification may be released, however, these changes are uncommon. According to Prof. Dr. Ir. Kasper Hettinga, the pasteurization process of Happy Goats Goodness does not alter the lipid composition (K. A. Hettinga et al., personal communication, February 20, 2026).

Heating can change the MFGM as the formation of foam could occur due to agitated milk. Liquid fat can alter the size of the globules during agitation, which can lead to coalescence and disruption. Skim milk proteins could replace membrane materials through adsorption due to the foaming. When the temperature of the heating exceeds 70°C, off flavours could be formed, (due to the release of H_2S), as some amino acid residues like cysteine could get exposed because of the denaturation of the proteins found in the membrane. Furthermore, a new layer for fat globules could be formed out of whey proteins that are denatured due to the reactions of disulphide interchange of whey proteins when the temperature exceeds 100°C (Fox et al., 2015, pp. 345–376).

Creaming of the fat globules is also impacted by the heating of milk. The globules have a diameter size range between 0.1 - 20 μm, with a mean of around 3-4 μm, and these fat globules form the cream layer by floating to the top because of the density differences between these globules and the aqueous phase. The fat globules in caprine (goat) milk experience slow creaming leading to a cream layer that is compact because the fat globules do not experience cryoglobulin (immunoglobulin) dependent agglutination. Heating milk at 70°C for 15 minutes results in the denaturation of cryoglobulins, inhibiting the creaming of milk (Fox et al., 2015, pp. 345–376).

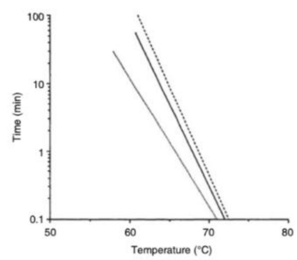

Figure 8 – Graph showcasing how the time-temperature combination alters different aspects, dotted line – inactivation of *M.tuberculosis*, solid line – inactivation of alkaline phosphate, dashed line – creaming ability of milk

Note. Fox, P. F., T Uniacke-Lowe, Mcsweeney, P. L. H., & O'mahony, J. A. (2015a). Dairy Chemistry and Biochemistry (Second, pp. 345–376). Cham Springer International Publishing. https://link.springer.com/book/10.1007/978-3-319-14892-2

As seen in Figure 8, from Fox et al., 2015, pp. 345–376, Happy Goats Goodness' time-temperature pasteurization inhibits the creaming of milk as the cryoglobulins are denatured. Freezing can damage the MFGM which can destabilize the complexes of lipoproteins, which is caused by physicochemical alterations due to dehydration, but also the formation of ice-crystals. During freezing, the degree of damage is determined by the fat content, as the more fat there is present, the more damage, and thus more destabilization. To decrease the damage, the milk should either be frozen quickly in thin shapes, or frozen in refrigerated drums continuously, pasteurized and homogenized before the milk is frozen or stored without any fluctuations in temperature and in temperatures of around -30°C (Fox et al., 2015b, pp. 69–144).

Due to the smaller size, goat milk fat globules do not aggregate easily as their larger surface area allows for better emulsification, leading to improved fat distribution, natural homogenization, faster and more uniform crystallization, and enhanced fat-protein interactions. These properties ensure an even fat dispersion in the ice cream, preventing fat coalescence and fat-cream separation. In turn, the characteristic of the fat globules and composition, along with its crystallization behaviour, contribute to a more stable ice cream structure, where it maintains creaminess and smooth texture during storage and consumption, making it easily consumable straight out the fridge as it is smoother in texture (Amigo & Fontecha, 2011).

The lipid content does not change due to the pasteurization process of Happy Goats Goodness, however, the physical properties are altered. Changes in the size of the milk fat globule membrane can result in agitation, and coalescence. In addition to this, the creaming of goat milk is also influenced, as heating results in the denaturation of cryoglobulin, which slows down creaming of the fat globules.

Digestion of Ice Cream

Fats in this ice cream come from goat milk and coconut oil. Goat milk fat is highly digestible due to its smaller fat globules and higher content of short- and medium-chain fatty acids, which require minimal digestion before being absorbed into the bloodstream. Coconut oil, rich in medium-chain triglycerides (MCTs), is even easier to digest, as MCTs bypass traditional fat digestion pathways and go directly to the liver for energy production (Noura S. M. Al-Nassir & Sakr, 2024).

Fat digestion interacts with protein digestion in complex ways. The small fat globules in goat milk provide a larger surface area for lipase enzymes to act upon, facilitating fat breakdown and emulsification (Chai et al., 2022). However, this process can have both positive and negative effects on protein digestion. While improved emulsification can create a more efficient digestive environment overall, fat can also stick to proteins, potentially hindering enzymes from reaching the proteins effectively. This interaction between fat and protein has been observed in goat milk, but it's important to note that this specific effect has not been tested in ice cream (Chilliard et al., 2003).

Processing plays a role in fat digestibility through homogenization and emulsification. The blending of milk fats with egg yolk phospholipids helps create a stable emulsion, which makes fat more accessible to pancreatic lipase, the enzyme that breaks it down into fatty acids and glycerol. This improved dispersion enhances fat absorption in the small intestine (Pan et al., 2025).

In conclusion, the lipid composition of goat milk and ice cream, including its smaller fat globules and higher levels of medium- and short-chain fatty acids, significantly improves its digestibility compared to cow milk. These fats are more easily absorbed into the bloodstream and require less digestive effort. The processing techniques, such as pasteurization and homogenization, further enhance lipid emulsification, contributing to better fat absorption. Additionally, the presence of coconut oil in ice cream, rich in medium-chain triglycerides, provides an even more easily digestible fat source. However, further research is needed to definitively prove these benefits and understand the long-term effects of consuming goat milk-based ice cream for individuals with digestive sensitivities.

Lactose

This section of the report evaluates the lactose in goat milk and its derivatives, such as ice cream, by analyzing factors like lactose composition, digestion, and the effects of processing. It examines how these elements influence the digestion process and how they may impact individuals with lactose intolerance, offering insights into the potential benefits of goat milk as an alternative to cow milk.

Composition

The lactose content in cow and goat milk differs only slightly, 4.5 grams vs 4.25 grams, as demonstrated in Table 5 from the Lipids composition section, making the difference negligible. This slightly lower lactose level may not be sufficient for all individuals with lactose intolerance to safely consume these products without experiencing adverse effects. Individual variations in lactose digestion capability and lactase enzyme activity play a crucial role in determining the safety and tolerance of different dairy products that can be safely consumed.

Digestion

The structure of lactose in goat's milk differs in how it interacts with other milk components, which can influence its digestibility. Goat's milk has smaller fat globules compared to cow's milk, allowing for more even dispersion of lactose. This enhances the interaction between lactose and digestive enzymes like lactase, making it more accessible for breakdown into glucose and galactose (Metzger, 2022). As a result, lactose in goat's milk is processed more efficiently in the digestive system, potentially reducing symptoms associated with lactose intolerance.

Goat's milk also contains a higher proportion of medium-chain triglycerides (MCTs), which contribute to faster gastric emptying (Roopashree et al., 2021). This means that lactose spends more time in the stomach and is slower administered to the intestine, resulting in more time and a larger surface area for the lactase to break down the lactose (Ugidos-Rodríguez et al., 2018). Fermentation of lactose by gut bacteria occurs primarily in the colon when there is insufficient lactase activity, leading to the production of gases and short-chain fatty acids, which can cause bloating and discomfort. While goat's milk facilitates quicker gastric emptying, its impact on lactose fermentation in the colon depends on individual lactase levels and overall digestion efficiency (Better Health Channel, 2022).

Another aspect influencing lactose digestibility is the absence of A1 β-casein in goat's milk. Cow's milk containing A1 β-casein releases BCM-7, which has been associated with gastrointestinal inflammation and slowed transit time. This can exacerbate lactose intolerance symptoms by making the gut environment less efficient at handling lactose digestion. Since goat's milk predominantly contains this alternative form of β-casein, avoids this issue, potentially providing a smoother digestion experience for sensitive individuals (Pal et al., 2015).

Processing

As stated by Fox et al., 2015, pp. 345–376, depending on the pH and heating conditions, lactose could be broken down into monosaccharides and acids, especially if the milk is strongly acidic, however, these alterations rarely occur during the heat treatment of milk. Furthermore, in slightly basic conditions and moderate temperatures, lactose is also unstable, where further reactions can occur, such as Lobry de Bruyn-Alberda van Ekenstein. Lactulose is a product that can be formed when milk is heated in conditions where the pH is mildly basic and heated at low temperatures. Lactulose is formed when the glucose present in the lactose molecule is converted into fructose through epimerization. When milk is treated according to the HTST conditions, lactulose is not produced. In addition, acid formation due to lactose degradation begins once the milk is heated and the temperature exceeds 100°C (Fox et al., 2015, pp. 345–376). For example, in the study conducted by Kosikowski & Wierzbicki, 1973, the percentage of hydrolysed lactose remained the same between raw milk and pasteurized milk at 73°C for 18 seconds and then cooled to 4°C. Maillard reaction could also take place when the treatment of milk occurs in intense conditions, and in milk in the form of powder when stored in high humidity and high temperatures (Fox et al., 2015, pp. 122–390).

According to Prof. Dr. Ir. Kasper Hettinga, who is a professor in dairy processing at the WUR, lactose is known to be chemically stable, and the pasteurization time-temperature combination used by Happy Goats Goodness (80°C for 5 minutes) will not impact the lactose content, as lactose isomerization and Maillard reaction occurs at more intense heat treatments (110°C for 30 minutes). Furthermore, the Maillard reaction could occur in powdered milk when the conditions are similar to room temperatures, however, for liquid milk this is not the case. Due to the chemical stability of lactose, the storage conditions would also result in a similar lactose content as raw milk (K. A. Hettinga et al., personal communication, February 20, 2026).

The pasteurization process for Happy Goats Goodness uses liquid fresh goats' milk, and a time-temperature combination that is not intense, and therefore Maillard reaction does not take place. Overall, due to the absence of the Maillard reaction and lactose isomerization, lactose content in the final product will remain similar to that of raw goat's milk, with a lactose content of 4.33% (Ahmed, 2016). The final product (120g/ 200ml) contains around 65% goat milk and therefore has around 3.38 grams of lactose per serving.

Digestion of Ice Cream

Lactose remains chemically stable under normal food processing conditions, meaning its structure remains unchanged during pasteurization. Because of this stability, the lactose content in the final product remains similar to that of fresh goat's milk, ensuring consistent digestibility for those who can tolerate small amounts of lactose (Center for Food Safety and Applied Nutrition, 2011).

In conclusion, while the lactose content in goat milk is slightly lower than in cow milk, this difference may not be sufficient to provide relief for all individuals with lactose intolerance. However, factors like smaller fat globules and more efficient digestion processes in goat milk may enhance lactose breakdown and improve tolerance for some individuals. The pasteurization process preserves lactose stability, ensuring consistent digestibility in the final product. Therefore, goat milk-based ice cream could be a more digestible option for those with mild lactose intolerance. Further research is needed to better understand the full extent of goat milk's benefits for those with lactose intolerance.

Other Compounds

Moreover, goat milk proteins contain bioactive components that offer numerous benefits for human nutrition, such as higher levels of oligosaccharides compared to cow milk. These oligosaccharides have prebiotic properties that promote the growth of beneficial gut bacteria, which may help support lactose digestion by enhancing gut microbiota, particularly in individuals with lower lactase activity. This prebiotic effect can improve overall gut function, reducing common symptoms of lactose intolerance, such as bloating and diarrhoea (Prosser, 2021; van Leeuwen et al., 2020).

Additionally, goat milk has higher alkalinity than cow's milk (Robinson, 2001), and certain goat breeds exhibit reduced or absent expression of αS1-casein while having higher levels of β-casein and αS2-casein. This composition influences the milk's allergenicity and digestibility, making it potentially more suitable for individuals with sensitivities (Rahmatalla et al., 2022). Furthermore, goat milk is an excellent source of calcium and phosphorus, which are essential for muscle function, cell signaling, and overall bone health.

Conclusions & Recommendations

Based on the detailed research and analysis done in this report, the main conclusion is that consuming one serving of Happy Goat Goodness containing approximately 3.38 grams of lactose should be symptom-free for lactose-intolerant people since the minimum dose of lactose that can be consumed by them is approximately 12 grams of lactose. The results that were obtained in this report may not be fully accurate since the literature on cow's milk was used in most cases due to limited resources on goat's milk. Further research has to be done to effectively analyze the potential of goat's milk ice cream for lactose intolerant individuals.

Lactose intolerance occurs due to the absence or reduced levels of the enzyme lactase which then leads to gastrointestinal symptoms upon consumption of food containing lactose. The amount of lactose that can be consumed before experiencing adverse symptoms depends on the individual. Goat milk (~4.25 g/100ml) has a slightly lower lactose content in comparison to cow milk (~4.5 g/100ml). This difference in the lactose content is negligible. However, since one serving of Happy Goat Goodness ice cream contains less than 12 grams of lactose, individuals with lactose intolerance should be able to consume it.

A cow's milk allergy arises due to an allergic reaction to a specific protein present in the cow's milk. In this case, the amount of lactose present in the milk does not make a difference in the level of symptoms experienced. Since approximately 90% of individuals with cow's milk allergy are also allergic to goat's milk because of the high cross-reactivity between proteins present in cow's milk and goat's milk, goat's milk cannot be used as an alternative for most individuals with cow's milk allergy. However, there is only a small percentage of the adult population that has cow's milk allergy since most people outgrow it by the age of six.

Goat milk is richer in nutrients such as calcium, phosphorus and certain proteins like β-casein and αS2-casein. When comparing the nutritional composition of goat and cow milk (and their respective ice cream products) to evaluate potential health benefits, several factors influence milk composition, including breed, genetics, diet, lactation stage, and environmental conditions. Nutritionally, goat milk is recognized to be more easily digestible due to the smaller fat dimers, higher β-casein content, and absence of agglutinins. Furthermore, the distinct and diverse fatty acid profiles also enhance gut microbiota and energy metabolism. Additionally, goat milk also contains a higher number of bioactive compounds, such as oligosaccharides, which contribute to a softer curd structure and faster enzymatic degradation in the stomach.

The digestibility of milk, whether from goats or cows, is influenced by a variety of factors, including fat composition, protein structure, and lactose metabolism. Some studies suggest that goat milk, with its smaller fat globules, unique protein profiles, and higher concentration of medium-chain triglycerides, may be more easily digested and better tolerated by individuals with sensitivities or digestive issues. These potential benefits may extend to products like ice cream, where the digestibility of goat milk is maintained through processes like emulsification and homogenization. However, further studies are needed to confirm these effects.

Unlike A1 β-casein in cow milk, which can release peptides linked to digestive discomfort, goat β-casein amino acid sequence is different from cow milk, specifically in the 78^{th} amino acid position, and therefore lacks the capability of producing β-casomorphin-7 (BCM-7), reducing its allergenic potential. While the difference between lactose content in both milk types is negligible, tolerances towards the kinds of milk vary between individuals.

From lactose, lipids and proteins, the production process impacts the proteins the most. The time-temperature combination used by Happy Goats Goodness for pasteurization (80°C for 5 minutes), is not an intense heat treatment to result in the Maillard reaction or isomerization of lactose, and therefore the lactose content remains similar between raw and pasteurized goat milk. Furthermore, the lipid content remains similar, however, the physical properties are altered leading to changes in the structure of the MFGM, which results in coalescence. Proteins are influenced the most, especially denaturation of whey proteins compared to caseins due to the difference in structure and thus leads to aggregation. The temperature used during pasteurization leads to irreversible denaturation of β-lactoglobulin which results in better digestibility by pepsin.

By focusing on the increased digestibility and health benefits of the ice cream, Happy Goats Goodness can effectively market their goat's milk ice cream as a healthier alternative for individuals who cannot consume cow's milk. One way to improve the recipe to make it more suitable for lactose intolerant people would be to add lactase to the ice cream. This lactase would break down the lactose, making it easier for lactose-intolerant individuals to consume it. Fortification of the ice cream with nutrients to increase its health benefits could be another way to increase the demand for the ice cream. Revising the claim on the package about using 100% A2 goat milk would help build trust. Spreading awareness about lactose intolerance and goat's milk could help educate customers which would encourage them to try Happy Goats Goodness' goat milk ice cream.

Valorisation Chapter

Entrepreneurial Strategy:

Happy Goats Goodness was created in 2023 by Victor Boone and Lars Hoffmann. It is a company that focuses on providing consumers who are sensitive to cow's milk with ice cream made from 100% Dutch goat's milk and real fruit (*Home-Eng - Goats Goodness*, 2024). The ice cream made by the company is sustainable as well as organic. The company is mainly located in Stellendam in the Netherlands. As of now, there are only two official employees working in the company and about 5-10 people working in the ice cream factory, so it is a small-scale company. The profit margin of the company is about 30-50% depending on where the product is sold.

The founders of the company were inspired by their graduation internship and one of the founders' experiences with goat farming to come up with the idea of making ice cream from goat milk. This is an example of an effectual thinking strategy in which the founders started with goat milk from a goat farm that they were familiar with and imagined a new product, which is the goat's milk ice cream. This also shows how the company used the 'bird in hand' principle by focusing on the means they had (the goat milk from the goat farm) to create a product (the goat's milk ice cream) which is innovative and sustainable.

The outcome of the Case:

The case is looking into whether goat's milk ice cream is an alternative for those individuals who have lactose intolerance or cow's milk allergy and comparing the production of cow's milk to goat's milk to determine if the latter is better than the former in terms of health benefits. The solution that the group is proposing is based on doing literature research to determine if goat's milk ice cream is a solution to make ice cream more accessible for individuals with health problems. The outcome is tailored to the company as they have "low on lactose" mentioned on the front of their ice cream package due to goat's milk having a slightly lower lactose content than cow's milk (Ahmed, 2016). Happy Goats Goodness wants to determine if people with cow's milk allergy and lactose intolerance can consume goat's milk-based ice cream without having any health symptoms. Through the research that will be done, findings will be presented to the company, which will provide evidence for the potential health benefits of goat's milk ice cream and if it's suitable for consumers with cow's milk allergy and lactose intolerance.

Reflection of Communication:

Meetings with supervisors are done in person ranging from once to twice a week depending on the progress of the group. On the other hand, meetings were arranged either in person or on Teams, depending on the availability of the commissioners. The supervisors were supportive, especially in recommending experts in different topics about milk to conduct interviews, as well as helping to book rooms, and they responded to emails in a timely manner. The commissioners were also helpful, especially when asking questions and were willing to share confidential information about their production process and ingredients for their goat milk ice cream. As a group, an agenda was prepared before the meeting, along with slides to show the supervisors and commissioners. The meetings were led by the chair, however, every group member contributed by explaining what they found or struggled with regarding the objective they did research on. During each meeting, questions were asked from all stakeholders, which ensured that everyone was on track.

During the first meeting, the meeting was not as smooth due to not knowing the expectations of the supervisors and the company, Happy Goats Goodness, but as the project progressed, everyone knew what was expected from the group. The first expert interview that was conducted with Swantje Breunig helped the group to notice that there were some misunderstandings about the different proteins found in goat milk, such as all the different sub-categories of caseins, and cow and goat milk proteins are not comparable. After the first interview, some aspects of the report had to be changed/edited and there was a need for further literature research.

Impact Of The Final Idea:

As Happy Goat Goodness is currently the only company producing and developing high-quality, premium goat milk-based ice cream in the Dutch market, its potential impact on the dairy sector is significant for the future. Given that approximately 65% of the human population has lactose intolerance (2), or a reduced ability to digest lactose, a sugar which is found in milk, after ingestion due to the decreased lactase enzyme activity, it is important to explore and create products which can be enjoyed by everyone.

By providing scientifically backed-up evidence and insights on whether Happy Goat Goodness products are a viable substitute for cow milk products, the target market can be expanded, allowing more people, especially those who are lactose intolerant or allergic to cow milk proteins, to enjoy nutritious, high-quality dairy-based ice cream. With Happy Goat Goodness, everyone will be able to enjoy ice cream products with various flavours from the fresh sauces, offering the same sensory properties and the indulgent taste as cow milk ice cream, but with the added benefits of improved digestibility and enhanced nutritional properties due to the unique composition of goat milk. The versatility that it possesses makes it appealing to diverse market opportunities and a wide range of consumers.

Happy Goat Goodness focuses on organic production, enhancing its premium quality while also catering to environmentally conscious consumers who prioritize eco-friendly food production. The ice creams are crafted using organic goat milk sourced from a family farm, ensuring the highest quality ingredients and sustainable farming methods (*Home-Eng - Goats Goodness*, 2024), minimizing the negative ecological footprint on a global scale. Additionally, as smaller ruminants, goats emit less methane compared to other livestock. By utilizing organic farming for goat milk production, Happy Goat Goodness supports environmental sustainability and helps reduce carbon emissions in the dairy sector, contributing to a greener future (Kerven, 2024).

The company can use the information given by the group to advertise the uniqueness of the product in marketing campaigns. The health benefits, better digestibility, premium quality, sustainability and organic accomplishments that are applied within the production line can be emphasized to position Happy Goat Goodness Ice Cream as a different product compared to other competitors in the market, retail, food service channels, and to health-conscious consumers.

References

References

Ahmed, I. (2016). Comparative Study of Cottage Cheese Prepared from Various Sources of Milk. *Proceedings of the Pakistan Academy of Sciences*, *53*(4), 269–282. https://www.researchgate.net/publication/312583378_Comparative_Study_of_Cottage_Cheese_Prepared_from_Various_Sources_of_Milk

Al-Beltagi, M., Saeed, N. K., Bediwy, A. S., & Elbeltagi, R. (2022). Cow's milk-induced gastrointestinal disorders: From infancy to adulthood. *World Journal of Clinical Pediatrics*, *11*(6), 437–454. https://doi.org/10.5409/wjcp.v11.i6.437

Alférez, M. J. M., Barrionuevo, M., Aliaga, I. L., Sanz-Sampelayo, M. R., Lisbona, F., Robles, J. C., & Campos, M. S. (2001). Digestive utilization of goat and cow milk fat in malabsorption syndrome. *Journal of Dairy Research*, *68*(3), 451–461. https://doi.org/10.1017/S0022029901004903

Almaas, H., Cases, A.-L., Devold, T. G., Holm, H., Langsrud, T., Aabakken, L., Aadnoey, T., & Vegarud, G. E. (2006). In vitro digestion of bovine and caprine milk by human gastric and duodenal enzymes. *International Dairy Journal*, *16*(9), 961–968. https://doi.org/10.1016/j.idairyj.2005.10.029

Amigo, L., & Fontecha, J. (2011). Milk | Goat Milk. *Elsevier EBooks*, 484–493. https://doi.org/10.1016/b978-0-12-374407-4.00313-7

Armand, M., Pasquier, B., André, M., Borel, P., Senft, M., Peyrot, J., Salducci, J., Portugal, H., Jaussan, V., & Lairon, D. (1999). Digestion and absorption of 2 fat emulsions with different droplet sizes in the human digestive tract. *The American Journal of Clinical Nutrition*, *70*(6), 1096–1106. https://doi.org/10.1093/ajcn/70.6.1096

Attaie, R., & Richter, R. L. (2000). Size Distribution of Fat Globules in Goat Milk. *Journal of Dairy Science*, *83*(5), 940–944. https://doi.org/10.3168/jds.s0022-0302(00)74957-5

Barłowska, J., Szwajkowska, M., Litwińczuk, Z., & Król, J. (2011). Nutritional Value and Technological Suitability of Milk from Various Animal Species Used for Dairy Production. *Comprehensive Reviews in Food Science and Food Safety*, *10*(6), 291–302. https://doi.org/10.1111/j.1541-4337.2011.00163.x

Barman, M., Gio-Batta, M., Andrieux, L., Stråvik, M., Saalman, R., Fristedt, R., Rabe, H., Sandin, A., Wold, A. E., & Sandberg, A.-S. (2024). Short-chain fatty acids (SCFA) in infants' plasma and corresponding mother's milk and plasma in relation to subsequent sensitisation and atopic disease. *EBioMedicine*, *101*, 104999. https://doi.org/10.1016/j.ebiom.2024.104999

Bellioni-Businco, B., Paganelli, R., Lucenti, P., Giampietro, P. G., Perborn, H., & Businco, L. (1999). Allergenicity of goat's milk in children with cow's milk allergy. *Journal of Allergy and Clinical Immunology*, *103*(6), 1191–1194. https://doi.org/10.1016/s0091-6749(99)70198-3

Benjamin-van Aalst, O., Dupont, C., van der Zee, L., Garssen, J., & Knipping, K. (2024). Goat Milk Allergy and a Potential Role for Goat Milk in Cow's Milk Allergy. *Nutrients*, *16*(15), 2402–2402. https://doi.org/10.3390/nu16152402

Better Health Channel. (2022, May 17). *Lactose intolerance*. Better Health Channel. https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/lactose-intolerance

Bevilacqua, C., Ferranti, P., Garro, G., Veltri, C., Lagonigro, R., Leroux, C., Pietrolà, E., Addeo, F., Pilla, F., Chianese, L., & Martin, P. (2002). Interallelic recombination is probably responsible for the occurrence of a new αs1 -casein variant found in the goat species. *European Journal of Biochemistry*, *269*(4), 1293–1303. https://doi.org/10.1046/j.1432-1033.2002.02777.x

BEVILACQUA, C., MARTIN, P., CANDALH, C., FAUQUANT, J., PIOT, M., ROUCAYROL, A.-M., PILLA, F., & HEYMAN, M. (2001). Goats' milk of defective α_{s1}-casein genotype decreases intestinal and systemic sensitization to β-lactoglobulin in guinea pigs. *Journal of Dairy Research*, *68*(2), 217–227. https://doi.org/10.1017/s0022029901004861

Bhattacharya, A. N. (1980). Research on Goat Nutrition and Management in Mediterranean Middle East and Adjacent Arab Countries. *Journal of Dairy Science*, *63*(10), 1681–1700. https://doi.org/10.3168/jds.s0022-0302(80)83130-4

Böhn, L., Störsrud, S., Törnblom, H., Bengtsson, U., & Simrén, M. (2013). Self-Reported Food-Related Gastrointestinal Symptoms in IBS Are Common and Associated With More Severe Symptoms and Reduced Quality of Life. *The American Journal of Gastroenterology*, *108*(5), 634–641. https://doi.org/10.1038/ajg.2013.105

Boman, H. G. (1991). Antibacterial peptides: Key components needed in immunity. *Cell*, *65*(2), 205–207. https://doi.org/10.1016/0092-8674(91)90154-q

Boone, V. (2025, February 15). *Happy Goats Goodness Questions* [Email to Aleksia Toprakchyolgu, Nabila Agatha, Willemijn Bleichrodt, Marije Oostenveld, Eline Verhoef, & Lakshmipriya Bhaskaran].

Boone, V. (2025, February 24). *Happy Goat Goodness Follow Up Questions* [Email to Alexia Toprakchyoglu].

Breunig, S., Crooijmans, R. P. M. A., Bovenhuis, H., Hettinga, K., & Bijl, E. (2024). Linking variation in the casein fraction and salt composition to casein micelle size in milk of Dutch dairy goats. *Journal of Dairy Science*, *107*(9), 6474–6486. https://doi.org/10.3168/jds.2023-24548

BRIGNON, G., MAHE, M., RIBADEAU-DUMAS, B., MERCIER, J., & François GROSCLAUDE. (1990). Two of the three genetic variants of goat α_{s1}-casein which are synthesized at a reduced level have an internal deletion possibly due to altered RNA splicing. *European Journal of Biochemistry*, *193*(1), 237–241. https://doi.org/10.1111/j.1432-1033.1990.tb19328.x

Brooke-Taylor, S., Dwyer, K., Woodford, K., & Kost, N. (2017). Systematic Review of the Gastrointestinal Effects of A1 Compared with A2 β-Casein. *Advances in Nutrition: An International Review Journal*, *8*(5), 739–748. https://doi.org/10.3945/an.116.013953

Caballero, B., Trugo, L., & Finglas, P. (2003). Encyclopedia of food sciences and nutrition: Volumes 1-10. *Encyclopedia of Food Sciences and Nutrition: Volumes 1-10.*, *1-10*, 6601. https://www.cabidigitallibrary.org/doi/full/10.5555/20033096645

Catota-Gómez, L. D., Manuel, P.-B. G., Cienfuegos-Rivas, E. G., Hernández-Meléndez, J., Sifuentes-Rincón, A. M., Martínez-González, J. C., Catota-Gómez, L. D., Manuel, P.-B. G., Cienfuegos-Rivas, E. G., Hernández-Meléndez, J., Sifuentes-Rincón, A. M., & Martínez-González, J. C. (2017). Frequency and association of polymorphisms in CSN3 gene with milk yield and composition in Saanen goats. *Ecosistemas Y Recursos Agropecuarios*, *4*(12), 411–417. https://doi.org/10.19136/era.a4n12.1165

Center for Food Safety and Applied Nutrition. (2011, November 1). *Raw Milk Misconceptions and the Danger of Raw Milk Consumption*. U.S. Food and Drug Administration. https://www.fda.gov/food/buy-store-serve-safe-food/raw-milk-misconceptions-and-danger-raw-milk-consumption

Chai, C., Oh, S., & Imm, J.-Y. (2022). Roles of Milk Fat Globule Membrane on Fat Digestion and Infant Nutrition. *Food Science of Animal Resources*, *42*(3), 351–371. https://doi.org/10.5851/kosfa.2022.e11

Chen, X., Wei, L., Mao, Y., Zhao, A., Pu, M., Liu, Y., & Wang, B. (2025). A Comparative Study of Ultrasound and Thermal Processing: Effects on Stability and Protein Structure in Goat Milk. *Journal of Dairy Science*. https://doi.org/10.3168/jds.2024-25918

Cieślińska, A., Fiedorowicz, E., Rozmus, D., Sienkiewicz-Szłapka, E., Jarmołowska, B., & Kamiński, S. (2022). Does a Little Difference Make a Big Difference? Bovine β-Casein A1 and A2 Variants and Human Health-An Update. *International Journal of Molecular Sciences*, *23*(24), 15637. https://doi.org/10.3390/ijms232415637

Clark, S., & Mora García, M. B. (2017). A 100-Year Review: Advances in goat milk research. *Journal of Dairy Science*, *100*(12), 10026–10044. https://doi.org/10.3168/jds.2017-13287

Corgneau, M., Scher, J., Ritie-Pertusa, L., Le, D. t. l., Petit, J., Nikolova, Y., Banon, S., & Gaiani, C. (2017). Recent advances on lactose intolerance: Tolerance thresholds and currently available answers. *Critical Reviews in Food Science and Nutrition*, *57*(15), 3344–3356. https://doi.org/10.1080/10408398.2015.1123671

Cow Milk vs Goat Milk: which is healthier? (2021, July 8). Nourish with Kristin. https://www.nourishwithkristin.com/blog/cowvsgoatmilk

Cox, A. L., Eigenmann, P. A., & Sicherer, S. H. (2021). Clinical Relevance of Cross-Reactivity in Food Allergy. *The Journal of Allergy and Clinical Immunology: In Practice*, *9*(1), 82–99. https://doi.org/10.1016/j.jaip.2020.09.030

Cui, Q., Lin, L., Lai, Z., & Mao, S. (2023). Effects of high-grain diet feeding on fatty acid profiles in milk, blood, muscle, and adipose tissue, and transcriptional expression of lipid-related genes in muscle and adipose tissue of dairy cows. *Journal of Animal Science and Biotechnology*, *14*(1). https://doi.org/10.1186/s40104-023-00847-y

Davoodi, S. H., Shahbazi, R., Esmaeili, S., Sohrabvandi, S., AmirMohamamd Mortazavian, Jazayeri, S., & Aghdas Taslimi. (2016). Health-Related Aspects of Milk Proteins. *Iranian Journal of Pharmaceutical Research : IJPR*, *15*(3), 573. https://pmc.ncbi.nlm.nih.gov/articles/PMC5149046/

Defilippi, C., Gomez, E., Charlin, V., & Silva, C. (1995). Inhibition of small intestinal motility by casein: a role of beta casomorphins? *Nutrition (Burbank, Los Angeles County, Calif.)*, *11*(6), 751–754. https://pubmed.ncbi.nlm.nih.gov/8719134/

Delger, M. (2021). *Effect of Seasonality and Processing on Physicochemical Characteristics of Goat and Sheep Milk*. http://hdl.handle.net/10179/16989

Di Costanzo, M., & Berni Canani, R. (2018). Lactose Intolerance: Common Misunderstandings. *Annals of Nutrition and Metabolism*, *73*(4), 30–37. https://doi.org/10.1159/000493669

Dupont, D., & Tomé, D. (2020). Milk proteins: Digestion and absorption in the gastrointestinal tract. *Milk Proteins*, 701–714. https://doi.org/10.1016/b978-0-12-815251-5.00020-7

Duszka, K. (2022). Versatile Triad Alliance: Bile Acid, Taurine and Microbiota. *Cells*, *11*(15), 2337. https://doi.org/10.3390/cells11152337

Dutch Ministery of economic affairs . (2016). *Advies van BuRO over allergenen in voedingsmiddelen*. Nvwa.nl. https://www.nvwa.nl/documenten/consument/eten-drinken-roken/allergenen/risicobeoordelingen/advies-van-buro-over-allergenen-in-voedingsmiddelen

Edwards, C. W., & Younus, M. A. (2020). *Cow Milk Allergy*. PubMed; StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK542243/

European Food Safety Authority. (24 C.E., September). *Lactose thresholds in lactose intolerance and galactosaemia | EFSA*. Www.efsa.europa.eu. https://www.efsa.europa.eu/en/efsajournal/pub/1777

F Grosclaude, Marie-Françoise Mahé, Brignon, G., Liliana Di Stasio, & R Jeunet. (1987). A Mendelian polymorphism underlying quantitative variations of goat αs1-casein. *Genetics Selection Evolution*, *19*(4), 399–399. https://doi.org/10.1186/1297-9686-19-4-399

Farrell, H. M., Jimenez-Flores, R., Bleck, G. T., Brown, E. M., Butler, J. E., Creamer, L. K., Hicks, C. L., Hollar, C. M., Ng-Kwai-Hang, K. F., & Swaisgood, H. E. (2004). Nomenclature of the Proteins of Cows' Milk—Sixth Revision. *Journal of Dairy Science*, *87*(6), 1641–1674. https://doi.org/10.3168/jds.s0022-0302(04)73319-6

Felipe, X., Capellas, M., & Law, A. J. R. (1997). Comparison of the Effects of High-Pressure Treatments and Heat Pasteurization on the Whey Proteins in Goat's Milk. *Journal of Agricultural and Food Chemistry*, *45*(3), 627–631. https://doi.org/10.1021/jf960406o

Fox, P. F., T Uniacke-Lowe, Mcsweeney, P. L. H., & O'mahony, J. A. (2015a). *Dairy Chemistry and Biochemistry* (Second, pp. 345–376). Cham Springer International Publishing. https://link.springer.com/book/10.1007/978-3-319-14892-2

Fox, P. F., T Uniacke-Lowe, Mcsweeney, P. L. H., & O'mahony, J. A. (2015b). *Dairy Chemistry and Biochemistry* (Second, pp. 69–144). Cham Springer International Publishing. https://link.springer.com/book/10.1007/978-3-319-14892-2

Francis, O. L., Wang, K. Y., Kim, E. H., & Moran, T. P. (2020). Common food allergens and cross-reactivity. *Journal of Food Allergy*, *2*(1), 17–21. https://doi.org/10.2500/jfa.2020.2.200020

François Grosclaude, Marie-Françoise Mahé, & Ribadeau-Dumas, B. (1973). Structure primaire de la caséine α_{s1} et de la caséine β bovines. *European Journal of Biochemistry*, *40*(1), 323–324. https://doi.org/10.1111/j.1432-1033.1973.tb03199.x

Gashaw Getaneh Dagnaw, Mebrat A, Wubie A, & Kendie H. (2016, November). *Review on Goat Milk Composition and its Nutritive Value*. ResearchGate; unknown. https://www.researchgate.net/publication/312429484_Review_on_Goat_Milk_Composition_and_its_Nutritive_Value

Gasteiger, E., Hoogland, C., Gattiker, A., Duvaud, S., Wilkins, M. R., Appel, R. D., & Bairoch, A. (2005). Protein Identification and Analysis Tools on the ExPASy Server. *The Proteomics Protocols Handbook*, 571–607. https://doi.org/10.1385/1-59259-890-0:571

Gaynor, P. (2016, March 16). *Nonfat Dry Goats' Milk and Goat Whey Protein Concentrate in Infant Formula*. https://www.fda.gov/files/food/published/GRAS-Notice-000644--Non-fat-dry-goat-milk-and-goat-whey-protein.pdf

Giannetti, A., Toschi Vespasiani, G., Ricci, G., Miniaci, A., di Palmo, E., & Pession, A. (2021). Cow's Milk Protein Allergy as a Model of Food Allergies. *Nutrients*, *13*(5). https://doi.org/10.3390/nu13051525

Giovanna, V., Carla, C., Alfina, C., Domenico, P., & Elena, L. (2012). The immunopathogenesis of cow's milk protein allergy (CMPA). *Italian Journal of Pediatrics*, *38*(1), 35. https://doi.org/10.1186/1824-7288-38-35

Giribaldi, M., Lamberti, C., Cirrincione, S., Giuffrida, M. G., & Cavallarin, L. (2022). A2 Milk and BCM-7 Peptide as Emerging Parameters of Milk Quality. *Frontiers in Nutrition*, *9*. https://doi.org/10.3389/fnut.2022.842375

Goat Milk vs Cow Milk | Summerhill Goat Dairy. (2021, May 4). Summerhilldairy.com. https://summerhilldairy.com/blog/goat-milk-vs-cow-milk/

Goh, S. H., Chong, K. W., Loh, W., & Goh, A. E. N. (2019). Goat's milk anaphylaxis in a cow's milk tolerant child. *Asia Pacific Allergy*, *9*(4). https://doi.org/10.5415/apallergy.2019.9.e34

Guo, M. R., Fox, P. F., Flynn, A., & Kindstedt, P. S. (1995). Susceptibility of β-Lactoglobulin and Sodium Caseinate to Proteolysis by Pepsin and Trypsin. *Journal of Dairy Science*, *78*(11), 2336–2344. https://doi.org/10.3168/jds.s0022-0302(95)76860-6

Happy Mrs. Jersey Chilla vanilla bio 500ml. (2025). Marma. https://marma.be/nl/product/HJ0010

Hettinga, K. A., Toprakchyoglu, A., Agatha, N., & Bleichrodt, W. (2026, February 20). *Happy Goats Goodness* (L. Bhaskarsan, Interviewer) [Personal communication].

Hicks, A., Fleischer, D., & Venter, C. (2024). The future of cow's milk allergy – milk ladders in IgE-mediated food allergy. *Frontiers in Nutrition*, *11*. https://doi.org/10.3389/fnut.2024.1371772

Home-Eng - Goats Goodness. (2024, November 25). Goats Goodness. https://goatsgoodness.nl/en/home-eng/#about

Immacolata, C., Mohamed Mustafa Ali, Yohannes Tesfaye Amera, Sungkutu Nyassi, Daniil Lisik, Athina Ioannidou, Rovner, G., Ekaterina Khaleva, Venter, C., Ronald van Ree, Worm, M., Berber Vlieg-Boerstra, Sheikh, A., Antonella Muraro, Roberts, G., & Nwaru, B. I. (2023). Prevalence estimates of eight big food allergies in Europe: Updated systematic review and meta-analysis. *Allergy*, *78*(9), 2361–2417. https://doi.org/10.1111/all.15801

Jane, M. (2016, April 2). *How Short-Chain Fatty Acids Affect Health and Weight*. Healthline; Healthline Media. https://www.healthline.com/nutrition/short-chain-fatty-acids-101

Jenness, R. (1980). Composition and Characteristics of Goat Milk: Review 1968−1979. *Journal of Dairy Science*, *63*(10), 1605–1630. https://doi.org/10.3168/jds.s0022-0302(80)83125-0

Jung, T.-H., Hwang, H.-J., Yun, S.-S., Lee, W.-J., Kim, J.-W., Ahn, J.-Y., Jeon, W.-M., & Han, K.-S. (2017). Hypoallergenic and Physicochemical Properties of the A2 β-Casein Fraction of Goat Milk. *Korean J. Food Sci. An*, *37*(6), 940–947. https://koreascience.or.kr/article/JAKO201708034060761.pdf

Kalscheur, K. F., Vandersall, J. H., Erdman, R. A., Kohn, R. A., & Russek-Cohen, E. (1999). Effects of Dietary Crude Protein Concentration and Degradability on Milk Production Responses of Early, Mid, and Late Lactation Dairy Cows. *Journal of Dairy Science*, *82*(3), 545–554. https://doi.org/10.3168/jds.s0022-0302(99)75266-5

Kerven, C. (2024). Contribution of goats to climate change: how and where? *Pastoralism: Research, Policy and Practice*, *14*. https://doi.org/10.3389/past.2024.13988

Kitabatake, N., & Kinekawa, Y.-I. (1998). Digestibility of Bovine Milk Whey Protein and β-Lactoglobulin in Vitro and in Vivo. *Journal of Agricultural and Food Chemistry*, *46*(12), 4917–4923. https://doi.org/10.1021/jf9710903

Kosikowski, F. V., & Wierzbicki, L. E. (1973). Lactose Hydrolysis of Raw and Pasteurized Milks by Saccharomyces lactis lactase. *Journal of Dairy Science*, *56*(1), 146–148. https://doi.org/10.3168/jds.s0022-0302(73)85129-x

Küpper, J., Chessa, S., Rignanese, D., Caroli, A., & Erhardt, G. (2009). Divergence at the casein haplotypes in dairy and meat goat breeds. *Journal of Dairy Research*, *77*(1), 56–62. https://doi.org/10.1017/s0022029909990343

Lawrence, R. M. (2013). Circumstances when Breastfeeding is Contraindicated. *Pediatric Clinics of North America*, *60*(1), 295–318. https://doi.org/10.1016/j.pcl.2012.09.012

Levitt, M., Wilt, T., & Shaukat, A. (2013). Clinical Implications of Lactose Malabsorption Versus Lactose Intolerance. *Journal of Clinical Gastroenterology*, *47*(6), 471–480. https://doi.org/10.1097/mcg.0b013e3182889f0f

Levy, M., Nachshon, L., Goldberg, M., Elizur, A., & Katz, Y. (2014). Cross-Desensitization To Goat and Sheep Milk Protein In Cow's Milk Protein Desensitized Patients. *Journal of Allergy and Clinical Immunology*, *133*(2), AB107. https://doi.org/10.1016/j.jaci.2013.12.395

Li, S. C., Goto, N. K., Williams, K. A., & Deber, C. M. (1996). Alpha-helical, but not beta-sheet, propensity of proline is determined by peptide environment. *Proceedings of the National Academy of Sciences*, *93*(13), 6676–6681. https://doi.org/10.1073/pnas.93.13.6676

Liao, G.-Q., Han, H.-L., Wang, T.-C., Li, H.-R., Qian, Y.-Z., Zhu, M.-X., Jia, Q., & Qiu, J. (2024). Comparative analysis of the fatty acid profiles in goat milk during different lactation periods and their interactions with volatile compounds and metabolites. *Food Chemistry*, *460*, 140427–140427. https://doi.org/10.1016/j.foodchem.2024.140427

Liliane, M., Maria, L., Jeremy Paul Hill, & Maria, A. (2023). Difficulties in Establishing the Adverse Effects of β-Casomorphin-7 Released from β-Casein Variants—A Review. *Foods*, *12*(17), 3151–3151. https://doi.org/10.3390/foods12173151

Lim, D.-H., Mayakrishnan, V., Lee, H.-J., Ki, K.-S., Kim, T.-I., & Kim, Y. (2020). A comparative study on milk composition of Jersey and Holstein dairy cows during the early lactation. *Journal of Animal Science and Technology*, *62*(4), 565–576. https://doi.org/10.5187/jast.2020.62.4.565

Lin, M., & Yanjun, C. (2024). Research progress on the mechanism of probiotics regulating cow milk allergy in early childhood and its application in hypoallergenic infant formula. *Frontiers in Nutrition*, *11*. https://doi.org/10.3389/fnut.2024.1254979

Lin, X., Chen, Y., & Lin, W. (2025). Bibliometric Analysis of Global Pediatric Research on Cow's Milk Protein Allergy. *Journal of Asthma and Allergy*, *18*, 85–100. https://doi.org/10.2147/JAA.S487698

Lindmark Månsson, H. (2008). Fatty acids in bovine milk fat. *Food & Nutrition Research*, *52*(1), 1821. https://doi.org/10.3402/fnr.v52i0.1821

Lonneke JanssenDuijghuijsen, Looijesteijn, E., van, Gerhard, B., Ziegler, M., Ariens, R., Tjoelker, R., & Geurts, J. (2023). Changes in gut microbiota and lactose intolerance symptoms before and after daily lactose supplementation in individuals with the lactase non-persistent genotype. *The American Journal of Clinical Nutrition*. https://doi.org/10.1016/j.ajcnut.2023.12.016

Loveday, S. M., Peram, M. R., Singh, H., Ye, A., & Jameson, G. B. (2014). Digestive diversity and kinetic intrigue among heated and unheated β-lactoglobulin species. *Food & Function*, *5*(11), 2783–2791. https://doi.org/10.1039/c4fo00362d

M.P. Bindal, & Wadhwa, B. K. (1993). Compositional differences between goat milk fat and that of cows and buffaloes. *Small Ruminant Research*, *12*(1), 79–88. https://doi.org/10.1016/0921-4488(93)90040-o

MacDonald, R., & Reitmeier, C. (2017). Nutrition and Food Access. *Understanding Food Systems*, 227–285. https://doi.org/10.1016/b978-0-12-804445-2.00007-7

Maga, E., P Daftari, D Kültz, & Penedo, M. C. T. (2009). Prevalence of s1-casein genotypes in American dairy goats. *Journal of Animal Science*, *87*(11), 3464–3469. https://doi.org/10.2527/jas.2009-1854

Maldonado-Valderrama, J., Wilde, P., Macierzanka, A., & Mackie, A. (2011). The role of bile salts in digestion. *Advances in Colloid and Interface Science*, *165*(1), 36–46. https://doi.org/10.1016/j.cis.2010.12.002

Malkoski, M., Dashper, S. G., O'Brien-Simpson, N. M., Talbo, G. H., Macris, M., Cross, K. J., & Reynolds, E. C. (2001). Kappacin, a Novel Antibacterial Peptide from Bovine Milk. *Antimicrobial Agents and Chemotherapy*, *45*(8), 2309–2315. https://doi.org/10.1128/aac.45.8.2309-2315.2001

Manea, M., Mezo, G., Hudecz, F., & Przybylski, M. (2007). Mass spectrometric identification of the trypsin cleavage pathway in lysyl-proline containing oligotuftsin peptides. *Journal of Peptide Science: An Official Publication of the European Peptide Society*, *13*(4), 227–236. https://doi.org/10.1002/psc.836

Mansor, M., Al-Obaidi, J. R., Intan Hakimah Ismail, Muhammad, Atiqah Farah Zakaria, Yii, B., Aliah Zannierah Mohsin, Rashidah Sukor, Jinap Selamat, Nor Khaizura Mahmud, & Nuzul Noorahya Jambari. (2023). *Cross-reactivity analysis of milk proteins from different goat breeds with cow's milk allergens using a proteomic approach*. *155*, 44–57. https://doi.org/10.1016/j.molimm.2022.12.016

Martin, P., Ollivier-Bousquet, M., & Grosclaude, F. (1999). Genetic polymorphism of caseins: a tool to investigate casein micelle organization. *International Dairy Journal*, *9*(3-6), 163–171. https://doi.org/10.1016/s0958-6946(99)00055-2

Martorell, A., Plaza, A. M., Boné, J., Nevot, S., García Ara, M. C., Echeverria, L., Alonso, E., Garde, J., Vila, B., Alvaro, M., Tauler, E., Hernando, V., & Fernández, M. (2006). Cow's milk protein allergy. A multi-centre study: clinical and epidemiological aspects. *Allergologia et Immunopathologia*, *34*(2), 46–53. https://doi.org/10.1157/13086746

Matthews, S. B. (2005). Systemic lactose intolerance: a new perspective on an old problem. *Postgraduate Medical Journal*, *81*(953), 167–173. https://doi.org/10.1136/pgmj.2004.025551

MedlinePlus [internet]. (2020, August 18). *Lactose intolerance: MedlinePlus Genetics*. Medlineplus.gov; Bethesda (MD): National Library of Medicine (US). https://medlineplus.gov/genetics/condition/lactose-intolerance/

Meisel, H. (1997). Biochemical properties of regulatory peptides derived from mil proteins. *Biopolymers*, *43*(2), 119–128. https://doi.org/10.1002/(sici)1097-0282(1997)43:2%3C119::aid-bip4%3E3.0.co;2-y

Mestawet, T. A., Girma, A., Ådnøy, T., Devold, T. G., & Vegarud, G. E. (2013). Newly identified mutations at the CSN1S1 gene in Ethiopian goats affect casein content and coagulation properties of their milk. *Journal of Dairy Science*, *96*(8), 4857–4869. https://doi.org/10.3168/jds.2012-6467

Metzger, M. (2022, July 22). *Goat milk versus cow milk: A comparison*. Sheep & Goats. https://www.canr.msu.edu/news/goat-milk-versus-cow-milk-a-comparison

Milk. (n.d.). THE NUTRITIONAL COMPOSITION of DAIRY PRODUCTS. https://milk.co.uk/nutritional-composition-of-dairy/milk/#wholemilk

Moatsou, G., Samolada, M., Panagiotou, P., & Anifantakis, E. (2004). Casein fraction of bulk milks from different caprine breeds. *Food Chemistry*, *87*(1), 75–81. https://doi.org/10.1016/j.foodchem.2003.10.020

Mollica, M. P., Trinchese, G., Cimmino, F., Penna, E., Cavaliere, G., Tudisco, R., Musco, N., Manca, C., Catapano, A., Monda, M., Bergamo, P., Banni, S., Infascelli, F., Lombardi, P., & Crispino, M. (2021). Milk Fatty Acid Profiles in Different Animal Species: Focus on the Potential Effect of Selected PUFAs on Metabolism and Brain Functions. *Nutrients*, *13*(4), 1111. https://doi.org/10.3390/nu13041111

Montoro-Huguet, M. A., Belloc, B., & Domínguez-Cajal, M. (2021). Small and Large Intestine (I): Malabsorption of Nutrients. *Nutrients*, *13*(4). https://doi.org/10.3390/nu13041254

Müller-Buschbaum, P., Gebhardt, R., Roth, S. V., Metwalli, E., & Doster, W. (2007). Effect of Calcium Concentration on the Structure of Casein Micelles in Thin Films. *Biophysical Journal*, *93*(3), 960–968. https://doi.org/10.1529/biophysj.107.106385

Muñoz-Salinas, F., Andrade-Montemayor, H. M., De la Torre-Carbot, K., Duarte-Vázquez, M. Á., & Silva-Jarquin, J. C. (2022). Comparative Analysis of the Protein Composition of Goat Milk from French Alpine, Nubian, and Creole Breeds and Holstein Friesian Cow Milk: Implications for Early Infant Nutrition. *Animals*, *12*(17), 2236. https://doi.org/10.3390/ani12172236

National Research Council (US). (2016). *Factors Affecting the Composition of Milk from Dairy Cows*. Nih.gov; National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK218193/

Neagu, A.-N., Jayathirtha, M., Baxter, E., Donnelly, M., Petre, B. A., & Darie, C. C. (2022). Applications of Tandem Mass Spectrometry (MS/MS) in Protein Analysis for Biomedical Research. *Molecules*, *27*(8), 2411. https://doi.org/10.3390/molecules27082411

Ng-Kwai-Hang, K. F., & F. Grosclaude. (2003). Genetic Polymorphism of Milk Proteins. *Springer EBooks*, 739–816. https://doi.org/10.1007/978-1-4419-8602-3_22

Noni, I. D., FitzGerald, R. J., Korhonen, H. J. T., Roux, Y. L., Livesey, C. T., Thorsdottir, I., Tome, D., & Witkamp, R. (2009). Review of the potential health impact of β-casomorphins and related peptides . *European Food Safety Authority*, *231*, 1–107. https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/j.efsa.2009.231r#:~:text=The%20%CE%B2%2Dcasein%20derived%20peptide,acid%20sequences%20of%20this%20protein

Noura S. M. Al-Nassir, & Sakr, S. S. (2024). In Vitro Digestibility Assessment of Whey from Goat and Camel Milk Fermented with Lactobacillus helveticus for Use as a Base in Formulating Follow-On Formula. *Foods*, *13*(4), 570–570. https://doi.org/10.3390/foods13040570

Nutrition Information Bush River All-Jersey Milk. (2025). Usjersey.com. https://jerseysites.usjersey.com/bushriver/nutrition.htm

Olivares, M., Schüppel, V., Hassan, A. M., Beaumont, M., Neyrinck, A. M., Bindels, L. B., Benítez-PáezA., Sanz, Y., Haller, D., Holzer, P., & Delzenne, N. M. (2018). The Potential Role of the Dipeptidyl Peptidase-4-Like Activity From the Gut Microbiota on the Host Health. *Frontiers in Microbiology, 9*. https://doi.org/10.3389/fmicb.2018.01900

Pal, S., Woodford, K., Kukuljan, S., & Ho, S. (2015). Milk Intolerance, Beta-Casein and Lactose. *Nutrients*, *7*(9), 7285–7297. https://doi.org/10.3390/nu7095339

Pan, Y., Zhang, L., Fu, X., Li, X., Liu, L., Wang, X., Zhang, J., & Zhou, W. (2025). Addition of Phospholipids Improved the Physical Stability and Fat Globule Structure of Processed Milk. *Foods*, *14*(3), 375. https://doi.org/10.3390/foods14030375

Park, Y. W. (Ed.). (2009). *Bioactive Components in Milk and Dairy Products*. Wiley-Blackwell. https://doi.org/10.1002/9780813821504

Park, Y. W. (2017). Goat Milk - Chemistry and Nutrition. *Handbook of Milk of Non-Bovine Mammals*, 42–83. https://doi.org/10.1002/9781119110316.ch2.2

Pellegrino, L., Cattaneo, S., & De Noni, I. (2016). *Nutrition and Health: Effects of Processing on Protein Quality of Milk and Milk Products*. Elsevier. https://doi.org/10.1016/B978-0-08-100596-5.00969-0

Pellegrino, L., Cattaneo, S., & Ivano De Noni. (2011). Nutrition and Health | Effects of Processing on Protein Quality of Milk and Milk Products. *Elsevier EBooks*, 1067–1074. https://doi.org/10.1016/b978-0-12-374407-4.00383-6

Peram, M. R., Loveday, S. M., Ye, A., & Singh, H. (2013). In vitro gastric digestion of heat-induced aggregates of β-lactoglobulin. *Journal of Dairy Science*, *96*(1), 63–74. https://doi.org/10.3168/jds.2012-5896

Prikkelbare Darm Syndroom (PDS). (2025, February 11). MDL Fonds. https://www.mdlfonds.nl/chronische-ziekten/pds-prikkelbare-darm-syndroom/

Prosser, C. G. (2021). Compositional and functional characteristics of goat milk and relevance as a base for infant formula. *Journal of Food Science*, *86*(2), 257–265. https://doi.org/10.1111/1750-3841.15574

Qausar Hamed ALKaisy, Jasim M. S. Al-Saadi, Al-Rikabi, A. K., Altemimi, A. B., Mohammad Ali Hesarinejad, & Tarek Gamal Abedelmaksoud. (2023). Exploring the health benefits and functional properties of goat milk proteins. *Food Science and Nutrition*. https://doi.org/10.1002/fsn3.3531

Rafiee Tari, N., Gaygadzhiev, Z., Guri, A., & Wright, A. (2021). Effect of pH and heat treatment conditions on physicochemical and acid gelation properties of liquid milk protein concentrate. *Journal of Dairy Science*, *104*(6). https://doi.org/10.3168/jds.2020-19355

Rahmatalla, S. A., Arends, D., & Brockmann, G. A. (2022). Review: Genetic and protein variants of milk caseins in goats. *Frontiers in Genetics*, *13*, 995349. https://doi.org/10.3389/fgene.2022.995349

Ramunno, L., Cosenza, G., Rando, A., Pauciullo, A., Illario, R., Gallo, D., Di Berardino, D., & Masina, P. (2005). Comparative analysis of gene sequence of goat CSN1S1 F and N alleles and characterization of CSN1S1 transcript variants in mammary gland. *Gene*, *345*(2), 289–299. https://doi.org/10.1016/j.gene.2004.12.003

RASMUSSEN, L. K., HØJRUP, P., & PETERSEN, T. E. (1992). Localization of two interchain disulfide bridges in dimers of bovine α_{s2}-casein. *European Journal of Biochemistry*, *203*(3), 381–386. https://doi.org/10.1111/j.1432-1033.1992.tb16561.x

Robinson, F. (2001). Goats milk – a suitable hypoallergenic alternative? *British Food Journal*, *103*(3), 198–208. https://doi.org/10.1108/00070700110386746

Roopashree, P. G., Shetty, S. S., & Suchetha Kumari, N. (2021). Effect of medium chain fatty acid in human health and disease. *Journal of Functional Foods*, *87*, 104724. https://doi.org/10.1016/j.jff.2021.104724

Ruprichová, L., Králová, M., Borkovcová, I., Vorlová, L., & Bedáňová, I. (2014). Determination of whey proteins in different types of milk. *Acta Veterinaria Brno*, *83*(1), 67–72. https://doi.org/10.2754/avb201483010067

S. Ah-Leung, Bernard, H., E. Bidat, Paty, E., F. Rancé, P. Scheinmann, & Wal, J.-M. (2006). Allergy to goat and sheep milk without allergy to cow's milk. *Allergy*, *61*(11), 1358–1365. https://doi.org/10.1111/j.1398-9995.2006.01193.x

Saikia, D., Hassani, M. I., & Walia, A. (2022). Goat milk and its nutraceutical properties. *International Journal of Applied Research*, *8*(4), 119–122. https://doi.org/10.22271/allresearch.2022.v8.i4b.9639

Sampson, H. A., O'Mahony, L., Burks, A. W., Plaut, M., Lack, G., & Akdis, C. A. (2018). Mechanisms of food allergy. *Journal of Allergy and Clinical Immunology*, *141*(1), 11–19. https://doi.org/10.1016/j.jaci.2017.11.005

Sánchez-Rivera, L., Ménard, O., Recio, I., & Dupont, D. (2015). Peptide mapping during dynamic gastric digestion of heated and unheated skimmed milk powder. *Food Research International*, *77*, 132–139. https://doi.org/10.1016/j.foodres.2015.08.001

Savaiano, D. A., Boushey, C. J., & McCabe, G. P. (2006). Lactose Intolerance Symptoms Assessed by Meta-Analysis: A Grain of Truth That Leads to Exaggeration. *The Journal of Nutrition*, *136*(4), 1107–1113. https://doi.org/10.1093/jn/136.4.1107

Schönfeld, P., & Wojtczak, L. (2016). Short- and medium-chain fatty acids in energy metabolism: the cellular perspective. *Journal of Lipid Research*, *57*(6), 943–954. https://doi.org/10.1194/jlr.R067629

Sebastián Domingo, J. J. (2021). Síndrome del intestino irritable. *Medicina Clínica*, *158*(2). https://doi.org/10.1016/j.medcli.2021.04.029

Selvaggi, M., Laudadio, V., Dario, C., & Tufarelli, V. (2014). Major proteins in goat milk: an updated overview on genetic variability. *Molecular Biology Reports*, *41*(2), 1035–1048. https://doi.org/10.1007/s11033-013-2949-9

Shkolnik, A., Maltz, E., & Gordin, S. (1980). Desert Conditions and Goat Milk Production. *Journal of Dairy Science*, *63*(10), 1749–1754. https://doi.org/10.3168/jds.s0022-0302(80)83134-1

Silva, P. D. L. da, Bezerra, M. de F., Santos, K. M. O. dos, & Correia, R. T. P. (2015). Potentially probiotic ice cream from goat's milk: Characterization and cell viability during processing, storage and simulated gastrointestinal conditions. *LWT - Food Science and Technology*, *62*(1), 452–457. https://doi.org/10.1016/j.lwt.2014.02.055

Suarez, F. L., Savaiano, D. A., & Levitt, M. D. (1995). A comparison of symptoms after the consumption of milk or lactose-hydrolyzed milk by people with self-reported severe lactose intolerance. *The New England Journal of Medicine*, *333*(1), 1–4. https://doi.org/10.1056/NEJM199507063330101

Swaisgood, H. E. (1993). Chemistry of the caseins. *Advanced Dairy Chemistry -1: Proteins*, 63–110. https://www.cabidigitallibrary.org/doi/full/10.5555/19930457634

Szilagyi, A., & Ishayek, N. (2018). Lactose Intolerance, Dairy Avoidance, and Treatment Options. *Nutrients*, *10*(12), 1994. https://doi.org/10.3390/nu10121994

Théoneste Umumararungu, Noël Gahamanyi, Janvier Mukiza, Gratien Habarurema, Katandula, J., Rugamba, A., & Vedaste Kagisha. (2024). Proline, a unique amino acid whose polymer, polyproline II helix, and its analogues are involved in many biological processes: a review. *Amino Acids*, *56*(1). https://doi.org/10.1007/s00726-024-03410-9

Toca, M. D. C., Fernández, A., Orsi, M., Tabacco, O., & Vinderola, G. (2022). Lactose intolerance: myths and facts. An update. *Archivos Argentinos de Pediatria*, *120*(1). https://doi.org/10.5546/aap.2022.eng.59

Ugidos-Rodríguez, S., Matallana-González, M. C., & Sánchez-Mata, M. C. (2018). Lactose malabsorption and intolerance: a review. *Food & Function*, *9*(8), 4056–4068. https://doi.org/10.1039/c8fo00555a

Umpiérrez, Quirce, Marañón, Cuesta, García-Villamuza, Lahoz, & Sastre. (1999). Allergy to goat and sheep cheese with good tolerance to cow cheese. *Clinical & Experimental Allergy*, *29*(8), 1064–1068. https://doi.org/10.1046/j.1365-2222.1999.00602.x

UniProt Knowledgebase: P02662 (aS1-Casein, Cow). (2024). UniProt. https://www.uniprot.org/uniprotkb/P02662/entry

UniProt Knowledgebase: P02663 (αS2-Casein, Cow). (2024). UniProt. https://www.uniprot.org/uniprotkb/P02663/entry

UniProt Knowledgebase: P02666 (A2 β-Casein, Cow). (2024). UniProt. https://www.uniprot.org/uniprotkb/P02666/entry

UniProt Knowledgebase: P02668 (κ-Casein, Cow). (2024). UniProt. https://www.uniprot.org/uniprotkb/P02668/entry

UniProt Knowledgebase: P11839 (β-Casein, Goat). (2024). UniProt. https://www.uniprot.org/uniprotkb/P11839/entry

UniProt Knowledgebase: P18626 (aS1-Casein, Goat). (2024). UniProt. https://www.uniprot.org/uniprotkb/P18626/entry

UniProt Knowledgebase: P33049 (αS2-Casein, Goat). (2024). UniProt. https://www.uniprot.org/uniprotkb/P33049/entry

UniProt Knowledgebase: P79377 (κ-Casein, Goat). (2024). UniProt. https://www.uniprot.org/uniprotkb/P79377/entry

van Leeuwen, S. S., te Poele, E. M., Chatziioannou, A. C., Benjamins, E., Haandrikman, A., & Dijkhuizen, L. (2020). Goat Milk Oligosaccharides: Their Diversity, Quantity, and Functional Properties in Comparison to Human Milk Oligosaccharides. *Journal of Agricultural and Food Chemistry*, *68*(47), 13469–13485. https://doi.org/10.1021/acs.jafc.0c03766

van Lieshout, G. A. A., Lambers, T. T., Bragt, M. C. E., & Hettinga, K. A. (2019). How processing may affect milk protein digestion and overall physiological outcomes: A systematic review. *Critical Reviews in Food Science and Nutrition*, *60*(14), 1–24. https://doi.org/10.1080/10408398.2019.1646703

Vasbinder, A. J., & de Kruif, C. G. (2003). Casein–whey protein interactions in heated milk: the influence of pH. *International Dairy Journal*, *13*(8), 669–677. https://doi.org/10.1016/s0958-6946(03)00120-1

Verruck, S., Dantas, A., & Prudencio, E. S. (2019). Functionality of the components from goat's milk, recent advances for functional dairy products development and its implications on human health. *Journal of Functional Foods*, *52*, 243–257. https://doi.org/10.1016/j.jff.2018.11.017

Wang, L., Li, X., Liu, L., da Zhang, H., Zhang, Y., Hao Chang, Y., & Zhu, Q. P. (2020). Comparative lipidomics analysis of human, bovine and caprine milk by UHPLC-Q-TOF-MS. *Food Chemistry*, *310*, 125865. https://doi.org/10.1016/j.foodchem.2019.125865

Wang, X., Ye, A., Lin, Q., Han, J., & Singh, H. (2018). Gastric digestion of milk protein ingredients: Study using an in vitro dynamic model. *Journal of Dairy Science*, *101*(8), 6842–6852. https://doi.org/10.3168/jds.2017-14284

Warren, C. M., Agrawal, A., Gandhi, D., & Gupta, R. S. (2022). The US population-level burden of cow's milk allergy. *World Allergy Organization Journal*, *15*(4), 100644. https://doi.org/10.1016/j.waojou.2022.100644

Wilt, T. J., Shaukat, A., Shamliyan, T., Taylor, B. C., MacDonald, R., Tacklind, J., Rutks, I., Schwarzenberg, S. J., Kane, R. L., & Micheael, L. (2010). Lactose intolerance and health . *Evidence Report/Technology Asesseement* , *192*, 1–410. https://europepmc.org/article/MED/20629478/NBK44619#_ch1_s3_

Yadav, A. K., Singh, J., & Yadav, S. K. (2016). Composition, nutritional and therapeutic values of goat milk: A review. *Asian Journal of Dairy and Food Research*, *35*(2). https://doi.org/10.18805/ajdfr.v35i2.10719

Yang, C., Pan, J., Pang, S., Hu, S., Liu, M., Zhang, X., Song, L., Ren, X., & Wang, Z. (2024). Comparative analysis of the nutritional composition, digestibility, metabolomics profiles and growth influence of cow, goat and sheep milk powder diets in rat models. *Frontiers in Nutrition*, *11*. https://doi.org/10.3389/fnut.2024.1428938

Yvon, M., Beucher, S., P. Guilloteau, I. Le Huerou-Luron, & T. Corring. (2025). Effects of caseinomacropeptide (CMP) on digestion regulation. *Reproduction Nutrition Development*, *34*(6), 527–537. https://doi.org/10.1051/rnd:19940602

Zhang, H., Xu, Y., Zhao, C., Xue, Y., Tan, D., Wang, S., Jia, M., Wu, H., Ma, A., & Chen, G. (2022). Milk lipids characterization in relation to different heat treatments using lipidomics. *Food Research International*, *157*, 111345–111345. https://doi.org/10.1016/j.foodres.2022.111345

Zhang, L., Zhou, R., Zhang, J., & Zhou, P. (2021). Heat-induced denaturation and bioactivity changes of whey proteins. *International Dairy Journal*, *123*, 105175. https://doi.org/10.1016/j.idairyj.2021.105175

Zhao, X., Cheng, M., Zhang, X., Li, X., Chen, D., Qin, Y., Wang, J., & Wang, C. (2020). The effect of heat treatment on the microstructure and functional properties of whey protein from goat milk. *Journal of Dairy Science*, *103*(2), 1289–1302. https://doi.org/10.3168/jds.2019-17221

Appendix

Report Tables and Pictures

Table 6 - *Comparative Nutrition Facts per 1 cup of Milk*

	Goat Milk	Cow Milk (from Jersey Cows)	Cow Milk
Calories	170 kcal	150 kcal	130 kcal
Total fat	10.10g	8g	7.4g
Saturated fat	6.5g	5g	4.7g
Cholesterol	27mg	35mg	17mg
Sodium	122mg	120mg	100mg
Total carbs	10.86g	12g	9.5g
Protein	9g	9g	7g
Ash (g/100g)	0.8	0.7	0.7
Vitamin A (I.U./100g)	185.0	126.0	126.0
Calcium	327mg	300mg	247mg
Potassium	498mg	362mg	323mg

Note. Data adapted from *Goat Milk vs Cow Milk | Summerhill Goat Dairy* (2021), *Cow Milk vs Goat Milk: Which Is Healthier?* (2021), *Nutrition Information Bush River All-Jersey Milk* (2025), Saikia et al. (2022), and *Milk* (n.d.).

Table 7 - *Comparative Nutrition facts per ¬100 g of Ice Cream*

Nutritional Values	HGG Cookie Dough Goat Milk Ice Cream*	Happy Mrs. Jersey Chilla Vanilla Organic Ice Cream **
Energy	204 kcal (856 kJ)	195kcal (815 kJ)
Total fat	10 g	9.9 g
Saturated fat	7.3 g	6.9 g
Carbs	25 g	21.9 g
Sugars	21 g	19.2 g
Protein	3.1 g	4.5 g
Salt	0.14 g	0.0001 g

Note. Data adapted from *HGG Cookie Dough Ice Cream (2025)* and *Happy Mrs. Jersey Chilla Vanilla Bio 500ml* (2025).

**The nutritional value for HGG cookie dough ice cream is taken from the packaging that was given during the first meeting with the commissioner on 11/02/2025.*

*** Happy Mrs. Jersey is used due to both companies using the same production type.*

Table 8 - *αS1-Casein Protein Sequence in Cows*

CASA1_BOVIN

Cow (Bos taurus)

Protein	αS1-Casein
Gene	CSN1S1
Amino acids	214
Variant	Sequence of B allele
Sequence	MKLLILTCLV AVALARPKHP **IKHQGLPQEV** LNENLLRFFV APFPEVFGKE **KVNELSKDIG** SESTEDQAME **DIKQMEAESI** SSSEEIVPNS **VEQKHIQKED** VPSERYLGYL EQLLRLKKYK VPQLEIVPNS **AEERLHSMKE** **GIHAQQKEPM** IGVNQELAYF **YPELFRQFYQ** LDAYPSGAWY **YVPLGTQYTD** APSFSDIPNP IGSENSEKTT MPLW

Note. Data from *UniProt Knowledgebase: P02662 (αS1-Casein, Cow), by UniProt Consortium, 2024, UniProt.* Retrieved from *https://www.uniprot.org/uniprotkb/P02662/entry*

Table 9 - *αS1-Casein Protein Sequence in Goats*

CASA1_CAPHI	
Goat (Capra hircus)	
Protein	αS1-Casein
Gene	CSN1S1
Amino acids	214
Variant	Sequence of A allele
Sequence	MKLLILTCLV AVALARPKHP **INHRGLSPEV** PNENLLRFVV APFPEVFRKE **NINELSKDIG** SESTEDQAME **DAKQMKAGSS** SSSEEIVPNS **AEQKYIQKED** VPSERYLGY LEQLLRLKKYN VPQLEIVPKS **AEEQLHSMKE** **GNPAHQKQPM** IAVNQELAYF **YPQLFRQFYQ** LDAYPSGAWY **YLPLGTQYTD** APSFSDIPNP IGSENSGKTT MPLW

Note. Data from *UniProt Knowledgebase: P18626 (αS1-Casein, Goat)*, by UniProt Consortium, 2024, *UniProt*. Retrieved from https://www.uniprot.org/uniprotkb/P18626/entry

Table 10 - *αS2-Casein Protein Sequence in Cows*

CASA2_BOVIN	
Cow (Bos taurus)	
Protein	αS2-Casein
Gene	CSN1S2
Amino acids	222
Variant	Sequence of A allele
Sequence	MKFFIFTCLL AVALAK**NTME** HVSSSEESII **SQETYKQEKN** MAINPSKENL C**STFCKEVVR** NANEEEYSIG **SSSEESAEVA** TEEVKITVDD KHYQKALNEI NQFYQKFPQY LQYLYQGPIV LNPWDQVKRN A**VPITPTLNR** EQLSTSEENS KKT**VDMESTE** VFTKKTKLTE EEKNRLNFLK **KISQRYQKFA** LPQYLKTVYQ HQKAMKPWIQ **PKTKVIPYVR** YL

Note. Data from *UniProt Knowledgebase: P02663 (αS2-Casein, Cow)*, by UniProt Consortium, 2024, *UniProt*. Retrieved from https://www.uniprot.org/uniprotkb/P02663/entry

Table 11 - *αS2-Casein Protein Sequence in Goats*

CASA2_CAPHI	
Goat (Capra hircus)	
Protein	αS2-Casein
Gene	CSN1S2
Amino acids	223
Variant	Sequence of A allele

Sequence	MKFFIFTCLL AVALAK**HKME** HVSSSEEPIN **IFQEIYKQEK** NMAIHPRKEK L**CTTSCEEVV** RNANEEEYSI **RSSSEESAEV** APEEIKITVD DKHYQKALNE INQFYQKFPQ YLQY**PYQGPI** VLNPWDQVKR N**AGPFTPTVN** REQLSTSEEN SKKT**IDMESTE** VFTKKTKLT EEEKNRLNFL **KKISQYYQKF** AWPQYLKTVD QHQKAMKPWT **QPKTNAIPYV** RYL

Note. Data from *UniProt Knowledgebase: P33049 (αS2-Casein, Goat)*, by UniProt Consortium, 2024, *UniProt*. Retrieved from https://www.uniprot.org/uniprotkb/P33049/entry

Table 12 - *κ-Casein Protein Sequence in Cows*

CASK_BOVIN	
COW (BOS TAURUS)	
PROTEIN	κ-Casein
GENE	CSN3
AMINO ACIDS	190
VARIANT	Sequence of E allele
SEQUENCE	MMKSFFLVVT ILALTLPFLG AQEQNQEQPI **R**CEKDERFF**S** DKIAKYIPIQ YVLSRYPSYG LNYYQQ**KP**VA LINNQFLPYP YYAKP**AA**VRS PAQI**L**QWQVL **S**NTVPAKSCQ **AQPTT**MARHP HPHLSFMAIP **PKKN**QDKTE**I** **PTINTIASGE** PT**STP**TTEAV **ESTVATLEDS** PEVIESPPEI NTVQVTSTAV

Note. Data from *UniProt Knowledgebase: P02668 (κ-Casein, Cow)*, by UniProt Consortium, 2024, *UniProt*. Retrieved from https://www.uniprot.org/uniprotkb/P02668/entry

Table 13 - *κ-Casein Protein Sequence in Goats*

CASK_CAPHI	
Saanen Goat (Capra hircus)	
Protein	κ-Casein
Gene	CSN3
Amino acids	192
Variant	Sequence of C allele
Sequence	MMKSFFLVVT ILALTLPFLG AQEQNQEQPI **C**CEKDERFF**D** DKIAKYIPIQ YVLSRYPSYG LNYYQQ**RP**VA LINNQFLPYP YYAKP**V**AVRS PAQ**T**LQWQVL **P**NTVPAKSCQ **DQPTT**LARHP HPHLSFMAIP **PKKD**QDKTE**V** **PAINTIASAE** PT**VHSTP**TTE**AIVNTVDNPE** ASSESIASAS ETNTAQVTST **EV**

Note. Data from *UniProt Knowledgebase: P79377 (κ-Casein, Goat)*, by UniProt Consortium, 2024, *UniProt*. Retrieved from https://www.uniprot.org/uniprotkb/P02670/entry

Interview – Swantje Breunig

1. Introduction

– Introduce yourself.

We are working with a company that makes ice cream using goat's milk for individuals with cow's milk allergy or lactose intolerance. Now, we are conducting research on the potential health benefits of goat's milk and goat's milk ice cream as an alternative to cow's milk. One of the partners of the company mentioned that their ice cream was made using 100% A2 goat milk. We aim to provide scientific insights that can support Happy Goat Goodness in positioning its products as a viable option for individuals with cow's milk allergy, lactose intolerance, and digestive sensitivities.

– Give a short description of the objectives of your project.

We aim to provide scientific insights that can support Happy Goat Goodness in positioning its products as a viable option for individuals with cow's milk allergy, lactose intolerance, and digestive sensitivities.

Some updates on the research objectives for the project:

- Summarize the Stages and Physiological Mechanisms of Lactose Intolerance and Cow's Milk Allergy
- Review the Health Benefits and Underlying Nutritional Composition of Goat's Milk and Goat's Milk Ice Cream Compared to Cow's Milk
- Assess the Digestibility of Goat's Milk and Goat's Milk Ice Cream Compared to Cow's Milk and Cow's Milk Ice Cream
- Identify the Suitability of Goat's Milk Ice Cream as an Alternative for Individuals with Cow's Milk Allergy and Lactose Intolerance
- Determine the Impact of Potential Degradation of Components During Production Processes in Goat's Milk Ice Cream
- Synthesize All Findings into Concise and Evidence-based Conclusions

– Tell what you like to be the focus and length of the interview. Agree on this.

We would like to focus on the Health Benefits and Underlying Nutritional Composition of Goat's Milk and Goat's Milk Ice Cream Compared to Cow's Milk, mostly asking questions about the A1/A2 casein protein fraction of the milk, as well as the differences in A2. Additionally, we also want to Assess the Digestibility of Goat's Milk and Goat's Milk Ice Cream Compared to Cow's Milk and Cow's Milk Ice Cream

2. Questions:

– Use a list of questions that you have prepared before. Make question that show that you did your preparation well. Estimate the time you have planned for all items to be addressed.

1. What are the key differences between A2 β-casein protein in milk of cows and goats? Aside from the amino acid sequence, how do these differences influence the digestibility and allergenicity of products made from these milks?

   Allergenicity does not necessarily have anything to do with A1 or A2 cow milk, it has a lot more to do with digestibility. Just because both cow milk and goat milk are called A1 and A2 does not mean that they are the same or that they have the same modifications. The letters like A1 and A2 indicate that you have a certain modification that's different from your reference but within the same animal. So, cow and goat milk in that sense is not related. The only thing you can compare is reference proteins for β-casein in cow milk and β-casein in goat milk. The A2 version of cow milk and the A2 version of goat milk are not the same, they have a lot of differences in their amino acid sequences. There is only 90% similarity in the amino acid sequence of cow and goat milk. So, calling goat milk as A2 is incorrect because it has a different β-casein.

2. Goat milk is widely reported in literature to contain only A2 β-casein, with little to no (around 0-25%) A1 β-casein, though some literature suggests variability between breeds specifically based on their alleles. Since Dutch White goats (that usually have E alleles) are used for milk production, how significant is this variation? Given the limited literature on this specific breed, would it be

reasonable to make an average estimate of % and conclude the presence of A1 β-casein based on data from other goat breeds?

E-allele is related to αS1-casein and not β-casein. There are 4 different groups of caseins: αS1-casein, αS2-casein, β-casein, and κ-casein. The amount of each group of these caseins that is present in cow and goat milk differs. You have different genetic variants of for example, β-casein, in every type of animal. So, your A1 β-casein has a different allele in a cow and your A2 β-casein has a different allele in the cow as well. αS1-E is also an allele of αS1. You cannot compare cow and goat milk directly because you have to consider what variation you have within an animal. Allergenicity has to do with a specific amino acid sequence, which is typically a small part of an entire protein, 1 casein, for example. If that particular fraction is the same in cows and goats, you will have a similar allergic reaction. If there is even just one amino acid change in the sequence, it might be different.

Just because the goat used in the production process has the A2 version of that amino acid, it does not mean that it has no allergy or more allergy than a cow because in other parts of that section, it has other amino acids. There is an 80-90% similarity between the amino acid sequence of cow and goat milk which means that they have similar characteristics. But this does not mean that you have the same allergic reactions in your body because often people that are intolerant or allergic to cow milk protein can also be allergic to goat milk protein. So, around 90% of the A2 β-casein of cow and goat milk is similar but they have different functionalities.

3. In terms of digestibility, how does the protein in goat milk compare to cow milk when used in ice cream production, considering that processing methods can affect protein structures? Also, are there any significant differences in how the proteins are broken down and absorbed by the body, especially when considering the potential impact of casein variants (A1 and A2) on digestibility in the frozen product?

   There is a lot of debate going on around whether A1 or A2 milk actually has an effect on the digestion. If you look at just protein digestion in cow and goat milk, goat milk typically has a higher digestibility. The effect of different types of fats present in goat and cow milk on digestion is not known yet. When you pasteurize milk, there is aggregation between proteins. The effect of this aggregation depends on the heat treatment of the milk. It also depends on whether you look at the whey protein or the casein interaction. For casein, heating may improve digestion. It has something to do with the structure and the clotting. For whey proteins, it depends on the heat treatment.

4. How do the unique amino acid profiles of whey proteins, including β-lactoglobulin and α-lactalbumin, differ between goat's and cow's milk, and how might these differences influence both digestibility and immune responses or allergies in individuals consuming these milks?

   The similarity is around 90% but you can easily look that up in protein databases like UniProt, for example, where you will find the reference protein sequence that you know, which you can then compare. I don't know much about the digestibility; all I can tell you is that they have similar modifications and similar structures. The only thing to note would be that the whey protein in goat milk has a lower denaturation temperature. I'm not sure if this affects the digestibility.

5. Does the A1 goat's milk have negative effects for humans like the A1 cow's milk?

   A1 goat milk is not the same as A1 cow milk so it has not been tested properly.

6. The goat milk ice cream is made with 100% A2 milk, we found that A1 and A2 milk both contain alpha S1-casein and alpha S2-casein and that the difference between A1 and A2 milk is that A1 milk contains A1 beta-casein and A2 milk contains A2 beta-casein, is this true?
   The difference between A1 and A2 cow milk is one amino acid (at a particular position) - histidine. When they say goat A2 milk, it is all based on that particular position in the amino acid sequence. So, they test whether the goat milk also has histidine in that position or not. But there are lots of other amino acids in the amino acid sequence of goat milk that differ from those of cow milk. This is not correct. You also cannot call it A1 or A2 goat milk because it's simply a different protein compared to cow milk. Be very careful when you read articles related to this topic because some of these studies claim that A2 is better than A1 cow milk simply because one has more protein than the other. Make sure to check if they look at different aspects in milk and not just one.

– Ask for additional literature sources and other experts.

Do you have any recommended literature that we can study or other experts we could reach out to?

There's a researcher named Gavour, he did a lot of work on A1 and A2 milk

– Ask if the expert is interested in a copy of the final report or to attend the final presentation.

Would you like a copy of the final report? The final report would be available on the 7th of March. If you would like to attend the final presentation, it will also take place on the 7th of March in the morning. We will let you know the exact time later.

– Thank the expert(s) for their cooperation.

Thank you so much for your time and insights today. Your input is valuable to our research, and we appreciate your support!

Interview – Kasper Hettinga

1. Introduction

– Introduce yourself.

We are working with a company that makes ice cream using goat's milk for individuals with cow's milk allergy or lactose intolerance. Now, we are conducting research on the potential health benefits of goat's milk and goat's milk ice cream as an alternative to cow's milk. We are currently looking at the cross-reactivity between goat milk and cow milk to understand and give advice to the company 'Happy Goat Goodness' about whether the ice cream they make is suitable for individuals with a lactose intolerance or cow's milk allergy.

– Give a short description of the objectives of your project.

We aim to provide scientific insights that can support Happy Goat Goodness in positioning its products as a viable option for individuals with cow's milk allergy, lactose intolerance, and digestive sensitivities.

Some updates on the research objectives for the project:

1. Summarize the Stages and Physiological Mechanisms of Lactose Intolerance and Cow's Milk Allergy

2. Review the Health Benefits and Underlying Nutritional Composition of Goat's Milk and Goat's Milk Ice Cream Compared to Cow's Milk

3. Assess the Digestibility of Goat's Milk and Goat's Milk Ice Cream Compared to Cow's Milk and Cow's Milk Ice Cream

4. Identify the Suitability of Goat's Milk Ice Cream as an Alternative for Individuals with Cow's Milk Allergy and Lactose Intolerance

5. Determine the Impact of Potential Degradation of Components During Production Processes in Goat's Milk Ice Cream

6. Synthesize All Findings into Concise and Evidence-based Conclusions

– Tell what you like to be the focus and length of the interview. Agree on this.

We would like to focus more on the cross-reactivity between the proteins present in goat and cow milk and how this would affect individuals with a lactose intolerance or cow's milk allergy. We also have an additional question about the processing of milk, especially what happens to lactose when the milk is pasteurized.

2. Questions:

– Use a list of questions that you have prepared before. Make question that show that you did your preparation well. Estimate the time you have planned for all items to be addressed.

1. Could there be other kinds of dairy sensitivities important for goat's milk besides cow's milk allergy and lactose intolerance?

   This is a tricky question because a lot of people think they have cow's milk allergy, but if you test them, they are neither cow's milk allergic or lactose intolerant. Some people experience gastrointestinal symptoms like bloating, or they have stomach cramps or intestinal cramps after drinking milk. If you then subsequently test them, you will see that they don't have IgE against cow milk protein, and therefore they are not lactose intolerant. This is the group that companies are sometimes looking for. In the end, that's also the difference between cow milk sensitivity versus cow's milk allergy. The strict definition of an allergy is that you need to have an IgE mediated immune response. And most people with a cow's milk IgE response will also respond to goat milk.

   We have done trials a few years ago where we actually tested this in young children, which is a bit different than adults with cow's milk allergy, but we saw very high cross-reactivity between cow and goat milk, if you specifically include only IgE mediated allergic people.

   And then the question is, could goat milk be a solution in these cases. The amount of lactose in cow and goat milk is similar. The cross-reactivity is very high between goat and bovine milk. So, if you really are diagnosed with IgE cow's milk allergy, I would never advise someone to consume goat milk as an alternative.

2. Is cow's milk allergy a problem for adults?

   Yes, but to a smaller extent than it is in children because most children who develop cow's milk allergy outgrow it. There's also a small group with persistent cow's milk allergy in which the cow's milk allergy either develops later or they don't outgrow it. It also seems that the allergy is not because milk contains a lot of proteins to which you can have an allergic reaction. There are indications that persistent cow's milk allergy is more against the casein fraction than it is to the whey protein fraction. But it's a bit difficult to conclude because different studies do not all report exactly the same.

It is clear however that cow's milk allergy in an adult is different. So, how strongly they respond, and to which proteins they respond to is not the same. So, even though we call it both a cow's milk allergy, it's actually two different diseases you could say.

3. We found that the level of αS1-casein is lower in goat milk compared to cow milk and we also found somewhere that it depends on the goat breed, is this true?
   All goats have more β-caseins and less α-caseins which is something you see in all studies, but the extent to which this happens differs between countries. It seems that the effect is smaller for Dutch goats, for example, than it is for other goats.

4. We found a paper that said that the proteins involved in cross-reactivity are different in different goat breeds, for e.g., αS1-casein and β-lactoglobulin are the proteins involved in cross-reactivity for the Saanen goat. Does it change according to the goat breed?

   We know that between breeds there are differences in the genetic makeup, that also translates to difference in the proteins present in their milk. But I have not come across any literature saying that this actually changes the allergenicity of the goat milk, that one breed is less allergic than the other.

5. We know that cross-reactivity has something to do with the proteins involved, especially with αS1-caseins. Does the lower αS1-casein level in the goat milk mean that individuals with CMA can still consume it even though there is a 90% probability of them being allergic to GM?
   In general, most people who are cow's milk allergic, especially as an adult, need very small quantities to have this allergic response. So, even if you would have only half the amount of the αS1-casein, you would still have this allergic response. Because it's generally not the case that the higher the intake, the stronger the allergic response. As soon as the immune system recognizes this protein, it blasts out the histamine which leads to allergic symptoms. So, it's not that if you drink half a glass of milk or a full glass of milk, that you would have different levels of allergy symptoms. It would be equally severe.

6. Yesterday we had another interview with an expert about the proteins in goat and cow milk. She said that the proteins in the goat milk and the cow milk cannot really be compared because they're not 100% similar. Does this have an effect on the cross-reactivity?
   Yes, this is why the cross reactivity is not 100%. It's not that everyone with a cow's milk allergy will also have allergic response to goat milk because you could be allergic to approximately 10 different cow's milk proteins. Within each protein, there are multiple potential epitopes, which is the part that the immune system recognizes. Some of the epitopes are identical or only differ by one amino acid. So, in those cases it's not a 100% cross reactivity. But in general, I would say that goat and cow milk are relatively close in their protein composition. There are also studies on other types of milk, like horse or other animals, that are genetically more distant from cow. They also have less homology in the amino acid sequence, and then the chance that you find exactly the same epitope is also smaller. The epitopes that people are allergic to differs per person. I think there are about 25-30 different epitopes known in the milk proteins. There are databases that you could use to look into them. You can use UniProt which is a database that has a tool for protein sequence alignment and there's also the IEDB database where you can find the epitope information of a lot of different proteins.

7. How does the pasteurization process and storage conditions of ice cream affect the lactose and fat content? There is contradictory information regarding how the pasteurization process

impacts lactose, as some studies show that the lactose content does not differ between raw milk and pasteurized milk, however, other sources say that isomerization and Maillard reaction occurs. It depends on the temperature, but the sources don't really mention an exact temperature but just say 'heat treatment of milk'. Could you clarify this (the company pasteurizes the milk at 80°C at 5 minutes)?
For normal pasteurization and even high pasteurization, there is no Maillard reaction taking place. There is also no lactose isomerization. For a Maillard reaction to occur, you really need to heat the milk for like half an hour above 110°C, which is not the case for ice cream production. Lactose is chemically, relatively stable. It is not that easy to destroy the basic structure of a lactose molecule. The lipid content will also not change during pasteurization or freezing. Since there is always air in your ice cream, lipid oxidation is a risk factor which would limit the shelf-life. The only thing that I would expect to happen during pasteurization is denaturing of the proteins. This does have a small effect on the allergenicity because denatured whey proteins are easier to digest in the stomach. Whether this changes the allergenicity or not is unclear.

– Ask for additional literature sources and other experts.

Do you have any recommended literature that we can study or other experts we could reach out to?

Hannah Zenker – paper about the detection of epitopes

Kasper Hettinga – paper about cow's milk sensitivity

– Always ask if the expert thinks there is other relevant information on the topic that you didn't ask for so far.

Is there anything else you think we should explore or consider regarding this topic?

– Ask if the expert is interested in a copy of the final report or to attend the final presentation.

Would you like a copy of the final report? The final report would be available on the 7th of March. If you would like to attend the final presentation, it will also take place on the 7th of March in the morning. We will let you know the exact time later.

– Thank the expert(s) for their cooperation.

Thank you so much for your time and insights today. Your input is valuable to our research, and we appreciate your support!

SWOT Analysis

Strengths	***Weaknesses***
• *Rich in nutrients such as calcium, phosphorus* • *Easy to digest due to smaller fat globules, higher β-casein content, absence of agglutinins and denaturation of β-lactoglobulin during ice cream processing*	• Not suitable for individuals with cow's milk allergy due to high cross-reactivity between proteins present in goat and cow milk • Lower lactose content only due to the smaller portion size, however, individuals have differences, and depends on how much lactose they have consumed during the day

Lower allergenic potential due to lower αS1-casein content and absence of BCM-7 *Lower lactose content (~3.38 g) so it can be consumed by lactose intolerant individuals*	Claim on the packaging is not accurate (“100% A2 goat milk”) as goat milk can’t be classified as A2
Opportunities	**Threats**
Increasing demand for alternative products for lactose-intolerant individuals. *Fortification of ice cream to increase health benefits* *Changes in the recipe, to include plant-based ingredients, making it more hybrid, and thus less lactose content*	- Competitive dairy alternative market - Transition to plant-based ingredients - Climate change resulting in changes in the nutritional composition of goat milk, such as protein synthesis due to physiological stress

Meeting Notes

Agenda Meeting - 11 February

Present: group + supervisors + commissioner

- Opening
- Introduction by Victor Boone from Happy Goats Goodness; Introduction Jacqueline from Horizon Flevoland; Introduction supervisors
- Project planning
- Questions
- Date next meeting
  - Set supervisor meeting on Thursday afternoon after handing in report
  - Commissioner meeting next week Wednesday around 11 o’clock via teams
  - If needed also make use of the Friday for meeting in person, let him know on Monday; If needed a room, ask supervisor

QUESTIONS

- Differences between the ice creams?

Soft, creamy, easy digestible, scoopable out of the freezer, consume with cow milk intolerance, maybe with lactose intolerance.

- What do consumers think

Flavor of the goat, easier alternative to intolerant people, luxury food, organic

- Why goat milk?

Girlfriend lactose intolerant, but can consume goat products, innovation on the shelf, goats better for climate, lower co2 foot print

- What do you want us to look at?

Is it innovative for cowmilk allergy and lactose intolerant

- What is the differences in processing?

Same in processing, depends on factory, made from fresh milk, big factories use powders, happy Ms. jersey ice cream same process

- What is the market status?

More expensive, but they can compete, cheaper than Haagen Daz and BJ but more expensive than Hertog Jan.

Goat is better for the climate, smaller CO2 footprint

Look into what happens to lactose when the milk is treated to make ice cream (how much lactose)

Cross reactivity (if you are allergic to cow's milk, how likely are you to be allergic to goats' milk)

Questions commissioner:

- Are there differences between cow's milk ice-cream and goat's milk ice cream in terms of sensory attributes (ex, texture)?
- What do consumers think about goats' milk-based ice-cream? #

Questions supervisor:

- How should the outline be for the final report?
- What are your expectations for the project?

To do:

- Summarize what is already known, and what we are going to research
- Lab work on lactose will be bring by
- Lookup how intolerant people are
- How much lactose is in the ice cream
- Test in the lab here, Qing will have a look.
- Does the processing of the ice cream change the lactose content > check
- Possible to consume intolerance and cow's milk allergy/intolerance, cross reactivity
- Digestion define how easy it is , ask supervisor she did a PhD on it
- AI tool: Scite
- The outline is to be decided with the supervisors

ADDITIONAL:

Notes

Mostly sold in farmer shops, but also in jumbo. And in 6 other countries

First company to make goat ice cream that is cheap and premium

3 flavours as of now; cookie dough is with vegan cookie dough

Been doing it for 1 and a half year, started from graduation

The only one producing goat milk ice cream in NL (premium); there are low levels from farmers

Questions

Differences between cow and goat milk ice cream

- Softer, creamy, scoopable out of the freezer, can be consumed with people of cow milk allergy (but dk about intolerance)

What do consumers think about the ice cream

- Different opinions; mixed feelings; some just about luxury, some organic, depending on which market we are selling it

Why goat milk?

- Lactose intolerance girlfriend; goats are better for the climate; co2 footprint is important these days

LOOK into: claims (is it good for cow milk into/allergic? Also lactose intolerant/allergy?)

Difference in processing?

- Same processes as cow milk; **happy goat is the only factory in NL with fresh milk**. Most companies use the powders

Organic goat milk is more expensive for production; but since its ran by themselves it can compete

In the market it is cheaper than ben and Jerrys but more expensive than Hertog (middle price)

Lab work? Sample the lactose content in the milk?

Look into the range of how lactose intolerant people are; some people are more some people are less

Look into how much lactose is still in the product after production

Look into cross-reactivity; if allergic to cow milk, also goat milk?

Look into the digestion (easy to digest > define!)

Supervisors; Look into the introduction lecture of the course; Refer to this one; 25 pages; mention the contribution

Slides from Xing

Presentation for supervisor meeting

Scite_

Making further appointments

Plan second meeting with commissioner for week 2

Deadline: send workplan before end of 12 Feb

Discuss with the supervisor of the work plan

Send invitations to the commissioner and the other woman

Agenda Meeting - 13 February

Present: group + supervisors

- Opening
- Presentation – group (progress)

Supervisor: about question 5; victor is willing to share the recipe and processing steps -> contact victor about this.

- Victor said its like of the normal ice cream processing. They probably used pasteurized milk.
- Supervisors think its skim milk – to remove the fat fraction -> this removes the goat flavor. (Goat flavor comes from the fat fraction)

There is fat in there but the fatty acid of goat flavor isn't in it -> so used other fatty acids? > check!

Talk about the range of lactose

Don’t include infants' digestion -> focus on adults

Do we need to keep a logbook? Supervisor: Its nice to have

Write the report for someone who doesn’t study food tech -> so for example what does lactose intolerance mean? And clearly explain the difference between everything > **MANAGEMENT SUMMARY**

If it’s called goat milk A2 it doesn’t mean it’s the same amino acid sequence or functionality as cow milk -> so you have to look into this (Look at the more general casein composition?)

Kasper Hettinga -> about the cow and goat milk allergy and cross reactivity.

Swantje Breunig –> knows about protein composition and caseins and the difference variance.

And use the paper of Qing.

Feedback from supervisor

- HGG would like to know if they can promote their product based on potential health benefits for certain groups of consumers. These groups include lactose intolerant people, people with a cow milk allergy and also groups with difficulties digesting cow milk ice cream. So the question to you is to look into all these potential health benefits (maybe even ones that were not listed yet).
- It is important to realize that the case commissioner has no food science or nutritional background, so it is important to start from the beginning and clearly explain the difference between allergy and intolerance and how it works
- ice cream can have a large variation in composition, so it would be nice to link these insights to the current recipe and composition of the HGG ice cream to answer this question
- (digestibility of goats milk (ice cream)) this one will probably not be so easy to answer, so you will have to discuss how the matrix of ice cream would be different from milk and how that could affect digestion
- it would be indeed good to check with Victor if there are some processing parameters that could be relevant to consider
- you will also need to write a management summary. This is especially important for this case as you need to translate the scientific language to a story that can be followed by people with different backgrounds. I would make this explicit because it is important that your report can be understood by different people in the company
- I am wondering how you will start with the literature research and divide tasks. We can discuss it during the meeting

- Discussion
- Questions
- Date next meeting

Victor share recipe > include the processing > contact him

No talking about infants; infant digestion is different from adults

- Infants has less mature digestive system; stomach digestion > has higher pH value (less acidic) and oral enzyme activity is lower
- Focus on adult digestion only

Logbook? Just do weekly overview

normal process like making ice cream at home: Milk > pasteurise (65% milk), stirring device to get air in

Goat milk has similar lactose content to cow milk (just say slightly lower lactose content; since there is only 65% milk there, the lactose content will also drop)

GOAT flavour is a very important point > due to fat fraction (Capric acid) (fatty acid which gives the distinct goat flavour

- Since the ice cream does not have much goat flavour, maybe they use skim milk? Remove fat fraction (usually not completely 0), mix in other types of fat to get the creaminess maybe

It is low in lactose; but is it safe for people with lactose intolerance? DIFFERENT TYPES OF CLAIMS

- He knows maybe he cannot say that it is ok for lactose intolerant people but why?

Differentiate between maldigestion, intolerance, and allergic

Compare lactose in cow milk and goat milk; LACTOSE QUANTITY

Goat milk beta casein have a variation in the alignment

Goat milk a2 does not have the same amino acid sequence as cow milk

Goat milk cannot be called a2; only cow

A peak for a2 in goat milk does not really mean that it is a2 protein has the same functionality as a cow a2 protein; if a2 cow is cleaved off and it is good for humans, goat usually is not the same (cleaved off but different amino acids)

NOT zoom in detail about genetic codes; look more into the general (LOOK into a2, but not too deep; investigate the higher protein level)

Swantje Breunig for a2 caseins

Kasper for lactose

Agenda Meeting - 18 February

To do

- Question meeting kasper
- Powerpoint for victor
- Powerpoint for supervisors

Overlap between group members:

- Eline and Nabila sometimes write the same thing

Nabila – composition of nutrition how much is present and if it's affecting the digestion and health, but not in dept for the mechanisms of why things are good

Eline – write how the mechanisms work of the composition things; in the biological side

A2 and a1 ? > check this

1 write the introduction and check for overlaps; if there is any, then use the first one and refer to it

- Laksmi: Is short on information so goes to help alexia or starts on the valorisation for this week

Valorisation --> Laksmi, Alexia, Nabila; deadline friday

- Introduction of the company and there main objective
- Outcome of the problem
- How the outcome is tailored to the company
- Reflect on the communication with everyone
- Potential impact
- What can the commissioner do with the product
- Potential user, and how to use

Summary management --> Eline, Willemijn, and Marije; deadline Monday of 3rd week

Wednesday afternoon 5 o'clock sent version 1 to supervisor for the meeting at Thursday

Thursday after meeting we do peer feedback, boundary crossing, project process evaluation (tick stuff)

Next week have an individual meeting with the supervisor for the portfolio > check

Tuesday meeting with supervisor to review the interview and chances

Wednesday 26 have your own parts done around 5 o'clock

27 Thursday 10 o'clock meet up to combine and finish everything in the morning

Supervisor Meeting – Swantje

Look for the audio file

AUDIO FILE

Supervisor Meeting – Kasper

AUDIO FILE

A lot of people think they have cow milks allergy; btu they're not that or lactose intolerant; they just experience the symptoms after drinking milk. After testing they do not have Ige against the protein > most people with cow's milk response also responds to goats' milk

Persistent cow milk allergy

- 2 different diseases between cow's milk allergy and others

All goats have more b casein and less a casein; to what extend depends on which countries; in Dutch it is commonly less

No good evidence that goat milk is less allergic

Align the sequences and look at the epitope difference; from database: UNIPROD (PROTEIN SEQUENCE ALIGNTMENT), IEDB (EPITOPE INFORMATION FOR LIVESTOCK)

Zenker and Kasper > look into their papers; detection of epitopes for both children and adults; better to look at all known epitopes

In milk, normal and high heat treatments will not really change the lactose

With HGG, there is no impact on the lactose

Lactose is relatively stable; not easy to destroy the chemical structure

Fat > lipids will not change in due to process; more due to the air (lipid oxidation)

Denatured whey proteins are easier to digest; but don't know if it changes the allergenicity

Cow's milk sensitivity is more apparent in female? > check

Cow's milk **IgE mediated** allergy

Hydrogen breath test > conformation for lactose intolerance

Goat milk is ok for lactose intolerant people; in ice cream the load of lactose that people get is relatively small

- But what is the difference between lactose intolerance and lactase persistence?

Kasper would like a copy; he'll send out the paper and his book

Agenda Meeting - 20 February

Supervisor Meeting with Qing

- Everyone updated what they found and did for their parts
- Qing gave a few feedbacks regarding the questions asked during the meeting

Qing recommended some literatures to help Eline for her part on the digestibility

Victor will come on Friday for the lactose sample testing; will give it to Axis > to Qing immediately

- Asked Qing if any students are needed in the lab with her to help out > no students needed, she will do the test and email the results

Do the PPE together; ask if Marije is okay with it and then hand it in

Do boundary crossing and peer feedback individually

Ask if we are supposed to make a supervisor meeting for the boundary crossing assignment

Division of Tasks

Subjects	**Names**
Workplan	Everyone
Valorisation	Nabila, Aleksia, Lakshmipriya
Management Summary	Eline, Willemijn, Marije
Introduction	Marije
Materials and Methods	Nabila
Results and discussions (based per objective)	Everyone
Chair	Lakshmipriya
Meeting notes	Nabila
Conclusion	Everyone
Recommendations	Lakshmipriya
Supervisor meeting PPT slides	Marije, Nabila

References	Everyone
Interview transcript	Lakshmipriya
SWOT Analysis	Lakshmipriya, Aleksia
Presenting	Marije, Willemijn
Presentation Slides	Nabila, Eline, Aleksia, Lakshmipriya
Layout	Everyone