Vliv přídavku vlákniny na konzistenci termizovaných sýrů

Bc. Miroslav Jaššo

Diplomová práce
2024

Univerzita Tomáše Bati ve Zlíně
Fakulta technologická

Univerzita Tomáše Bati ve Zlíně
Fakulta technologická
Ústav technologie potravin

Akademický rok: 2023/2024

ZADÁNÍ DIPLOMOVÉ PRÁCE

(projektu, uměleckého díla, uměleckého výkonu)

Jméno a příjmení:	**Bc. Miroslav Jaššo**
Osobní číslo:	**T22644**
Studijní program:	**N0721A210004 Technologie potravin**
Forma studia:	**Prezenční**
Téma práce:	**Vliv přídavku vlákniny na konzistenci termizovaných sýrů**

Zásady pro vypracování

I.Teoretická část
Obecná charakteristika čerstvých sýrů.
Technologie výroby čerstvých sýrů a termizovaných sýrů.
Faktory působící na funkční vlastnosti termizovaných sýrů.
II.Praktická část
Vyrobte modelové vzorky čerstvých termizovaných sýrů.
Proveďte vybrané analýzy.
Vyhodnoťte výsledky a vyvoďte závěry.

Forma zpracování diplomové práce: **tištěná/elektronická**
Jazyk zpracování: **Angličtina**

Seznam doporučené literatury:

[1] Michel, S. E. S., Scheermeijer, R., Ambühl, M., & Fernández Farrés, I. (2022). Novel plant-based cream cheese: A tribology perspective. Journal of Food Engineering, 335
[2] Brighenti, M., Govindasamy-Lucey, S., Jaeggi, J. J., Johnson, M. E., & Lucey, J. A. (2021). Effect of substituting whey cream for sweet cream on the textural and rheological properties of cream cheese. Journal of Dairy Science, 104(10), 10500-10512
[3] Tadeu da Veiga Correia, V., D'Angelis, D. F., Neris dos Santos, A., Silva Roncheti, E. F., Vieira Queiroz, V. A., Fontes Figueiredo, J. E., Azevedo da Silva, W., Ferreira, A. A., & Fante, C. A. (2022). Tannin-sorghum flours in cream cheese: Physicochemical, antioxidant and sensory characterization. LWT, 154
[4] Wolfschoon Pombo, A. F. (2021). Cream cheese: Historical, manufacturing, and physico-chemical aspects. International Dairy Journal, 117

Vedoucí diplomové práce: **doc. Ing. Richardos Nikolaos Salek, Ph.D.**
Ústav technologie potravin

Datum zadání diplomové práce: **1. ledna 2024**
Termín odevzdání diplomové práce: **10. května 2024**

L.S.

prof. Ing. Roman Čermák, Ph.D.
děkan

Ing. Robert Gál, Ph.D.
ředitel ústavu

Ve Zlíně dne 10. února 2024

PROHLÁŠENÍ AUTORA DIPLOMOVÉ PRÁCE

Beru na vědomí, že:

- diplomová práce bude uložena v elektronické podobě v univerzitním informačním systému a dostupná k nahlédnutí;
- na moji diplomovou práci se plně vztahuje zákon č. 121/2000 Sb. o právu autorském, o právech souvisejících s právem autorským a o změně některých zákonů (autorský zákon) ve znění pozdějších právních předpisů, zejm. § 35 odst. 3;
- podle § 60 odst. 1 autorského zákona má Univerzita Tomáše Bati ve Zlíně právo na uzavření licenční smlouvy o užití školního díla v rozsahu § 12 odst. 4 autorského zákona;
- podle § 60 odst. 2 a 3 autorského zákona mohu užít své dílo – diplomovou práci nebo poskytnout licenci k jejímu využití jen s předchozím písemným souhlasem Univerzity Tomáše Bati ve Zlíně, která je oprávněna v takovém případě ode mne požadovat přiměřený příspěvek na úhradu nákladů, které byly Univerzitou Tomáše Bati ve Zlíně na vytvoření díla vynaloženy (až do jejich skutečné výše);
- pokud bylo k vypracování diplomové práce využito softwaru poskytnutého Univerzitou Tomáše Bati ve Zlíně nebo jinými subjekty pouze ke studijním a výzkumným účelům (tj. k nekomerčnímu využití), nelze výsledky diplomové práce využít ke komerčním účelům;
- pokud je výstupem diplomové práce jakýkoliv softwarový produkt, považují se za součást práce rovněž i zdrojové kódy, popř. soubory, ze kterých se projekt skládá. Neodevzdání této součásti může být důvodem k neobhájení práce.

Prohlašuji,

- že jsem na diplomové práci pracoval samostatně a použitou literaturu jsem citoval. V případě publikace výsledků budu uveden jako spoluautor.
- **že odevzdaná verze diplomové práce a verze elektronická nahraná do IS/STAG jsou obsahově totožné.**

Ve Zlíně dne:

Jméno a příjmení studenta:

……………………………..

podpis studenta

ABSTRAKT

Smetanový sýr se vyznačuje jemnou smetanovou, máslovou chutí a mírně nakyslou mléčnou chutí bez známek hořkosti. Jeho textura může být od křehké až po roztíratelnou, často lesklou, což z něj činí charakteristický výrobek. Cílem této práce bylo posoudit, zda měl přídavek 1,0 % (w/w) citrusové vlákniny významný stabilizační účinek na texturu konečného výrobku. Toho bylo dosaženo provedením analýz sušiny, pH, aktivity vody, texturní profilovou analýzou, reologie, tribologie, in-situ výroby a senzorických analýz. Bylo zjištěno, že citrusová vláknina je vhodnou možností stabilizace textury smetanového sýra. Analýzou textury bylo zjištěno, že díky tomuto přídavku je smetanový sýr pevnější, pružnější a hůře se roztírá. Reologické analýzy zjistily zvýšené hodnoty elastického a ztrátového modulu. Tyto výsledky byly potvrzeny senzorickou analýzou. Doporučuje se další výzkum hodnocení přídavku 0,5 a 0,75 % (w/w) citrusové vlákniny.

Klíčová slova: smetanový sýr, citrusová vláknina, TPA, reologie, tribologie, in-situ, senzorická analýza

ABSTRACT

Cream cheese is characterised by its mild creamy, buttery flavour and slightly dairy-sour taste, devoid of bitterness. Its texture can range from brittle to spreadable, often glossy, making it a distinctive acid-coagulated fresh cheese product. This thesis aims to assess if adding 1,0 % (w/w) citrus fibre has a significant stabilising effect on the final product's texture. This was accomplished by performing dry matter, pH, water activity, texture profile analysis, rheology, tribology analyss, in-situ manufacturing and sensory analysis. The citrus fibre was found to be a viable option for stabilising cream cheese's texture. Texture analyses have found that this addition makes the cream cheese firmer, more elastic, and harder to spread. Rheology analyses have found increased values in storage and loss moduli. These results have been confirmed by sensory analysis. Further evaluation of adding 0,5 and 0,75 % (w/w) citrus fibre is recommended.

Keywords: cream cheese, citrus fibre, TPA, rheology, tribology, in-situ, sensory analysis

“First appearances are often deceptive. Not everything monstrous-looking
is evil, and not everything fair is good… and in every
fairytale, there is a grain of truth.”

Geralt of Rivia

Acknowledgements:

I want to thank my supervisor, doc. Ing. Richardos Nikolaos Salek, Ph.D., for his professional advice and leadership and Ing. Anna Vinová for her expertise concerning the measurements. Last but not least, my beloved partner for her unconditional support.

I hereby declare that the print version of my Bachelor's/Master's thesis and the electronic version of my thesis deposited in the IS/STAG system are identical.

CONTENTS

INTRODUCTION

Cream cheeses have been around since the late 19th century, first manufactured in the United States of America. Since then, they have become increasingly popular, spreading into other parts of the world, mainly Europe. Predictions indicate that worldwide cheese production will reach approximately 21,3 million tonnes in 2020, with the market value estimated to be between 65 and 68 billion USD. The EU-27 is responsible for around 10,3 million tonnes, while the USA contributes nearly 6,1 million. Germany is the foremost producer of cream cheese in the European Union, paralleling the USA's leading position in America. Cream cheese, a fresh dairy commodity, is gaining considerable economic significance in the food industry, with an anticipated global cheese market value of approximately 8,3 billion USD by 2026 (Pombo, 2021).

Cream cheese is characterised by its mild creamy, buttery flavour and slightly dairy-sour taste, devoid of bitterness. Its texture can range from brittle to spreadable, often glossy, making it a distinctive acid-coagulated fresh cheese product. The versatility of cream cheese lends itself to various uses across the food industry. The cheese serves as an ideal base for incorporating flavours, fibres, herbs, condiments, and even air or for augmentation with pre- and probiotics (Tamime, 2009; Alves et al., 2013).

With late trends in dietetics, low-fat cream cheeses have become increasingly available, posing technological difficulties with manufacturing. Engineers have found many solutions to stabilise cream cheese, mainly using hydrocolloids such as locust bean gum, xanthan gum, sodium alginate, tara gum or κ-carrageenan (Hansen, 1994).

This thesis aims to add a way to stabilise cream cheese using an easily obtainable resource, citrus fibre. The effect of its addition of 1,0 % (w/w) was monitored through numerous fundamental, textural, rheological and sensory analyses.

I. THEORY

1 DEFINITIONS AND LEGISLATION OF FRESH CHEESES

In the case of studying the rheological properties of cream cheeses, we must first understand the basics on which the cheese-making process relies. This chapter will describe current definitions and legislation requirements regarding fresh cheeses, with a particular focus on cream cheese products.

1.1 Codex Alimentarius

The Codex Alimentarius provides international food standards, guidelines, and codes of practice, all of which add to the global food trade's safety, quality, and fairness and protect consumer health. The Codex standards are based on reasoned science provided by independent international risk assessment bodies (FAO, 2024). In the Codex, standards for unripened (fresh) and cream cheeses are very well specified.

1.1.1 Unripened cheese, including fresh cheese

As of the last amendment in 2022, the definition of the group stands as "Unripened cheeses including fresh cheeses are products in conformity with the General Standard for Cheese (CXS 283-1978), which are ready for consumption shortly after manufacture." (Codex Alimentarius, 2001). This definition points to the General Standard for Cheese, describing cheese as a product obtained by coagulation of the protein of milk, cream, whey cream or buttermilk (Codex Alimentarius, 1978). It defines raw materials, permitted ingredients, and food additives.

1.1.2 Cream cheese

It is defined as "a soft, spreadable, unripened and rindless cheese in conformity with the Group Standard for Unripened Cheese Including Fresh Cheese (CXS 221-2001) and the General Standard for Cheese (CXS 283-1978). The cheese has a near-white through to light yellow colour. The texture is spreadable and smooth to slightly flaky and without holes, and the cheese spreads and mixes readily with other foods."

It defines raw materials, permitted ingredients, and additives. There are several more requirements for milk fat in dry matter content (min. 25 %, w/w), moisture content on a fat-free basis (min. 67 % w/w) and dry matter content (min. 22 %, w/w) (Codex Alimentarius, 1973).

1.2 European Union

In the majority of European countries, the legislation of dairy products is defined by the European Union (EU) regulations, specifically Regulation (EC) No. 853/2004, which lays down specific rules on the hygiene of food of animal origin for food business operators along with Regulation (EC) No. 852/2004 specifying hygiene of foodstuffs in general.

A few of the most critical points of Regulation (EC) No. 853/2004 include definitions of raw milk, dairy products, health requirements for raw milk production, criteria for raw milk and requirements concerning dairy products. Furthermore, it sets requirements for the hygiene of milk production holdings, packaging, labelling and refrigeration (The European Parliament and the Council of the European Union, 2004a and 2004b).

However, neither of the regulations mentioned above specifies "fresh cheese" or "cream cheese". In particular, to get more precise answers, legislation on a national level must be studied.

The mandatory legislative act in the Czech Republic is Decree 397/2016 Sb., which specifies requirements for milk, milk products, frozen creams and edible fats and oils. The Decree contains a more specific definition of a category: "cheese" is defined as "a milk product made by precipitating milk protein from milk by the action of rennet or other suitable coagulating agents, separating the whey fraction and then souring or ripening". Furthermore, cheeses are divided into subcategories where the subcategory "fresh cheese" is defined as "unripened cheese, including thermised unripened cheese". The manufacturing process of cream cheese satisfies both definitions, categorising cream cheese as fresh cheese in Czech legislation (Czech Republic, 2016).

1.3 USA

All food for human consumption is subject to the Code of Federal Regulations under Title 21. In the USA, the term cream cheese is well known and defined in § 133.133 as "the soft, uncured cheese prepared by the procedure set forth in paragraph (a)(2) of this section, or by any other procedure which produces a finished cheese having the same physical and chemical properties. The minimum milkfat content is 33 percent by weight of the finished food, and the maximum moisture content is 55 percent by weight, as determined by the methods described in § 133.5. The dairy ingredients used are pasteurised."

Furthermore, it allows “safe and suitable ingredients: milk, nonfat milk, cream, clotting enzymes, salt, cheese whey, concentrated cheese whey, dried cheese whey, or reconstituted cheese whey and stabilizers”. Following § 133.134 allows mixing cream cheese with other foods listed as “properly prepared fresh, cooked, canned, or dried fruits or vegetables; cooked or canned meats, relishes, pickles, or other suitable foods“ (USA, 2024).

2 MANUFACTURE PROTOCOL REGARDING FRESH AND CREAM CHEESES

Following the definition of fresh and cream cheeses, understanding milk's physical and chemical properties, and using different coagulation methods allow us to grasp the basis of cheese making entirely. The next chapter focuses on milk properties and ways of precipitating proteins, laying down the foundation of the thesis.

2.1 Physical and chemical properties of milk regarding the production of cheese

2.1.1 Physical Properties

A few of the essential physical properties to mention include milk's density, freezing point, and titratable acidity.

Milk's density typically ranges between 1027 to 1033 kg.m^{-3} at 20 °C. This parameter is essential for the separation of milk components during cheese production. The general rule here is that higher fat content lowers the density. Meanwhile, higher fat-free dry matter (the content of proteins, lactose, and minerals) increases it. For example, skimmed milk's density usually rises over 1032 kg.m^{-3} at 20 °C (Goff, 2022).

The freezing point of milk, generally between -0.512 to -0.550 °C, with an average of around -0.522°C, affects the storage and handling of milk before cheese making and could be used as a reference factor to detect any dishonest practices (Goff, 2022; Bhandari et al., 2016).

Titratable acidity is a more specific parameter to well-known active acidity (pH) and corresponds to lactic acid content in milk. Usually, the main reason behind the increased titratable activity is a higher amount of lactic acid originating from microbial spoilage or milk being measured right after milking (dissolved CO_2 reacts acidly, producing H^+ and HCO_3^-) (Bhandari et al., 2016).

2.2 Chemical composition of milk

2.2.1 Fat

Usually, the fat in milk depends on the cow's breed and ranges from 3,5 to 5,5 % (w/w), with an average value of 4,0 % (w/w). As in all animal fats, nearly all the fatty acids are bound in triacylglycerols. There are many fatty acids present; the most prevalent include palmitic acid (approx. 30,4 %, w/w), oleic acid (approx. 18,8 %, w/w), myristic acid (approx. 12,1 %, w/w), and stearic acid (approx. 10,6 %, w/w). Others range from butyric to arachidic acid in small quantities (under 4 %, w/w) (Taylor and Macgibbon, 2011).

Since fat is immiscible with the water basis, it must be emulsified to achieve a homogenous structure in the milk. Fat is present in the form of microglobules (0,1-22,0 μm, usually 2,0-3,5 μm) with phospholipid-protein membrane on its outer layer. The layer provides emulsification properties to the system and keeps fat globules from separating or joining into bigger units (Fox, 2011a).

Suppose the milk is exposed to enzymes or mechanical agitation (shaking, freezing, or mixing milk at various temperatures). In that case, the fat globules tend to break, and fat becomes available to the environment, resulting in technological problems (such as inducing fat aggregates and changes to viscoelastic properties), possible oxidation and sensory defects (rancidity) (Fox, 2011a).

2.2.2 Proteins

The content of milk proteins is approximately 3,2 % (w/w). They are usually divided into casein (approx 82 % w/w) and whey proteins (approx 18 % w/w).

The term casein defines a family of phosphoproteins in milk present as calcium caseinate complex, which consists of several fractions – α_{s1}-, α_{s2}-, β-. and κ-. α_{s1} and β-caseins, the most and second-to-most present forms, are very susceptible to calcium ions and precipitate easily if present. α_{s2}-casein is less susceptible to the calcium ions yet still precipitates in their presence. As hydrophobic substances, their presence in water solution containing calcium ions is based on micelle formation. The micelle, a 3D "ball-like" arrangement, consists of several submicelles, similar ball-like structures made of folded phosphoproteins. The only difference between submicelles is the casein fraction (α_{s1}, α_{s2}, β) ratio. A micelle is held together by hydrophilic interactions provided by PO_4 groups (present as calcium phosphate), hydrophobic interactions and hydrogen and disulphide bonds. In the outer shell of a micelle, there is a high prevalence of κ-casein. It plays a crucial role in avoiding the precipitation of caseins in milk. It acts as a protecting agent in the outer part of a micelle. Its micelle-protecting aspect is lost during cheese manufacturing that uses enzymatic curd formation (more in Chapter 2.4) (Farrell, 2011).

Conversely, whey proteins stay soluble at pH 4,6 and resist enzymes used to coagulate whey proteins. The most prevalent are α-lactalbumin, β-lactoglobulin and serum albumin. In low quantities (except in colostrum), immunoglobulins are present to ensure the microbial stability of the milk. Some of the other proteins include lactoferrin and proteose peptones (Brew, 2011; Loveday and Sawyer, 2016).

2.2.3 Saccharides

In cow's milk, the primary saccharide representative is lactose, whose content is around 4,5-5,0 % (w/w). This disaccharide, β-D-Galactopyranosyl-(1-4)-D-glucose, is an energy source, provides osmotic pressure and positively affects calcium metabolism. It reacts with amino acids during milk treatment through Maillard reactions, altering the final product's organoleptic properties.

It is the primary substrate for all microbiota (both desirable and undesirable) to utilise. When desirable microbiota is used, such as lactic acid bacteria, lactose is generally metabolised into lactic acid. With its accumulation, the pH of the milk lowers, leading to coagulation of the casein and prolonged shelf life due to the inhibition of unwanted microbiota (Fox, 2011b).

Nowadays, lactose intolerance is more and more common due to the lower production of the enzyme lactase in the affected population. This enzyme breaks down lactose in the digestive tract into galactose and glucose. If not broken down, lactose, primarily in the colon, is a substrate for microbiota, which produce gases. Due to its osmotic properties, it also pulls more water into the colon. Both mechanisms contribute to the common symptoms: abdominal pain, bloating, diarrhoea, flatulence and nausea (Swallow, 2016).

2.2.4 Gases

While not mentioned often, freshly milked milk usually contains around 4,5 to 6 % (v/v) of gases, the majority being CO_2. This affects titratable acidity until the dissolved and environmental gases balance. To obtain accurate results, it is necessary to leave the milk still - for CO_2, which reacts acidly, content to lower, while N_2 and O_2 content rise. One risk concerning dissolved gases is that high O2 levels might compromise milk's oxidation stability and reduce its shelf life (Hardwood and Drake, 2022).

2.2.5 Minority Components

They are usually present in quantities under 1 % (w/w), mainly minerals and vitamins.

Minerals can be present in different forms: dissolved in the solution, colloid form, or bound to milk's components. These forms are in balance and affect the osmotic pressure (especially Na and K together with lactose) and size and properties of casein micelles (especially Ca, Mg, P, citrates). The content of Ca affects curd firmness during cheese making and the viscosity of the final fermented products. Mg, Fe, Zn, Cu, I, Co and Mo are present from the other minerals, usually bound to proteins (Gaucheron, 2011).

From vitamins, practically all of them are present since the milk has to provide all necessary nutrients for the calf. The important ones include carotenoids, which help to colour the milk; riboflavin, which gives whey its fluorescent properties; and vitamin C, which provides its antioxidant properties. Other minority components, such as enzymes (alkaline phosphatase, peroxidase, etc.) or hormones, may also be mentioned (Cifelli et al., 2011).

2.3 Coagulation using acid

As mentioned above, the casein isoelectric point lies closely around pH value 4,6. When the pH level of milk decreases, the calcium caseinate complex begins to break down, detaching Ca^{2+} ions into the solution. Protons attach to the casein, and its charge increases (from its original negative charge due to an excess of negatively charged groups). The casein charge becomes neutral as pH drops lower and lower, down to around the casein's isoelectric point (4,6 to 4,9, depending on the fraction). Due to the lack of same-charged ions between casein micelles, they do not repel each other during collisions and slam together. From a macro perspective, this can be observed as precipitation and formation of the curd.

Two main ways of acidifying milk or cream are adding acid directly or fermenting them. The first way is used to make a few varieties of cheese, such as paneer, queso blanco, mascarpone, or cottage cheese, by directly adding organic acids, such as lactic, acetic or citric acids. Most commonly, though, acidification is achieved by lactic acid produced by lactic acid bacteria by metabolising lactose. Additionally, in the latter way, most quark cheeses, cream cheeses, and fermented dairy products (yoghurts, kefir, acidified milk, etc.) are manufactured (Lucey, 2022).

2.4 Coagulation using enzymes

Another widespread way of obtaining casein curd is to disrupt the protective function of κ-casein by adding enzymes to pasteurised and standardised milk. Historically, most enzymes were part of rennet, but bacterial enzymes with similar activity are prevalent nowadays. The principle lies in specific proteolysis, breaking the bond 105-106 Phe-Met in κ-casein, splitting it in para-κ-casein (1-105) and casein macropeptide (106-169). These split parts of previously κ-casein no longer protect α_{s1}, α_{s2}, and β casein from Ca^{2+} ions, and the micelle's overall charge rises. From a macro perspective, casein precipitates and the curd is formed. This way, most aged and non-aged cheeses worldwide are made (Andrén, 2011).

2.5 Cream cheese manufacturing

As mentioned above, cream cheese manufacturing is based on acidifying the milk via fermentation with the help of lactic acid bacteria. Worldwide, two methods are commonly used – the "hot pack" and the "cold pack" methods, respectively:

The typical "hot pack" procedure includes standardisation (blending whole milk and cream), pasteurisation, homogenisation, fermentation, gelation due to accumulated lactic acid, and heating the curd to approximately 80 °C with shearing. The cream cheese is then directly packed (at 80 °C) and cooled to the final temperature (below 8 °C) to allow fat crystalization and product structuring. An outline of the process is shown in the Figure 1 (Tamime, 2009; Pombo, 2021):

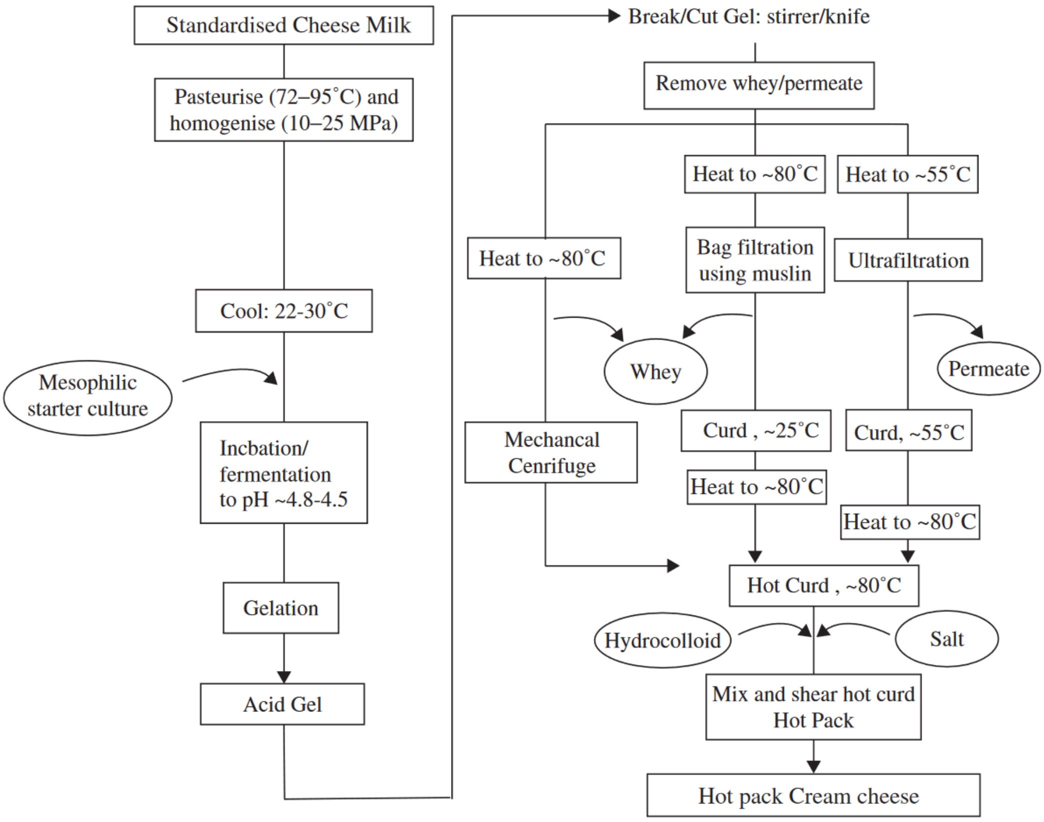

Figure 1: Outline of the manufacturing process for cream cheese (Tamime, 2009)

The term "cold pack" commonly refers to a procedure where the milk never reaches high temperatures, such as in the process above. From the "hot pack" procedure, the key differences are:

- Pasteurisation temperature (around 65 °C as opposed to 72-95 °C)
- Shearing temperatures (around 55 °C as opposed to 80 °C)
- Packing temperature (around 55 °C as opposed to 80 °C)

This procedure allows the final products to be more mealy, whereas the "hot pack" procedure produces a more soft and sticky texture (Pombo, 2021; Lundstedt, 1954).

3 FACTORS AFFECTING FUNCTIONAL FEATURES OF CREAM CHEESE

3.1 Composition

Increasing the moisture level of cream cheese has a notable impact on its consistency, resulting in a softer texture, which makes the final product harder to cut into slices (Ma et al., 2007). Consequently, when producing cream cheese with higher moisture content, such as low-fat cream cheese with approximately 65 % (w/w) compared to the 55 % (w/w) found in high-fat cream cheese, a different blend of hydrocolloids may enhance its elasticity (Section 3.5). European patents have outlined techniques for creating high-moisture cheese with the same or even greater firmness than cheese with lower moisture levels. These techniques involve utilising whey protein that has undergone high heat treatment and been polymerised at a higher pH level (7-9) (Lindstrom et al., 2005) or aggregated at a lower pH level (3,5-4,5) (Laye et al., 2002; Ma et al., 2007). The whey protein is then subjected to high-pressure homogenisation and can be used as a total or partial substitute for casein.

The impact of raising the pH of cream cheese and North American-style Neufchatel cheese was examined in experimental studies. In these studies, thin slices of retail samples were subjected to ammonium hydroxide for either 5 or 10 minutes. This treatment raised the pH from 4,6 to 5,4 after a 5-minute exposure and 5,8 after a 10-minute exposure. The slices were then vacuum-packed and stored at 4 °C for five days.

The findings revealed a significant inverse relationship between the pH level and the firmness of both types of cheese. The softening effect at higher pH levels was attributed to increased protein hydration. Consequently, when the cheese was re-acidified to a pH of 4,6 through exposure to hydrochloric acid, its firmness was restored. These results shed light on how altering the pH level away from the casein's isoelectric point, where the aggregation is most pronounced, can modify the texture properties of the cheese. This includes firmness, spreadability, and smoothness (Sadler, Murphy 2010; Karastogianni et al., 2016).

3.2 Homogenisation of cheese milk

The process of homogenising cheese milk results in the formation of a modified milk fat globule membrane, which consists of caseins and whey protein. This leads to the conversion of fat globules into pseudo-protein particles that become an essential part of the gel structure. As a result, it is anticipated that a higher degree of homogenisation would result in smaller emulsified fat globules that are more resistant to heat and shear forces during the heating and shearing of the gel after fermentation.

In practical terms, it has been observed that increasing the homogenisation pressure from 5 to 25 MPa (while keeping the first-stage pressure constant at 5 MPa) leads to cream cheeses that are firmer, more brittle, less spreadable, and exhibit reduced flow when heated (Guinee et al., 2000).

3.3 Holding the hot curd at high temperature while shearing

At a commercial level, modifying the duration of holding the hot curd at a high temperature (while shearing and stirring) is a significant factor in adjusting the textural qualities of cream cheese. As the holding time is prolonged, the product becomes progressively firmer, shorter, and more fragile, with a tendency to develop cracks. This response to holding is similar to the "over creaming" process in processed cheese, where prolonged processing (at temperatures of 75-85 °C) leads to a thicker product with a firmer texture, reduced ability to stretch, and decreased meltability. These changes are attributed to increased fat emulsification and protein aggregation caused by hydrophobic interaction at high temperatures. These effects align with the increased firmness observed in cream cheese through homogenisation and slow cooling compared to fast cooling, as discussed in the subsequent sections (Guinee et al., 2004; Sanchez et al., 1994).

3.4 Homogenisation of the hot molten cream cheese

The application of increasing homogenisation pressures to the hot molten cream cheese curd, ranging from 0 to 20 MPa, has been found to have a significant impact on product firmness and viscosity. Additionally, high homogenisation pressures can lead to a decrease in the perception of sandiness. Based on the research, it is concluded that homogenisation at 15 MPa yields the best textural quality (Tamine, 2009; Ortega-Fleitas et al., 2000).

These trends can be attributed to the reduction in the size of fat globules caused by increasing homogenisation pressure. This reduction in size results in a decreased displacement of the structure-forming protein-covered fat particles within the cheese matrix. This effect is particularly noticeable when considering a fixed solid-to-liquid fat ratio and the application of stress (assuming that the degree of displacement of a fat particle is proportional to its radius, approximately equal to πr) (Ortega-Fleitas et al., 2000; Kůrová et al., 2022).

3.5 Addition of whey protein

Patents have revealed a new method for producing exceptionally firm cream cheeses. This is achieved by substituting casein with polymerised whey proteins created by heating aqueous dispersions (5 to 20 %, w/w) at temperatures ranging from 70 to 95 °C. The pH values during this process should be in the range of 7,0 to 9,0, facilitating the formation of intermolecular covalent disulphide bonds. These findings were documented in studies conducted by Lindstrom et al. (2005) and Ma et al. (2007).

Sanchez et al. (1996) found that incorporating a commercial whey protein concentrate (WPC, containing 65 g protein per 100 g) into hot curd during the heating stage (85°C) after fermentation resulted in a significant decrease in the firmness of the resulting cream cheese (approximately 15 % reduction). This was determined by cone penetrometry after storing the cheese at 5 °C for 9 days. Additionally, when the temperature at which the product was cooled before storage at 4 °C was lowered from 40 to 15 °C, the cream cheese with added WPC exhibited a more significant breakdown, appearing softer, shinier, and stickier compared to the control product with similar overall composition (except for a lower pH). The addition of WPC was attributed to the formation of aggregates of whey proteins, which disrupted network formation during cooling and caused the breakdown of casein and casein-covered fat aggregates. These findings highlight the significance of pH in influencing the interactions between heat-denatured whey proteins and their impact on the final product's structure.

3.6 Hydrocolloids

In cream cheese manufacturing, various hydrocolloids can be used. Some examples are locust bean gum, xanthan gum, sodium alginate, tara gum or κ-carrageenan. When considering the role of hydrocolloids in cream cheese, it is helpful to define the product during the addition of hydrocolloids: a system with low pH and high temperature, which also has a high apparent concentration of protein due to the milk being homogenised before fermentation and gelation (Tamime, 2009).

This system is highly susceptible to isoelectric aggregation of caseins (and whey proteins if they are included), leading to large aggregates of protein and/or fat particles covered in protein and syneresis. As a result, the cream cheese produced would be relatively heterogeneous, with a granular or grainy consistency and some separation of serum. Therefore, the main functions of hydrocolloids in cream cheese are as follows:

- Binding water, thus, increases the viscosity of the aqueous phase and restricts the movement of protein and protein-fat particles.
- The product is structured to achieve the desired level of viscoelasticity and rheological characteristics. This can be accomplished by adjusting firmness, brittleness, spreadability, and shear thinning. For example, this can be achieved by forming a weak gel or entanglement of polymers or binding to the protein and protein-fat particles to create a particle network.
- Minimises the risk of a granular or grainy structure by limiting the extent of interaction between protein and protein-fat particles.

In general, a combination of hydrocolloids is most suitable for these functions due to the synergistic effects that enhance the functionality of the blend. For instance, anionic hydrocolloids like κ-carrageenan or xanthan gum minimise the phase separation effects of neutral hydrocolloids such as guar gum or locust bean gum with casein. Meanwhile, neutral hydrocolloids contribute to achieving the desired level of “body" or firmness without excessive stickiness or rigidity through their limited phase separation. When used individually, anionic hydrocolloids bind with casein and increase its negative charge, resulting in a more spreadable consistency with reduced rigidity.

Furthermore, the ratio of galactose to mannose plays a role in altering the elastic and viscous character of the final product. Guar gum has a galactose-to-mannose ratio of 1:2, while locust bean gum has a ratio of 1:4. This difference allows for convenient manipulation of the elastic-to-viscous characteristics ratio. A lower galactose content found in locust bean gum (branching off the mannose chain) enables the alignment of chains and results in a closely packed arrangement with stronger intermolecular interactions. Consequently, cream cheese made with locust bean gum exhibits a firmer and more elastic texture than that manufactured with guar gum or tara gum (Hunt et al., 1997; Vincova et al., 2023).

In the production of cream cheese, a combination of xanthan gum with guar gum and/or locust bean gum is often used to achieve a smooth and creamy texture and a desirable body and sliceability. According to Laye et al., in 2005, a similar blend enhanced the baking performance of low-protein cream cheese. Therefore, in practical applications, LBG, guar gum, and xanthan gum are the most commonly utilised additives in cream cheese production. These gum blends' wide usage is due to their ability to create diverse textures and consistencies, ranging from spreadable to firm and gummy, suitable for various culinary applications. Achieving different textures and consistencies requires adjusting the proportions of the gums in the blend.

4 THEORY BACKGROUND FOR SELECTED PHYSICAL AND CHEMICAL ANALYSES

4.1 pH

The acidity and alkalinity of aqueous solutions, where most natural reactions occur, are determined by the concentration of hydronium (H_3O^+) and hydroxyl (OH^-) ions, per the Arrhenius definition of acids and bases. The former is measured using the pH scale, initially proposed by Danish chemist Søren Peder Lauritz Sørensen in 1909 and later revised in 1924 to align with the definitions used in electrochemical cell measurements. pH is the decimal logarithm of the reciprocal of the hydrogen ion activity, a_{H+}, in a given medium:

$$pH = -log_{10}\alpha_{H^+}$$

For significantly diluted solutions, pH can be directly related to the proton concentration:

$$pH = -\,log_{10}c_{H^+}$$

pH is a measurable parameter, and the electronic device used to measure the pH of a liquid (or, in some cases, semisolid compounds such as cream cheese) is referred to as a pH meter. The primary component of a typical pH meter is its unique measuring probe, which can be a glass electrode or, for specific applications, an ion-selective field-effect transistor (ISFET). This probe is connected to an electronic meter that calculates and displays the pH reading. All pH meters undergo calibration using buffer solutions with known hydrogen ion activity. The International Union of Pure and Applied Chemistry (IUPAC) has recommended using a set of buffer solutions (operational pH standards) for this purpose (Sadler and Murphy, 2010; Karastogianni et al., 2016).

4.2 Dry matter

As mentioned in Chapter 3.6, water content in the cream cheese plays a significant role in determining its physical properties. The dry matter is usually measured using the gravimetric method, although several other methods (such as Karl Fisher Titration or NIR spectroscopy) do exist.

The gravimetric method is determined by the norm ISO 5534:2004. The analysis principle is drying the sample at 102 °C until constant weight is achieved. The dry matter is calculated as per cent of the original weight from weighing the sample before and after drying. The norm requires 3,0 g of the sample to be weighed on an analytical balance scale with 0,1 mg accuracy (ISO, 2004).

4.3 Water activity

Water activity (a_w) refers to the ratio of the partial vapour pressure of water in a given solution to that of a standard state of pure water. This is a familiar concept in food science, where the standard state is typically defined as pure water at an equivalent temperature. According to this definition, the water activity of pure distilled water is precisely one. Essentially, water activity represents the thermodynamic behaviour of water as a solvent and mirrors the relative humidity of the surrounding air after it reaches equilibrium (ISO, 2017a).

Water activity is often a crucial control point within Hazard Analysis and Critical Control Points (HACCP) schemes. Regular food product samples are taken from the production site and tested to verify that the water activity values fall within a predetermined range. This is done to ensure both the quality and safety of food items. These measurements, often completed in a few minutes, are conducted routinely in most major food manufacturing establishments (Center for Food Safety and Applied Nutrition, 2024).

The norm ISO 18787 determines the water activity analysis: "Foodstuffs – Determination of water activity". According to the norm, the measurement might be based on determining the water dew point, the electrolyte's electrical conductivity change, or the polymer's permittivity change. It also determines that the measuring device's output must be linear on the scale from 0 to 1, have a temperature regulation system so that the sample is measured at 25 ± 1 °C, display at least 10^{-3} a_w units and have an internal resolution of at least 10^{-4} a_w units (ISO, 2017a).

4.4 Texture Analysis

Due to its versatile nature, texture analysis has found widespread use across various sectors to examine a specific or broad spectrum of features or attributes linked to the behaviour of a material - how it moves, fractures, flows, adheres, flexes, and so on.

Prominent manufacturing firms regularly utilise texture analysis methodologies to create new products and as an integral part of quality assurance at every manufacturing stage. They conduct extensive measurements to assess raw materials or additives, semi-finished goods, packaging, and final products.

This method is an efficient way to understand the impact of raw material, additive quality, or formula or processing parameter alterations on the final product's acceptability. This could be measuring the sensory experience of food in the mouth, the flow characteristics of creams and pastes, the susceptibility to fracture or flexing of a product, or the stickiness of adhesives (Stable Micro Systems, © 1989-2024).

Various examinations for texture analysis, such as the Bloom Strength evaluation for gelatinous gels, are acknowledged globally as International Standards. Conversely, others have gained recognition as standard assessments within specific industries, like the Texture Profile Analysis frequently used for many food items (Gelatin Manufacturers Institute of America, Inc., 2019; Meullenet et al., 1998).

The effectiveness of these assessments relies heavily on the Texture Analyser's robustness and the appropriate choice of testing technique. It also greatly depends on the manufacturing precision of the probe or attachment utilised and the analytical software's accuracy in delivering results unambiguously and succinctly.

The primary objective of numerous texture research initiatives is to construct one or multiple mechanical evaluations that have the potential to supplant human sensory assessment as a method for texture analysis. Examinations that provide primary and experimental product traits are thoroughly established, while the significance of comprehensive imitative test methods is also growing. The importance of these methods lies in their ability to mimic real-world scenarios, facilitating much easier data interpretation (Stable Micro Systems, © 1989-2024; Saint-Eve et al., 2015; Chen and Opara, 2013).

4.5 Viscoelastic Properties

The assessment of viscoelastic characteristics is an appropriate method to gauge the rheological attributes of cream cheeses, given their hybrid nature of viscosity and elasticity. The underlying principle of this approach involves the deliberate distortion of a modelled sample, followed by the scrutiny of its flow characteristics. This evaluation process determines the shear storage (G´) and shear loss (G´´) moduli.

The storage modulus indicates the sample's elasticity level, while the loss modulus signifies its degree of viscosity. The phase angle, a significant metric in this process, can be derived from the ratio of these two moduli. Notably, as the phase angle value increases, there is a corresponding decrease in the sample's elasticity proportion.

The phase angle can be calculated using the subsequent correlation:

$$\tan\delta = \frac{G''}{G'}$$

Furthermore, the samples' resistance to deformation can be calculated as the complex module G^* (Černíková et al., 2022):

$$G^* = \sqrt{(G)' + (G)''}$$

4.6 Tribology

Tribology, a relatively recent technique within the food industry, is employed to assess the textural attributes of goods. The foundation for tribological examination lies in the interaction of two surfaces. When consuming food, one surface would be the tongue, while the other would be the mouth's palate. Hence, tribology can be defined as resistance when two interacting surfaces - the tongue and the palate - are pressured together (Bhandari et al., 2013). Numerous studies are available that delve into the tribology of dairy products, revealing that those with a higher fat content possess a lesser friction coefficient than low-fat alternatives (Ningtyas et al., 2017).

Tribology also serves as a tool for identifying undesirable substances in food items, including melamine, frequently incorporated into baby formula to augment its protein content. Several techniques exist to spot these unwanted elements, such as mass spectrophotometry or liquid chromatography. However, these procedures are often lengthy and expensive. Hence, the recent preference leans towards tribology due to its simplicity and cost-effectiveness in performing the analysis (Sethupathy et al., 2020).

4.7 Colour

Colour consistency in dairy products, particularly in cream cheese, is a crucial indicator of quality and freshness, underscoring the importance of precision in colour measurement. Instrumental methods, such as spectrophotometers, offer objective and precise evaluations over traditional visual assessments. This ensures the uniformity crucial for consumer satisfaction and product quality in the milk and cream cheese industry. The significance of colour measurement extends beyond aesthetics, as variations can suggest changes in the production process or ingredient quality, potentially affecting the perceived flavour of cream cheese. High-quality cream cheese is characterised not only by its consistent colour but also by its lightly acidic and cultured diacetyl flavour, smooth texture, and spreadability at room temperature, making proper colour measurement essential for maintaining product standards (Sensegood Instruments Private Limited, 2023; Phadungath, 2005).

The foundational principles of colour measurement in the food industry, including cream cheese, are colourimetry and spectrophotometry. Colourimetry involves quantifying colour by measuring the three primary colour components (red, green, and blue) the human eye perceives. Conversely, spectrophotometry measures the spectral reflectance or transmittance across the visible light spectrum (400 nm to 700 nm), providing a detailed and accurate colour assessment.

Various instruments and techniques are employed for precise colour measurement. Standard tools include traditional visible spectrophotometers, Visible and Near-Infrared Reflectance (VNIR) Spectrophotometry, and Tristimulus Colorimetry. These instruments are essential in various stages of dairy processing, from ante-processing to quality control, ensuring that the colour of cream cheese meets industry standards (Dufossé, 2010).

Colour identification can be achieved through a series of numerical scales present in what is referred to as a colour space. A frequently utilised colour space is the CIE $L^*a^*b^*$, where the lightness L^* (also known as brightness) corresponds to values ranging from 0-100 (with 0 representing black and 100 representing white). The coordinates $a^*$and b^* signify distinct parts of the wavelength spectrum, positioned along the horizontal axis, which determines the hue and saturation of the colour. The parameter a^* represents the spectrum ranging from red to green (from green being $-a^*$ to red being $+a^*$), and the parameter b^* represents the spectrum ranging from yellow to blue (from blue being $-b^*$ to yellow being $+b^*$) (Kuehni, 1996; Wang and Sun, 2003).

II. ANALYSIS

5 OBJECTIVES OF THE THESIS

The objectives of the current thesis were set as follows:

- Manufacture three samples of cream cheese with a fat content of 10,0, 15,0 and 20,0 % (w/w)
- Manufacture three samples of cream cheese with a fat content of 10,0, 15,0 and 20,0 % (w/w) with the addition of citrus fibre at 1,0 % (w/w)
- Perform basic chemical, textural, rheological, and sensory analyses
- Conclude if citrus fibre is a viable option as a thickening ingredient in hot-packed cream cheeses

6 CREAM CHEESE MANUFACTURING

6.1 Parameters of the model samples and utilised materials

Selected analyses were performed on the six designed samples. The target values were as follows in Table 1 below:

Table 1: Target values of the model cream cheese samples (%, w/w)

Sample number	Dry matter	Total fat	Fat in dry matter	NaCl	Citrus fibre
1	30,0	10,0	33,3	1,0	0
2	30,0	15,0	50,0	1,0	0
3	30,0	20,0	66,6	1,0	0
4	30,0	10,0	33,3	1,0	1,0
5	30,0	15,0	50,0	1,0	1,0
6	30,0	20,0	66,6	1,0	1,0

To achieve such compositions, the following products were chosen as ingredients (Table 2, Figure 2):

Table 2: Parameters of the selected products (%, w/w)

Product	Dry matter	Total fat
Quark cheese	22,0	2,0
Crème fraîche	43,0	36,0
Water	0	0
NaCl	99,5	0
Citrus fibre	99,5	0

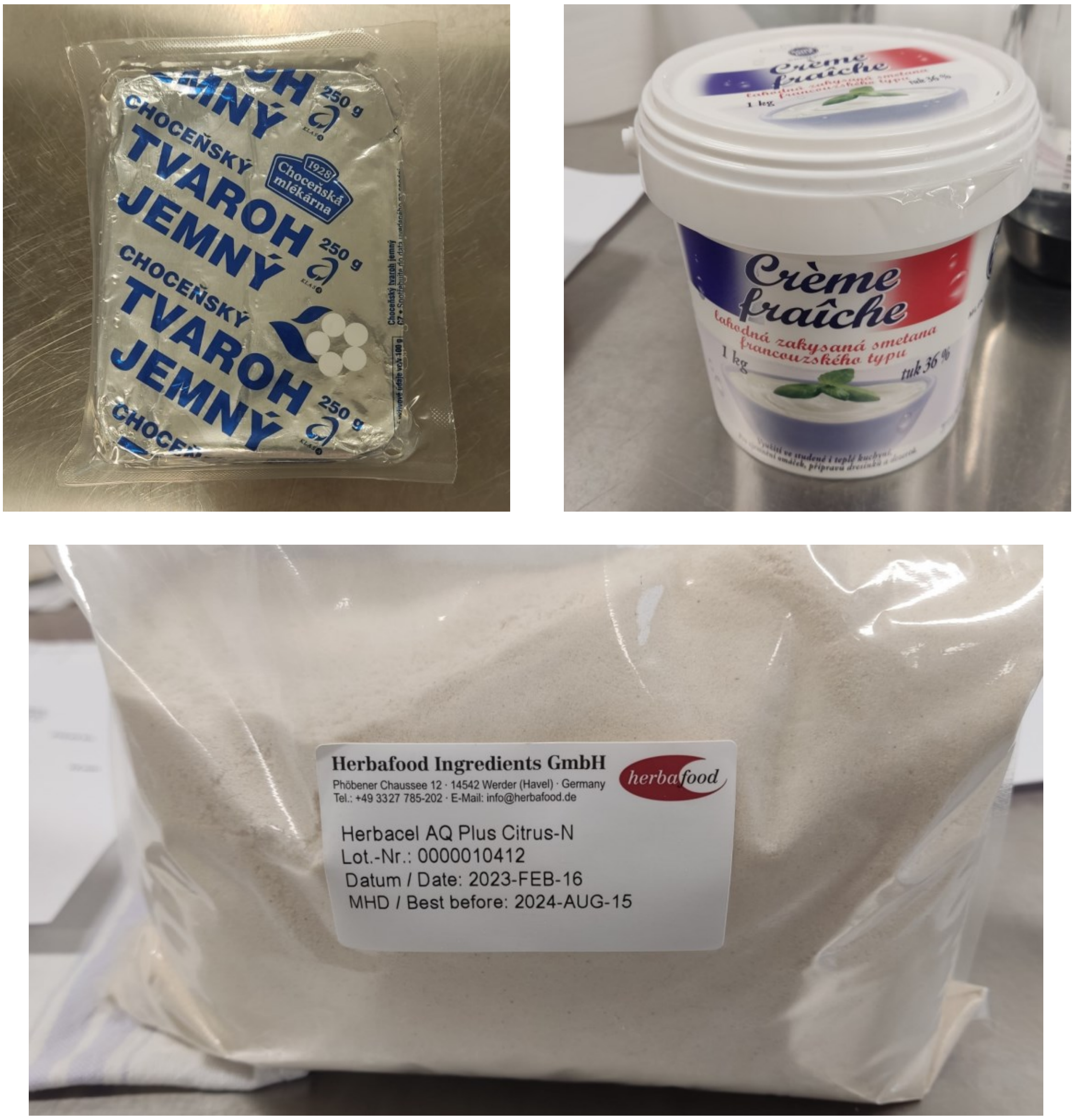

Figure 2: Ingredients used in cream cheese manufacturing (quark cheese: top left; crème fraîche: top right, citrus fibre: bottom – author's archive)

Obtaining weights of the individual ingredients can be easily calculated with the following system of equations:

$$m_{cheese} \times S_{cheese} + m_{creme} \times S_{creme} = S - m_{salt} \times S_{salt} - m_{fibre} \times S_{fibre}$$

$$m_{cheese} \times F_{cheese} + m_{creme} \times F_{creme} = F$$

$$m_{cheese} + m_{creme} + m_{water} = m - m_{salt} - m_{fibre}$$

Where m_{cheese} stands for the calculated weight of the quark cheese, m_{creme} stands for the calculated weight of the crème fraîche, m_{water} stands for the calculated weight of the water, and *m* stands for the total weight of the batch. *S,* with their respective indexes, stands for individual ingredients' dry matter and total dry matter. *F,* with their respective indexes, stands for individual ingredients' fat contents and total fat content.

The following example is a calculation of the sample 6. The batch size has been chosen as 1000 g.

$$m_{cheese} \times 0{,}22 + m_{creme} \times 0{,}43 = 300 - 10 * 0{,}995 - 10 * 0{,}995$$

$$m_{cheese} \times 0{,}02 + m_{creme} \times 0{,}36 = 200$$

$$m_{cheese} + m_{creme} + m_{water} = 1000 - 10 - 10$$

Solving the system, the final weights for sample 6 are:

- m_{cheese} = 210,14 g
- m_{creme} = 543,88 g
- m_{water} = 225,98 g

Working with natural ingredients, it is possible to round the calculated weights to the nearest 5 g while retaining sufficient accuracy. Table 3 below displays all final recipes for the samples. In the case of samples 1 and 4, solving the systems of equations gave negative weights for added water, suggesting that some water should be evaporated from the system to achieve the desired composition. These compositions were manually adjusted for slightly lower dry matter and higher fat content to eliminate this issue (minimum of 29 %, w/w, solids and a maximum of 11 %, w/w, fat).

Table 3: Sample recipes (%, w/w)

Sample number (abbr.)	**Quark cheese**	**Crème fraîche**	**Water**	**NaCl**	**Citrus fibre**
1 (10C)	72,5	26,5	0	1,0	0
2 (15C)	56,5	38,5	4,0	1,0	0
3 (20C)	26,0	54,0	19,0	1,0	0
4 (10F)	72,5	25,5	0	1,0	1,0
5 (15F)	51,5	39,0	7,5	1,0	1,0
6 (20F)	21,0	54,5	22,5	1,0	1,0

6.2 Cream Cheese Manufacturing

The samples were made according to the recipes in Table 3 above. Following the process chart in Figure 3 below, the manufacturing proceeded in order:

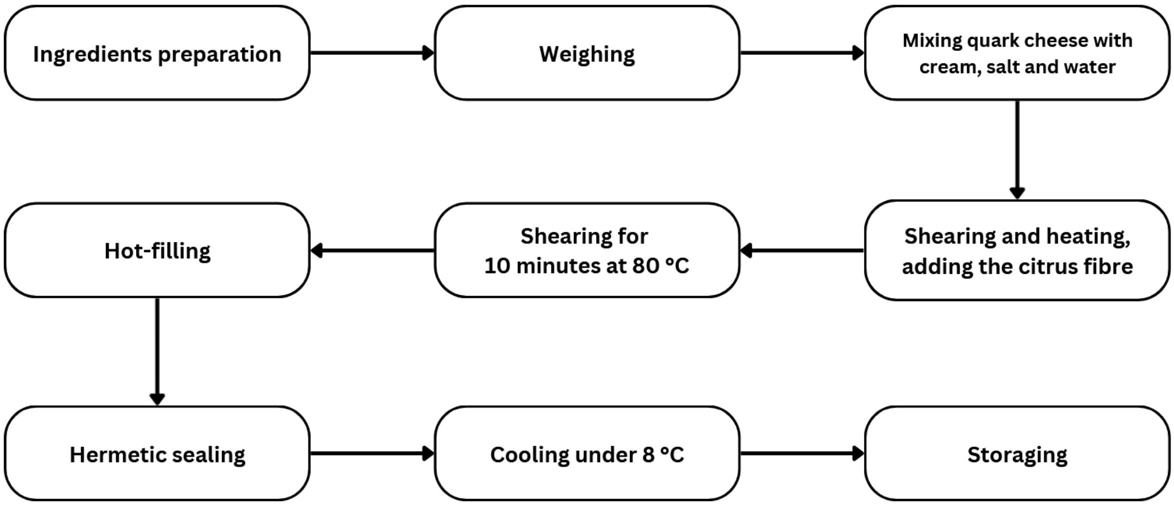

Figure 3: Cream cheese manufacturing process chart

1. Obtaining the necessary ingredients and equipment
2. Weighing the ingredients on an analytic scale according to the Table 3
3. Mixing the quark cheese with crème fraîche, salt and water
4. Shearing at 5000 RPM (Vorwerk Thermomix®), simultaneously heating the batch, and adding the citrus fibre in 3-4 doses
5. Shearing at 80 °C for 10 minutes
6. After the period, immediately filling into aluminium containers, hermetically sealing and storing in a refrigerator until analysis.

After three days, all six samples developed a distinct cream cheese texture and flavour upon checkup. It is possible to state that all samples were manufactured successfully. The samples were photographed, and records are available in Figure 4 below:

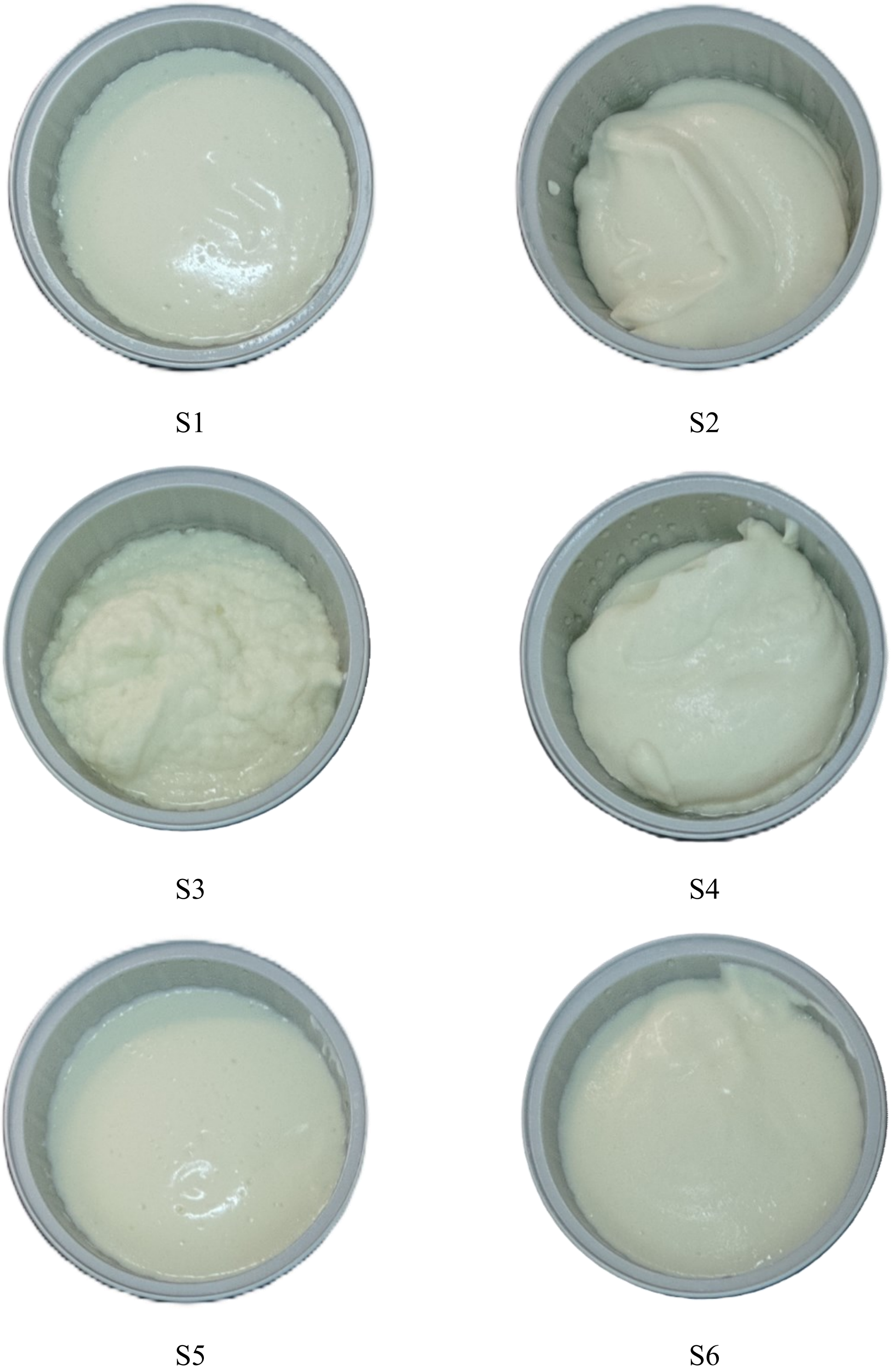

Figure 4: Manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F) – author's archive

7 METHODOLOGY

All measurements were conducted using the manufactured samples described above and took place 5 to 9 days after the manufacturing.

7.1 Dry matter

The dry matter measurement proceeded according to the norm ISO 5534:2004 (ISO, 2004). An aluminium container filled with approximately 20 g of sand has been weighed on an analytical scale with a precision of 0,1 mg. Then, the container was filled with approximately 3,0 g of the sample, weighed again, and dried in a dryer at 102 °C until constant mass (for approximately 5 hours). Upon removal, the sample was placed into a desiccator to cool down to lab temperature and remove any remaining humidity. After that, the dried sample was weighed, and the dry matter was calculated using the formula:

$$w_t = \frac{m_2 - m_0}{m_1 - m_0} \times 100\ \%$$

Where: w_t stands for the dry matter in % (w/w), m_0 for the mass of the aluminium container (in grams), m_1 for the container filled with the sample before drying (in grams) and m_2 for the container with the sample after drying (in grams).

All samples have been measured three times, the standard deviation has been calculated using the formula below, and the results are expressed to two decimal places ± the standard deviation:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

Where σ stands for the standard deviation, N for the number of measurements, x_i for one particular measurement and $\bar{x}$ for the average of the measurements from i to N.

7.2 Water activity

The water activity measurement proceeded according to the ISO 18787 (ISO, 2017a) norm, using the AquaLab Dew Point Water Activity Meter 4TE. Before measurement, all samples were tempered to 25 °C and the Activity Meter was calibrated using a standardised solution with the a_w of 0,9200.

A single measurement consisted of carefully loading the sample into the measurement tray, placing it into the Activity Meter and measuring. Every sample was measured three times, and in between every set, the Activity Meter was recalibrated using the standardised solution. The standard deviation was calculated the same way as in Chapter 7.1, and the results are expressed to three decimal places ± the standard deviation.

7.3 pH

The pH measurement was conducted using the HI 99161 pH meter from the company Foodcare®. Before the measurement, all samples were tempered to 20 °C and the pH meter was calibrated using pH 4 and pH 7 buffer solutions. A single measurement consisted of inserting the probe directly into the sample, registering the value, cleaning the probe with distilled water, and drying it.

Every sample was measured six times, and every measurement was taken from a section of the sample different from the previous measurements. The standard deviation was calculated the same way as in Chapter 7.1, and the results are expressed to two decimal places ± the standard deviation.

7.4 Texture Profile Analysis and Spreadability

The parameters examined via texture profile analysis (TPA) for the thesis included the hardness, cohesiveness, stickiness, elasticity, chewiness, and gumminess of cream cheese sample models. The graph in Figure 5 illustrates the texture profile analysis curve, highlighting the relationship between the force required for force (N) and the time (s) these textural parameters assessed.

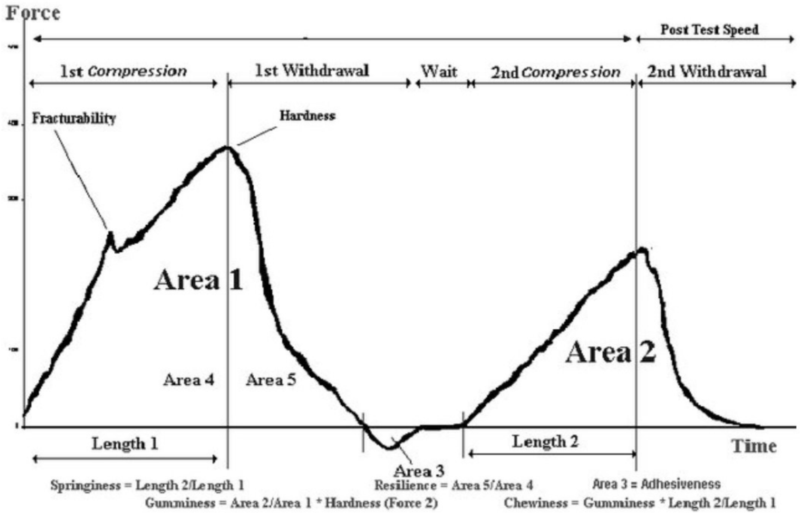

Figure 5: Graphic explanation of TPA - force dependency on time (Aday et al., 2010)

The initial texture characteristic studied was the hardness or strength of the processed cheeses. The hardness signifies the necessary force needed to achieve deformation or penetration of the analysed product. From a sensory analysis perspective, hardness is discerned through food compression between the teeth and palate while eating. As per the texture profile analysis curve, the hardness of a product can be derived from the maximum peak value (A1). If these maximum peak values are more significant, the product has a higher hardness level and consequently requires more force to deform the processed cheese (Szczesniak, 2002).

The next aspect that was closely observed is cohesiveness, which is also known as cohesiveness. This is a different texture property and it can be defined as the power of the internal bonds that form a specific food. Cohesiveness can be calculated from the ratio of the area of A2 to A1, as gleaned from the curve of the texture profile analysis (Lee and Klostermeyer, 2001).

Relative stickiness is yet another fundamental parameter of texture. It illustrates the effort needed to counteract the pulling forces between the surface of the food and the probe surface. Essentially, it denotes the force necessary to detach any adhering substance from a material, for instance, a fragment of food lodged onto the teeth or palate within the oral cavity. This parameter can also be determined by the peak area ratio in the texture profile analysis curve, more specifically by the ratio of the absolute value of the negative peak area A3 to the positive peak area A1 (Lee and Klostermeyer, 2001).

Other factors that define the texture of a substance include its elasticity, which is determined by how quickly the material reverts to its original form after being deformed. Another critical characteristic is chewability, which describes the energy needed to masticate solid foods to the point where they are safe and comfortable to swallow. Lastly, gumminess is a parameter that quantifies the energy necessary for the optimal breakdown of food in the oral cavity (Salek et al., 2020).

All samples were subjected to the TPA and spreadability tests. The texture analyser TA.XT Plus (Stable Micro Systems Ltd.®, based in Godalming, UK) was used for the measurements. The analysis involved cream cheese samples, which were examined in aluminium containers after the detachable lid was removed for TPA, and for spreadability tests, the samples were carefully spread into a P/60C antipole container. A cylindrical stainless steel probe with a diameter of 20 mm was used for TPA, while a P/60C conical probe was employed to measure spreadability.

The analytical procedure hinged on the double penetration of the probe into each sample, delving to a depth of 10 mm at a velocity of 2 $mm.s^{-1}$. This was done with an initial force of 5 g and a strain capacity of 20 %. A peak chart was produced throughout this process and during the probe's penetration. This graph represented the stress curve relating to the textural parameters corresponding to the analysed cream cheese sample.

7.5 Viscoelastic Properties

The viscoelastic properties measurements of the manufactured samples were performed on the Malvern Kinexus Pro+® rheometer using the plate-plate geometry of diameter 35 mm. The gap during measurement was set to 1 mm, and the shear stress amplitude was set to 5,0 Pa. Before the measurement, the samples (approximately 2 g) were allowed to reach room temperature (25 °C) over 4 hours. Then, a sample was spread out between the geometry's plates and tempered to 37 °C for 5 minutes. During measurement, shear storage and shear loss moduli dependency on the frequency (0,1-100 Hz) was recorded, and the data was measured five times per decade. After the measurement, complex module G^* and phase angle tan δ were calculated.

7.6 Tribology

Cream cheeses' tribological properties were evaluated using the Malvern Kinexus Pro+® rheometer on a coarse plastic surface (3M Transpore surgical tape 1527-0), which replicated the texture of a human tongue. As per Nguyen et al. (2016), this tape shares characteristics similar to those of the human tongue with wetting and surface roughness. The tape was trimmed into a square (50 mm x 50 mm), placed and pressed securely on top of the base plate tribological geometry. On this, the sample (approximately 2 g) was spread out, covering the tape with a layer roughly 2 mm thick.

Following every measurement, the tape was renewed, and the surface was meticulously cleaned using deionised water before being dried with lab wipes. The tested cream cheese samples were allowed to reach room temperature (25 °C) over 4 hours in anticipation of the tribological measurements conducted under the corresponding simulation circumstances of an oral environment at 37 °C. These measurements were carried out with a chosen axial force of 1 N over a distance of 27,17 m across 100 cycles at an increasing speed from 0,015 to 1463,85 $mm.s^{-1}$ (from 0,001 to 97,59 $rad.s^{-1}$ with the radius of the tribological geometry of 15 mm).

The frictional (or lubrication) traits of the cream cheese samples were identified through the coefficient of friction (CoF), which is essentially the fraction of friction stress to the normal stress, represented as $\mu = dF/dN$, where F represents torque (Nm), and N is equal to 1 N. The resulting friction curves were attained by charting CoF against the sliding velocity. The minimum CoF (CoF_{min}) and the initial CoF (CoF_i) were obtained from this graph.

7.7 In-situ Manufacturing

In-situ measurements were carried out to gain in-depth knowledge about the formation of cream cheese texture. The Malvern Kinexus Pro+® rheometer was used in the in-situ manufacturing, utilising a Peltier Cylinder Cartridge coupled with a shearing mechanism. Before each test, the cartridge underwent a thorough cleaning process using a soap-water mixture, followed by a rinse with distilled water and denatured ethanol before being dried.

The sample (roughly 35 g adhering to the proportions detailed in Table 3) was placed into the cartridge using a miniature scoop. It was tempered to a temperature of 40 °C whilst being stirred at a rate of 100 RPM. Subsequently, the specimen was concurrently heated to a temperature of 80 °C over a span of 8 minutes while being subjected to a shear speed of 500 RPM, with viscosity readings taken every 5 seconds. Once the internal temperature hit 80 °C, a shear duration of 10 minutes was induced, followed by a cooling period back to 40 °C over an additional 8 minutes, all the while keeping up with the viscosity readings throughout the entire procedure. The gathered data was later evaluated by plotting a graph of complex viscosity against internal temperature.

7.8 Colour

The colour assessment of the cream cheese was performed in a controlled lab environment utilising an UlraScan PRO spectrophotometer from HunterLab. Before any readings were taken, adjusting the device to black ($L^* = 0$), white ($L^* = 100$), and daylight (D65) standards was crucial. Each sample's resultant coordinate values were determined by altering the strength of the rays that passed through. In the scope of this thesis, all cream cheese samples went through three rounds of analysis, with the recorded values subsequently evaluated within the framework of the CIE $L^*a^*b^*$ colour space. Additionally, hue (h) and chroma (C*) were calculated.

7.9 Sensory Analysis

The scope of the sensory analysis was to determine six aspects of the manufactured samples on six five-point scales:

- Appearance (1 – perfect, 5 – unacceptable)
- Consistency (1 – perfect, 5 – unacceptable)
- Spreadability (1 – perfect, 5 – unacceptable)
- Hardness (1 – too hard, 3 – neither hard nor soft, 5 – too soft)
- Flavour (1 – perfect, 5 – unacceptable)
- Off-flavours (1 – without off-flavours or negligible, 5 – dominant)

The sensory analysis was conducted in order with ISO 6658 (ISO, 2017b) in Brno, Czechia, on a sample of 21 informed assessors aged from 25 to 60 years. Both genders and assessors' affinity towards cream cheese were equally represented. The samples were served anonymously under three-digit codes on a white plate, with a spoon, knife and a neutraliser (pastry and still water). The assessors were asked to rate the samples according to the questionnaire listed in Appendix I.

8 RESULTS AND DISCUSSION

8.1 Dry matter

The dry matter content of the manufactured samples was measured according to Section 7.1. The dry matter percentage and standard deviation results are available below in Figure 6:

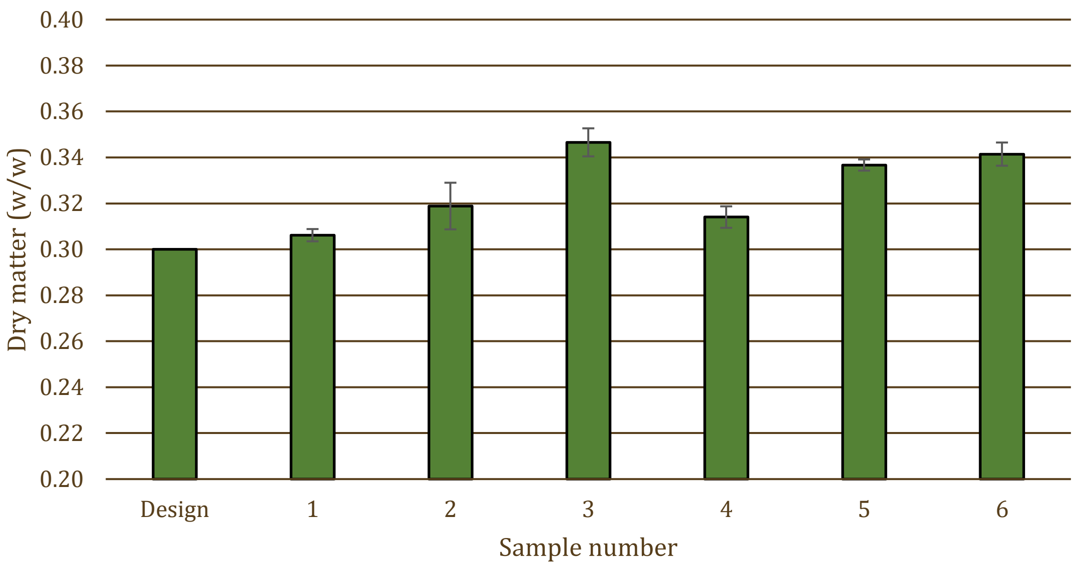

Figure 6: Measured dry matter (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

The justification for such high dry matter dispersity from the original design (30 %, w/w) has been attributed to the fact that the ingredients do not precisely match the stated parameters. Both increased fat content and the usage of citrus fibre slightly increased the dry matter of the samples, suggesting that crème fraîche may have had somewhat higher dry matter than stated and that adding citrus fibre may have caused more intense evaporation during manufacturing.

Based on this fact, no additional statistical analysis was performed since apparent differences between samples were present.

8.2 Water Activity

The water activity of the manufactured samples was measured according to Section 7.2. The results and standard deviation are available below in Figure 7:

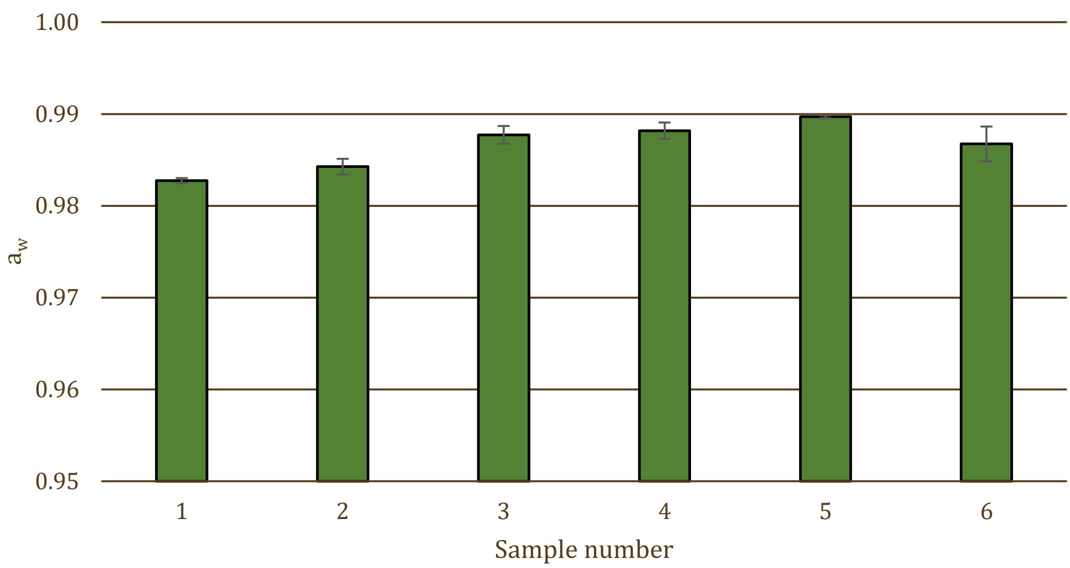

Figure 7: Measured water activity (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

As expected, water availability for any microbial activity is high in cream cheeses as it is not even lowered to 0,93. From this point of view, cream cheeses fall into foods highly susceptible to microbial spoilage. The packaging has to be airtight, and all these foods must be stored under refrigeration and have a relatively short shelf life.

Statistical analysis via ANOVA (Analysis of Variance) test has shown the F-statistic to be 13,14 and a p-value of $1{,}6.10^{-4}$, suggesting a statistical difference between the samples at pretty much any chosen α (as long as the p-value is lower as α, this indicates a statistically significant difference between the group of samples). Below in Table 4 are the p-values of sample pairs obtained through the post-hoc Tukey HSD (honestly significant difference) test:

Table 4: Tukey HSD results for statistical a_w differences (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Sample pair combination	S1-S2	S1-S3	S1-S4	S1-S5	S1-S6	S2-S3	S2-S4	S2-S5
p-value	0,66	0,004	0,002	0,0001	0,02	0,045	0,02	0,001
Sample pair combination	S2-S6	S3-S4	S3-S5	S3-S6	S4-S5	S4-S6	S5-S6	-
p-value	0,22	0,99	0,43	0,91	0,66	0,72	0,11	-

The analysis showed that samples 1 and 2 significantly differ at α = 0,05 from the other samples. This suggests that higher fat content and citrus fibre addition may promote water availability in the final product. However, this effect is insignificant to the product's shelf life since other means (such as high-temperature treatment and storage under refrigeration) are used to counter this.

8.3 pH

The pH level of the manufactured samples was measured according to Section 7.3. The results and standard deviation are available below in Figure 8:

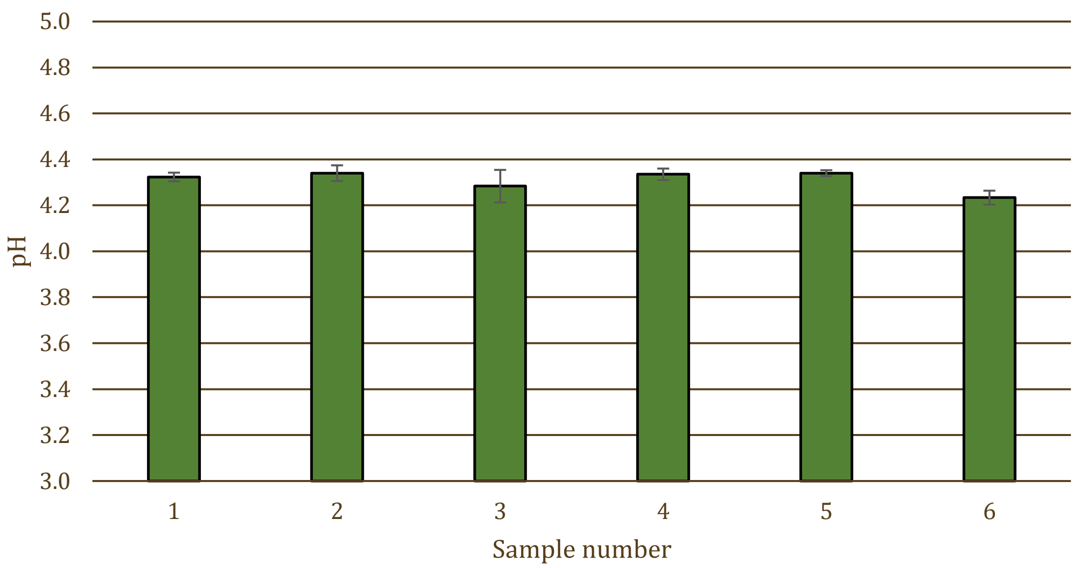

Figure 8: pH measurement (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Overall, the pH level is slightly below what would be expected – the data show values of around 4,3. This fact, unfortunately, comes from the nature of the selected ingredients; both quark cheese and crème fraîche are sour products, and the acidity of the manufactured samples depends heavily on the acidity of the ingredients.

Statistical analysis by ANOVA test has shown the F-statistic to be 6,68 with a p-value of 2,7.10-4, suggesting a statistical difference between the samples at pretty much any chosen α. Below in Table 5 are the p-values of sample pairs obtained through the Tukey HSD test:

Table 5: Tukey HSD results for statistical pH differences (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Sample pair combination	S1-S2	S1-S3	S1-S4	S1-S5	S1-S6	S2-S3	S2-S4	S2-S5
p-value	0,98	0,54	0,99	0,98	0,007	0,18	0,99	0,99
Sample pair combination	S2-S6	S3-S4	S3-S5	S3-S6	S4-S5	S4-S6	S5-S6	-
p-value	0,001	0,27	0,18	0,30	0,99	0,002	0,001	-

The statistical analysis showed statistically significant differences (at α = 0,05) between the pH values between sample 6 and samples 1, 2, 4, and 5. This result indicates that higher crème fraîche content, in combination with added citrus fibre, lowers the pH value.

8.4 Texture Profile Analysis

In the TPA, hardness, stickiness, elasticity, cohesiveness, chewiness and gumminess were evaluated. All of these parameters were measured using the cylindrical stainless steel probe. The results are available in Figures 9-14 below:

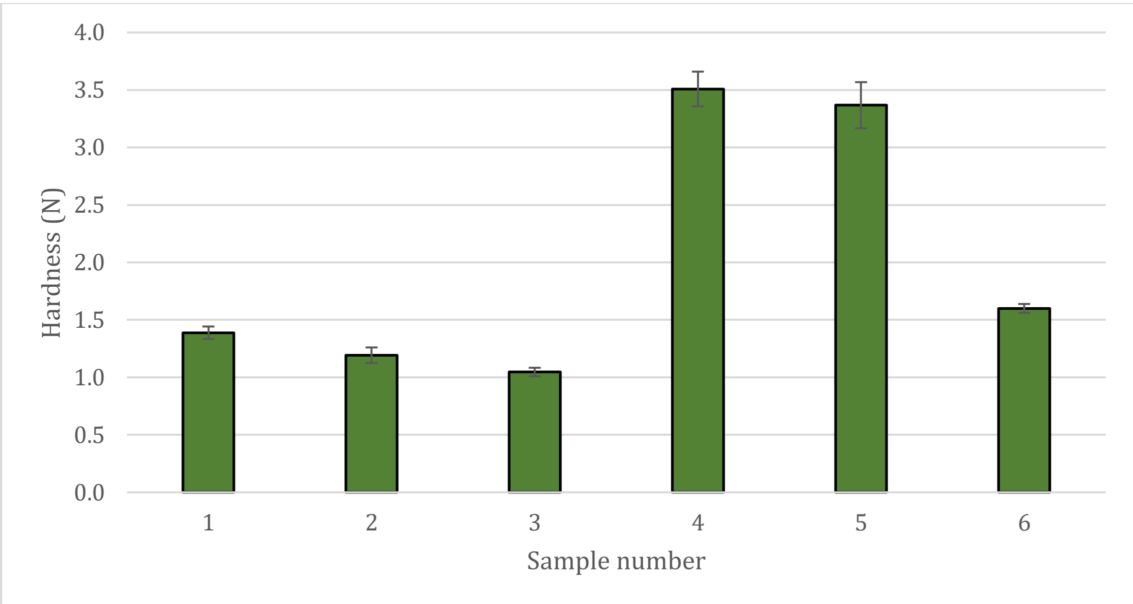

Figure 9: Hardness of the manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Figure 9 clearly shows the dependency of the hardness of the samples on fat content and citrus fibre addition. Higher fat content shows the need for less force to be applied to compress a sample; meanwhile, citrus fibre addition elevates the needed force significantly.

Notably, a linear increase in fat content does not reduce the required force linearly, as seen from the force drop in sample 6.

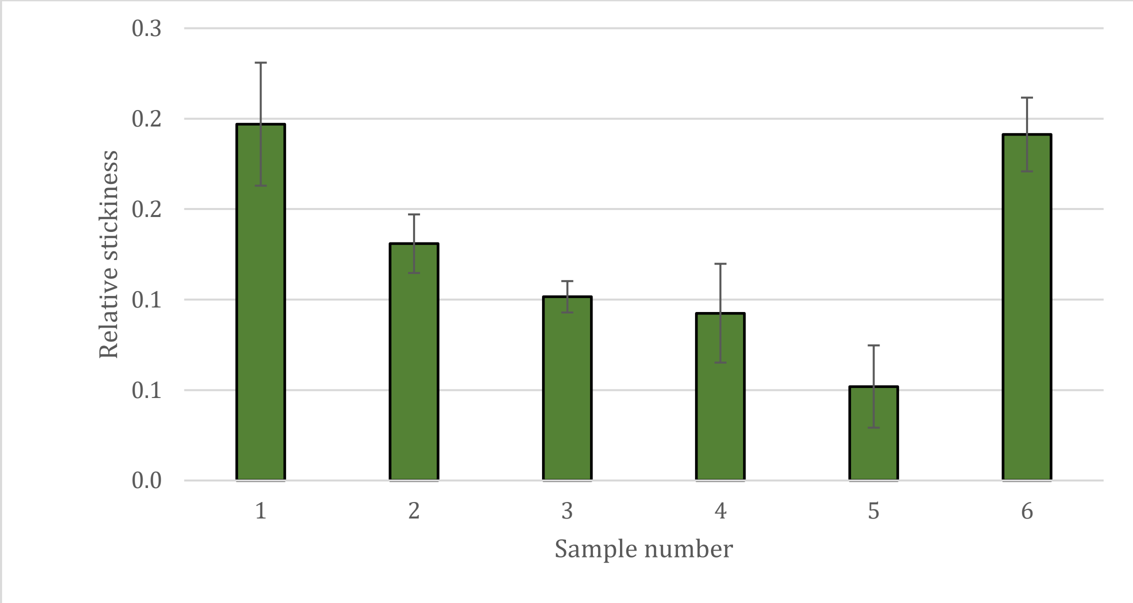

Figure 10: Relative stickiness of the manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

The effect of fat content and citrus fibre addition on stickiness shows a decreasing force when the fat content increases or citrus fibre is added. Sample 6 has demonstrated exciting results with a rapid increase in stickiness, making this relation more complex and exhibiting a need for further investigation.

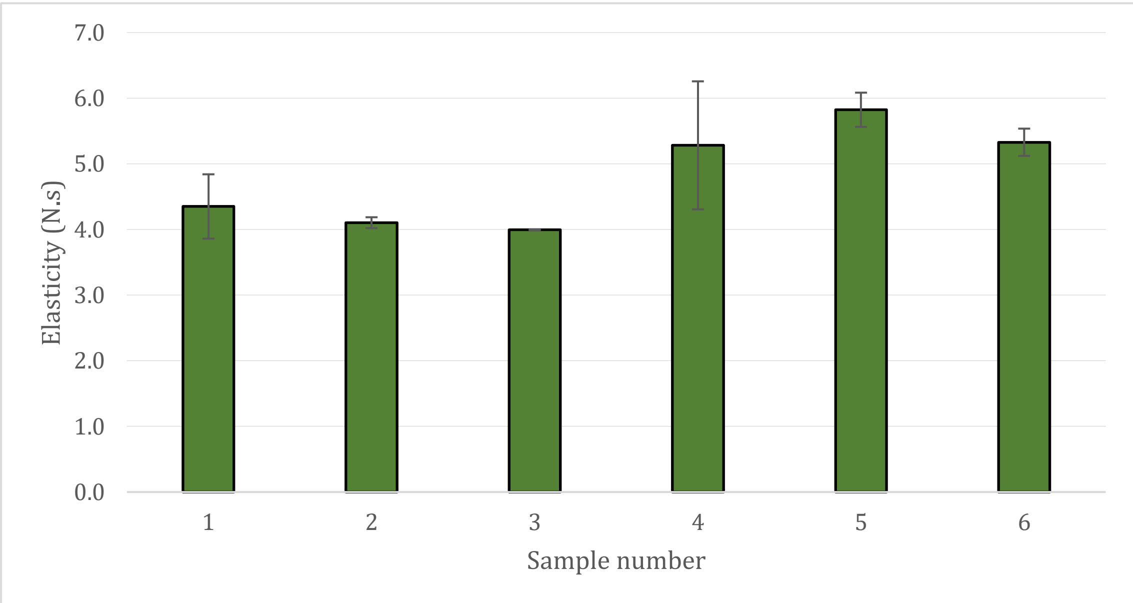

Figure 11: Elasticity of the manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

The ANOVA test at α = 0,05 was used to determine the effect of fat content and citrus fibre addition on the samples' elasticity. The samples were tested separately in groups with and without citrus fibre addition. The results are available in the Table 6 below:

Table 6: ANOVA test results for elasticity (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Group	F-statistic	p-value
S1-S3	0,80	0,49
S4-S6	0,51	0,62

The results showed that varying fat content has no statistically significant impact on the product's elasticity, but citrus fibre addition makes the product more elastic.

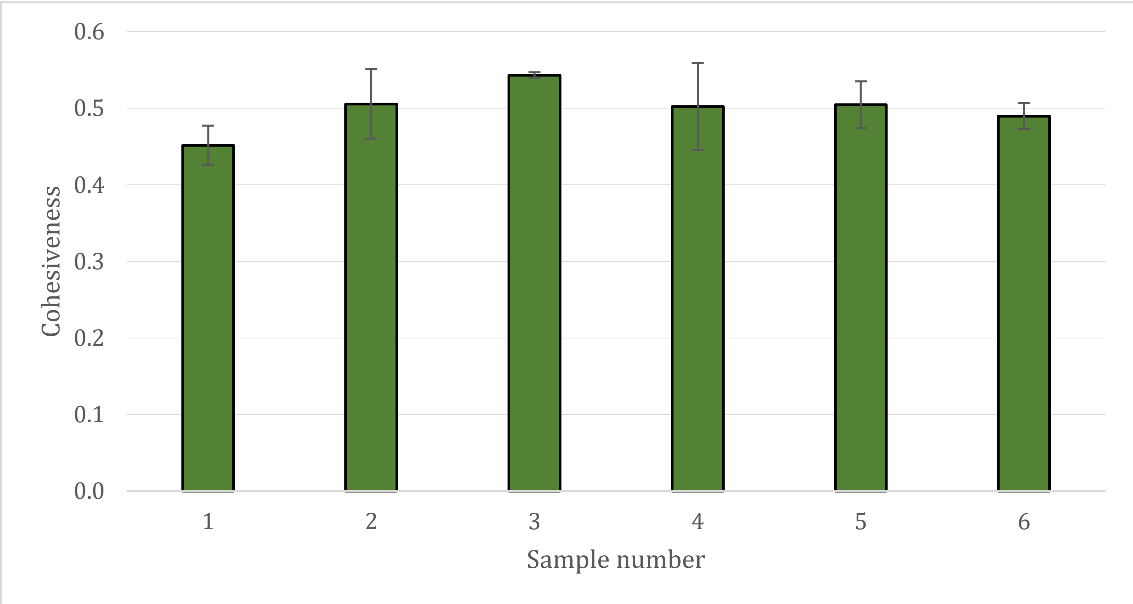

Figure 12: Cohesiveness of the manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

The ANOVA test at α = 0,05 was used to determine the effect of fat content and citrus fibre addition on the samples' cohesiveness. The calculations gave back an F-statistic of 1,47 and a p-value of 0,27. Thus, no statistically significant evidence exists that fat content and citrus fibre addition affect the samples' cohesiveness.

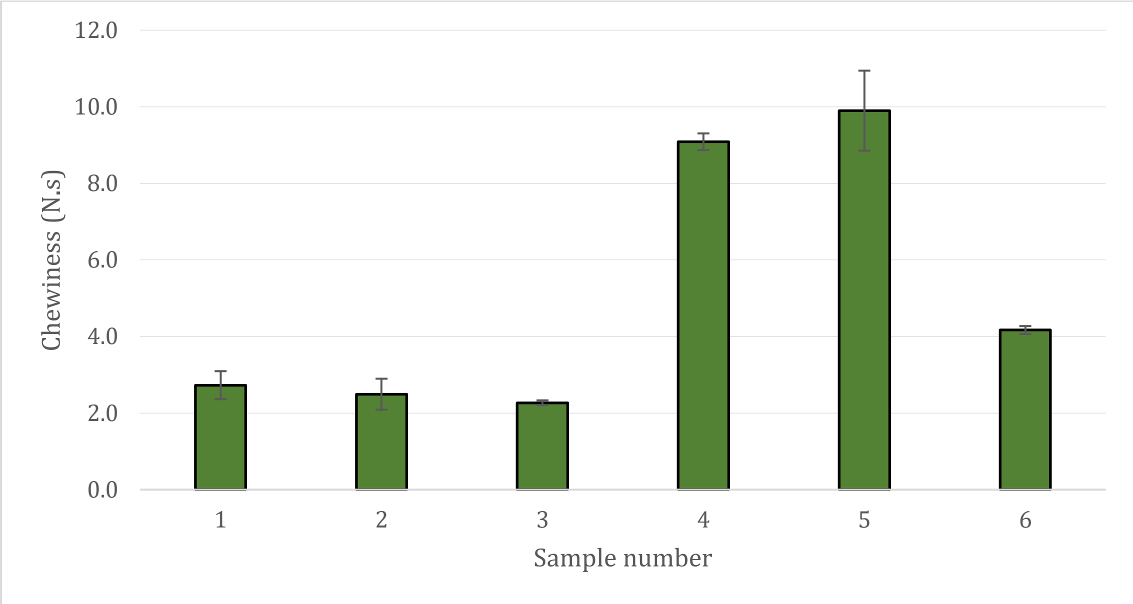

Figure 13: Chewiness of the manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

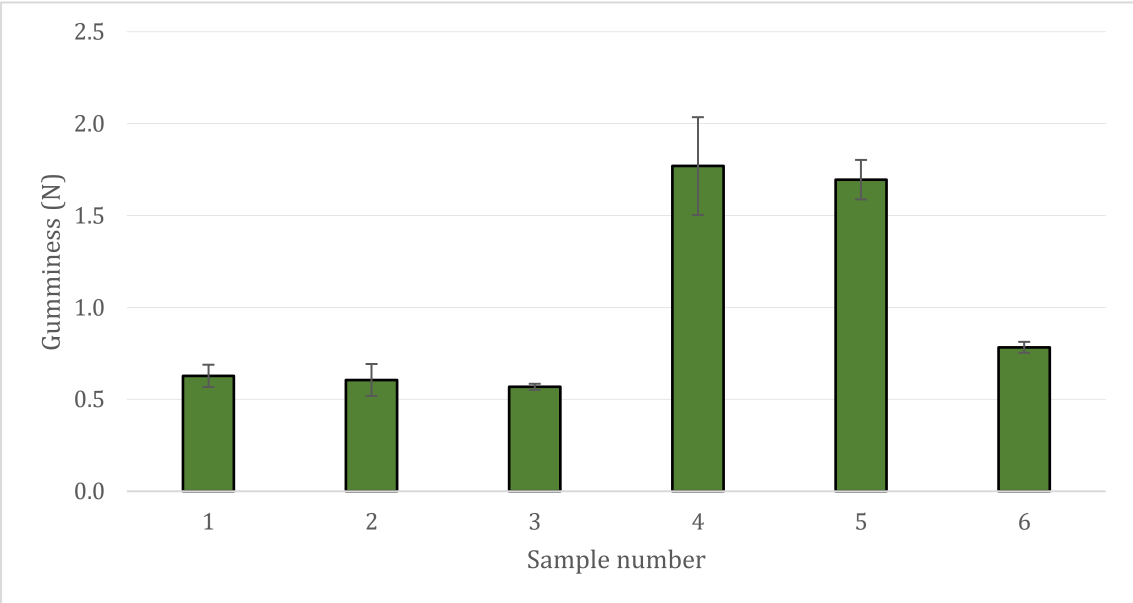

Figure 14: Gumminess of the manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Similarly, as in the case of hardness, citrus fibre addition has a significant effect on the product's chewiness and gumminess. While the fibre increases them, a high-fat content lowers them significantly.

8.5 Spreadability

A P/60C cylindrical probe was used to penetrate the samples to measure spreadability. The results are available below in Figure 15:

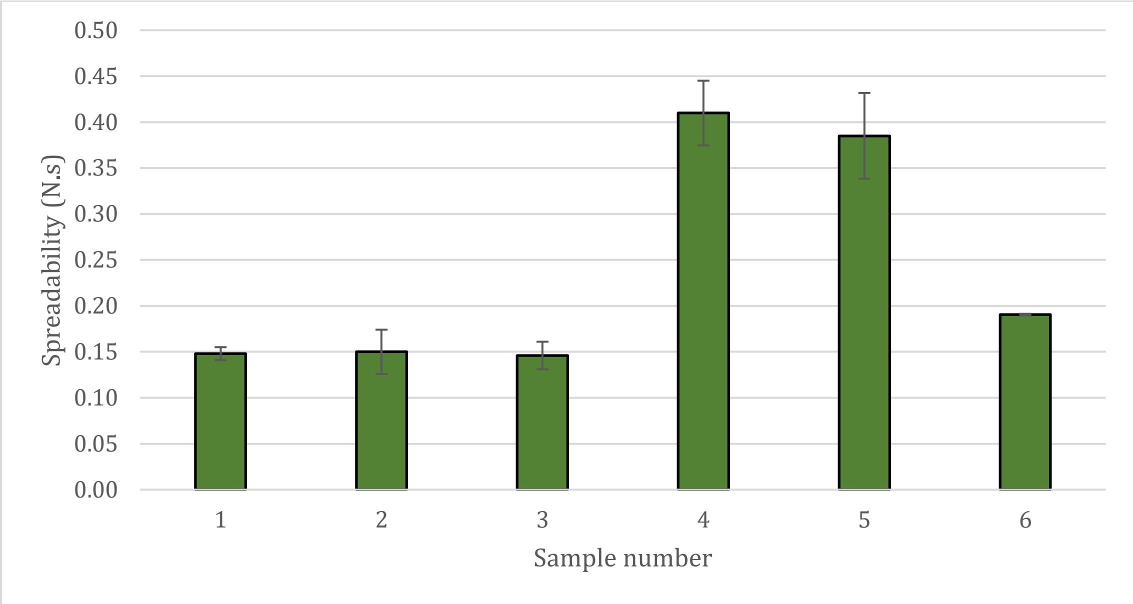

Figure 15: Spreadability of the manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Spreadability is a property similar to hardness, and the measurements gave results comparable to the hardness test. An increasing fat content lowers the force and time needed for the sample to spread, making it more spreadable. On the other hand, adding citrus fibre increases the force and time. As in the Figures above, a high-fat content hinders the citrus fibre's effect on a sample spreadability.

8.6 Viscoelastic Properties

One of the main goals of the Thesis is to determine if citrus fibre is a viable option as a thickening agent in cream cheese recipes. The viscoelastic measurements give viable answers to this posed question. Firstly, the shear storage (G') and shear loss (G'') moduli were analysed. The results are available in Figure 16:

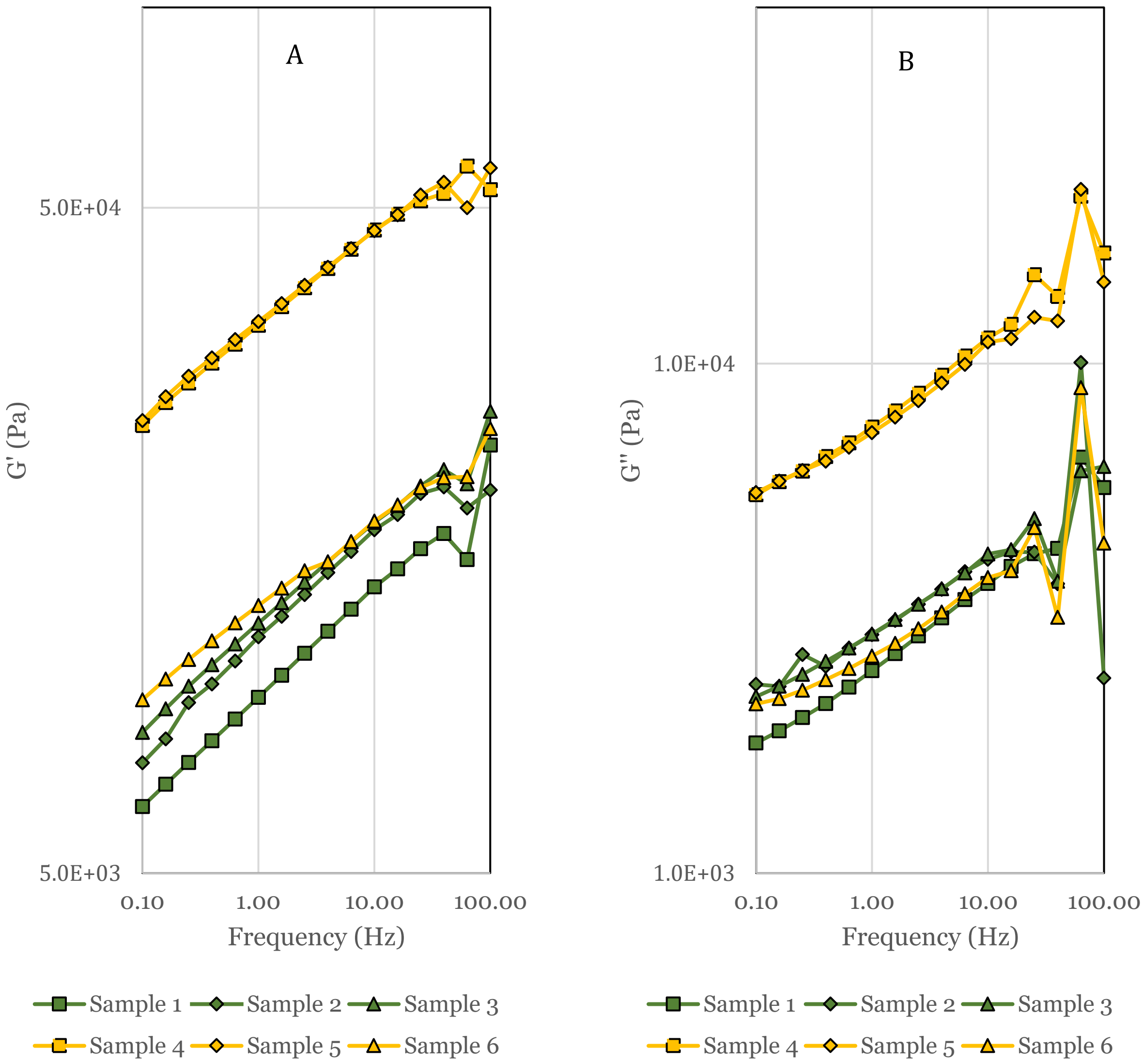

Figure 16: Shear storage (G'; A) and shear loss (G''; B) moduli of the manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

As seen from the Figure above, both shear storage and shear loss moduli were significantly affected by adding citrus fibre, increasing the moduli's value by nearly a decade, making the samples‘ consistency much denser. This correlates with the hardness measured above in TPA. In samples without the citrus fibre, the fat content did not play a significant role in modifying the moduli's values. Still, again, the high-fat content in sample 6 significantly hindered the citrus fibre's effect on shear storage and shear loss, bringing the sample 6 values down to levels comparable to samples 1-3.

In all samples, there is a significant swing of values near the frequency of about 80-90 Hz, probably caused by the samples' texture collapsing under high mechanical agitation.

The same results can be obtained if shear storage and shear loss moduli are observed at a stable frequency of 1 Hz, as seen in Figure 17 below:

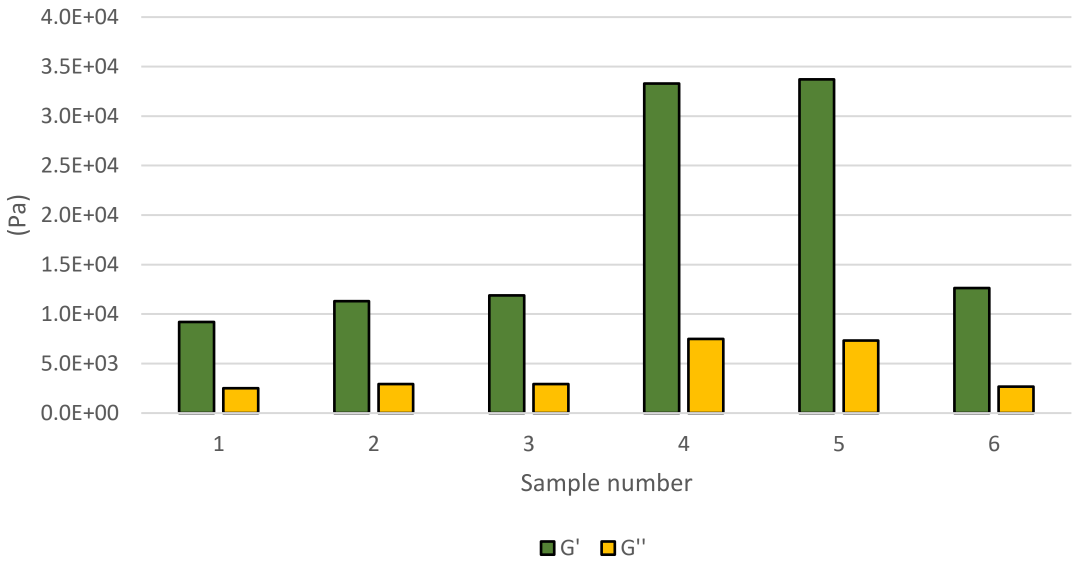

Figure 17: Shear storage (G') and shear loss (G'') moduli of the manufactured samples at a stable frequency of 1 Hz (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Lastly, to analyse if the samples exhibit more viscous or pseudoplastic physical behaviour, the phase angle (tan δ) was calculated. The graph is shown below in Figure 18:

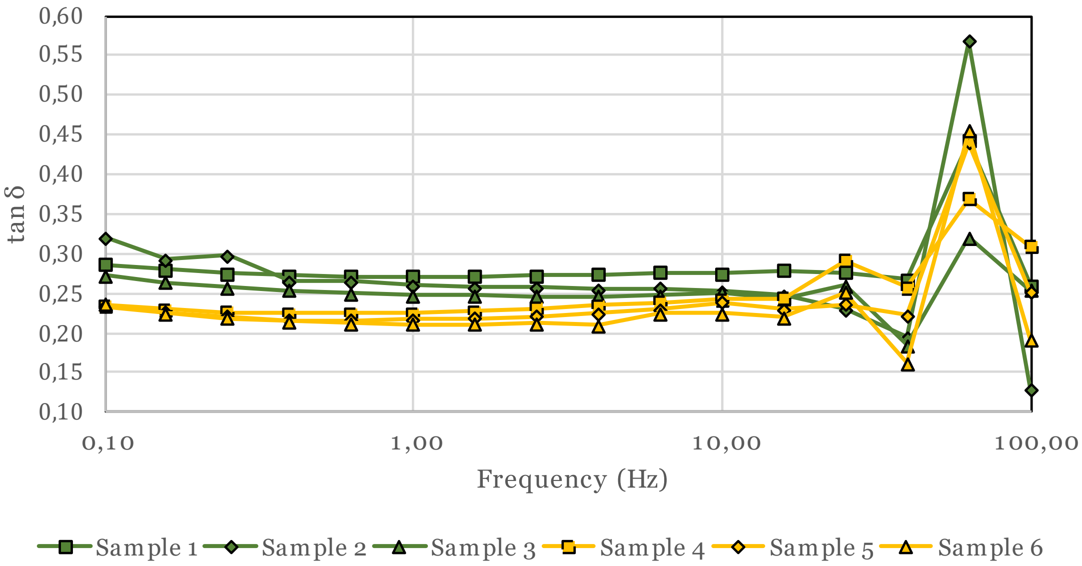

Figure 18: Phase angle tangent of the manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Since all the calculated data show tan $\delta < 1$, all samples exhibited more pseudoplastic than viscous behaviour. However, adding citrus fibre lowered the phase angle tangent by about 0,05, pointing out that citrus fibre helps the products act more like solid substances. This is in order with the previous analyses that showed that samples with added citrus fibre manifested increased hardness, elasticity, chewiness, gumminess and lower spreadability.

8.7 Tribology

In addition to viscoelastic properties, a tribology analysis was performed to understand the flavour and mouthfeel of adding citrus fibre to cream cheese in more depth. A graph charting the coefficient of friction (CoF, provided as a 9-point moving average) over velocity is shown below in Figure 19:

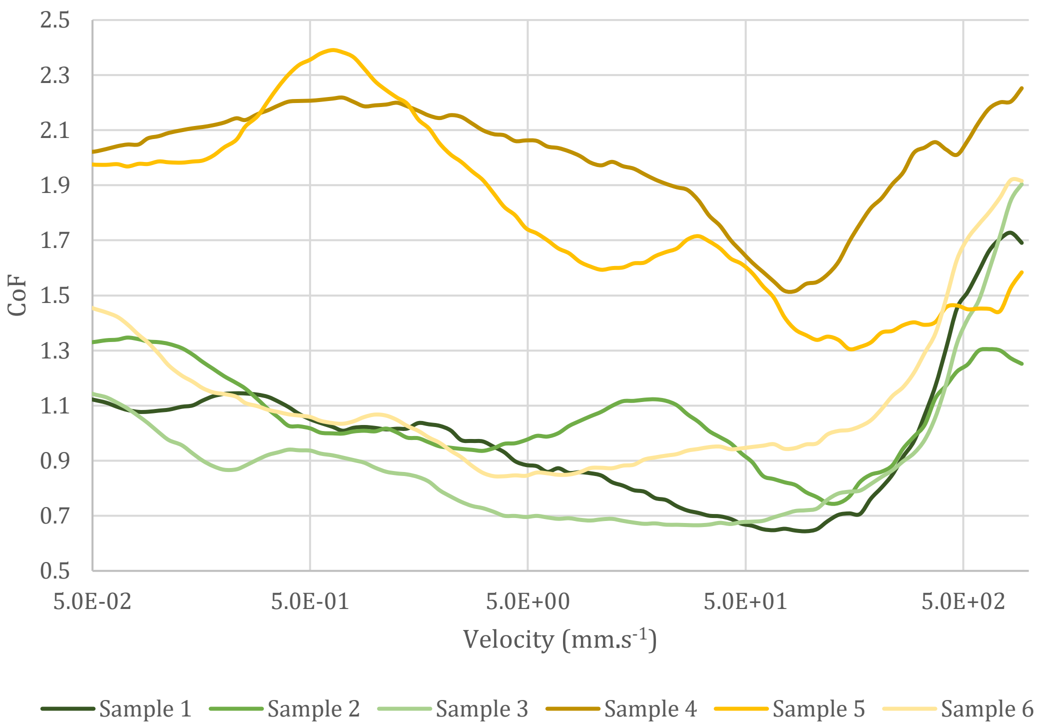

Figure 19: Stribeck curves of the manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

In boundary and mixed regimes (in Figure 19 from 5.10^{-2} to approx. 150 $mm.s^{-1}$), the values of CoF differ significantly between samples 4 and 5 and the rest, showing increased friction as an effect of the citrus fibre addition. Sample 6, as in measurements earlier, showed behaviour similar to the samples without citrus fibre, most possibly due to the high-fat content. In the hydrodynamic regime (velocities over 150 mm.s-1), the friction of all samples increases dramatically, and its steepness and final value were no longer primarily dependent on fat and citrus fibre content but rather on run-specific variables such as the exact mass of cream cheese around the tribology unit or wear of the surgical tape.

A graph of the minimal coefficient of friction value, CoF_{min}, is shown below in Figure 20:

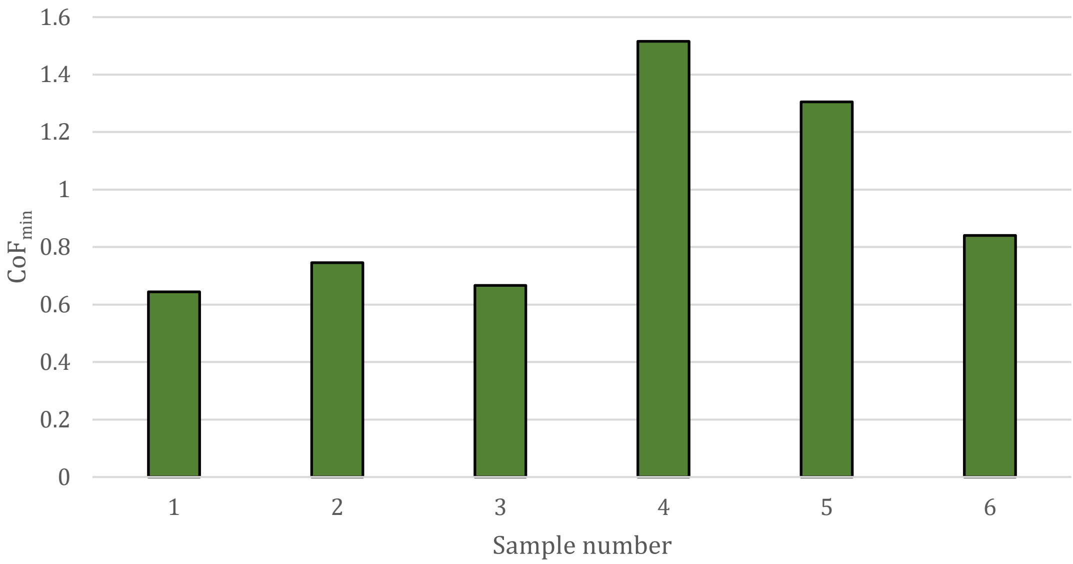

Figure 20: Minimal coefficient of friction of the manufactured samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

The CoF_{min} values differentiate the samples similarly to the previous analyses. Samples 4 and 5 show significantly higher CoF_{min} than samples 1-3 due to citrus fibre addition, and Samples 6, due to a high-fat content, have CoFmin closer to the samples without the citrus fibre rather than to samples 4 and 5.

8.8 In-situ Manufacturing

All following results are interpreted as a 7-point moving average. Figure 21 shows a graph plotting complex viscosity and temperature against time. This graph outlines the in-situ manufacturing process, showing viscosity development over time while manifesting the impact of temperature.

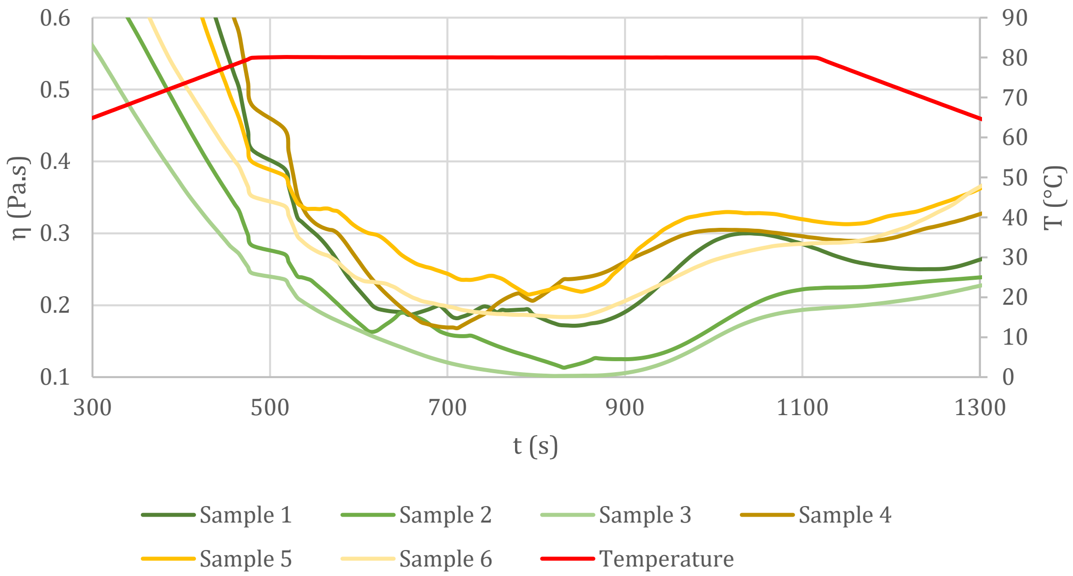

Figure 21: Viscosity development over time during in-situ manufacturing (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Below, in Figure 22, is a graph plotting viscosity development over temperature during in-situ manufacturing. This graph does not show the time variable but outlines the viscosity development throughout the manufacturing process (300 to 1300 seconds due to the clarity of the graph).

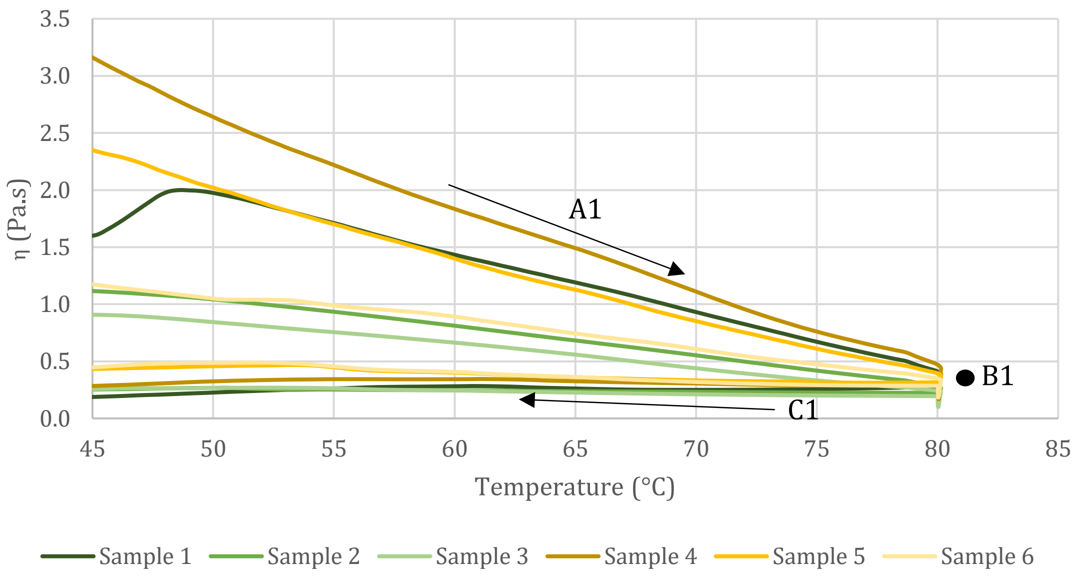

Figure 22: Viscosity development over temperature during in-situ manufacturing, showcasing Stages A1 (heating), B1 (hold time at 80 °C), and C1 (cooling); (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

The process can be divided into three stages (marked in Figure 22):

A1. Stirring and heating - the ingredients are stirred and heated to 80 °C. The viscosity is unstable initially (as seen in sample 1) due to the mass not being homogenous enough. After that, the viscosity rapidly drops due to an increasing temperature.

B1. The combination of shearing and high temperature forms the cream cheese texture, which will be discussed further below.

C1. Cooling - the cream cheese structure stabilises into the final state. This stage is disrupted by shearing (due to the need for measurements). This makes it impossible to measure the final viscosity of the samples.

Further analysis of the cream cheese texture is possible by analysing Stage B1 in Figure 22. Figure 23 below shows detailed data during this phase:

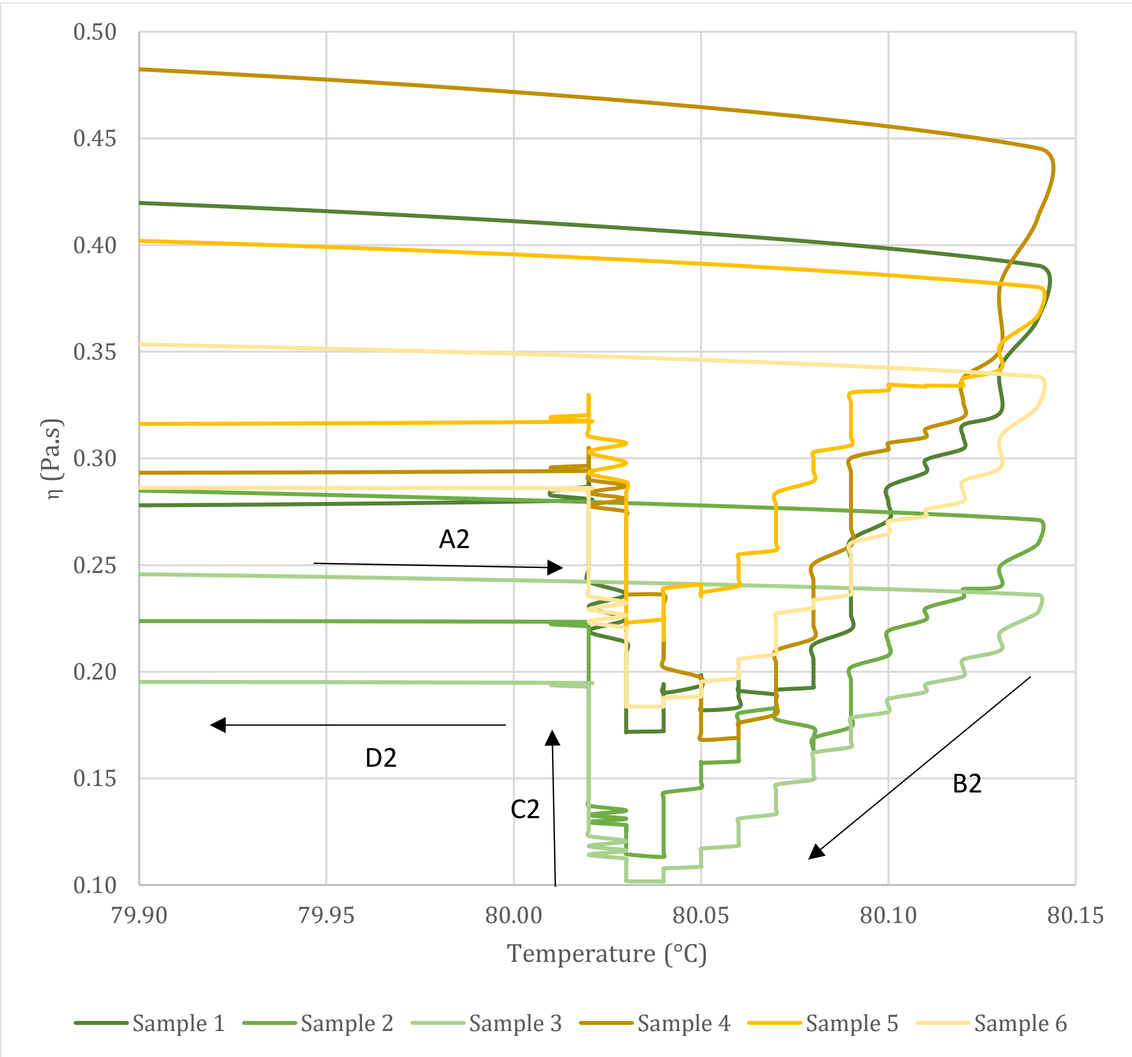

Figure 23: Viscosity development over temperature (detail), showcasing Stages A2 (end of the heating), B2 and C2 (hold time at 80 °C), and D2 (beginning of the cooling); (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Figure 23 above shows that the viscosity keeps decreasing as the temperature approaches the 80 °C mark and during the hold time (A2 and B2). At around 700 to 800 s (C2 and Figure 21), the viscosity stops dropping and, during the next approximately 200 s, starts to ramp up back, usually to a local maximum (during and after maximum heat treatment, D2). Further agitation during cooling effectively halts following fat crystallisation and product structuring (Tamime, 2009; Pombo, 2021). From these measurements, the following can be evaluated:

- Shearing and heat treatment cause the intermediate product's viscosity to decrease, followed by a prompt increase as a sign of the product's structuring.
- Every pair of samples with the same fat content (1 and 4; 2 and 5, and 3 and 6) shows that adding citrus fibre increases the local maximum viscosity to a higher value. Thus, citrus fibre helps to stabilise the cream cheese's texture during manufacturing.
- Every sample with different fat content has a distinct local viscosity maximum. Samples with lower fat content have shown higher local viscosity maxima than samples with higher fat content, suggesting that an increase in fat content destabilises the texture of cream cheese during manufacturing.
- Sample 1 (10 % fat content, no citrus fibre) has shown an interesting result – a higher local viscosity maximum than sample 6 (20 % fat content, with the addition of citrus fibre). This indicates that a 10 % (w/w) increase in fat content might have a more significant destabilising effect on the texture of cream cheese than the stabilising effect of adding 1 % (w/w) citrus fibre.

8.9 Colour

The samples have shown high lightness values (91,08-92,70), suggesting that the samples are very bright in general. The chromaticity, chroma, and hue values suggest a slightly yellow colour of all samples. The results of the colour analysis are available in Table 7 below:

Table 7: Values of lightness (L^*), chromaticity on a green-to-red axis (a^*), chromaticity on a blue-to-yellow axis (b*), hue angle (h °) and chroma (C*) of the model cream cheese samples (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Sample number	***L****	***a****	***b****	**h (°)**	**C***
1	92,70 ± 0,14	-1,13 ± 0,05	13,98 ± 0,04	85,38 ± 0,18	14,03 ± 0,04
2	91,80 ± 0,07	-0,92 ± 0,09	15,34 ± 0,08	86,56 ± 0,32	15,36 ± 0,09
3	92,28 ± 0,21	-0,49 ± 0,06	15,49 ± 0,30	88,19 ± 0,19	15,49 ± 0,31
4	91,25 ± 0,18	-0,70 ± 0,02	14,49 ± 0,01	87,25 ± 0,07	14,50 ± 0,01
5	91,52 ± 0,21	-0,41 ± 0,02	14,44 ± 0,14	88,39 ± 0,05	14,45 ± 0,14
6	91,08 ± 0,19	-0,14 ± 0,02	15,64 ± 0,24	89,49 ± 0,08	15,46 ± 0,24

An ANOVA test was performed to calculate if there was any statistically significant difference between the samples if α = 0,05. During the test, samples 1-6 were assigned to groups 1-6, and the group contents were individual results of the measurements (n = 3). The results gave F-statistics between 25,27-140,44, with p-values of 10^{-5} and less in every variable calculated. Thus, there is a statistically significant difference between the samples in every measured or computed variable.

A Tukey HSD test was performed to determine which pairs differ statistically significantly. The p-values are available in Table 8 below:

Table 8: p-values for Tukey HSD test comparing pairs of samples at variables mentioned in Table 7 (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Pair combination	**p (*L**)**	**p (*a**)**	**p (*b**)**	**p (h)**	**p (C*)**
S1-S2	2.10^{-3}	0,01	5.10^{-5}	2.10^{-4}	6.10^{-5}
S1-S3	0,23	3.10^{-7}	2.10^{-5}	2.10^{-8}	2.10^{-5}
S1-S4	3.10^{-5}	2.10^{-5}	0,10	2.10^{-5}	0,13
S1-S5	2.10^{-4}	7.10^{-8}	0,15	1.10^{-8}	0,22
S1-S6	1.10^{-5}	2.10^{-9}	6.10^{-6}	2.10^{-10}	9.10^{-6}
S2-S3	0,13	2.10^{-5}	0,95	8.10^{-6}	0,97
S2-S4	0,08	7.10^{-3}	4.10^{-3}	0,02	3.10^{-3}
S2-S5	0,63	3.10^{-6}	2.10^{-3}	2.10^{-6}	2.10^{-3}
S2-S6	0,01	3.10^{-8}	0,52	1.10^{-8}	0,62
S3-S4	8.10^{-4}	0,01	1.10^{-3}	2.10^{-3}	1.10^{-3}

Pair combination	p (L^*)	p (a^*)	p (b^*)	p (h)	p (C*)
S3-S5	9.10^{-3}	0,58	6.10^{-4}	0,86	6.10^{-4}
S3-S6	2.10^{-4}	1.10^{-4}	0,94	9.10^{-5}	0,95
S4-S5	0,65	1.10^{-3}	0,99	3.10^{-4}	0,99
S4-S6	0,91	1.10^{-6}	2.10^{-4}	3.10^{-7}	2.10^{-4}
S5-S6	0,19	2.10^{-3}	2.10^{-4}	4.10^{-4}	2.10^{-4}

The Tukey HSD test results can be interpreted as follows:

- In the group of samples without the citrus fibre (S1-S3), the only variable which did not differ was lightness (L^*) between sample 3 and samples 1 and 2.
- In the group of samples with the citrus fibre (S4-S6), there was not a statistical difference in lightness and sample 4 showed similar blue-to-yellow chromaticity (b^*) and chroma (C*) to sample 5.
- In pairs of samples with the same fat content (S1 and S4, S2 and S5, and S3 and S6), pairs sample 1 and sample 4, and sample 3 and sample 6 showed similar blue-to-yellow chromaticity (b^*) and chroma (C*) the same way as in the previous point. Sample 2 and sample 5 astonishingly showed a difference in blue-to-yellow chromaticity (b^*) and chroma (C*) but were similar in terms of lightness (L^*).
- The most significant differences (lowest p-value) are between sample 1 and sample 6, which differ by citrus fibre content and the highest fat content.

In conclusion, the statistically significant differences in various colour parameters are present in most compared pairs. For certainty, citrus fibre addition and fat content affect the final product's colour, but more precise research is needed to determine the dependencies with higher accuracy.

8.10 Sensory Analysis

To evaluate sensory analysis, it is necessary to calculate statistically significant differences ($\alpha = 0,05$) between samples in every question asked. For this, the Kruskal-Wallis test was used. The results are available in Table 9 below. Data obtained from sensory analysis is available in Appendix II.

Table 9: Kruskal-Wallis evaluation for performed sensory analysis

Parameter	Appearance	Consistency	Spreadability	Hardness	Flavour	Off-flavours
Q*	4,06	6,88	21,47	34,80	1,86	1,08
X^2	11,07	11,07	11,07	11,07	11,07	11,07

The Kruskal-Wallis test has pointed to statistically significant differences between the samples regarding spreadability and hardness. A Nemenyi test was used to evaluate the differences further. The results are available below in Tables 10 and 11. The critical value for 21 assessors and 6 samples at α = 0,05 is 674,4. A value in Tables 10 and 11 above the critical value indicates a statistically significant difference between the pair of samples.

Table 10: Nemenyi test results for spreadability (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Spreadability	S2	S3	S4	S5	S6
S1	503,5	51,0	472,0	593,0	71,5
S2	-	452,5	31,5	89,5	575,0
S3	-	-	421,0	542,0	122,5
S4	-	-	-	121,0	543,5
S5	-	-	-	-	664,5

Even though the Kruskal-Wallis test pointed to differences between the samples regarding spreadability, the following post-hoc Nemenyi test did not show any statistically significant differences with 95 % certainty. Thus, there is insufficient statistical evidence to back up claims that the samples are different in terms of spreadability.

Table 11: Nemenyi test results for hardness (S1 = 10C; S2 = 15C; S3 = 20C; S4 = 10F; S5 = 15F; S6 = 20F)

Hardness	S2	S3	S4	S5	S6
S1	538,5	14,5	871,0	841,5	52,5
S2	-	553,0	332,5	303,0	486,0
S3	-	-	885,5	856,0	67,0
S4	-	-	-	29,5	818,5
S5	-	-	-	-	789,0

Contrary to the spreadability post-hoc test, Table 11 shows numerous statistically significant differences between the samples regarding hardness. The detected differences are as follows:

- In the group of Samples without the citrus fibre (S1-S3), no differences were detected.
- In the group of samples with the citrus fibre (S4-S6), sample 6 was more soft than sample 4 and sample 5.
- In pairs of samples with the same fat content (S1 and S4, S2 and S5, and S3 and S6), the only detected difference was that sample 1 was more soft than sample 4.
- In samples with a difference in both fat and citrus fibre content, the detected differences were:
    - Sample 1 was more soft than sample 4 and sample 5
    - Sample 3 was more soft than sample 4 and sample 5

The summary of the sensory analysis evaluation is as follows :

- The assessors did not detect a difference in appearance between the samples. The most common answers were “Very good“ (2) and “Perfect“ (2).
- The assessors did not defect a difference in consistency between the samples. The most common answer was “Very good“ (2).
- The assessors did not detect a difference in spreadability between the samples. The most common answers were “Very good“ (2) and “Perfect“ (1).
- The assessors did detect significant differences in hardness between the samples. The answers were ranging from “Hard“ (2) to “Too soft“ (5). Adding citrus fibre increases the hardness of cream cheese and makes a fat’s effect on the hardness more noticeable. It is important to note that high-fat content makes the citrus fibre’s effect on hardness unnoticeable.

- The assessors did not detect a difference in flavour between the samples. The most common answers were “Good“ (3) and “Very good“ (2).
- The assessors did not detect a difference in off-flavours between the samples. The most common answer was “Without off-flavours or negligible” (1).

9 DISCUSSION

In this thesis, the target value for dry matter of the manufactured samples was 30,0 % (w/w) with fat content of 10,0 to 20,0 % (w/w). The measured dry matter values moved from 30,62 to 34,66 % (w/w). The Code of Federal Regulations in Part 133 (USA, 2024) specifies a minimum milk fat content of 33 % (w/w) and a maximum moisture content of 55 % (w/w). Thus, the manufactured products do not satisfy the CFR for the term “cream cheese”. The USDA Specifications for Cream Cheese, Cream Cheese with other Foods, and Related Products (USDA, 1994) specifies the term “Light/lite Cream cheese” as cream cheese (CFR) with a maximum fat content of 16,5 % (w/w) and maximum moisture content of 70,0 % (w/w) and a term “Reduced fat Cream cheese” with a maximum fat content of 20,0 % (w/w) and maximum moisture content of 70,0 % (w/w). The manufactured samples 1, 2, 4, and 5 can be classified as “Light cream cheese”; samples 3 and 6 can be classified as “Reduced fat Cream cheese” following these definitions.

The pH analysis showed values of around 4,3 for samples 1-5 and 4,2 for sample 6. These values are somewhat low compared to commercial cream cheeses, which are fermented to pH levels between 4,8 and 4,5 (Tamime, 2009). The USDA Specifications for Cream Cheese mentioned above add a pH level range for Light/lite Cream cheese between 4,4 and 5.2. This means that the manufactured samples would not satisfy this requirement, and pH adjustment would have to be performed, or a new recipe would have to be developed.

As expected, the water activity analysis showed results of around 0,99. These values are nowhere near potential inhibition zones for any microorganisms, correlating with measurements performed by Schmidt and Fontana (2007), who measured a_w of Philadelphia cream cheese to be 0,991, or Møller et al. (2012), whose cream cheese samples had water activity levels between 0,986 and 0,997.

The observed citrus fibre addition effect is similar to a study performed by Vincová et al. (2022). In the study, the effects of the addition of different algal hydrocolloids (κ-carrageenan, ι-carrageenan, furcellaran, and sodium alginate) at concentrations of 0,5, 0,75, and 1,0 % (w/w) to viscoelastic and textural properties of cream cheese products were observed. Adding these hydrocolloids increased the viscoelastic moduli and made a firmer texture and less spreadable cream cheeses. This study also pointed to a correlation between the added concentration of a hydrocolloid and its effects. On this basis, it is reccomended to further study the citrus fibre’s impact on cream cheeses’ texture, mainly at different concentrations, such as 0,50 % or 0,75 % (w/w). The effect of the citrus fibre has been attributed to protein structure reinforcement in the cream cheese, making it denser and, thus, affecting the rheological measurement in the observed way, similar to Vincová et al. (2022).

These results are further supported by studies led by Kůrová et al. (2022) and Schädle et al. (2022), who obtained similar results in rheological, textural and tribological analyses.

Obtained results regarding the effect of fat content contradict studies on cream cheeses' textural and rheological properties (Macdougall et al., 2019; Brighenti et al., 2008; Kealy, 2006). All studies have shown that increasing fat content increases hardness and makes the product more viscous and elastic. This is contributed to fat globules, which are, after homogenisation, partially covered with casein and participate in the aggregation of the casein particles, which reinforces the structure of the product. However, the influence of fat on texture properties differs from those of the mentioned studies since the homogenisation was not performed, and the fat globules were not covered by casein as much. The study conducted by Ningtyas and Bhandari (2017) does not mention homogenisation, and their findings are that higher fat content makes the final products less firm and more spreadable.

From the tribological perspective, Ningtyas and Bhandari (2017) found that when low-fat cream (with a 0,5 %, w/w, fat content) cheese is compared to medium-fat (containing 5,5 %, w/w, fat) and high-fat cheese samples (containing 11,6 %, w/w, fat), it demonstrated a notably elevated friction coefficient. This was accompanied by a unique stick-and-slide pattern that set it apart significantly. Similar results were published by Michel et al. (2022), who also demonstrated the impact of starch and polysaccharides on the Stribeck curve. This thesis demonstrated mainly the impact of citrus fibre on the elevation of the Stribeck curve, but the effect of fat content is noticeable to some extent as well.

The colour measurements showed that fat content and adding citrus fibre statistically significantly impacted the final products' colour. Still, in this thesis, it was impossible to determine an exact effect. Notably, in sensory analysis, there was no statistically significant difference in appearance of the samples, suggesting that assessors did not perceive a difference between the samples by eyesight. Vincova et al. (2022) came to similar results, finding a statistically significant difference between cream cheese samples that differed by a hydrocolloid content, but concluded that these differences were not perceivable to the human eye. Contrary to these results, Rafiq and Ghosh (2017) found that up to 6 % (w/w) inulin addition to processed cheese had no statistically significant effect on the product's colour.

10 CONCLUSION

In the thesis, three samples of cream cheeses with a fat content of 10,0, 15,0 and 20,0 % (w/w) and three samples with a fat content of 10,0, 15,0 and 20,0 % (w/w) with an addition of 1,0 % (w/w) of citrus fibre were manufactured.

Based on the data obtained in textural and rheological analyses, it was concluded that 1,0 % (w/w) citrus fibre addition has significantly increased the samples' hardness, elasticity, gumminess, and chewiness and made it harder to spread. It has also increased the storage and complex moduli. These findings correspond to recent research mentioned in the discussion.

These findings prove that adding 1,0 % (w/w) citrus fibre to the cream cheese formula helps to stabilise the final product's consistency. The citrus fibre was found to be a viable option as a thickening ingredient in hot-packed cream cheeses. Further research regarding an addition of 0,5 and 0,75 % (w/w) is recommended.

BIBLIOGRAPHY

ADAY, M. S., CANER, C. and YÜCEER, Y. K., 2010. Instrumental and sensory measurements of Ezine cheese texture. Akademik Gida. Online. 1 January 2010. Vol. 8, no. 3, p. 6–10. Available from: https://www.cabdirect.org/cabdirect/abstract/20103267484

ALVES, L. L., RICHARDS, N. S. P. D. S., MATTANNA, P., DE ANDRADE, D. F., REZER, Adriano P. S., MILANI, L. I. G., DA CRUZ, A. G. and FARIA, J.A.F., 2012. Cream cheese as a symbiotic food carrier using Bifidobacterium animalis Bb-12 and Lactobacillus acidophilus La-5 and inulin. International Journal of Dairy Technology. Online. 25 September 2012. Vol. 66, no. 1, p. 63–69. DOI 10.1111/j.1471-0307.2012.00880.x.

ANDRÉN, A., 2011. Cheese | Rennets and coagulants. In: Elsevier eBooks. Online. p. 574–578. DOI 10.1016/B978-0-12-374407-4.00069-8.

BHANDARI, B, TAN, D. D. Y. and CHEN, J., 2013. Applications of tribology in studying food oral processing and texture perception. Food Research International. Online. 1 December 2013. Vol. 54, no. 2, p. 1627–1635. DOI 10.1016/j.foodres.2013.10.010.

BHANDARI, V. M. and SINGH, H., 2016. Physical methods. In: Elsevier eBooks. Online. p. 497–503. DOI 10.1016/B978-0-08-100596-5.00610-7.

BREW, K., 2011. Milk proteins | A-Lactalbumin. In: Elsevier eBooks. Online. p. 780–786. DOI 10.1016/B978-0-12-374407-4.00432-5.

BRIGHENTI, M., GOVINDASAMY-LUCEY, S., LIM, K., NELSON, K. L. and LUCEY, J.A., 2008. Characterization of the Rheological, Textural, and Sensory Properties of Samples of Commercial US Cream Cheese with Different Fat Contents. Journal of Dairy Science. Online. 1 December 2008. Vol. 91, no. 12, p. 4501–4517. DOI 10.3168/jds.2008-1322.

CENTER FOR FOOD SAFETY AND APPLIED NUTRITION, 2024. Hazard Analysis and Risk-Based Preventive Controls for Human Food: Draft Guidance for Industry. Online. Available from: https://www.fda.gov/media/99572/download.

ČERNÍKOVÁ, M., BUŇKA, F. and SALEK, R. N., 2022. Technological aspects of processed cheese: Properties and structure. In: Elsevier eBooks. Online. p. 211–248.

CHEN, L. and OPARA, U. L., 2013. Texture measurement approaches in fresh and processed foods — A review. Online. Food Research International. Vol. 51, no. 2, p. 823-835. Available from: https://doi.org/10.1016/j.foodres.2013.01.046.

CIFELLI, C. J., GERMAN, J. B. and O'DONNELL, J. A., 2011. NUTRITION AND HEALTH | Nutritional and Health-Promoting Properties of Dairy products: Contribution of dairy foods to nutrient intake. In: Elsevier eBooks. Online. p. 1003–1008. DOI 10.1016/B978-0-12-374407-4.00374-5.

CODEX ALIMENTARIUS, 1973. CXS 275-1973, Standard for Cream Cheese. 2022

CODEX ALIMENTARIUS, 1978. CXS 283-1978, General Standard for Cheese. 2022

CODEX ALIMENTARIUS, 2001. CXS 221-2001, Group Standard for Unripened Cheese Including Fresh Cheese. 2022.

CZECH REPUBLIC, 2016. Vyhláška č. 397/2016 Sb. o požadavcích na mléko a mléčné výrobky, mražené krémy a jedlé tuky a oleje. In: Sbírka zákonů.

DUFOSSÉ, L. and GALAUP, P., 2010. Color of dairy foods. In: Handbook of Dairy Foods Analysis. Online. 1. CRC Press. Available from: https://www.researchgate.net/publication/258149128_Color_of_dairy_foods

FARRELL, H. M., 2011. Milk Proteins | Casein Nomenclature, Structure, and Association. In: Elsevier eBooks. Online. p. 765–771. DOI 10.1016/B978-0-12-374407-4.00430-1.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2024. About Codex Alimentarius. Online. About Codex Alimentarius. Available from: https://www.fao.org/fao-who-codexalimentarius/about-codex/it/.

FOX, P. F., 2011a. Milk lipids | fat globules in milk. In: Elsevier eBooks. Online. p. 675–679. DOI 10.1016/B978-0-12-374407-4.00336-8.

FOX, Patrick F., 2011b. LACTOSE AND OLIGOSACCHARIDES | Lactose: Chemistry, Properties. In: Elsevier eBooks. Online. p. 173–181. DOI 10.1016/B978-0-12-374407-4.00273-9,

GAUCHERON, F., 2011. MILK SALTS | Distribution and analysis. In: Elsevier eBooks. Online. p. 908–916. DOI 10.1016/B978-0-12-374407-4.00355-1.

GELATIN MANUFACTURERS INSTITUTE OF AMERICA, INC., 2019. Standard Testing Methods For Edible Gelatine. Available from: http://gelatin-gmia.com/uploads/1/1/8/4/118450438/gmia_official_methods_2019.pdf.

GOFF, H. D., 2022. Physical Properties of Milk. Online. Dairy Science and Technology eBook. Available from: https://books.lib.uoguelph.ca/dairyscienceandtechnologyebook/chapter/physical-properties-of-milk/.

GUINEE, T. P.; AUTY, M. A. E.; MULLINS, C.; CORCORAN, M. O. and MULHOLLAND, E. O., 2000. PRELIMINARY OBSERVATIONS ON EFFECTS OF FAT CONTENT AND DEGREE OF FAT EMULSIFICATION ON THE STRUCTURE-FUNCTIONAL RELATIONSHIP OF CHEDDAR-TYPE CHEESE. Online. Journal of Texture Studies. Vol. 31, no. 6, p. 645-663. Available from: https://doi.org/10.1111/j.1745-4603.2000.tb01026.x.

GUINEE, T.P.; CARIĆ, M.; KALÁB, M; CORCORAN, M. O. and MULHOLLAND, E. O., 2004. Pasteurized processed cheese and substitute/imitation cheese products. Online. Major Cheese Groups. Cheese: Chemistry, Physics and Microbiology. Vol. 31, no. 6, p. 349-394. Available from: https://doi.org/10.1016/S1874-558X(04)80052-6.

HANSEN, P.M.T., 1994. Food hydrocolloids in the dairy industry. In: Springer eBooks. Online. p. 211–224. DOI 10.1007/978-1-4615-2486-1_32.

HARWOOD, W.S. and DRAKE, M.A., 2022. Manufacture of milk and Whey products: Impact of processing on sensory characteristics of milk and dairy products. In: Elsevier eBooks. Online. p. 103–117.

HUNT, C.C.; MAYNES, J.R.; MULLINS, C.; CORCORAN, M. O. and MULHOLLAND, E. O., 1997. Current Issues in the Stabilization of Cultured Dairy Products. Online. Journal of Dairy Science. Vol. 80, no. 10, p. 2639-2643. Available from: https://doi.org/10.3168/jds.S0022-0302(97)76221-0.

ISO, 2004. 5534:2004, Cheese and processed cheese Determination of the total solids content (Reference method). 2nd ed.

ISO, 2017. 6658:2017, Sensory analysis. Methodology. General guidance. 3rd ed.

ISO, 2017. 18787:2017, Foodstuffs: Determination of water activity. 1st ed.

KARASTOGIANNI, S.; GIROUSI, S. and SOTIROPOULOS, S., 2016. PH: Principles and Measurement. Online. In: Encyclopedia of Food and Health. Elsevier, pp. 333-338. Available from: https://doi.org/10.1016/B978-0-12-384947-2.00538-9.

KEALY, T. J., 2006. Application of liquid and solid rheological technologies to the textural characterisation of semi-solid foods. Food Research International. Online. 1 April 2006. Vol. 39, no. 3, p. 265–276. DOI 10.1016/j.foodres.2005.07.016.

KUEHNI, R. G. Color: An Introduction to Practice and Principles. New York: John Wiley and Sons, 1996, pp. 186. ISBN 0-471-14566-1.

KŮROVÁ, V., SALEK, R. N., VAŠINA, M., VINKLÁRKOVÁ, K., ZÁLEŠÁKOVÁ, L., GÁL, R., ADÁMEK, R. and BUŇKA, F., 2022. The effect of homogenization and addition of polysaccharides on the viscoelastic properties of processed cheese sauce. Journal of Dairy Science. Online. 1 August 2022. Vol. 105, no. 8, p. 6563–6577. DOI 10.3168/jds.2021-21520.

LAYE, I.M-F., CHA, A.S., LOH, J.P., LINDSTORM, T.R. & RODRIGUEZ, A.P. (2005) Low protein cream cheese. European Patent Application, EP 1579769A1.

LAYE, I.M.-F., LOH, J.P., PECHAK, D.G., CHA, A.S., CAMPBELL, B.E., LINDSTORM, T.R. & ZWOLFER, M. (2002) High moisture cream cheese texture control. European Patent Application, EP 1214884A2.

LEE, S.K. and KLOSTERMEYER, H., 2001. The effect of pH on the rheological properties of reduced-fat model processed cheese spreads. Lebensmittel-Wissenschaft + Technologie/Food Science & Technology. Online. 1 August 2001. Vol. 34, no. 5, p. 288–292. DOI 10.1006/fstl.2001.0761.

LINDSTORM, T.R., MEHRING, A.D. & HUDSON, H.M. (2005) Cream cheese made from whey protein polymers. European Patent Application, EP 1561383 A1.

LOVEDAY, S. M. and SAWYER, L., 2016. Β-Lactoglobulin: Nomenclature, structure, and function. In: Elsevier eBooks. Online. DOI 10.1016/B978-0-08-100596-5.00940-9.

LUCEY, J.A., 2022. Acid- and Acid/Heat coagulated cheese. In: Elsevier eBooks. Online. p. 6–14.

LUNDSTEDT, E., 1954. Manufacture of quality cream cheese. Journal of Dairy Science. Online. 1 February 1954. Vol. 37, no. 2, p. 243–245. DOI 10.3168/jds.s0022-0302(54)70251-5.

MACDOUGALL, P. E., ONG, L., PALMER, M. and GRAS, S. L., 2019. The microstructure and textural properties of Australian cream cheese with differing composition. International

Dairy Journal. Online. 1 December 2019. Vol. 99, p. 104548. DOI 10.1016/j.idairyj.2019.104548.

MA, Y., LINDSTORM, T.R., LAYE, I., RODRIGUEZ, A.P., SCHMIDT, G.M. & DOYLE, M.C. (2007) High moisture, low fat cream cheese with maintained product quality and method for making same. European Patent Application, EP 1769683A1.

MEULLENET, JEAN-FRANCOIS; LYON, B.G.; CARPENTER, JOHN A. and LYON, C.E., 1998. RELATIONSHIP BETWEEN SENSORY AND INSTRUMENTAL TEXTURE PROFILE ATTRIBUTES. Online. Journal of Sensory Studies. Vol. 13, no. 1, p. 77-93. Available from: https://doi.org/10.1111/j.1745-459X.1998.tb00076.x.

MICHEL, S., SCHEERMEIJER, R., AMBÜHL, M. E. and FARRÉS, I. F., 2022. Novel plant-based cream cheese: A tribology perspective. Journal of Food Engineering. Online. 1 December 2022. Vol. 335, p. 111172. DOI 10.1016/j.jfoodeng.2022.111172.

MØLLER, S. M., HANSEN, T. B., ANDERSEN, U., LILLEVANG, S. K., RASMUSSEN, A. and BERTRAM, H. C., 2012. Water Properties in Cream Cheeses with Variations in pH, Fat, and Salt Content and Correlation to Microbial Survival. Journal of Agricultural and Food Chemistry. Online. 9 February 2012. Vol. 60, no. 7, p. 1635–1644. DOI 10.1021/jf204371v.

NETZSCH, © 2024. Food. Online. Available from: https://analyzing-testing.netzsch.com/en/applications/life-sciences/food.

NGUYEN, P. T. and BHANDARI, B., 2016. Tribological method to measure lubricating properties of dairy products. Journal of Food Engineering. Online. 1 January 2016. Vol. 168, p. 27–34. DOI 10.1016/j.jfoodeng.2015.07.011.

NINGTYAS, D. W. and BHANDARI, B., 2017. A tribological analysis of cream cheeses manufactured with different fat content. International Dairy Journal. Online. 1 October 2017. Vol. 73, p. 155–165. DOI 10.1016/j.idairyj.2017.06.005.

ORTEGA-FLEITAS, F.O., REINERY, P.L., ROCAMOARA, Y., REAL-DEL-SOL, E., CABRERA, M.C. & CASALS, C. (2000) Effect of homogenization pressure on texture properties of soy cream cheese. Alimentaria, Vol. 313, p. 125–127.

PHADUNGATH, C., 2005. Cream cheese products: A review. Online. Songklanakarin Journal of Science and Technology. Vol. 27, no. 1, p. 191-199. Available from: https://www.thaiscience.info/Journals/Article/SONG/10462522.pdf.

POMBO, A. F. W., 2021. Cream cheese: Historical, manufacturing, and physico-chemical aspects. International Dairy Journal. Online. 1 June 2021. Vol. 117, p. 104948. DOI 10.1016/j.idairyj.2020.104948.

RAFIQ, S. M., GHOSH, B. C., 2017. Texture, meltability, color and sensory properties of processed cheese as affected by the addition of inulin. Indian Journal of Dairy Science, 2017, 70.6: 658-664.

SADLER, G. D. and MURPHY, P. A., 2010. PH and Titratable Acidity. Online. Food Analysis. Food Science Texts Series. p. 219-238. Available from: https://doi.org/10.1007/978-1-4419-1478-1_13.

SAINT-EVE, A.; PANOUILLÉ, M.; CAPITAINE, C.; DÉLÉRIS, I. and SOUCHON, I., 2015. Dynamic aspects of texture perception during cheese consumption and relationship with bolus properties. Online. Food Hydrocolloids. Vol. 46, p. 144-152. Available from: https://doi.org/10.1016/j.foodhyd.2014.12.015.

SALEK, R. N., LORENCOVÁ, E., MÍŠKOVÁ, Z., LAZÁRKOVÁ, Z., PACHLOVÁ, V., ADÁMEK, R., BEZDĚKOVÁ, K. and BUŇKA, F., 2020. The impact of Chios mastic gum on textural, rheological and melting properties of spread-type processed cheese during storage. International Dairy Journal. Online. 1 October 2020. Vol. 109, p. 104755. DOI 10.1016/j.idairyj.2020.104755.

SANCHEZ, C.; BEAUREGARD, J.-L.; CHASSAGNE, M.-H.; BIMBENET, J.-J. and HARDY, J., 1994. Rheological and textural behaviour of double cream cheese. Part I: Effect of curd homogenization. Online. Journal of Food Engineering. Cheese: Chemistry, Physics and Microbiology. Vol. 23, no. 4, p. 579-594. Available from: https://doi.org/10.1016/0260-8774(94)90113-9.

SANCHEZ, C.; BEAUREGARD, J.-L.; BIMBENET, J.-J. and HARDY, J., 1996. Flow Properties, Firmness and Stability of Double Cream Cheese Containing Whey Protein Concentrate. Online. Journal of Food Science. Vol. 61, no. 4, p. 840-843. Available from: https://doi.org/10.1111/j.1365-2621.1996.tb12215.x.

SCHÄDLE, C. N., BADER-MITTERMAIER, S. and SANAHUJA, S., 2022. The effect of corn dextrin on the rheological, tribological, and aroma release properties of a Reduced-Fat model of processed cheese spread. Molecules/Molecules Online/Molecules Annual. Online. 13 March 2022. Vol. 27, no. 6, p. 1864. DOI 10.3390/molecules27061864.

SCHMIDT, J.S., FONTANA A.J. Jr. Water activity in foods, 2007. In: Water Activity in Foods: Fundamentals and Applications. Online. DOI 10.1002/9780470376454

SENSEGOOD INSTRUMENTS PRIVATE LIMITED, 2023. Color Measurement for Quality and Consistency Control in Dairy Products using Sensegood Spectrophotometer. Online. In: Linkedin.com. Available from: https://www.linkedin.com/pulse/color-measurement-quality-consistency-control-dairy.

SETHUPATHY, P., MOSES, J.A. and ANANDHARAMAKRISHNAN, C., 2020. Food Oral Processing and Tribology: Instrumental Approaches and Emerging Applications. Food Reviews International. Online. 16 January 2020. Vol. 37, no. 5, p. 538–571. DOI 10.1080/87559129.2019.1710749.

STABLE MICRO SYSTEMS, © 1989–2024. Why measure texture? Online. Available from: https://www.stablemicrosystems.com/TextureAnalysis.html.

SWALLOW, D.M., 2016. Lactose and oligosaccharides: lactose intolerance. In: Elsevier eBooks. Online. DOI 10.1016/B978-0-08-100596-5.00866-0.

SZCZESNIAK, A. S., 2002. Texture is a sensory property. Food Quality and Preference. Online. 1 June 2002. Vol. 13, no. 4, p. 215–225. DOI 10.1016/s0950-3293(01)00039-8.

TAMIME, A.Y. (ed.), 2009. Dairy fats and related products. Blackwell Publishing.

TAYLOR, M. W. and MACGIBBON, Alastair, 2011. Milk lipids | Fatty acids. In: Elsevier eBooks. Online. p. 655–659. DOI 10.1016/B978-0-12-374407-4.00332-0.

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2004a. Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. In: Official Journal of the European Union.

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2004b. Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. In: Official Journal of the European Union.

USA, 2024. PART 133—Cheeses and Related Cheese Products. In: Code of Federal Regulations.

USDA, 1994. USDA Specifications for Cream Cheese, Cream Cheese with other Foods, and Related Products. Online. Available from: https://www.ams.usda.gov/sites/default/files/media/creamcheese.pdf

VINCOVÁ, A.; ŠANTOVÁ, K.; KŮROVÁ, V.; KRATOCHVÍLOVÁ, A.; HALÁMKOVÁ, V. et al., 2023. The Impact of Divergent Algal Hydrocolloids Addition on the Physicochemical, Viscoelastic, Textural, and Organoleptic Properties of Cream Cheese Products. Online. Foods. Vol. 12, no. 8, p. 2639-2643. Available from: https://doi.org/10.3390/foods12081602.

WANG, H. and SUN, D.-W., 2003. Assessment of cheese browning affected by baking conditions using computer vision. Journal of Food Engineering. Online. 1 March 2003. Vol. 56, no. 4, p. 339–345. DOI 10.1016/s0260-8774(02)00159-0.

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CoF	Coefficient of Friction
HACCP	Hazard Analysis and Critical Control Points
HSD	Honestly significant difference
IUPAC	The International Union of Pure and Applied Chemistry
ISFET	Ion-selective field-effect transistor
S1-S6	Sample 1 to Sample 6
TPA	Texture profile analysis
WPC	Whey protein concentrate
10C	Sample 1 – 10 % (w/w) fat, control
15C	Sample 2 – 15 % (w/w) fat, control
20C	Sample 3 – 20 % (w/w) fat, control
10F	Sample 4 – 10 % (w/w) fat, fibre
15F	Sample 5 – 15 % (w/w) fat, fibre
20F	Sample 6 – 20 % (w/w) fat, fibre

LIST OF FIGURES

LIST OF TABLES

APPENDIX I: QUESTIONNAIRE FOR THE SENSORY ANALYSIS

Senzorické hodnocení čerstvých termizovaných smetanových sýrů

Dobrý den, vítám vás na senzorické analýze čerstvých termizovaných smetanových sýrů. Prosím, z každé otázky vyberte tvrzení, které se nejvíce podobá hodnocenému výrobku. Výsledky uvádějte do tabulky na konci dotazníku. Děkuji.

Miroslav Jaššo

A. Vzhled
  1. Výborný (bílá hutná barva, konzistentní v celém výrobku)
  2. Velmi dobrý
  3. Dobrý
  4. Uspokojivý
  5. Neakceptovatelný

B. Konzistence
  1. Výborná (nerozpadavá, homogenní, bez odděleného tuku)
  2. Velmi dobrá
  3. Dobrá
  4. Uspokojivá
  5. Neakceptovatelná

C. Roztíratelnost
  1. Výborná
  2. Velmi dobrá
  3. Dobrá
  4. Uspokojivá
  5. Neakceptovatelná

D. Tuhost
  1. Příliš tuhý
  2. Tuhý
  3. Středně tuhý
  4. Měkký
  5. Příliš měkký

E. Chuť a vůně
   1. Výborná
   2. Velmi dobrá
   3. Dobrá
   4. Uspokojivá
   5. Neakceptovatelná

F. Cizí chutě
   1. Nepřítomny nebo zanedbatelné
   2. Rozeznatelné
   3. Zřetelné
   4. Výrazné
   5. Převažující

Číslo hodnotitele:

Otázka/Vzorek	104	265	711	524	852	388
A.						
B.						
C.						
D.						
E.						
F.						

APPENDIX II: DATA OBTAINED FROM THE SENSORY ANALYSIS

	Sample	Question	Assessor																				
			741	MROR	1111	003	7811	137911	2299	Aa52	X481	987	a1BC42d	5961	6969	aFcg	gromp	815	Kroft	53	80c	1616	1617
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
S3	104	Appearance	1	2	1	1	1	2	1	2	2	2	2	3	3	3	3	1	3	1	4	1	2
		Consistency	1	2	2	1	1	3	1	2	2	3	2	1	2	1	2	1	4	2	2	1	2
		Spreadability	1	1	1	1	1	1	1	1	1	3	1	1	3	1	1	1	2	1	3	1	1
	fat 20 no fibre	Hardness	3	4	4	3	4	4	4	5	4	4	2	4	4	4	4	4	4	4	4	4	4
		Flavour	1	4	3	1	2	1	3	2	3	3	3	2	1	1	1	5	3	4	5	3	3
		Off-flavours	1	5	1	1	1	1	3	1	1	2	1	2	2	1	2	4	2	4	4	1	1
S2	265	Appearance	2	4	1	2	2	2	2	3	2	2	2	2	2	2	2	3	1	3	1	1	3
		Consistency	2	4	2	2	1	3	3	4	3	5	2	1	3	1	2	5	1	3	2	1	3
		Spreadability	1	1	1	2	3	3	3	3	2	1	1	1	1	2	1	5	1	3	3	1	2
	Fat 15 no fibre	Hardness	2	2	4	2	5	3	2	2	3	4	4	3	4	3	4	4	3	3	3	4	3
		Flavour	1	1	1	1	1	2	3	3	3	4	2	2	3	3	1	4	4	4	3	3	4
		Off-flavours	1	2	1	1	1	1	2	1	1	4	1	2	2	3	1	3	1	3	2	1	1
S5	711	Appearance	1	1	1	1	2	2	3	2	2	1	1	1	1	1	3	3	3	2	1	3	2
		Consistency	1	2	2	1	1	4	3	3	2	2	1	1	4	1	2	3	3	3	2	1	2
		Spreadability	1	2	2	1	2	4	1	2	2	2	1	1	3	2	2	3	3	2	1	1	2
	Fat 15 with fibre	Hardness	3	3	2	4	2	2	1	3	3	3	3	3	1	3	4	3	2	3	3	4	3
		Flavour	1	2	1	1	4	3	3	2	3	2	2	2	3	2	2	3	1	3	2	3	3
		Off-flavours	1	4	1	1	1	2	3	1	2	2	1	2	2	2	1	3	5	3	1	1	1
S4	524	Appearance	2	2	1	1	3	2	1	2	2	1	1	1	1	1	4	3	1	3	1	1	2
		Consistency	1	2	1	1	1	2	1	1	2	2	2	1	3	2	4	3	1	3	2	1	3
		Spreadability	1	2	1	1	1	3	2	1	3	2	1	1	4	2	2	4	1	2	1	1	3
	Fat 10 with fibre	Hardness	3	4	3	4	2	2	2	3	3	3	3	3	1	3	2	3	1	3	3	4	2
		Flavour	2	2	1	1	1	3	4	3	3	3	2	2	2	3	1	3	1	3	2	3	4
		Off-flavours	1	1	1	1	1	2	4	2	1	2	1	2	3	2	2	1	2	2	1	1	2
S6	852	Appearance	2	1	1	1	1	3	3	2	2	2	2	2	2	2	3	1	3	1	2	1	1
		Consistency	2	1	1	1	3	2	1	2	2	1	2	1	2	2	2	1	4	1	2	3	4
		Spreadability	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1	3	1	1	1	1
	Fat 20 with fibre	Hardness	4	4	4	4	5	3	4	4	4	4	2	4	1	4	3	4	5	4	3	5	4
		Flavour	3	1	1	1	1	2	3	3	2	2	3	2	1	2	1	2	4	3	3	3	4
		Off-flavours	1	2	1	1	1	1	2	2	2	1	1	2	1	1	1	2	4	3	2	1	1
S1	388	Appearance	1	2	1	1	2	2	2	2	3	4	2	2	3	2	2	2	1	1	3	1	4
		Consistency	1	2	2	1	3	3	2	3	3	3	2	1	2	2	2	5	1	1	4	2	5
		Spreadability	1	1	1	1	1	1	1	1	1	3	1	1	3	1	1	1	1	1	1	1	3
	Fat 10 no fibre	Hardness	5	5	4	4	4	3	5	5	5	2	2	4	2	4	3	5	3	5	5	5	2
		Flavour	3	2	3	1	1	4	2	4	3	3	3	2	2	3	1	2	1	3	3	3	5
		Off-flavours	1	3	1	2	1	3	3	2	1	3	1	2	1	4	1	1	1	3	1	1	1