ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

PROCESSED CHEESE PRODUCTION WITHOUT USING EMULSIFYING SALTS

M.Sc. THESIS

Berna ÇEKİLARIZ

Department of Food Engineering

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FEBRUARY 2024

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EMÜLSİFİYE EDİCİ TUZLAR KULLANILMADAN ERİTME PEYNİRİ ÜRETİMİ

YÜKSEK LİSANS TEZİ

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Berna ÇEKİLARIZ, a M.Sc. student of ITU Graduate School student ID 506201528, successfully defended the thesis/dissertation entitled **“**PROCESSED CHEESE PRODUCTION WITHOUT USING EMULSIFYING SALTS**”,** which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my beloved mom,

FOREWORD

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February 2024

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(Food Engineer)

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ABBREVIATIONS

AC	: Acid Casein
ANOVA	: Analysis of Variance
AOAC	: Association of Official Analytical Chemists
BMP	: Butter Milk Powder
ES	: Emulsifying Salt
FDA	: Food and Drug Administration
HACCP	: Hazard Analysis and Critical Control Points
κ-casein	: Kappa casein
MCC	: Micellar Casein Concentrate
MPC	: Milk Protein Concentrate
PC	: Processed Cheese
PCP	: Processed Cheese Product
RC	: Rennet Casein
SC	: Sodium Caseinate
T	: Temperature
TPA	: Texture Profile Analysis
WHO	: World Health Organization
WPC	: Whey Protein Concentrate
WPI	: Whey Protein Isolate

SYMBOLS

°C	: Celsius
°F	: Fahrenheit
g	: Gram
G'	: Storage modulus
G''	: Loss modulus
G''/ G'	: Loss tangent
mL	: Milliliter
mm	: Millimeter
mg	: Milligram
N	: Newton
Nmm	: Newton millimeter
Pas	: Pascal second
rpm	: Revolutions per minute
s	: Second

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PROCESSED CHEESE PRODUCTION WITHOUT USING EMULSIFING SALTS

SUMMARY

Emulsifying salts are essential ingredients in processed cheese dispersing and solubilizing caseins to obtain a homogeneous structure. However, they are food additives with high sodium content that can affect health adversely. In addition, they are imported additives that increase the cost of production. This study aimed to manufacture a processed cheese without using emulsifying salts resembling hard cheese. For this purpose, firstly, composition and structural properties of commercial hard processed cheeses were analyzed. Next, formulation studies were carried out by using different dairy ingredients including Kaşar cheese, acid casein source, milk protein concentrate (MPC) and whey protein concentrate (WPC). Basic formula was determined considering the composition and pH of hard processed cheese and the composition of the ingredients. Three different formulations were developed using the basic formula with different amounts of the MPC and WPC. While the total amount of MPC and WPC was held constant at 10,6%, the mass percentage of them was changed as 100:0, 50:50, and 0:100. Composition, pH, calcium content, meltability, oiling off, textural and rheological properties of the samples were measured after storage for 3 days at 4°C.

Processed cheese samples had pH around 5,41-5,55 and contained 44-47 % dry matter, 22-23% protein, 25-26% fat, 1,65-1,77% ash and 0,43-0,57% calcium. The hardness of the processed cheese samples was found to be dependent on the type of protein concentrate in the formula. The sample with only MPC had the highest hardness, while that with only WPC had the lowest. Cohesiveness of the produced samples followed a similar trend. Chewiness of only MPC-containing sample was higher than those of the samples with WPC.

The type of protein concentrate used in the formulation also affected the meltability of processed cheese. While the sample with only MPC had meltability close to that of commercial cheeses, the sample with both MPC and WPC had lower meltability. The sample with only WPC did not melt. The oiling off was observed in all samples except the sample with 100% WPC. The melting or flow temperature was also measured by temperature sweep test performed with a rheometer. The flow temperatures of the samples with only MPC and MPC-WPC were 58.51 °C and 57.47 °C, respectively. The sample with only WPC did not show a clear melting or flow.

Sensory properties of processed cheese samples were also evaluated in comparison to those of a commercial sample. The type of protein concentrate used in cheese formulation significantly impacted texture and flavor attributes. The sample with only MPC had the highest hardness among the samples; however, it was softer than the commercial control sample. The study also examined the cohesiveness, elasticity, and crumbliness of processed cheese samples and control sample. The control

sample had the highest elasticity value, while processed cheese samples had similar elasticity. The highest crumbliness value was found in the sample containing only WPC, which had a gritty and coarse texture. When the flavor characteristics of the products were analyzed, no foreign taste or flavor was detected in any of the processed cheese samples. The taste of control sample was found to have the most intense Kaşar taste and the sample with only MPC followed the control sample in this attribute. The most acceptable sample in terms of textural and taste characteristics was the sample containing only MPC. The sensory textural analysis results were found to be compatible with the those obtained from instrumental textural analysis.

EMÜLSİFİYE EDİCİ TUZLAR KULLANILMADAN ERİTME PEYNİRİ ÜRETİMİ

ÖZET

Eritme peyniri, farklı peynirlerin karışımından belirli yapısal özellikler ve lezzette uzun raf ömürlü bir ürün elde etmek için ek işlemlerle üretilen bir peynir türüdür. Bu yönüyle eritme peyniri üretimi, doğal gıda kaynaklarının geri kazanımını ve tüketime sunulmasını sağlayarak sürdürülebilir gıda sistemlerinin geliştirilmesinde önemli bir uygulamadır. Doğal peynirin emülsifiye edici tuzlar, koruyucu maddeler ve diğer bileşenlerle harmanlanmasıyla yapılır. Emülsifiye edici tuzlar eritme peynir üretiminde önemli bir rol oynar ve peynirin dokusuna, stabilitesine ve erime özelliklerine katkıda bulunur. Emülsifiye edici tuzlar, temelde peynirdeki kazeinlerin dispersiyonu ve çözündürülmesinde yardımcı olan ve bu şekilde eritme peynirinde homojen bir yapı sağlayan temel bileşenlerdir. Ancak üretim maliyetini artıran bu ithal ürünler, sağlığı olumsuz etkileyebilecek yüksek sodyum içeriğine sahip gıda katkı maddeleridir. Eritme peyniri üretiminde emülsifiye edici tuzların kullanımının yerine daha doğal bileşenler kullanmak ve içeriği değiştirmek hem sağlık açısından hem de ekonomik açıdan faydalar sağlayabilir.

Bu çalışmanın amacı, emülsifiye edici tuzlar kullanılmadan sert ve eriyebilen bir eritme peyniri üretmektir. Ayrıca iki süt bazlı protein bileşeni olan süt proteini konsantresi (MPC) ve peynir altı suyu proteini konsantresinin (WPC) eritme peyniri kalitesi ve işlevselliği üzerindeki etkileri de araştırılmıştır. Çalışmada ticari sert eritme peynirlerinin sahip olduğu eriyebilirlik, dokusal ve reolojik özelliklere esas sahip bir eritme peyniri üretmek hedeflenmiştir. Bu amaçla, öncelikle ticari sert eritme peynirlerinin bileşim ve yapısal özellikleri analiz edilmiştir. Elde edilen verilere ve literatürdeki verilere göre, asit kazein kaynağı, Kaşar peyniri, MPC ve WPC gibi farklı süt bileşenleri kullanılarak içerik çalışmaları yürütülmüştür. Emülsifiye edici tuzlar yerine kalsiyum içeriği düşük asitle çökeltilmiş kazein tercih edilmiştir. Ancak asit kazeinin çözünürlüğü ve eriyebilirliği düşük olduğundan farklı protein kaynakları hem emülsiyon kapasitesini artırmak hem de formülde yeterli protein oranını sağlamak için tercih edilmiştir.

Ürün formülasyonu ürünün kalitesini, duyusal ve yapısal özelliklerini belirlemektedir. Formülasyon ürün bileşimini, kuru madde, protein, yağ ve kalsiyum içeriğini belirlemekte ve bu bileşenler ürün yapısını oluşturmaktadırlar. Formülasyonun geliştirilmesinde eritme peynirde kullanılacak olan bileşenlerin miktarı ve türü, toplam kalsiyum içeriği, pH değeri, yağ ve protein oranları dikkate alınmıştır. Ayrıca formülasyona eklenecek bileşenlerin miktarı hesaplanırken nihai üründe hedeflenen fizikokimyasal özellikler ile birlikte yönetmeliklerde belirtilen yasal düzenlemeler de dikkate alınmıştır. Eritme peynirinde kullanılacak protein konsantrelerinin etkisini anlayabilmek için geliştirilen formülde farklı oranlarda MPC ve WPC kullanılarak üç farklı formül geliştirilmiştir. Formülde protein konsantresi oranı %10,6'da sabit tutulmuş ve bu protein oranını sağlayacak MPC ve

WPC oranları 100:0, 50:50 ve 0:100 olarak değiştirilmiştir. Üretimi gerçekleştirilen eritme peynir örnekleri 4°C'de 3 gün depolandıktan sonra kuru madde, yağ, nem, pH, protein ve kalsiyum içerikleri belirlenmiştir. Yapısal özelliklerinin belirlenmesi için fırında eriyebilirlik ve serbest yağ miktarı analizi yapılmıştır. Tekstür cihazı kullanılarak sertlik, iç yapışkanlık, çiğnenebilirlik, elastiklik, sakızımsılık ve dış yapışma kuvveti gibi diğer özellikleri ölçülmüştür. Örneklerin akma sıcaklığı reometre ile sıcaklık taraması yapılarak belirlenmiştir. Ayrıca tanımlayıcı duyusal analiz yapılarak bir ticari eritme peynir örneği ile üç eritme peynir örnekleri doku ve lezzet özellikleri açısından karşılaştırılmıştır.

Eritme peynir örneklerinin görsel incelemesinde farklı oranda protein konsantresi içeren örneklerin yapılarının birbirinden farklı olduğu ortaya çıkmıştır. MPC içeren örneklerin yapısal bütünlük açısından yalnızca WPC içeren örneklere göre daha iyi olduğu gözlemlenmiştir. Sadece WPC içeren örneklerin ufalanan bir yapıya sahip olması, yapısal olarak parçalanması ve diğer numuneler kadar homojen olmadığı da gözlenmiştir.

Fizikokimyasal analizler sonucunda, eritme peyniri örneklerin %44-47 kuru madde, %22-23 protein, %25-26 yağ, %1,65-1,77 kül ve %0,43-0,57 kalsiyum içerdikleri tespit edilmiştir. Eritme peynir örneklerinin pH'sı 5,41-5,55 aralığında bulunmuştur. Eritme peynir örneklerinin Türk Gıda Kodeksi'ne uygun kuru madde, yağ ve protein içeriklerine sahip oldukları bulunmuştur. Üç farklı eritme peyniri örneklerinin kuru madde, yağ, protein, kül ve kalsiyum içeriklerinde yapılan formülasyon ayarlaması nedeniyle beklendiği gibi herhangi bir farklılık tespit edilmemiştir.

Tektür profil analizi sonucunda, eritme peynir örneklerinin sertliğinin içerdikleri protein konsantresi türüne bağlı olduğu bulunmuştur. Sadece MPC içeren örnek en yüksek sertliğe sahipken, WPC içeren örneklerin daha düşük sertliğe sahip olduğu tespit edilmiştir. Eritme peynir örneklerinin iç yapışkanlığı da benzer bir eğilim izlemiştir. Yalnızca MPC içeren örneklerin çiğnenebilirliği WPC içeren örneklere göre daha yüksek bulunmuştur. Sertlik ile ilgili sonuçların çiğnenebilirlik sonuçlarıyla paralel olduğu görülmüştür. Üç farklı eritme peyniri örneklerinin elastikliği, sakızımsılığı, çiğnenebilirliği ve dış yapışma kuvveti de benzer bir eğilim göstermiştir. Tekstür profil analizi sonucunda yalnızca MPC içeren eritme peyniri örneklerinin, WPC içeren örneklerden daha iyi yapısal özelliklere sahip olduğu tespit edilmiştir.

Eritme peyniri örneklerinin eriyebilirliği ve serbest yağ miktarı incelendiğinde, protein konsantresi türünün eritme peyniri örneklerinin eriyebilirliğini etkilediği tespit edilmiştir. Yalnızca MPC içeren örneğin eriyebilirliği ticari peynirlerin eriyebilirliğine yakın iken, eşit oranda MPC ve WPC içeren örneğin erime kabiliyeti daha düşük bulunmuştur. Yalnızca WPC içeren örnek erimemiştir. Diğer yandan örneklerin serbest yağ miktarı analizi sonucunda, sadece WPC içeren örnek dışında örneklerde yağ ayrılması gözlemlenmiştir. Eriyebilirlik açısından eritme peyniri örneklerinin birbirinden farklı olduğu, ancak serbest yağ miktarı açısından sadece MPC içeren örnekle MPC ve WPC'yi eşit oranda içeren örneğin birbirlerine benzer olduğu tespit edilmiştir.

Eritme peyniri örneklerine ait reolojik özellikler, reometre ile gerçekleştirilen sıcaklık tarama testiyle ölçülmüştür. Yalnızca MPC içeren örneğin ve aynı oranda MPC ve WPC içeren örneğin akış sıcaklığı öncesi G' değeri, G'' değerinden daha yüksek çıkmıştır. Bu durum eritme peyniri örneklerinin erimeden önce elastik davranışa sahip olduğunu göstermektedir. Ayrıca eritme peyniri örneklerinin elastik

(G′) ve viskoz (G″) modüllerinde sıcaklığa bağlı olarak meydana gelen değişimler incelenmiştir. Ancak sadece WPC içeren örnek herhangi bir erime göstermediğinden G' ve G" kesişmemiş ve erime sıcaklığı elde edilememiştir. Yalnızca MPC içeren örneğin ve aynı oranda MPC ve WPC içeren örneğin akış sıcaklıkları sırasıyla 58,51 °C ve 57,47 °C olarak ölçülmüştür. Yalnızca WPC içeren örnek net bir erime veya akış sıcaklığı göstermemiştir. Yalnızca MPC içeren örneğin ve aynı oranda MPC ve WPC içeren örneğin reolojik özelliklerinin istatistiksel açıdan birbirine benzer fakat yalnızca WPC içeren örnekten farklı olduğu tespit edilmiştir.

Son olarak, ticari kontrol örneği ve üç farklı eritme peyniri örneklerinin yapısal ve lezzet özellikleri tanımlayıcı duyusal analiz yapılarak karşılaştırılmıştır. Eritme peyniri içeriğinde kullanılan protein konsantresi türünün, eritme peynirinin doku ve lezzet özelliklerini istatistiksel olarak önemli ölçüde etkilediği görülmüştür. Örnekler yapısal özellikler yönünden incelendiğinde, sadece MPC içeren örnek WPC içeren örneklerle kıyaslandığında, en yüksek sertliğe sahip olmasına rağmen ticari kontrol örneğinden daha az sertliğe sahip olduğu bulunmuştur. Ürünlerin iç yapışkanlık özellikleri karşılaştırıldığında, kontrol örneğinin yalnızca MPC içeren eritme peyniri örneğine istatistiksel olarak benzer olduğu ancak WPC içeren örneklerden farklı olduğu tespit edilmiştir. Ticari kontrol örneği ve üç farklı eritme peyniri örneklerinin krem rengi ve matlık değerleri birbirlerine benzer bulunmuştur. En yüksek ufalanabilirlik değeri (parçacıklı-heterojen yapı) yalnızca WPC içeren örnekte gözlemlenmiştir. Ticari örnekle üç farklı eritme peyniri tekstürel olarak karşılaştırıldığında, yalnızca MPC içeren örneğin ticari kontrol örneğine en yakın örnek olduğu tespit edilmiştir. Ürünlerin tat özellikleri incelendiğinde, kontrol örneğinin ve eritme peyniri örneklerinin hiçbirinde yabancı tat veya aroma tespit edilmediği saptanmıştır. Ayrıca örnekler arasında ekşilik, tatlılık, tereyağı aroması ve tuzluluk açısından istatistiksel olarak önemli düzeyde farklılığın olmadığı saptanmıştır. Panelistler tarafından Kaşar tadına en yakın olan örneğin kontrol örneği olduğu ve onu sadece MPC içeren örneğin takip ettiği bildirilmiştir. Üretilen üç farklı eritme peyniri örnekleri arasında yapısal ve lezzet özellikleri açısından en beğenilen örnek sadece MPC içeren örnek olmuştur. Tanımlayıcı duyusal analiz sonuçlarının enstrümental yapısal analiz sonuçlarıyla uyumlu olduğu tespit edilmiştir.

1. INTRODUCTION

Processed cheese can be produced by combining cheese curd and cheeses at different maturity with emulsifying salts and water. Other ingredients such as dairy proteins and hydrocolloids can be added depending on the end use. Heating and mixing are applied during the production of processed cheeses to obtain a uniform cheese structure with a long shelf life. The functional properties of processed cheeses (meltability, microstructure, viscosity, and stretchability) are the most essential quality aspects which also contribute to the taste and aesthetic appeal of the food during preparation and consumption. The ingredients and processing parameters used have an impact on the functional characteristics of processed cheeses. Processed cheese products are versatile and suitable for various applications, including raw and heated forms. They can be creamy, smooth, spreadable or hard, elastic, and sliceable. They can be used as a substitute for natural cheese, spread, sauces, dips, and as an ingredient in various dishes. They can also be dried for soup or sauce mixes (Guinee et al., 2004).

Emulsifying salts such as citrates, and phosphates are essential in the formulation of processed cheese as they bind calcium and convert the insoluble calcium para-caseinate into soluble sodium para-caseinate with the help of heat. This is required for emulsification of fat by casein and to obtain a homogeneous structure. The solubility of casein and cheese increases as a result of using emulsifying salts. (Kosikowski and Mistry, 1997; Solowiej et al., 2020).

Although emulsifying salts have unique contributions to the quality of the processed cheese, the use of emulsifying salts in cheese also has some negative effects. Emulsifying salts improve the structural properties of processed cheeses; however, they are essentially food additives. Additionally, emulsifying salts may cause a salty and milder taste when added to obtain the desired flavor and taste. The use of emulsifying salts causes high sodium amount in the cheese because these salts contain sodium in their structure in addition to the table salt. Excessive sodium intake is strongly linked to high blood pressure, heart disease and stroke. Reducing salt intake can lower blood pressure and reduce the risk of associated disorders (He & MacGregor, 2010). The World Health Organization (WHO) recommends that individuals consume less than 2 g of sodium per day, which corresponds to less than 5 g of salt. It is reported that salt consumption in Turkey is 15 g per day (Öztürk and Garipağaoğlu, 2018). Average daily sodium intake of adults worldwide was reported as 4.31 g (equal to 10.78 g salt). This is more than double of the amount recommended by WHO (WHO, 2023). Food manufacturers are aiming to lower the amount of salt in their products over the past few years in response to the public demand to lower the sodium content of both domestic and international products.

Since emulsifying salts are very effective components in blending different ingredients in processed cheese, these functional properties may enable the reuse of poor-quality cheese. Legal regulations of many countries impose certain limitations on the amount of emulsifying salts. In such cases, different methods can be tried to produce processed cheese without compromising market product quality. Furthermore, even though many nations have regulations on the use of additives, more amounts may be utilized than necessary. Nevertheless, emulsifying salts play an important role in the production of processed cheese. Therefore, the role of these salts in processed cheese and potential technologies to reduce sodium are being investigated. Since emulsifying salts are costly ingredients, using more natural materials instead of reducing these additives can provide both health and economic benefits (Smith et al., 2008; Mozuraityte et al., 2019, Dularia et al., 2023).

In this study, it was aimed to manufacture processed cheese without using emulsifying salts. Although there are studies on reducing the emulsifying salts in processed cheese, there are limited studies on processed cheese production without emulsifying salts. Production of a hard and meltable processed cheese with a composition according to the regulations was targeted. In order to produce this targeted processed cheese, ingredients and their proportion were determined to give the desired composition, taste, texture and functional properties to the final product. Acid casein source, Kaşar cheese, butter and water were main ingredients in the formulation. Protein contents of the cheese was adjusted by using milk protein concentrate and whey protein concentrate. To determine which protein concentrate yields a good quality processed cheese, three processed cheeses including %100 MPC, 50%MPC-50%WPC and 100% WPC were prepared and analyzed.

1.1 Purpose of Thesis

The objective of this study was to produce a hard and meltable processed cheese without using emulsifying salts. In addition, the effects of two dairy-based protein ingredients, milk protein concentrate and whey protein concentrate, on the quality and functionality of the processed cheese were investigated.

1.2 Hypothesis

Processed cheese with desired quality and functionality can be produced by using an acid casein source and milk-based protein concentrates unlike conventional production by using emulsifying salts.

2. LITERATURE REVIEW

2.1 Processed Cheese

Processed cheese, whose consumption continues to increase worldwide, is preferred as an alternative to natural cheese. Processed cheeses are advantageous in terms of their low production cost, structural stability, long shelf life, ability to be produced in accordance with special-purpose diets by changing their composition (flavored, low-calorie, low-fat), and allowing the use of leftover cheeses (Guinee 2007).

Processed cheese is covered in legislations about cheese products. The naming, classification, composition, and allowed ingredients in processed cheese manufacturing may differ due to local needs and demands. The code of Federal Regulations in the United States defines four classes of processed cheese products based on allowed components and compositions. This approach, as specified in the Code of Federal Regulations, Food and Drugs, Part 133 (Edition 4-1-93), identifies four basic kinds of processed cheese products: pasteurized processed cheese (PC), pasteurized PC foods, pasteurized PC spread, and pasteurized blended cheese. The classification criteria include authorized substances and compositional factors. United States Food and Drug Administration guidelines state that only items made with natural cheese and salts (3%, w/w) and having a specific amount of moisture (43%, w/w) and fat content (greater than 47%, w/w) qualify as processed cheese (Oliveira et al., 2016). In the United Kingdom, there are two types of processed cheese products: processed cheese and cheese spread (as defined by the Cheese and Cream Regulations (HMSO, 1995). It classified processed cheeses based on fat-in-dry matter and moisture content, and allowed the use of starch and gelatin. Currently, processed cheese is a customary product, but is recognized by the Food Standard Agency as part of the "cheese and cheese products" group. European legislation for processed cheese is limited, but general measures and detailed requirements can facilitate production. Processed cheese manufacturers must adhere to EU Regulations, HACCP system, and guidelines developed in compliance with European Parliament and Council regulations, Codex recommendations, and ISO 22000:2018. On the other hand, Turkey is harmonizing its laws with those of the European Union, with the Ministry of Agriculture and Forest publishing a compulsory Food Codex Cheese Standard in 2015. This regulation defines processed cheese as a product made from curd, cheese types, dairy ingredients, and pasteurization. The cheese must be suitable according to the same regulation and have a moisture content of less than 60% (El-Bakry and Mehta, 2022). Until the regulation was published in Turkey in 2015, block cheeses made using emulsifying salts by the method called "dry cooking" were called as Kaşar cheese. With the publication of the regulation about cheese in 2015, the phrase "Kaşar cheese" cannot be written on the label of processed cheese. The Turkish Food Codex Cheese Regulation defines Kaşar cheese as boiled curd cheese that is made by processing raw curd obtained by coagulating milk with rennet. Depending on the method, the cheese can be classified as fresh or ripened depending on the differences in the production stages and has distinctive characteristics unique to its type. In Turkish regulation, processed cheese is defined as a product obtained by mixing cheese curd, one or more types of cheese, dairy ingredients such as milk powder, whey powder, butter, cream if necessary, by applying heat treatment at pasteurization norm or higher temperatures and adding emulsifying salts (TFC, 2015).

Unlike natural cheeses produced directly from milk, processed cheeses are produced by using cheese curd and one or more types of cheese with varying maturity and emulsifying salts with the help of heat treatment and mixing (Salek et al., 2017). In order to make processed cheese, a variety of cheeses can be used. The processed cheese can be blended with Cheddar, Kaşar, Feta, and additional dairy products like cheese curd, whey, yoghurt, milk, or whey powder and fat or cream (Şimşek and Kavas 1991). Ingredients are blended in steam cooking-stretching machines that apply high shear force and efficient mixing. In addition, homogeneous structure in processed cheese is achieved not only by the steam cooking-stretching machine but also by additives. In a natural fresh cheese, after the milk is turned into curd using rennet or acid, the curd is further treated depending on the type of cheese to be produced, such as vacuuming, soaking in brine, pressing, salting, and ripening. Unlike natural fresh cheese, in processed cheese manufacturing, curd and other ingredients go through a kind of kneading-cooking process in steam cooking-stretching machines with a certain power, speed and temperature. Formulation and heating process allow production of various processed cheeses (Dixon, 2011).

In block type cheese, meltable cheeses are generally the main ingredients as they are the most preferred cheese types in the food industry. Mostly hard and semi-hard cheeses such as Emmental, Gruyere, Cheddar, Kaşar, Guada, Mozzarella, Edam are preferred because these cheeses have high dry matter and required casein level. Therefore, they positively affect the stability that is required for processed cheese (Rafiq and Ghosh, 2017; Nogueira et al., 2018; Topcu et al., 2020).

On the other hand, formulation is the stage of deciding which ingredients to use to obtain the desired composition, flavor, and functional properties to the final product. The amount and type of cheese, total calcium content, dry matter content, fat content, protein content, casein content, pH value, amount and type of emulsifying salts, and whey protein content are important for formulation of processed cheese (Kapoor and Metzger, 2008). It has been stated that if the fat and moisture contents of the processed cheese formulation are not standardized, a product with the desired functional properties cannot be obtained (Tamime, 2011). Although various limits on the composition of processed cheese vary according to legal regulations, similar ranges exist for certain types of processed cheese. Apart from legal regulations, the formulation can be changed or adjustments can be made according to the desired quality characteristics of the product (Fox et al., 2017).

Processed cheese, a leading cheese variety globally, is popular for its versatility in various food preparations. It is produced in various forms like loaves, slices, shreds, and spreads, thanks to its unique functional properties. Manufacturers have numerous possibilities for producing processed cheese with different physicochemical properties due to a range of options in ingredients and formulations, as well as processing conditions, which leads to a variety of flavor, functional properties, and end-use applications as desired by food industry and consumers. One of the reasons why processed cheeses are so preferred is that the production steps are easier than natural cheese. Also, its popularity with children of various ages can be attributed to its safe ingestible consistency, moderate flavors, and packaging (color, strength, convenience of opening, size) and form (e.g., triangles, fingers, cartoon characters) that is typically appealing and practical for lunch boxes. Furthermore, processed cheese can provide low cost in comparison to natural cheese due to the use of low-grade natural cheese, off-cuts, and less expensive non-cheese milk solids (e.g., skim milk powder, whey, casein, and caseinates). On a weight basis, casein and fat in cheese are often more expensive than casein and fat in substances such as casein powders and butter oil. Improvements in technology in manufacturing, emulsifying salt mixes and functional dairy additives have made it easier to produce consistently high-quality cheeses with specialized form, size, and appearance (Guinee et al., 2004).

2.2 Principles of Processed Cheese Production

The initial stage of processed cheese manufacturing involves selecting ingredients and formulating a mixture of natural cheese, emulsifying salts, colors, flavors, and various other dairy and nondairy ingredients. The selection of these ingredients significantly impacts the physicochemical and functional properties of the cheese. Once the proper formulation has been prepared, the ingredient blend is heated and mixed to create a homogenous mass that is packaged and cooled as shown in Figure 2.1.

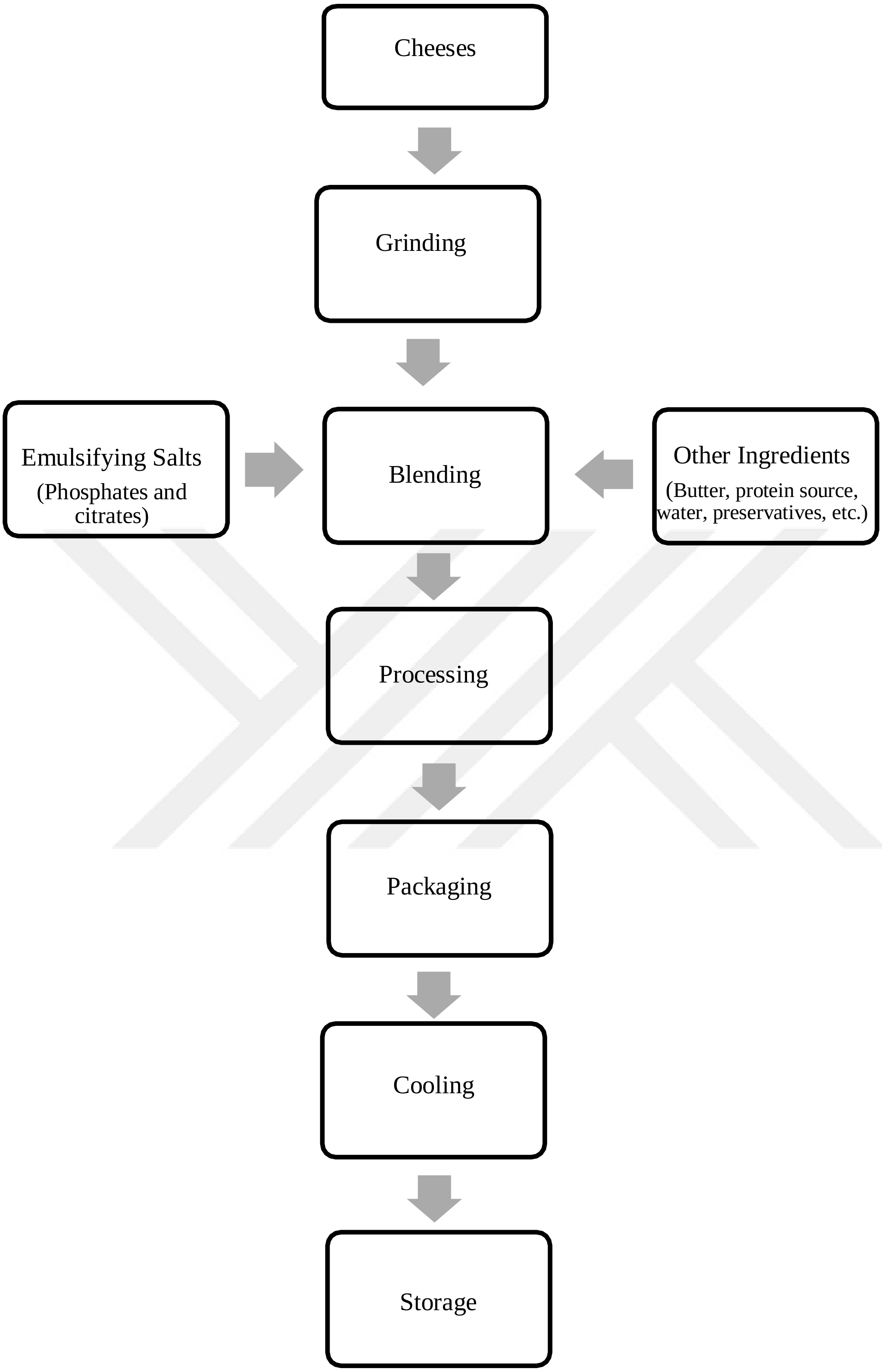


Figure 2.1 : Flowchart for the production of processed cheese (Oliveira et al., 2016).

Processed cheese manufacturers use various cookers with varying designs and operating conditions, based on production mode, mixing systems, and heating mechanism. Direct steam injection is the primary heating method. Process conditions like cooking time, temperature, agitation, and cooling rate significantly impact functional properties of cheese. Processed cheese manufacturers have numerous options for producing physicochemical properties, leading to various flavor, functional properties, and end-use applications. The selection of ingredients and processing conditions is crucial for targeted functional properties. Fat, protein, and moisture content determination is also critical, with testing carried out to ensure compliance with the component criteria determined by legislations (Suna and Ersan, 2020).

2.3 Ingredients Used for Processed Cheese

The components of processed cheese are protein, fat, water, emulsifying salts, and other components such as acidifying agents and additives that are used in small amounts. The basic components used in processed cheese, the functions/effects of these ingredients, and examples of these ingredients are listed in Table 2.1.

Table 2.1 : Ingredients used in the production of processed cheese (El-Bakry & Mehta, 2022).

Component	Function/effect	Ingredient
Milk Fat	-Standardization of composition -Flavor, texture, and cooking characteristics	Milk fats, cream, butter
Milk Proteins	-Standardization of composition -Texture and rheological properties -Thickening, emulsifying and melting	Casein, caseinates, milk/whey protein concentrates
Water	-Texture and melting -Solubilizing emulsifying salts	-
Emulsifying Salts	-Protein solubilization and hydration -Aid in emulsifying and stabilization -Texture and melting -pH stabilization	Phosphates and citrates
Acidifying Agents	-Adjustment of pH	Organic acids like lactic, acetic acid
Preservatives	-Prevention of mold growth, extension of shelf life	Nisin, potassium sorbate, propionates

2.2.1 Natural cheese

One of the most significant components in processed cheese is natural cheese. Natural cheese is the main source of the intact casein among processed cheese ingredients. The amount, ripening degree, pH, and calcium content of the natural cheese directly affect the quality and functional properties of the processed cheese. For example, the intact casein content of natural cheese reduces as it ages. As natural cheese ages, enzymes and bacteria hydrolyze proteins into peptides, reducing casein content. This affects functional properties like body and texture. In excessively ripened natural cheese casein is hydrolyzed into small peptides, allowing for easy hydration and dispersion during processed cheese manufacturing and leading to a strong protein network with restricted flow properties. Various types of natural cheeses, such as Cheddar, Kaşar, Swiss, and Gouda, are used to make processed cheese, depending on the country of manufacture, availability, and market demand. In the United States, Cheddar cheese is the most common form of natural cheese used in the production of processed cheese. The quantity of natural cheese in a processed cheese formulation varies from 51% to 80% of the finished processed cheese depending on the type of processed cheese generated (FDA, 2006; Kapoor and Metzger, 2008).

2.3.2 Protein sources

Casein, which makes up approximately 80% of milk proteins, is found in milk as micelles. Approximately 93% of the dry matter of casein micelles consists of casein proteins, while the remaining part consists of minerals and organic acids. Calcium and phosphate, which are bound to protein in the form of colloidal calcium phosphate, are the minerals with the highest amount. Casein forms a complex with these substances, and this complex is referred to as calcium caseinate-phosphate or colloidal calcium phosphate. For this reason, casein is accepted as a phosphoprotein. Caseins are well known for their emulsifying properties among food proteins and are therefore included in the formulation of many foods. They maintain emulsion stability by reducing surface tension between the aqueous phase and the oil phase (Walstra et al., 2005).

The coagulation property of milk is the primary factor in cheese yield and quality during the cheese-making process. For this reason, the dairy industry places a lot of weight on the coagulation of milk with rennet, which is the basis for the manufacture of cheese. The basis of cheese-making is the coagulation of casein micelles. Coagulation generally occurs in two different ways: acid and enzyme. In both methods, casein passes into insoluble form and forms a network structure that does not break down. While the protein network is loose in coagulation with acid, the protein network becomes tight and elastic in coagulation with enzymes. Acidification of casein micelles leads to demineralization, decreased solubility, and hydration, causing precipitation and gelation. Acid curd (acid casein) is produced by coagulation that occurs at pH 4.6, the isoelectric point of casein, where the positive and negative electrical charges are equal. Heat treatment also affects coagulation with acid, forming S-S bridges with kappa-casein (κ-casein). Unlike rennet curd, the casein matrix of acid curd contains all caseins, including the glycomacropeptide of κ-casein. However, loss of colloidal calcium phosphate occurs due to the dispersion of micelles and solubility of colloidal calcium phosphate at the low pH of the gel during whey separation. For this reason, cheeses with acid curd have low calcium and inorganic phosphate levels. The pH value affects cheese structure during production and storage, with low pH resulting in hard, semi-hard, soft, and brittle structures, while high pH results in sticky, moist, and flexible structures (Hammam et al., 2023). Lee et al. (1996) reported that a pH of 5.4 would not be sufficient to make processed cheese using acid curd. The quality of the product was found to be acceptable. In order to obtain processed cheese with acid curd, some part of acid curd should be transformed to sodium or calcium caseinate by using NaOH or $Ca(OH)_2$ because the solubility of the acid curd is low (O'Malley et al., 2000).

Rennet curd (rennet casein) is produced by coagulation with kimozin. Rennet curd and acid curd have quite different compositions. Rennet curd has a lower water binding ability than acid curd due to the absence of the hydrophilic C-terminal of κ-casein in the form of the glycomacropeptide. Rennet curd can be considered a very fresh cheese in terms of calcium content and structure formation which is hydrophobic just like cheese (O'Connell and Flynn, 2007). Rennet casein is used to make the majority of processed cheese alternatives, because it consists of insoluble calcium para-casein. Emulsifying salts dissolve rennet casein, so it becomes soluble by converting from calcium para-casein to sodium phosphate para-caseinate by heat (Miralles et al., 2006). In processed cheese production, cheeses made with rennet curd are generally preferred as natural cheese. The reason for this is that processed cheese produced with rennet casein has a more fibrous structure and higher meltability than those prepared with acid casein. In addition, rennet casein is preferred in processed cheese production because it provides better flavor (Guinee et al. 2004).

Abou-El-Nour and Buchheim (2002) investigated the possibilities of using acid curd in processed cheese production by using rennet casein powder and 20% - 80% acid curd in the production of hard processed cheese. It has been reported that meltability, springiness and cohesiveness values of the cheese samples were not significantly affected. On the other hand, hardness, adhesiveness, gumminess and chewiness values decreased by using acid curd. According to the sensory evaluation, it was stated that the use of 60% of acid curd does not significantly affect the sensory properties.

2.3.3 Fat sources

Milk fat is one of the main ingredients used in the production of processed cheese. Fat provides the desired composition, structure and meltability in cheese. Generally, milk fat is added to the mixture to increase the total fat content of the processed cheese. Milk fat is distributed uniformly within the casein matrix of the cheese, providing the typical smoothness of cheese. The globule membrane of milk fat has an emulsifying action and is rich in surface-active substances. The texture of cheese is influenced by this phenomenon (Guinee et al., 2004).

2.3.4 Water

In the production of processed cheese, water is used to bind calcium, dissolve emulsifying salts, hydrate the protein and disperse the components. Water binds to protein and fills the gaps between the casein matrix and fat, resulting in a viscoelastic cheese matrix. Increasing the water content reduces the hardness and firmness of the cheese and increases the solubility of the product. It has been stated that this trend is associated with increased free water, large fat globules and decreased protein-protein interaction. It is thought that free water disrupts the continuity in the protein network structure, weakening the structure, and the weaker structure requires less energy to melt. The function of water in processed cheese is that it provides softness in spreadable cheeses and meltability in harder cheeses (Hennelly et al., 2005).

2.3.5 Emulsifying salts

Emulsifying salts are required for homogeneous processed cheese structure. They bind calcium between caseins and enhance the solubility of casein by masking the effect of calcium. This allows the release of the casein, increases their emulsification capacity, and enables their dispersion and binding more water (Walstra et al., 2005). More information about emulsifying salts will be given section 2.4.1.

2.3.6 Milk protein concentrates

Milk protein concentrate (MPC) is a powder ingredient that can improve the structural and quality properties of processed cheese. MPC which is produced by processing milk through a number of steps contains natural casein and serum proteins (80% casein and 20% whey proteins). The degree of protein concentration in the process determines the level of protein, lactose and minerals. The goal of the process of making MPC is to extract the fat from the milk and produce a low-fat and high protein dairy product. Microfiltration and ultrafiltration are applied for obtaining condensed milk protein in liquid form, evaporation and drying processes are applied to the liquid product in order to obtain powdered MPC. When MPC is preferred as liquid, evaporation and drying processes are not performed. After the ultrafiltration process, it can be pasteurized and used. With the pasteurization process, possible pathogens are eliminated and a safe product is obtained. Since milk protein concentrate does not have a certain protein level, commercially available products range from 35% to 90% protein level. MPC with high protein levels contain low carbohydrate content and very little lactose (Crowley et al., 2014). Using MPC in processed cheese manufacturing can have some advantages, these are (El-Bakry and Mehta, 2022):

- MPC can positively affect the emulsion structure of processed cheese.

- MPC can increase the solubility of casein.

- By binding the water in the structure of the processed cheese, it can provide a more homogeneous structure.

In the study of El-Nour et al. (1996), possible use of MPC instead of rennet casein in the production of hard processed cheese was investigated.

The addition of MPC reduced the meltability while improving the hardness, sliceability gumminess, adhesiveness and chewiness with acceptable sensory and properties.

In addition, according to Souza et al. (2014), MPC supports not only composition, but also stability of processed cheese. It is important to solubilize MPC by applying constant mixing and heating together in the process. However, compared with other milk protein ingredients, such as caseinates and whey protein concentrates and isolates, MPCs can suffer from the development of insolubility, and as a result, elevated reconstitution temperatures and/or prolonged reconstitution times are required. In addition, it should be considered that the solubility of MPC is higher when dissolved in milk or milk permeate than in water (Huppertz and Gazi, 2017). Because MPC has weak reconstitution ability, end users must alter current unit operations or product compositions in order to accelerate powder rehydration (Crowley et al., 2015). In the study of Crowley et al. (2015), increasing the protein content of MPC powders (from 35% to 90%) augmented the rehydration problem and caused sediment formation after mixing at 25°C for 90 min. When the temperature was increased to 50°C, 90-min mixing reduced the sediment height by 41% while using rehydrated in milk permeate or 80 mM KCl were effective in reducing sediment height by 89.9% and 99.5%, respectively. However, they observed that primary large particles still existed in the solution by particle size analysis. Authors stated that temperature and ionic strength had synergistic effect on rehydration of MPC.

The research of Anema et al. (2006) examined how storage temperature affects the solubility of MPC85. MPC85 was stored at temperatures ranging from 20 to 50°C for up to 60 days. This study found that the solubility of MPC85 was reduced significantly with the increase in storage temperature. Solubility of MPC85 was steady at 20°C for up to 60 days, but declined fast at 50°C. For storage at 30 to 40 °C, the solubility curves indicated three phases, initial, rapid drop, and final near the minimum value. This implies that the reactions that lead to insolubility must be advanced before a decrease in solubility may be detected. This research also revealed only casein became insoluble after storage. This suggests that whey proteins do not play a significant role in the insolubility phenomenon.

The insoluble complexes must be permeable enough to allow whey proteins to migrate from the MPC85 powder to the liquid phase (Anema et al., 2006).

2.3.7 Whey protein concentrates

Whey proteins, which make up 20% of milk protein fraction, remain in whey during cheese production. Whey is a nutritionally valuable milk component, an attractive alternative to other ingredients and its utilization reduces disposal costs and environmental pollution. Whey protein concentrate (WPC), which contains high amounts of protein with functional properties and high nutritional value, is widely used as an ingredient in the production of various foods. Using WPC in the processed cheese formulations causes to increase serum proteins in the processed cheese. Since whey proteins can cross-link with both casein and among themselves at high temperatures, the high level of serum proteins in processed cheese leads to an increase in the hardness and a decrease in the meltability affecting the sensory properties. WPC has low emulsifying ability but they are less sensitive to pH changes compared with caseins. Whey proteins can partially replace rennet casein without significantly altering properties of cheese (Mleko and Foegeding, 2001). Whey protein products are known to have a large proportion of phospholipids in their fat fraction and these phospholipids might increase emulsifying ability of WPC (Young, 1999). The functionality and overall/particular effects of WPC are shown in Table 2.2.

Table 2.2 : The functionality and overall/particular effects of WPC.

Functionality	Overall Effect	Particular Effects on the Processed Cheese Product
Solubility	Smooth texture	Less of a "powdery" or "gritty" sensation
Viscosity	Thickening	Provide body, texture
Emulsification	Form stable fat/oil emulsions	Casein protein replacement, Prevent oiling off
Flavor, aroma	Mild dairy or no flavor	Compatible with other dairy flavors, low flavor impact
Nutrition	Source of high-quality proteins and calcium	Good option for enrichment and fortification purposes

In the research of Sołowiej et al. (2014), the processed cheese analogues were made using only acid casein or rennet casein, and blended with WPC80 or WPI. It was found that WPC increased hardness, adhesiveness, and viscosity, while it decreased meltability. Rennet casein containing samples were harder but less cohesive than acid casein samples. These results suggested that textural/rheological properties and meltability of processed cheese analogues can be controlled by using appropriate protein ingredients.

Abd El-Salam et al. (1996) investigated the effect of 0%, 20%, and 40% WPC addition on the composition and rheological properties of spreadable processed cheese. the authors stated that the addition of 40% WPC increased the amount of serum protein in the final product by 6%. When it was compared with the control spreadable processed cheese without WPC addition, the addition of WPC increased the pH value by 0.3, the lactose content by 2.5% and the moisture content by 0.8%. It has been reported that when the amount of WPC in spreadable processed cheese was increased, meltability, flavor and other sensory properties were also improved due to the increase in moisture content.

2.4 Important Factors Affecting Quality of Processed Cheese

2.4.1 Emulsifying salts

Phosphates and citrates are the most commonly utilized emulsifying salts, which are either used alone or in combination during the preparation of processed cheese (Dularia et al., 2023). In processed cheese manufacturing, the addition of emulsifying salts such as disodium phosphate and trisodium citrate help in increasing the emulsification capabilities of caseins by displacing the calcium phosphate complexes in the insoluble calcium para-caseinate network found in natural cheese and in adjustment of pH with a buffering effect. This calcium phosphate complex displacement breaks the primary molecular bond that connects the different casein monomers in the network. As a result of the breakdown of the calcium phosphate complex by heating and mixing with es, the calcium para-caseinate network becomes sodium para-caseinate as partially dispersed and hydrated. The partially distributed calcium para-caseinate complex interacts with fat through hydrophobic interactions in addition to being hydrated. Hence, the structure of processed cheese is largely made up of a fat phase that is equally dispersed in casein gel network (Guinee, 2004).

Phosphate salts bind calcium better than citrate salts, but when the two are used together, a processed cheese with appropriate hardness and melting properties is obtained (El Bakery, 2010). Choosing the correct emulsifying salts is one of the most critical aspects in the manufacturing of processed cheese blends. This component ensures the formation of a homogeneous structure with the appropriate consistency. They have a substantial impact on the pH, functional and sensory qualities of processed cheese, as well as texture and microstructure (Solowiej et al., 2020).

2.4.2 Calcium

The overall calcium content of a processed cheese determines not only its manufacturing but also its final functionalities such as hardness and melting. A high total calcium level in a processed cheese formula complicates processed cheese production because additional calcium must be separated from caseins by the emulsifying salts added during processed cheese production. Natural cheese is a key component that leads to changes in the overall calcium level of a processed cheese composition. When a natural cheese with a high total calcium content is utilized to manufacture processed cheese, the resulting processed cheese is firmer and less meltable (Kapoor and Metzger, 2008). Calcium can solubilize from casein during processed cheese production due to acid generation and a resulting decrease in pH. The quantity of this solubilization is depending on how the cheese is created (e.g. rate of acid development). This soluble calcium, which is in the aqueous phase of the curd, can be lost into the whey during cheese production, altering the total calcium content of the cheese. Quantitative data on how much calcium is lost during processes in cheese production could give cheese makers more control and allow them to tailor their production procedures accordingly (Swaminathan et al., 2023).

Calcium ions have a significant impact on the para-casein aggregation process and range of hydration, which affects the capacity of casein matrix to bind water as well as its rheological characteristics after heat treatment (Guinee, 2004). Many reactions and interactions between ingredients take place during the cooling of the melted curd, including the creation of disulphide and calcium bridges as well as casein cross-linkages. The presence of cross-linkages in the product matrix is correlated with the hardness of processed cheese (Sołowiej et al., 2014).

2.4.3 pH

There are many factors that affect the quality and textural properties in cheese production, but one of the biggest and easiest indicators of the final product quality and texture is the pH value measured throughout and at the end of production. The pH value provides guidance to manufacturers from the beginning of the process to the final product. Many factors such as the degree of ripening, pH value and type of natural cheese used in the production of processed cheese, the amount, type and pH value of emulsifying salt, relative amount of casein and solubility of casein have significant effects on the pH value of the final product in the processed cheese production (Gupta et al., 1984). As the acidity in the cheese increases, the colloidal calcium found in the caseins dissolves, giving the cheese an elastic, doughy, and workable structure. When the acidity of cheese approaches the isoelectric point of caseins, the electrostatic repulsive forces are reduced and the hydrophobic interactions between caseins increase, resulting in a brittle structure similar to white cheese. The pH value of the processed cheese plays an important role in determining the final textural properties such as hardness, elasticity, adhesiveness, and cohesiveness (Guinee et. al., 2004). Processed cheeses with a low pH value show a hard, semi-soft and crumbly structure, while those with a high pH value show a sticky, moist and elastic structure (Gupta et al., 1984). If the pH value of processed cheeses is lower than 5.4, brittleness occurs in the process cheese. When the proteins in processed cheese approach the isoelectric point, the net negative charges on the proteins decrease, causing reduction of repulsive forces between protein molecules and causing an increase in protein-protein interactions. For this reason, proteins aggregate among themselves and lead to a processed cheese emulsion with a crumbly or gritty structure (Shirashoji et al., 2006). Different researchers have stated that the pH range of a good quality processed cheese should be between 5.4 and 5.8. (Guinee, 2004; Hammam et al., 2023; Kapoor and Metzger, 2008). Piska and Stetina (2004) stated that the pH value of fresh cheese is between 5.20-5.40 when phosphates are used at a rate of 2.6% as emulsifying salt.

In the study of Lee et al. (2003), changes in the structure of processed cheese (that include phosphates and citric acid as emulsifying salts) during heat treatment was investigated and it was reported that the pH value of cheese should be 5.70. In addition, Lee et al. (2005) examined how the rheological properties and colloidal calcium were affected in Cheddar cheese by pH lower than 5. A decrease in pH below 5.0 in Cheddar cheese caused the cheese to acquire a hard and brittle structure with cracks in the structure.

Preferring pH less than 5, as opposed to the generally preferred higher pH values, causes water release in cheese and a decrease in solubility.

2.4.4 Moisture

Cheese is a product with high and variable moisture. The moisture present in cheese after production diffuses throughout the protein network during storage and influences the structure of the cheese. It is preferred that the moisture content of the processed cheese is less than 43% with a pH more than 5.3. (El-Bakry and Mehta, 2022).

There are many studies on the effect of composition of processed cheese on quality. Gupta and Reuter (1993) stated that when the moisture content of processed cheese increases, the firmness of the cheese decreases and its meltability increases. Tamime and Younis (1991) processed cheeses that included 3% emulsifying salts, 13% - 20% water and Cheddar cheese mixtures, contained dry matter between 49 - 55%, fat between 24% - 26%, with pH value changing between 5.4- 5.8. They determined that the taste and quality of the processed cheese made from 25% fresh + 75% mature Cheddar cheese mixture was high.

2.4.5 Production parameters

The emulsion formation and the functional features of the final processed cheese are mostly controlled by processing parameters like temperature and time of heating, and rate of cooling (Kapoor et al., 2004). According to the previous studies, the cook temperature used varies from 70°C to over 100°C based on the type of cooker and the type of processed cheese that is produced (Kapoor and Metzger, 2008).

The temperature and time applied during the heating directly affect the shelf life and functional properties of the final product. At the same time, the type of ingredients used in the product, its water holding capacity, and its physical and chemical properties are the most important factors that determine the viscosity and functional properties of the product (El-Bakry et al., 2011; Guinee, 2016). The kind and quantity of natural cheese, emulsifying salts, and other components employed have an impact on its characteristics. When the production temperature is between 70-90°C, the degree of emulsification of fat increases and the flowability of cheese decreases in the production of processed cheese (Fox et al., 2000). As mentioned before, the use of melting units with mixers (batch or continuous cookers) is common in the production of processed cheese. Glenn et al. (2003) investigated the effect of production conditions of processed cheese on cheese meltability by using 5 different mixing speeds/heat treatment temperatures for the production of Cheddar-based processed cheese. The processed cheese samples were produced with the parameters of 1, 5, 10, 15, 25 and 35 minutes using a combination of 74°C/50 rpm, 86°C/50 rpm, 86°C/100 rpm, 74°C/150 rpm and 86°C/150 rpm. When the meltability of cheeses was evaluated with the Schreiber melting test, it was found that the meltability decreased as the heat treatment temperature, time and mixing speed were increased. This study also showed that processed cheeses melted better at 74 °C than at 84 °C regardless of mixing. (Glenn et al., 2003). It has been reported that smaller fat globules are formed and their dispersion rate in the protein increases as the mixing speed increases in processed cheese production. Therefore, the color of the final product was whiter, the dispersion of processed cheese decreased, and the adhesiveness and hardness increased (Noronha et al., 2006). It is stated that large fat globules increase the flow and dispersion properties of cheese, and therefore there is an inverse proportion between the degree of homogenization and dispersion (Tamime, 2011).

2.5 Functional Properties of Processed Cheese

The desired functional features of processed cheese can be divided into two main categories including unmelted structural properties and melted structural properties depending on the end-use application. The major unmelted structural properties associated with processed cheese are hardness, fracturability, springiness, and adhesiveness. On the other hand, the major melted structural properties associated with processed cheese are meltability, viscosity, strechability and oiling Certain processed cheese applications necessitate an optimal correlation between melted and unmelted textural properties for their unique functional properties. For instance, an ideal processed cheese slice for a toasted sandwich should not only have firmness, cohesiveness, and restricted adhesiveness to provide appropriate machinability during manufacture, but it should also melt during toasting. As a result, the functional qualities required for each processed cheese product type are distinct. The unmelted textural properties can be measured by low temperature dynamic stress rheometry and texture profile analysis (Kapoor and Metzger, 2008).

2.5.1 Textural properties

The texture of the processed cheese is an important quality criterion. A good processed cheese should be homogeneous and uniform in color without air gaps (Chambre and Daurelles, 2000). Different cheeses have different structural properties depending on their composition and production methods. Hardness, cohesiveness, springiness and chewiness can be measured instrumentally and associated with sensory properties that are used to describe cheese texture (Gunesekaran and Ak, 2003).

Texture profile analysis (TPA) was done on a cylindrical sample of cold processed cheese to measure its unmelted textural features such as hardness that describes the firmness of the cheese. The data in the force-time graph obtained by two consecutive compressions on the sample under the pressure plate were used to determine the parameters like hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness through the software of the device.

As a result of the TPA measurement, the properties described below are obtained:

Hardness: It is defined as the force that must be applied to ensure a certain deformation in the structure of the cheese sample. Hardness value of the cheese sample is the point where the first compression ends and the retreat begins. Cheeses are classified as soft, firm and hard with respect to their hardness values. According to Henelly et al. (2005), decrease in hardness with rising moisture content are most likely due to increased hydration of the protein matrix, which weakens protein-protein connections and hence plasticizes the matrix.

Adhesiveness: It is the tendency of processed cheese to resist separation from the material it comes into contact with. It is also defined as the work required overcoming the force of attraction between the surface of the cheese sample and the surface it contacts (tooth, tongue, package, palate or probe).

Since consumers dislike items that are difficult to remove from the packaging, high adhesiveness of processed cheese to the packaging material is one of the factors restricting their consumption (So1owiej, 2012a).

Springiness: It is the tendency of the processed cheese to return to its original dimensions when the applied force is removed.

Cohesiveness: It shows the strength of the internal bonds that form the structure of the food material.

Fracturability: It is the tendency of processed cheese to break into pieces when subjected to an external force.

Gumminess: It is defined as the energy required to break down a semi-solid cheese sample until it is ready to swallow. It is also known as the chewability of the semi-solid food items.

Chewiness: It is defined as the energy required to break down a solid cheese sample until it is ready to swallow (Gunasekaran and Ak, 2003; Guinee et. al., 2004; Kapoor and Metzger, 2008).

2.5.2 Meltability

The major melted structural properties associated with processed cheese are meltability, viscosity, strechability and oiling off. Meltability is tendency of processed cheese to soften and flow when heated. Processed cheese should maintain a uniform flow with minimal oiling-off when used on heated food preparations. Viscosity is the consistency and spread after it melts entirely. In the production of processed cheese, the product must be meltable enough to be pumped, but the final product must have the desired amount of meltability. The melted textural properties can be measured by some techniques like Arnott test, Schreiber melt test, dynamic stress rheometry, rapid visco analyzer and melt profile analysis (Gunasekaran and Ak, 2003).

Meltability is a property directly proportional to the ripening index of cheeses (Daniella et al. 2012). The mechanism of cheese melting is explained by changes in the protein network of cheese structure. Natural cheese made from milk has a three-dimensional network of para-caseinate, and the integrity of this structure is provided by cross-links between proteins. The integrity of the para-caseinate network structure is provided by internal and external bonds such as various hydrophobic and electrostatic attractions. When temperature is increased depending on pH or emulsifying salt addition, partial hydration, coalescence, contraction and degradation of oil-in-water emulsion are observed in the para-caseinate network structure (Fox et al., 2000). As temperature rises in an aqueous environment, hydrophobic bonds of proteins are strengthened. However, increasing temperature decreases the number and intensity of other interactions such as hydrogen bonding. The change in force equilibrium the influences interactions between casein and water. Cheese melting involves major structural changes, including the transition of fat into a liquid state. These adjustments have a substantial impact on cheese melting qualities. Milk fat melts at temperatures ranging from 0 to 40°C, whereas the protein network softens primarily between 30 and 70°C. The rheological qualities of the two phases work together to determine cheese melting characteristics. Other major components of cheese include casein and some serum proteins (present in the serum phase). Although proteins do not melt, alterations in their interactions can result in flow (Atik & Huppertz, 2023).

On the other hand, the type and quantity of protein sources have a major impact on processed cheese characteristics. Casein's ability to form a gel network makes it ideal for processed cheese applications, providing both a solid unmelted texture and a fibrious, elastic melted texture. In contrast, whey proteins create a processed cheese with limited melt properties and a heat-induced irreversible gel is formed (Salunke and Metzger, 2022).

The oiling off property of processed cheese, also known as free oil formation or fat leakage, occurs when liquid fat separates from the melted processed cheese body and forms oil pockets, especially on the top (Wang & Sun, 2004). It has been suggested that emulsified fat globules, as opposed to free oil trapped in protein matrix gaps, are responsible for the generation of free oil. The interaction between fat and para-casein plays an important role for free oil, as homogenization of milk or cream significantly reduces oiling-off ability (Richoux et al., 2008). The quantity of free oil that forms is closely correlated with the size of the fat globules. It has also been demonstrated that cheese with increased fat content has more free oil (Rowney et al., 2003). Moderate oiling off enhances the appearance of food, such as pizza, whereas excessive fat leaking is regarded unacceptable (Wang & Sun, 2004).

2.5.3 Rheological properties

Rheology is a field of study in food technology that focuses on the structure, elasticity, and viscosity of food. The rheological features of processed cheeses were determined by dynamic small-amplitude or large amplitude oscillatory rheology. Cheese exhibits a viscoelastic behavior. In dynamic small-amplitude oscillatory analysis, a small sinusoidal stress is applied to the cheese and the resulting response is measured. Two viscoelastic properties are measured, one G' (elastic or storage modulus) and the other G" (viscous or loss modulus). These two properties show the liquid-like and solid-like properties of a substance. In addition to these, G"/G', that is, loss tangent, is determined. Examination of these parameters at the heating temperature also shows the melting properties of the product (El-Bakry & Mehta, 2022).

While the G' value represents the energy stored and later released in the sample structure as a function of the applied stress, the G″ value represents the flow response of the studied sample and represents the energy lost as a function of applied stress. The fact that G′ and G″ values change with frequency suggests that the cheeses have a viscoelastic character. If G′ is larger than G″ throughout the frequency scan, this indicates that the sample has an elastic feature (Celebi et al., 2020).

2.6 Effect of Formulation on Quality and Functionality of Processed Cheese

In processed cheese production, regulations for permitted ingredients allow manufacturers to select from a diverse range of dairy products to optimize cost, quality, and waste reduction. Native or minimally processed ingredients can reduce waste and preserve milk components, such as whey proteins. Dairy byproducts can be better utilized in processed cheese, such as salty whey, whey cream, or whey butter. On the other hand, clean label concept is another driver for dairy ingredient development, with various ingredients potentially replacing all or part of emulsifying salts in processed cheese. There are studies that have a different perspective and a new direction regarding processed cheese production. For example, Gupta and Rueter (1993) replaced 20% of Cheddar cheese with whey protein concentrate. Trisodium citrate was used as emulsifying salt and the amount of trisodium citrate was increased from 2.5% to 3% with WPC addition. Consequently, it was realized that firmness and meltability decreased with the addition of WPC. With the emulsifiying salt increase, a significant increase in melting in processed cheeses with added WPC. Thus, it was understood that when using WPC in processed cheese, adding emulsifying salt is an important factor to prevent low meltability.

In the study of Kapoor and Metzger (2004), it was aimed to explore the use of salty whey that is expelled during the final step of cheese salting, when it dissolves into the curd particles, resulting in whey expulsion. Most of this whey is drained or physically expelled during pressing as an ingredient in processed cheese. Due to its high salinity, salty whey is underutilized and leads to disposal costs. Pasteurized processed cheese, pasteurized processed cheese food, and pasteurized processed cheese spread were produced along with corresponding control samples. There were no significant differences in composition or functionality of the cheeses compared to the controls. The results suggested that salty whey can be used without affecting cheese quality. As a result, using salty whey as a component in processed cheese seems like a good substitute that might drastically cut down on the amount of salty whey that needs to be disposed of and related costs.

Souza et al. (2014) studied the textural properties of processed cheese produced with using milk protein concentrate and whey protein concentrate at pH 5.6 and 6.2. They discovered that the proportions of WPC and MPC in processed cheese influenced the hardness, elasticity, and adhesiveness of the processed cheese. When the WPC ratio was increased from 25% to 100 % in the samples, higher hardness values were observed because of the difference in the size of the aggregates of serum proteins and/or the greater degree of denaturation at pH value of 6.2. When the amount of MPC in the products was increased, a greater effect on elasticity and adhesiveness was obtained because of the lower degree of denatured serum proteins and their interactions with κ–casein after thermal processing. Although using equal amounts of MPC and WPC in processed cheese did not give good enough textural properties, using only MPC made the cheese samples more texturally acceptable.

Solowiej et al. (2014) examined the texture, viscosity, rheological properties, and meltability of processed cheese analogues using only acid casein (AC) or rennet casein (RC) or 10% AC or RC plus whey protein concentrate80 or isolate (WPI). The study found that the usage of RC resulted in harder cheeses that were good for shredding but had lower melting qualities, especially when WPI and WPC80 were added.

The usage of AC with whey products, on the other hand, resulted in a spreadable-type cheese equivalent that was less adhesive, more cohesive, and had better melting qualities.

The study of Kelimu et al. (2017) examined the impact of sodium caseinate (SC) and butter milk powder (BMP) on the particle size, rheological properties, emulsion stability, and microstructure of hot cheese emulsions made from Cheddar and soft white cheese. Results showed that SC had better emulsification ability than BMP, suggesting a potential strategy to replace emulsifying salts in cheese powder production that include cutting the cheese, adding water and emulsifying salts, mixing, emulsifying and spray drying.

In the research of Solowiej et al. (2020), the impact of polymerized whey protein isolate (WPI) as an emulsifying salt replacer on the properties of processed cheese with acid casein (AC) was investigated. While the amount of WPI in the samples was increased from 0.2% to 0.4%, the required amount of disodium phosphate was reduced from 0.8% to 0.4%. Results showed that partial replacement of emulsifying salts with WPI (as using 0.4% ES and 0.4% WPI) improved textural properties and viscosity, but higher concentrations of WPI (>0.4) decreased hardness and adhesiveness. The highest initial storage and loss moduli were recorded at a WPI concentration of 0.4% which was also correlated with the highest hardness and adhesiveness. Although the products with whey protein concentrate were better emulsified and have good meltability, the best meltability was found in the sample without WPI and with the lowest AC content in this research. According to the authors, the ratio of water to protein should be increased in order to improve meltability because the presence of unbound water facilitates the flow of cheese particles during the heating process. The study suggests that WPI can be a potential emulsifying salt replacer in processed cheeses.

Hammam et al. (2023) aimed to develop a novel processed cheese product (PCP) by using cultured micellar casein concentrate (MCC) without emulsifying salts (ES). Skim milk was pasteurized and microfiltered to produce liquid MCC, which was then spray dried to produce MCC powder. Acid curd was obtained by acidification with lactic acid bacteria at pH 4.6. Three PCP treatments were formulated with different ratios of MCC and acid curd, targeting a composition with 19.0% protein, 45.0% moisture, 30.0% fat, and 2.4% salt. Acid curd was prepared from MCC with different protein content (3, 6, and 9%). Use of acid curd relative to MCC at a ratio of 2:1 was successful in producing PCP without ES. No significant differences were detected in the composition of PCP made with different ratios of 3, 6, and 9%.The pH of PCPs formed from acid curd and MCC was around 5.4, and there were no significant changes between treatments made without ES. The pH differences between the control and experimental PCPs can be related to the usage of ES, which is essential for pH buffering and calcium chelation. The findings showed that the PCP produced without ES was harder than the PCP used as a control with ES. The increased hardness of PCP with no ES might be due to increased protein-protein interactions of caseins at pH 5.4, causing a firmer product. There were no variations in the melting diameter and melt area between the various PCP formulations. The control sample resulted in increased meltability because of the high pH in this formulation compared with other PCP formulations made without ES. The reason of this, increased protein-protein interactions in PC made without ES. The research suggested that it is possible to manufacture processed cheese without ES by a 2:1 ratio of acid curd relative to MCC resulting in a largely de-aggregated casein network that functions similarly to processed cheese produced with ES.

In the study of Salunke and Metzger (2022), MPC and MCC were used in various proportions in processed cheese production. It was aimed to use more concentrates as protein sources and less Cheddar cheese in PC production to understand the effect of concentrates. The PC formulations that included disodium phosphate as emulsifying salt were standardized to contain 15% and 25% MPC or MCC. Consequently, processed cheese formulations containing MCC had high intact casein and lower lactose and whey protein contents than processed cheese formulations containing MPC. Furthermore, MCC25 had considerably higher textural properties than those of the other treatments (MPC15, MPC25, and MCC15). The study discovered that TPA-hardness was significantly increased with the increased amount of added protein. A higher level of intact casein and a lower percentage of whey proteins in MCC25 improved hardness. When compared to MCC-produced PC, MPC-produced PC was softer. Overall, processed cheese manufactured from 25% MPC and 15% MCC had similar textural properties.

There are also published patents about the production of processed cheese with new methods or ingredients other than traditional methods. For instance, in a patent by

Saarentola V., (2013) has invented a dairy based ingredient with good emulsification properties that can be used in processed cheese production. This product is calcium-depleted sodium caseinate that can be used instead of classical emulsifying salts. The inventor suggested that calcium-depleted sodium caseinate is a good emulsifier and free of whey protein. This emulsifier was used as an ingredient of two processed cheeses including spreadable processed cheese and processed cheese slices. It was observed that spreadable PC had favorable organoleptic features and texture, and produced PC slices had similar structure as conventional processed cheese slices with classical emulsifying salts.

The patent of Smith and Rivera (2017) focused on producing processed cheese without significant amounts emulsifying salts, offering a cheese resistant to phase separation and maintaining desirable organoleptic properties. The claimed method involved generating a blend of Cheddar cheese and calcium-reduced casein source in a cooker to produce a processed cheese product. The combination was pasteurized and cooked to 71°C (160°F), with no major emulsifying salts. The processed cheese product was manufactured in a variety of forms, including dips, spreads, blocks, slices, and shredded cheeses. Numerous procedures, such as ultrafiltration, diafiltration, cation exchange, acidification, dialysis, and chelation, were used to create the calcium-reduced casein source. The calcium-reduced casein source contained calcium up to 350 ppm. The processed cheese had a calcium-reduced casein supply of 0.8 to 25% and less than 0.5% emulsifying salts. The produced processed cheeses as a result of this invention were less salty, more uniform and had a more aged cheese taste than traditional processed cheeses. The shelf life of the produced processed cheeses was not different from the traditional one.

3. MATERIAL AND METHOD

3.1 Materials

In the production of three different hard type processed cheese, strained yogurt (Mychef, Metro Grosmarket Bakırköy Alışveriş Hizm. Tic. Ltd. Şti., İstanbul), Kaşar cheese (Ak Gıda A.Ş., İzmir), unsalted butter (Pınar A.Ş., Eskişehir), MPC (Slava Ltd. Şti., Karaman), WPC (Barborassa Ltd. Şti., İstanbul), and table water (Erikli A.Ş., Bursa) were used as raw materials. Both MPC and WPC had 70% protein in dry matter. The chemical composition of the ingredients used in the production of processed cheese is given in Table 3.1.

Table 3.1 : Chemical analysis results of the raw materials to be used in the research.

	Dry Matter (%)	Fat (%)	Protein (%)	Lactose (%)	Salt (%)	Calcium (%)	pH
Strained yogurt (Metro Chef, 2023)	17	5.5	7.5	4	0	0.14	4.2
Kaşar (İçim, 2023)	56	26.2	23.2	1.7	1.6	0.58	5.3
Butter (Pınar, 2023)	84	82	0.3	0.4	0	0.048	6.5
MPC70 (Huppertz and Gazi, 2017)	95	1.4	70	20	0.16	1.8	6.4
WPC70 (El-Bakry and Mehta, 2022)	95	6	70	17	0.26	0.46	6.3

In order to compare the structural properties of the experimental processed cheeses with those of the commercial processed cheeses, three different types of vacuumed packaged commercial processed cheese samples were obtained from (Ak Gıda A.Ş., İzmir) as control samples. The control cheeses were stored at 4°C until measurements were made.

3.2 Methods

3.2.1 Processed cheese formulation and experimental design

In this study, a basic processed cheese formula was developed according to the composition of hard type processed cheese in accordance with the values in the Turkish Food Codex as shown in Table 3.2 (TFC, 2015). Although 3 different formulations have been developed, the reason why the same chemical composition is preferred in all three formulations is to understand the effect of MPC and WPC.

Table 3.2 : The targeted chemical composition of the three types of processed cheese.

Component	Amount
Dry Matter (%)	48
Fat (%)	22
Protein (%)	21
Salt (%)	1
Calcium (mg/100g)	520-380

Only MPC was used in the first formulation of 3 different cheese types designed. In the second formulation, WPC was added to the composition in equal proportion with the amount of MPC. In the third formulation, only WPC was used in the composition. The table of the 3 formulas targeted to be produced in the experimental design is as shown in Table 3.3.

Table 3.3 : Processed cheese formulations developed according to the targeted chemical composition.

Ingredients (%)	Formulation 1 (100% MPC)	Formulation 2 (50% MPC-50% WPC)	Formulation 3 (100% MPC)
Strained Yogurt	23.5	23.5	23.5
Kaşar	48.5	48.5	48.5
Butter	8.8	8.8	8.8
MPC70	**10.6**	**5.3**	0.0
WPC70	0.0	**5.3**	**10.6**
Water	8.5	8.5	8.5

While these three formulations were produced twice, the amounts of ingredients used in each batch are given in Table 3.4.

Table 3.4 : The amount of the ingredients for one batch of processed cheese.

	Formulation 1 (100% MPC) (g)	Formulation 2 (50% MPC-50% WPC) (g)	Formulation 3 (100% MPC) (g)
Strained Yogurt	80	80	80
Kaşar	165	165	165
Butter	30	30	30
MPC70	**36**	**18**	0
WPC70	0	**18**	**36**
Water	29	29	29
Total	340	340	340

3.2.2 Manufacturing of processed cheese samples

In this study, development of a hard processed cheese without using emulsifying salts was aimed. Firstly, a hard process cheese composition was desired to be obtained within the limits allowed by law. In addition, a process cheese with meltability, textural and rheological properties of commercial hard process cheeses was targeted. In development of formulation, the amount and type of natural cheese, its composition, total calcium content, pH value, fat and other ingredients were considered (Guinee, 2004; Kapoor and Metzger, 2008; Hammam et al., 2023). In preliminary experiments, different types of ingredients at varying proportions were tried to give the desired composition, taste, texture and functional properties to the final product. When formulating processed cheese with certain physico-chemical and functional properties, it is necessary to control the amount and type of natural cheese, total calcium content, pH value, fat and other ingredients to obtain good structure that is important for the quality of the processed cheese. In addition, when calculating the amount of ingredients to be added in the formulation, the targeted moisture, fat, protein, pH and calcium value of the final product and the legal regulations specified in the regulations should be taken into consideration. It is known that if the fat and moisture content of the melted cheese formulation is not standardized, a product with the desired functional properties cannot be obtained

One of the major effects of emulsifying salts in process cheese is to convert the insoluble calcium para-caseinate into soluble sodium para-caseinate with the help of heat. This emulsification process allows the casein to function as an emulsifier of fat. The most important parameter in this process is the binding of calcium ions by emulsifying salts. In this way, the solubility of casein increases and the cheese becomes meltable (Kosikowski and Mistry, 1997; Solowiej et al., 2020). Since no emulsifying salts was used in this study, an acid-precipitated casein with low calcium content was preferred. Acid casein is a type of coagulated casein that is produced by low pH and heat and contains all of the casein. Unlike rennet casein, the calcium level is much lower in acid casein. For this reason, in this study, it was aimed to use strained yoghurt as an acid casein source (Hammam et al., 2022). However, calcium is still an important component for the final product structure. Therefore, in order to bring the low calcium amount to a sufficient level, it was decided to add Kaşar at the last stage (Swaminathan et al., 2023). However, since the solubility and meltability of acid casein is low and its solubility is not as good as rennet casein, different protein sources should be preferred that will both increase the emulsion capacity and provide sufficient protein ratio in the formula. MPC and WPC can be good ingredients due to their functional properties and the amount of protein they will add to the structure. These functional properties are expected to contribute to the structural properties of the processed cheese (Crowley et al., 2014). On the other hand, WPC has good solubility over a wide pH range. Therefore, using WPC with acid casein at low pH levels can give good results. Additionally, since WPC can provide a stable oil emulsion, it can prevent the oiling off observed in process cheeses (Mleko and Foegeding, 2001). For these reasons, strained yogurt as acid casein source, MPC, WPC and Kaşar cheese were preferred in the targeted process cheese. It was decided to add unsalted butter and water to the structure to ensure the necessary moisture and fat ratios. At the same time, the water and butter added to the structure can soften the cheese, and improve its melting properties (Guinee et al. 2004). Three different formulations with MPC and WPC were created to better understand the effects of these ingredients in the processed cheese.

Flow chart of processed cheese production is given in Figure 3.1. In manufacturing, three different formulations with 100% MPC, 50% MPC and 50%WPC, and 100% WPC were produced twice on different days. As can be shown in Table 3.4, each formulation was produced as 340 grams on the first production day in Thermomix food processing machine (Thermomix TM6, Vorwerk, Wuppertal, Germany). The same amount of three different formulations was produced as a second batch after 1st day. First, MPC and/or WPC were mixed with strained yogurt, water and butter in the Thermomix at 150 rpm for 30 minutes at 40^{o}C.

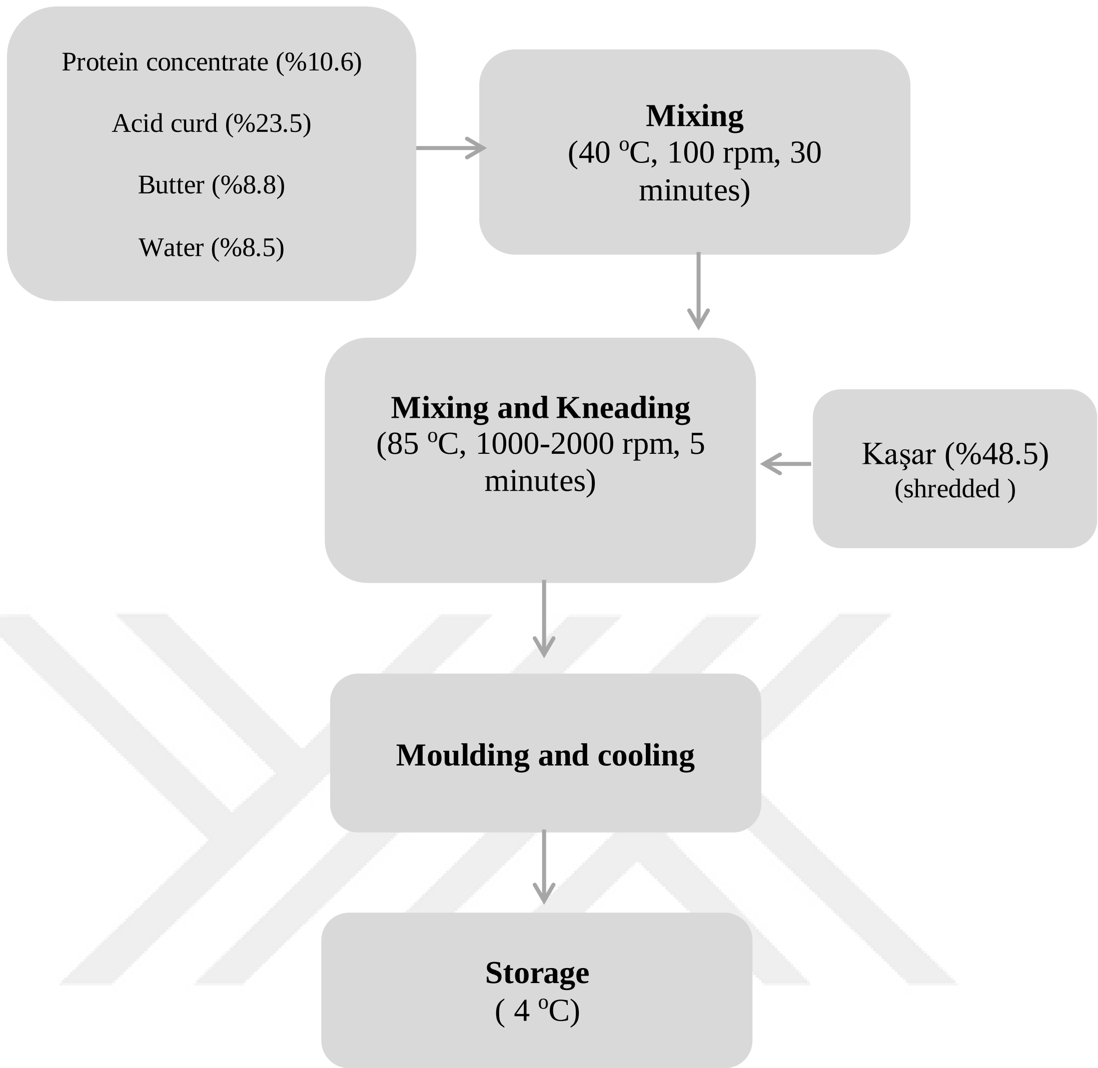


Figure 3.1 : Flowchart of the manufacturing of processed cheese samples.

Then, shredded Kaşar cheese was added to the product and the temperature was increased to 85°C. Two-way mixing was performed at this temperature and at a speed of 1500-2000 rpm, and the mixing process was continued for 7 minutes to make the mixture homogeneous. The mixture was transferred to a cylindrical mould with a diameter of 11 cm and held there until the temperature reached room temperature, and then stored at 4°C for three days.

3.2.3 Physicochemical analysis of processed cheese samples

In gravimetric method was used at 105±2°C for dry matter determination (AOAC, 1997). Approximately 3 g of cheese sample was spread into a nickel container and the cheese sample was dried at 105±2°C until reaching a constant mass. The cooled containers were coded, tared and their tares were recorded. Approximately 3 g of cheese sample was spread into a nickel container and the net weight of the cheese was recorded. Then, the cheese samples were dried at 105±2°C for 4 hours. The samples in the dried nickel containers were placed in a desiccator, cooled, weighed, and the total amount was recorded and the percentage dry matter content was calculated (Metin and Öztürk, 2002).

Fat content of processed cheeses was analyzed according to the Gerber method. Briefly, 3 grams of sample was weighed into a butyrometer, 10 mL of sulfuric acid was slowly added and then 3 mL of distilled water at 60°C was added. The cheese sample wrapped in oil-resistant cellophane paper is placed in the butyrometer and water at 60°C and 1 mL of amyl alcohol are added. To completely dissolve the cheese particles, the butyrometer is shaken well and centrifuged at 1300 rpm for 5 minutes. The butyrometer is placed in a water bath at 65°C with the stopper down and kept for 2–3 minutes. The fat content of the product is determined by reading the fat percentage from the column of the butyrometer (IDF, 2008).

The Kjeldahl method was used for determination of the total protein content of the cheese samples. One gram of the cheese sample was weighed and placed in the Kjeldahl tube, 25 mL of concentrated sulfuric acid and a catalyst tablet were added to the tube. The sample was burned in the combustion unit at 350-400°C until it becomes clear. Next, the tube was distilled in the distillation unit after adding 35% sodium hydroxide and ammonium released was distilled into 4% boric acid solution. The amount of nitrogen is determined by titrating the distillate with 0.2N hydrochloric acid solution. To determine the crude protein content of cheeses, % nitrogen is multiplied by a factor of 6.38 (IDF, 2001).

pH values of cheeses were determined with a digital pH meter. Before determining the pH values of the cheeses during storage, the cheese samples were kept at room temperature (24°C) and then the pH meter was dipped into the cheese sample and the reading was made.

In ash analysis, the porcelain crucibles were placed in the muffle furnace set at 550 °C and kept in the muffle furnace for 4 hours to reach a constant weight. The crucibles removed from the muffle furnace were placed in a desiccator and allowed to cool. After the cooling process, 3 g of cheese samples were weighed into the tared crucibles and placed in the oven and the burning process was continued until a constant weight was reached at 550°C. The % ash amount was calculated from the difference between weighings (Metin, 2012).

Amount of calcium was measured by the EDTA titration method (Kosikowski and Mistry, 1997). In this method, the cheese sample was homogeneously ground with a blender. Five g of sample was weighed and mixed with 150 mL of distilled water and 10 mL HCl (10%). Then, 2 mL 9 N NAOH was added and 2 drops of calconcarboxylic acid indicator were added. Distilled water was added up to a volume of 400 mL. After adding 8 mL of NAOH again, titration was performed with 0.1 N EDTA until a stable blue-gray color was obtained. The amount of EDTA used was recorded. Then 1 mL of calcium chloride (2 g/L) was added. Titration was performed again with 0.1 N EDTA until a stable blue-gray color was obtained. Amount of calcium (mg/100 g) was calculated by the formula [(Total volume (mL) of EDTA -1) x 200/sample mass (g)].

3.2.4 Structural analysis of processed cheese samples

The Arnott test was applied for meltability with modifications (Arnott et al., 1957). Samples with a height of 14.5 mm and a diameter of 17 mm were taken from the samples using a cylindrical cutter and wire mechanism. The samples were kept in closed glass petri dishes to reach room temperature (20±1°C). The samples were placed in a preheated drying oven and kept at 100°C for 15 minutes. A measuring sheet scaled to consist of concentric circles alternating at 2.5mm intervals was used (Appendix B). The measuring paper was placed under the petri dish and the radius of the melting area was measured from 6 different points of the melting mass. Values are reported according to the score scale on the measurement sheet. Measurements were repeated twice.

Oiling off measurement was performed according to Kinstedt and Rippe (1990). Cheese samples of 5 mm height and 17 mm diameter were taken from the samples. A cylindrical cutter and wire apparatus was used to take samples. Before the samples were analyzed, they were placed in Petri dishes and allowed to reach room temperature. The samples placed in the middle of the preheated oven at 100°C. The oil leakage that may occur after the samples kept in the oven for 10 minutes and at room temperature for 30 minutes were determined by using the same scale paper used in the meltability measurement. Measurements were repeated twice.

A texture analyzer (TA Plus Texture Analyzer, Lloyd Instruments, Fareham, UK) was used to measure the textural properties of the samples. The measurement parameters were chosen based on the study by Van-Hekken et al. (2007). Samples of 14.5 mm height and 14.5 mm diameter were taken from the samples using a cylindrical cutter and wire apparatus. The samples were kept at room temperature (20±1°C) for equilibration. A 50 N load cell and a 2.5 cm-diameter cylindrical probe were used in the measurements. A trigger force of 0,3N head speed of 100 mm/min and a compression ratio of 50% were applied. Measurements were repeated twice.

A controlled-stress rheometer (Rheostress1, Thermo-Haake, Karlsruhe, Germany) was used with a 35 mm diameter plate sensor. Samples were taken from the cheeses with a cork borer with an internal diameter of 25 mm. Samples were extruded as a cylinder from the cork borer using a plunger and sliced into a slice with a thickness of 1 mm using a cheese slicer wire. Then, the sample was heated from 25°C to 90°C at a rate of 0.07°C/sec. A frequency of 1 Hz and a strain of 0.005 were used. The elastic modulus (G´) and loss modulus (G´´) were measured as response. Measurements were repeated twice.

3.2.5 Sensory analysis

Sensory analysis was carried out according to descriptive sensory analysis method by panelists familiar with the processed cheeses. A scale between none (1) and extreme (7) was used in the evaluation. Texture and flavor characteristics of the three processed experimental cheese samples and a commercial control cheese were evaluated by at least 15 panelists. A three-digit random numbers were used to code the samples and the commercial control cheese. Two replicated sensory analyses were performed at different times.

3.2.6 Statistical analysis

The statistical analyses were performed by using the Minitab Statistical Software (Minitab 2018, Minitab, Coverty, United Kingdom). Effect of formulation on measured properties of the cheese samples was evaluated by one way analysis of variance (ANOVA). Tukey's test was used to compare means when a statistically significant effect was determined. A significance level of 0.05 was used in the analyses.

4. RESULTS AND DISSCUSSION

4.1 Physicochemical and Structural Properties of Commercial Products

Commercial hard processed cheese samples with different fat content, reduced fat PC, full fat PC1 and full fat PC2, were analyzed for composition and structural properties to determine expected structure and the relation between composition and structure. In physico-chemical analysis, dry matter, protein, fat, ash, pH and calcium contents of the samples were determined. To determine the structural properties, rheological, textural, meltability and oiling off properties were measured.

Physico-chemical properties of the samples are presented in Table 4.1. The physico-chemical properties of the commercial samples had dry matter, fat and protein ratios in accordance with the Turkish Food Codex. In general, PC samples had different dry matter, fat, protein, ash and calcium contents.

Table 4.1 : Physicochemical properties of commercial hard processed cheeses.

Type	Dry Matter (%)	Protein (%)	Fat (%)	Ash (%)	Calcium (mg/100g)	pH
Reduced fat	53.48±0.30^{ab}	22.71±0.13^{a}	23.20±0.00^{c}	1.81±0.04^{a}	584±5.29^{b}	5.38
Full fat PC1	53.27±0.05^{b}	20.73±0.17^{c}	25.10±0.00^{b}	1.71±0.03^{b}	578±3.46^{b}	5.48
Full fat PC2	53.78±0.15^{a}	21.84±0.10^{b}	26.10±0.00^{a}	1.37±0.02^{c}	605±4.36^{a}	5.49

[1] Mean ± standard deviation (n=3). Means in a column not sharing a common superscript are different ($p < 0.05$).

According to the TPA analysis, the springiness, gumminess, chewiness, and stiffness of these three different commercial samples were not different (Table 4.2.). On the other hand, the hardness and cohesiveness of the samples were significantly different. The hardness values of the samples were observed to be correlated to the protein content.

Table 4.2 : Textural properties of commercial processed cheeses.

	Hardness (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (Nmm)	Stiffness (N/mm)
Reduced fat	12.5±1.6[a]	0.15±0.02[b]	4.00±0.03[a]	3.2±0.5[a]	12.8±2.1[a]	4.4±0.5[a]
Full fat PC1	9.5±0.3[b]	0.18±0.04[ab]	3.90±0.02[a]	3.5±1.0[a]	13.6±4.6[a]	4.2±1.7[a]
Full fat PC2	15.1±0.9[a]	0.19±0.02[a]	4.10±0.03[a]	3.8±1.1[a]	15.5±5.4[a]	3.9±0.8[a]

[1] Mean ± standard deviation (n=3). Means in a column not sharing a common superscript are different ($p < 0.05$).

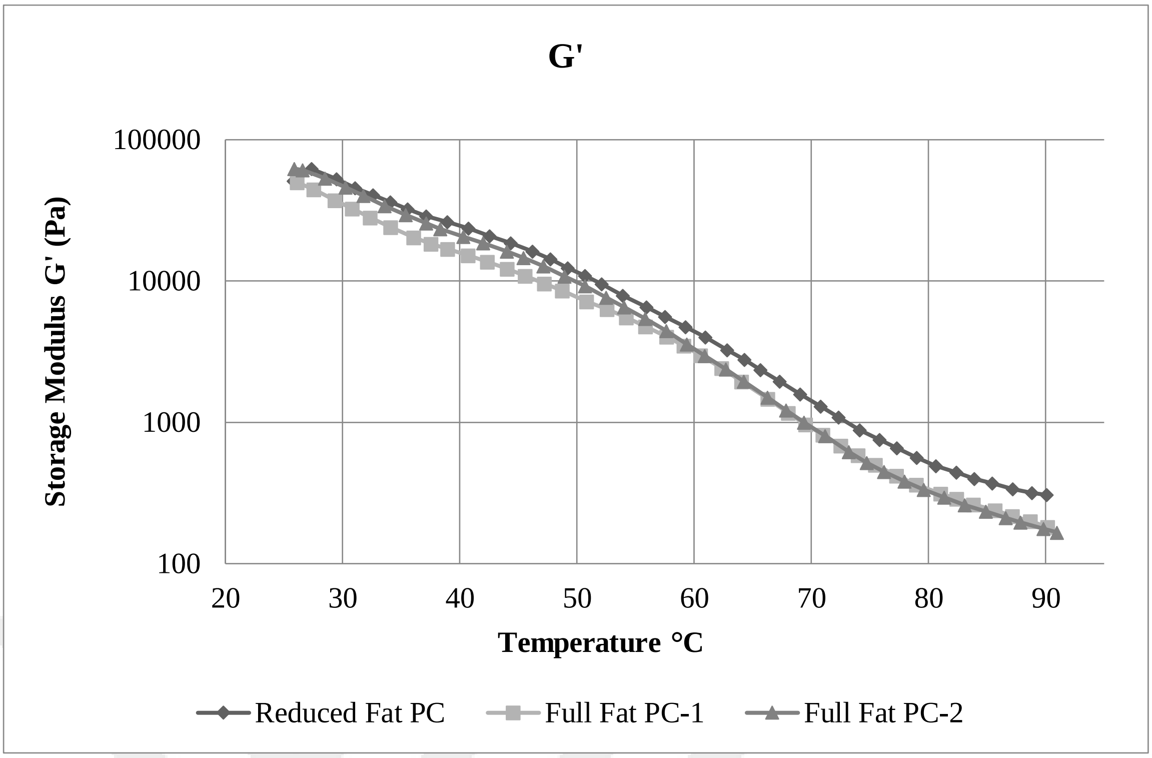
When the melting and oiling off properties of the samples were examined as score, the meltability values of the samples were found to be similar, but differences were observed in the oiling off values (Table 4.3). The full-fat hard PC-1 sample was found to be the processed cheese with the best melting properties but the highest oiling off. On the other hand, oiling off was detected in all samples. Accordingly, it can be said that the oil was not sufficiently emulsified in the structure in all samples (Cumhur, 2008). Moreover, it has been determined that the differences in the composition of hard PC samples do not have a statistically significant effect on meltability. It is thought that this result is due to the variation in the analysis results obtained, and this is due to heterogeneities in the sample structure or low repeatability of the analysis method.

Table 4.3 : Meltability and oiling off of commercial processed cheese.

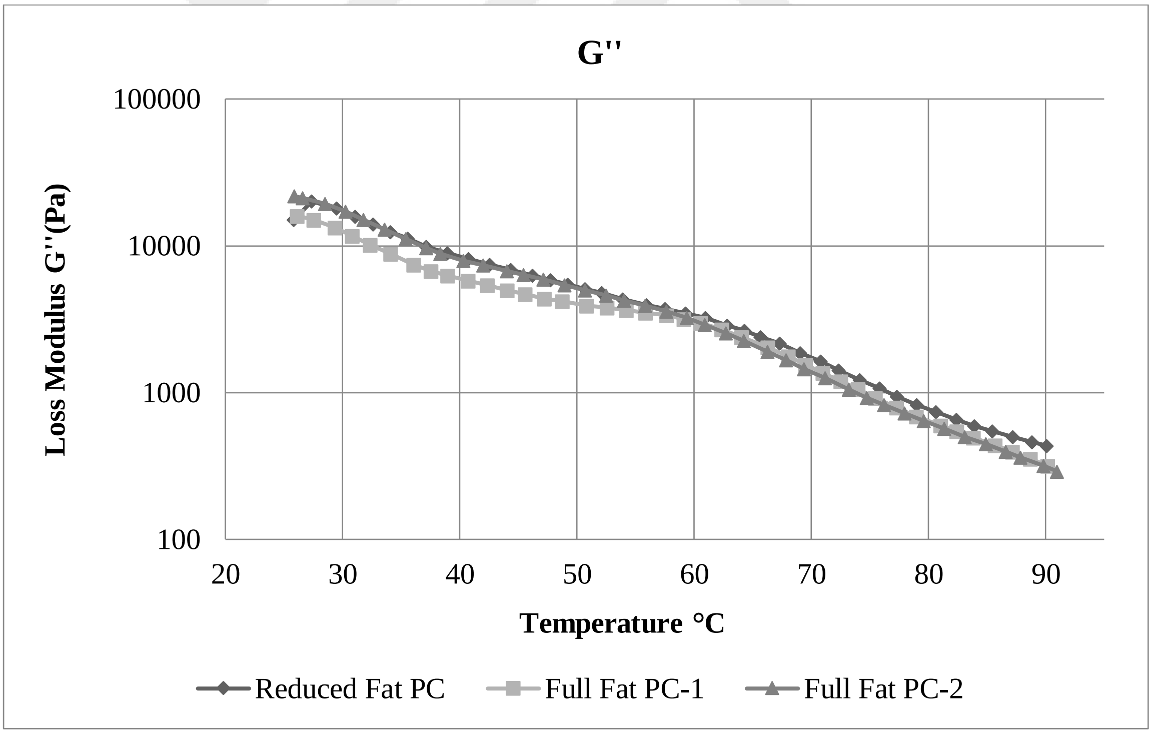
	Meltability (score)	Oiling Off (score)
Reduced fat	3.45±0.28[a]	0.70±0.16[ab]
Full fat PC1	3.57±1.05[a]	1.08±0.18[a]
Full fat PC2	3.25±0.34[a]	0.55±0.28[b]

[1] Mean ± standard deviation (n=3). Means in a column not sharing a common superscript are different ($p < 0.05$).

Changes in elastic (G′) and viscous (G″) modules of commercial cheese samples depending on temperature are presented in Figure 4.1a-b. Figure 4.1(a) shows that the G' value of reduced fat PC is the highest, while full fat PC1 is the lowest, which means reduced fat PC was more elastic than the other samples (Solowiej et al., 2020). The G' decreased with increasing temperature from 20°C to 90°C, indicating that the cheese matrix began to loosen with increasing temperature (Dularia et al., 2023). At a certain temperature, G' and G'' crossed over and this temperature was taken as the flow point which is related to the meltability (Table 4.4). Flow temperature of the full fat PC1 was the lowest, this result could be related to the high fat and low protein content of this sample.



(a)



(b)

Figure 4.1 : Rheological properties of commercial processed cheeses. (a) Elastic modulus (G’) and (b) Viscous modulus (G’’).

In all commercial processed cheeses, values of G' and G" modulus decreased from the starting values with the increasing temperature, indicating that elasticity was the existing attribute of commercial products (Solowiej et al., 2020).

As seen in Table 4.4, differences were observed in the flow temperature values of the samples. The flow temperature was found to be directly proportional to the protein content and inversely proportional to the fat content.

Table 4.4 : Rheological properties of commercial processed cheeses.

Type	Yield stress at crossover point of G'-G" (Pa)	Flow temperature (^{o}C)
Reduced fat	2520±296^{a}	65.33±0.76^{a}
Full fat PC1	2975±285^{a}	60.58±0.46^{b}
Full fat PC2	2853±369^{a}	61.24±1.59^{b}

[1] Mean ± standard deviation (n=3). Means in a column not sharing a common superscript are different ($p < 0.05$).

The hardness and flow temperature values of the samples showed the differences between the samples and it was revealed that these structural properties could be controlled by regulating the composition.

4.2 Production of Processed Cheese Samples

In the production of processed cheese samples, a composition without emulsifying salts was developed according to the national regulation and literature studies (TFC, 2015). The amounts of the ingredients to be used were calculated to provide this composition. Strained yogurt was used as an acid casein source along with dairy protein ingredients, MPC and WPC. Unsalted butter was used as a fat source. Kaşar cheese was used as the cheese ingredient but it is partially replaced by strained yogurt and dairy protein ingredients as MPC and WPC. The compositions of the three formulations were kept constant to better understand the effect of MPC and WPC. MPC is known to have low rehydration capacity (Crowley et al., 2015). Therefore, it was decided to mix the protein concentrates with water, strained yogurt and butter at 40°C for 30 min at 100 rpm in order to dissolve MPC (Crowley et al., 2014; Corredig et al., 2019). Thermomix that is a food processing unit that can generate batches of 1-2 kg of product was preferred to mix, heat and knead the ingredients because this device can mix and heat at the same time similar to the steam cooking machine. MPC powder was dissolved with the ingredients sufficiently within 30 minutes. Afterwards, the mixture was heated to 85°C and shredded Kaşar cheese was added and mixed at a speed of 1000 rpm. The structure of the sample with MPC was hard and it was not stretchable to a high extent. The visual of the first production sample before molding is given in Figure 4.2.

Figure 4.2 : The visual of the first formulated sample with 100% MPC before moulding.

In the production of the second formulation containing 50% MPC and 50% WPC, it was observed that the powder mixture of equal amounts of MPC and WPC reached total solubility faster than the first formulation. However, due to the principle that the treatments should be the same for each formulation, the dissolution process of the powder mixture was continued for 30 minutes. While the samples of the second formulation were produced and molded, it was observed that the samples were softer and more fluid than the sample with 100% MPC.

When 100% WPC powder was used in the formulation, it has been visually observed that WPC dissolved much more easily unlike MPC. In addition, during production and moulding, it was observed that the samples were softer and more fluid than the samples with 100% MPC and 50% MPC-50% WPC. Contrary to what was observed in the other two formulations, the strechability and elongation of the final product was much higher.

On the other hand, it was determined that the structure of the samples containing 100% WPC was not hard and appeared more heterogeneous (aggregations and crumbly structure) during the molding stage. The visual of the sample of the third formulation before molding is given in Figure 4.3.

Figure 4.3 : The visual of the sample of the third formulation with 100% WPC before moulding.

After the samples of three different formulations were cooled and matured at 4 °C for 3 days, visual inspection of the products revealed that their structures were different from each other. The visual of samples of three different processed cheeses produced is presented in Figure 4.4. It has been observed that samples containing MPC are better than samples containing 100% WPC in terms of structural integrity. Another observable situation is that the product containing 100% WPC has crumbly structure, structural disintegration and it is not as homogeneous as other samples.

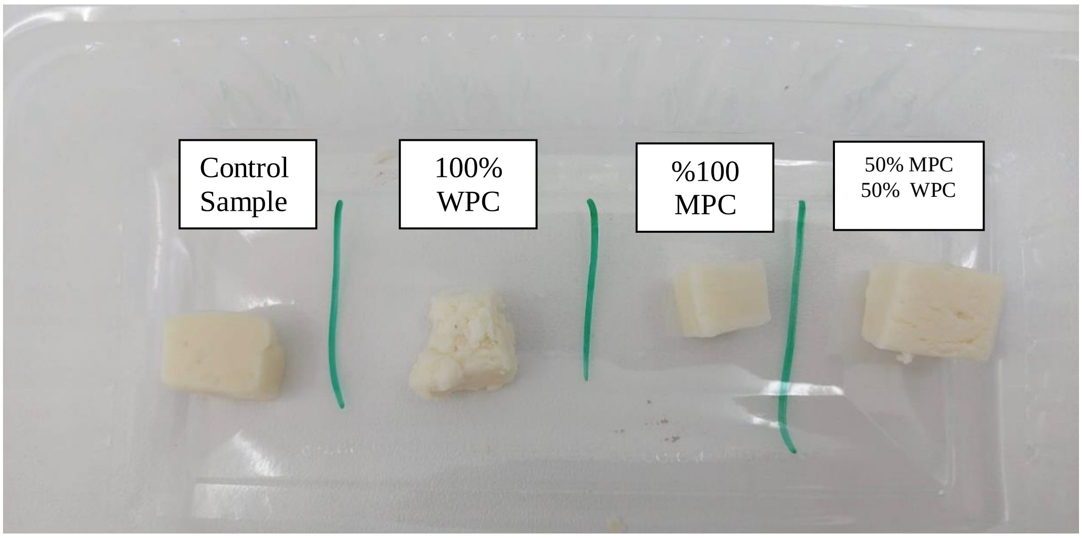


Figure 4.4 : The visual of samples from the three different processed cheeses.

4.3 Physico-Chemical Properties of Experimental Processed Cheeses

Physico-chemical properties of the experimental processed cheese samples had dry matter, fat and protein contents in accordance with the Turkish Food Codex (Table 4.5). No differences were detected in the dry matter fat, protein, ash and calcium contents of produced samples ($p > 0.05$) as expected because of the formulation adjustment. There was a significant difference between the pH values of the formulations where the lowest pH was observed in the sample with WPC. It has been reported that the pH of processed cheese containing natural cheeses and emulsifying salts can range between 5.4 and 5.8 (Hammam et al., 2023). In this research, the pH of all formulations was in this range. Because of the effects on protein interactions, pH changes could affect the structure and quality of final processed cheese, and hence its functional qualities (Hammam et al., 2023).

Table 4.5 : Physicochemical properties of processed cheese samples.

	Dry Matter (%)	Protein (%)	Fat (%)	Ash (%)	Calcium (mg/100 g)	pH
Formulation-1 (100% MPC)	46.04±1.30^{a}	22.73±1.32^{a}	26.10±0.00^{a}	1.65±0.27^{a}	571.0±4.2^{a}	5.55±0.02^{a}
Formulation-2 (50% MPC-50% WPC)	46.15±1.67^{a}	23.08±0.99^{a}	25.85±0.35^{a}	1.71±0.22^{a}	431.0±32.5^{a}	5.47±0.06^{ab}
Formulation-3 (100% WPC)	44.75±2.31^{a}	22.15±0.51^{a}	25.35±0.35^{a}	1.77±0.22^{a}	429.5±98.3^{a}	5.41±0.09^{b}

[1] Mean ± standard deviation (n=2). Means in a column not sharing a common superscript are different ($p < 0.05$).

4.4 Textural Properties of Experimental Processed Cheeses

The results of the texture analysis are presented in Table 4.6. Type of protein concentrate affected the textural properties of the processed cheese. The hardness of the sample with 100% MPC was the highest. The reason for this result can be that MPC has more intact casein and low amount of whey protein compared with WPC. Using increased amount of whey proteins decreased the firmness of the processed cheese (Salunke and Metzger, 2022). On the other hand, the hardness of the sample with 50% MPC-50% WPC was found similar to that of the sample with 100% WPC. This result could be due to the variation in the analysis results obtained originating from the structural heterogeneity of the sample with WPC. Moreover, all hardness values of the three produced formulations were significantly lower than those of the commercial processed cheese samples (Table 4.2). According to Kapoor and Metzger (2008), if the calcium content of the processed cheese higher, the hardness of the processed cheese will also be higher. The total calcium content of PC has an impact on its functional characteristics. The calcium content of the sample with %100 MPC was the highest and this sample was the hardest one among the samples. Additionally, the control samples contained emulsifying salts, but the three produced formulations did not. El-Bakry et al. (2010) reported that when the amount of emulsifying salts is higher, the hardness of the product is also higher. It was explained that the emulsifying salts helps to form hydrogen bonds in the cheese structure, which strengthen the composition of the cheese. This finding are also in agreement with the hardness results of this research.

Table 4.6 : Textural properties experimental processed cheeses.

	Hardness (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (Nmm)	Fracture force (N)	Adhesive force (N)	Stiffness (N/mm)
Formulation-1 (100% MPC)	9.30±1.61[a]	0.26±0.03[a]	4.11±0.37[a]	2.43±0.49[a]	10.02±2.49[a]	0.314±0.011[a]	0.32±0.10[a]	2.19±0.76[a]
Formulation-2 (50% MPC-50% WPC)	3.84±1.28[b]	0.14±0.06[b]	2.78±0.78[b]	0.53±0.23[b]	1.61±0.97[b]	0.299±0.005[b]	0.18±0.07[b]	0.84±0.21[b]
Formulation-3 (100% WPC)	4.50±0.65[b]	0.07±0.01[c]	2.24±0.58[b]	0.31±0.10[b]	0.69±0.32[b]	0.302±0.006[b]	0.15±0.10[b]	1.10±0.26[b]

[1] Mean ± standard deviation (n=2). Means in a column not sharing a common superscript are different ($p < 0.05$).

When the cohesiveness values of the produced samples are examined, it can be said that the type of protein concentrate affects the cohesiveness of the processed cheese. The cohesiveness value of the sample containing 100% MPC was found to be the highest, and the sample containing 100% WPC was found to have the lowest cohesiveness value. Whey proteins in the samples created certain heterogeneity, especially in the sample with 100% WPC. The formulation containing 100% MPC where casein was more dominant in the structure of cheese, had high cohesiveness due to its strong protein network (Beykont, 2009).

Chewiness measurements of the formulations showed that the type of protein concentrate influences the chewiness of the samples. Chewiness of the samples with WPC was lower than that of the sample with 100% MPC. Guinee et al. (2004) stated that as the calcium content of the cheese decreases, its structure softens, and its chewiness decreases. As a result of the study, it was observed that the results regarding hardness were parallel to the chewiness results. Similar trend was observed in springiness, gumminess, chewiness, adhesive force and stiffness of the samples. Sample containing 100% MPC showed higher results than the other samples. This situation shows that using MPC instead of WPC in processed cheese produces a good structure. This situation is in agreement with some studies in the literature (Salunke and Metzger, 2022; El-Bakry and Mehta, 2022). The differences in the proteins that make up the MPC and WPC and the fact that MPC contain a higher casein content which can form a tighter protein network and a homogeneous structure can explain the textural results obtained. It has been reported that integrity and flexibility of the processed cheese depend on the amount of protein, and that these properties express the resistance of the structure to deformations and the number and strength of bonds in the structure (Solowiej et al., 2020).

When the textural properties of the produced processed cheeses are compared with the commercial control samples, it can be said that the first sample containing 100% MPC is the closest sample to the control samples in terms of textural properties.

4.5 Meltability and Oiling Off of Experimental Processed Cheeses

The meltability scores of the three formulations were found different from each other as shown in Table 4.7.

Table 4.7 : Meltability and oiling off properties of experimental processed cheeses.

Sample	Meltability (score)	Oiling Off (score)
Formulation-1 (100% MPC)	2.96±0.05[a]	0.74±0.42[a]
Formulation-2 (50% MPC-50% WPC)	2.17±0.25[b]	0.60±0.33[a]
Formulation-3 (100% WPC)	-	-

[1] - : Not detected.
[2] Mean ± standard deviation (n=2). Means in a column not sharing a common superscript are different (p < 0.05).

While the sample produced with 100% MPC had a value close to the meltability of commercial control cheeses, the meltability of the sample produced with 50% MPC-50% WPC was found to be lower. On the other hand, the third sample containing 100% WPC did not melt. The visual of samples after meltability analysis is presented in Figure 4.5.

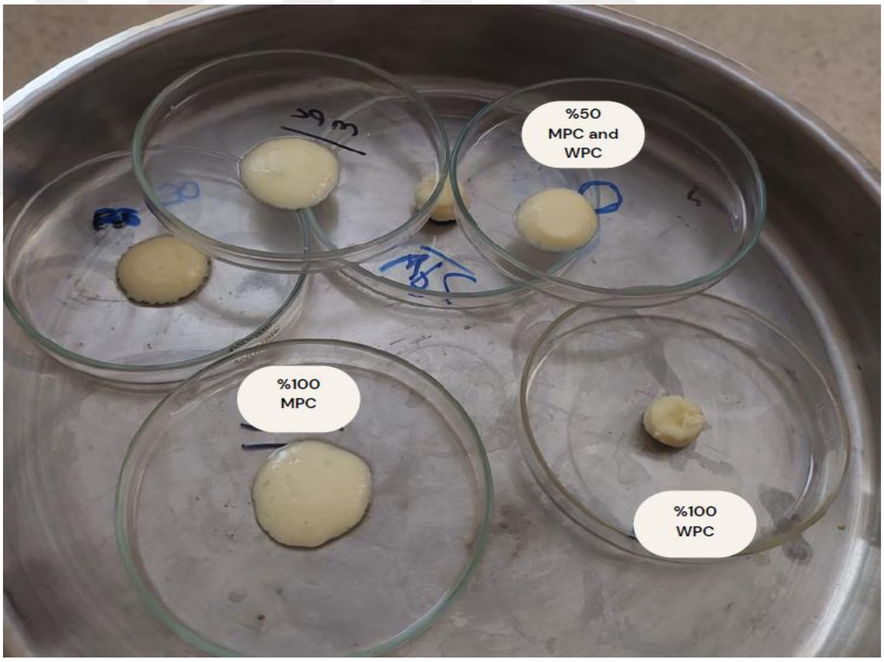


Figure 4.5 : The visual of samples after meltability analysis.

The results are consistent with the results of some previous studies. The addition of more WPC resulted in a significantly substantial decrease in the meltability of processed cheeses (Gupta and Reuter, 1993). In another study, whey proteins were added to processed cheese analogs with rennet casein. When the final product composition contains more protein, they have observed a decrease in the melting. The authors claimed that the interaction between κ-casein and β-lactoglobulin is what caused the alterations in melting (Mleko and Foegeding, 2000). The decrease in meltability is also connected with whey proteins acting as active fillers in the casein network, resulting in a stronger mixed gel structure, as well as the fibrous structure that these proteins produce around the fat globules. These finding is thought to be the reason why the third sample containing 100% WPC does not show any melting or oiling off.

When the oiling off results were examined, except the sample containing 100% WPC, oiling off was observed in all other samples, including control samples. It is known that there is no or very little oiling off in processed cheeses with good emulsification (Cumhur, 2005). Improper emulsification of the processed cheese can occur for a number of reasons, including insufficient or excessive emulsifying salt levels, low final pH of the processed cheese, low level of intact casein in the processed cheese, or insufficient or excessive processing temperature and/or time during processed cheese manufacture (El-Bakry and Mehta, 2022).

4.6 Rheological Measurements of Processed Cheese With MPC and WPC

Rheological properties of the processed cheese samples are shown in Figure 4.6. The fact that G′ and G″ values change with frequency suggests that the cheeses have a viscoelastic character (Celebi et al., 2020). Flow temperature was determined from temperature sweep measurements. Flow temperature is the lowest temperature where a sample changes from firstly elastic to viscous. The mean values of the melt temperature of the three formulations are given in Table 4.8. The flow temperature of the samples with 100% MPC and 50%MPC-50%WPC were found similar.

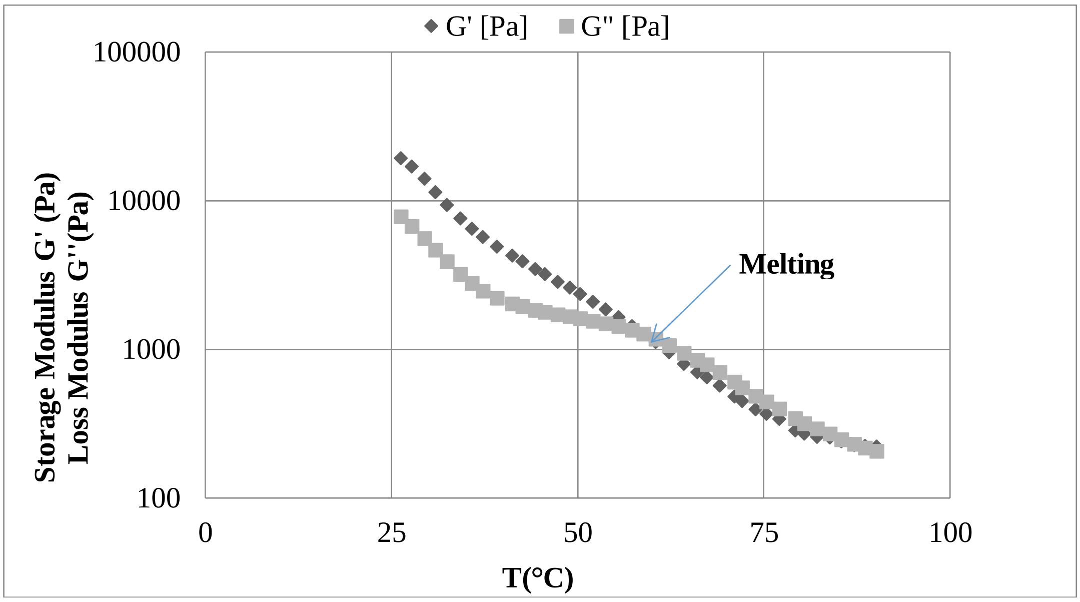
Table 4.8 : Rheological properties of the experimental processed cheeses.

Sample	Yield stress at crossover point of G'-G'' (Pa)	Flow temperature (°C)
Formulation-1 (100% MPC)	1248±241[a]	58.51±3,58[a]
Formulation-2 (50% MPC-50% WPC)	1063±380[a]	57.47±1.86[a]
Formulation-3 (100% WPC)	-	-

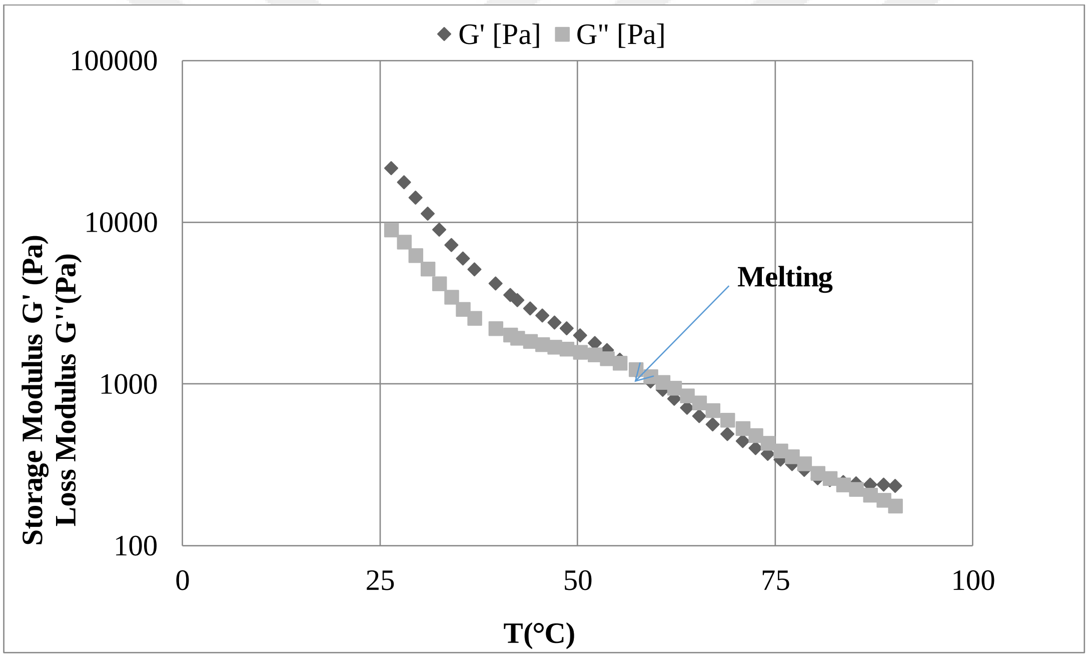
[1] - : Not detected.
[2] Mean ± standard deviation (n=2). Means in a column not sharing a common superscript are different ($p < 0.05$).

Since the sample with 100% WPC did not show any melting, G' and G" did not intersect and the melting temperature was not obtained. The lower melt temperature of produced processed cheese samples compared with those of the commercial samples can be related to low calcium in the formulations. As Kapoor and Metzger (2008) and Kommineni (2022) mentioned in their studies, higher calcium level causes a heat-induced irreversible gel resulting in a processed cheese with more restricted melt properties. In addition, this may also be related to the use of emulsifying salts in commercial processed cheese which contributes more fat emulsification. The lower flow temperature of samples with 100% MPC and 50%MPC-50%WPC may also be caused by reduced degree of solubilization of the proteins compared to those of the commercial samples (Kommineni, 2022).

Changes in elastic (G′) and viscous (G″) modules of cheese samples depending on temperature are presented in Figure 4.6a-b. The G' decreased with increasing temperature from 20°C to 90°C, indicating that the cheese matrix began to loosen (Dularia et al., 2023; Solowiej et al., 2020). A similar trend was found in other studies (Guinee and O'Kennedy, 2009; Hammam et al., 2023). Furthermore, the decreasing of G' from 20 to 90 °C shows that the cheese matrix loses its solid structure elasticity as the temperature rises. This is due to the weakening of casein network and melting of fat (Salunke and Metzger, 2022). On the other hand, the G' of the samples before flow temperature (intersection point) was higher than G". According to the study of Hammam et al. (2023), this demonstrates that produced processed cheese samples has more elastic behavior than viscous behavior before flowing.



(a)



(b)

Figure 4.6 : Rheological properties of experimental processed cheeses. (a) for sample with only MPC and (b) for sample with MPC and WPC.

4.7 Sensory Properties of Experimental Processed Cheeses

Three produced processed cheese samples and a commercial control sample were subjected to sensory evaluation. The sensory evaluation results are given in Appendix B.

When the textural and flavor properties of the control and trial cheeses were examined by analysis of variance, it was found that the effect of the type of protein concentrate used in the processed cheese formulations was often significant ($p<0.05$).

As a result of sensory evaluation, the hardness values of the samples were found to be different from each other and the hardest sample was the control sample. The control sample is followed by the sample containing only MPC in terms of hardness. The sample with the lowest hardness was determined as the sample containing only WPC. The results of instrumental textural analysis and sensory analysis indicate that the hardness values were consistent.

When the cohesiveness values of the samples were examined, it was determined that the type of protein concentrate used in the processed cheese had an effect on the integrity and the sample with only MPC was similar to the control sample.

According to the elasticity results, the processed cheese with the highest elasticity value was found to be the control sample followed and the experimental samples had lower elasticity. It can be said that the results obtained in the sensory evaluation were compatible with the instrumental springiness data. Chewability of the samples followed a similar trend to that of elasticity, whereas there was no difference in cream color and dullness values of the samples.

When the crumbly texture values were compared, it was determined that the sample with only MPC was similar to the control sample. On the other hand, the samples with WPC had higher crumbly texture. This trend can be attributed to the fact that whey proteins cause more protein-protein interactions in the processed cheese. As a result, the proteins aggregate together, producing a weaker cheese emulsion that has a gritty and crumbly texture (El-Bakry and Mehta, 2022).

When the textural properties are examined in general as shown in Figure 4.7, the control sample and the sample with only MPC gave similar results in terms of hardness, cohesiveness, elasticity and crumbly texture, but differed from the sample containing 50% MPC and 50% WPC and the sample with only WPC. However, the dullness and cream color properties of the control sample as well as the three samples containing MPC and WPC were found to be similar to each other.

Except for the dullness and cream color properties, the sample containing 50% MPC and 50% WPC and the sample with only WPC gave lower scores in the texture section of the sensory analysis compared to the sample with only MPC.

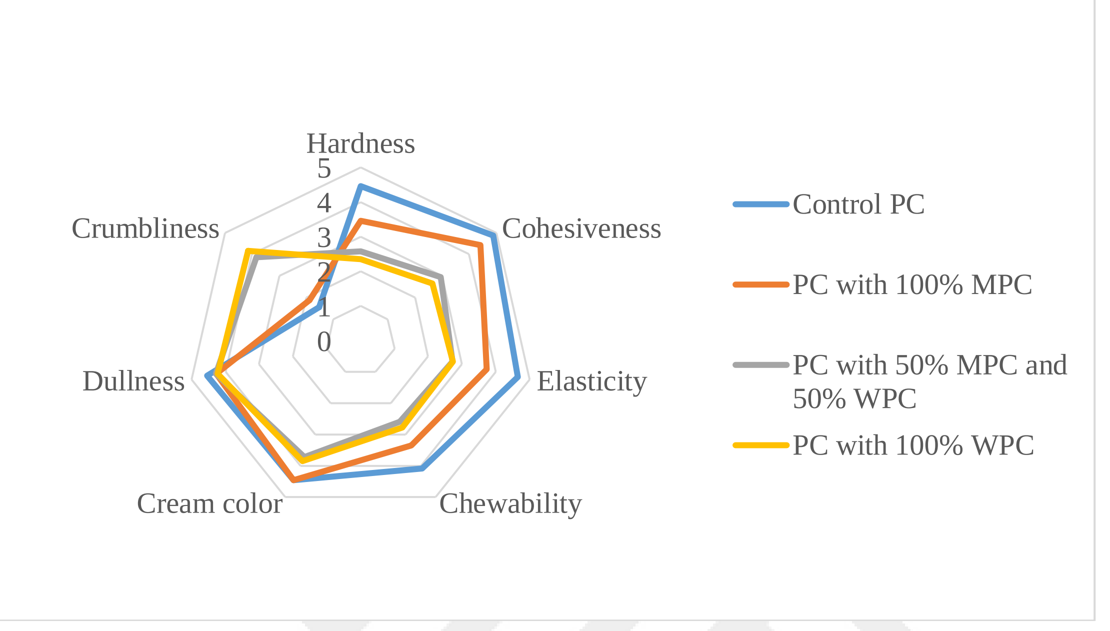


Figure 4.7 : Textural properties of the control and the experimental processed cheeses.

In the second part, the taste characteristics of processed cheeses were examined as shown in Figure 4.8. It was revealed that the control sample was the most similar to Kaşar in terms of flavor. The sample containing only MPC had more Kaşar cheese flavor compared to the samples with WPC. In addition, it is seen that the trends in Kaşar cheese taste and overall acceptability scores were similar. The reason for this may be that Kaşar cheese is one of the most consumed cheese types in Turkey. On the other hand, there was no difference in sourness, sweetness, butter flavor and saltiness of the cheeses.

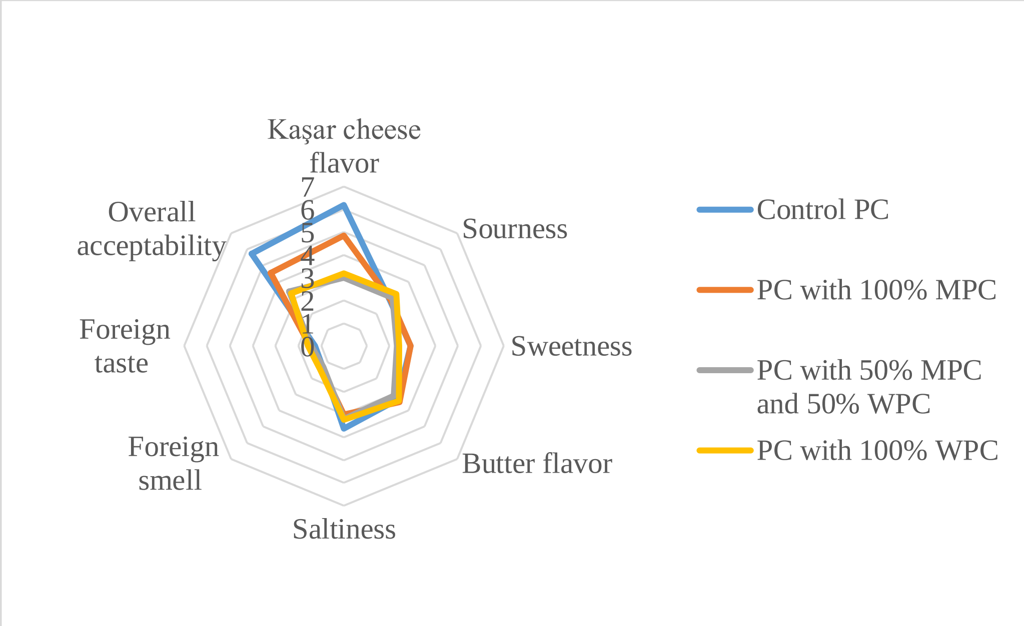


Figure 4.8 : Flavor attributes of the control and the experimental processed cheeses.

According to these results, the most appreciated sample in terms of taste characteristics was the produced sample containing only MPC. If we need to rank the scoring given in terms of structure from largest to smallest; the control sample, the sample containing only MPC, the sample containing 50% MPC and WPC, and finally the sample containing only WPC.

5. CONCLUSIONS

This study aimed to produce processed cheese without emulsifying salts, which are essential additives in processed cheese manufacture. For this purpose, strained yoghurt was used as an acid casein source along with MPC and WPC. A basic formula was developed to adjust dry matter, protein and fat contents by using strained yoghurt, Kaşar cheese, butter and a dairy protein ingredient. Three different formulations were designed where dairy protein ingredient was 100% MPC, 50% MPC-50%WPC and 100%MPC. Physicochemical analyses revealed that the dry matter, fat, protein and ash contents of processed cheese samples were acceptable according to the Turkish Food Codex. Type of dairy protein ingredient affected the textural properties of the samples and the processed cheese with 100% MPC had the highest hardness and other textural values. While the processed cheese with 100% MPC and 50% MPC-50% WPC were meltable or flowable, the sample with 100% WPC did not exhibit melting. Sensory analyses showed that experimental processed cheese sample with 100% MPC was the most similar to control commercial sample in terms of textural and flavor attributes.

This study showed that acceptable hardness, meltability and textural properties can be achieved by using strained yoghurt as an acid casein source and MPC as a dairy protein ingredient in the formulation of processed cheese. Further studies are required for determination of storage stability in terms of structural and sensory properties of the developed product.

REFERENCES

Abd El-Salam, M. H., Al-Khamy, A. F., El-Garawany, G. A., Hamed, A. & Khader, A. (1996). Composition and rheological properties of processed cheese spread as affected by the level of added whey protein concentrates and emulsifying salt. *Egyptian Journal of Dairy Science, 24,* 309-322.

Abou-El-Nour, A.M. & Buchheim, W. (2002). Using rennet casein and buttermilk curd in the manufacture of processed cheese analogue. *Egyptian J. Dairy. Sci., 30(2),* 315-324.

Anema, S., Pinder, D., Hunter, R., & Hemar, Y. (2006). Effects of storage temperature on the solubility of milk protein concentrate (MPC85). *Food Hydrocolloids, 20*(2–3), 386–393.

Beykont, E. (2009). *Peynir Benzeri Bir Üründe Depolama Süresinde Meydana Gelen Değişimler*. (Yüksek lisans tezi). Istanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, ISTANBUL.

Çakır, Ç. A., Bedir, T. B., & Paksoy, Ö. İ. (2021). Kargi tulum peynirinin bazi kimyasal, tekstürel ve mikrobiyolojik özelliklerinin belirlenmesi. *Euroasia Journal of Mathematics, Engineering, Natural & Medical Sciences, 8*(17), 127-134.

Çelebi, M., & Şimşek, B. (2020). Taze ve olgunlaşmış Kaşar peynirlerinde bazı kimyasal ve tekstürel özelliklerin belirlenmesi. *Yüzüncü Yıl Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 25*(2), 64-74.

Chambre, M., & Daurelles, J. (2000**).** Processed cheese: In & (Eds.), Cheesemaking: from Science to quality assurance. Editors: Eck A., Gillis J.C. *Lavoisier Publishing Inc*. Paris France. 641–657.

Cumhur, Ö. (2008). *Peynir Benzeri Bir Üründe Farklı Protein Kaynaklarının Yapısal Özelliklere Etkilerinin Belirlenmesi* (Yüksek lisans tezi). Istanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, ISTANBUL.

Crowley, S. V., Megemont, M., Gazi, I., Kelly, A. L., Huppertz, T., & O'Mahony, J. A. (2014). Heat stability of reconstituted milk protein concentrate powders. *International Dairy Journal, 37*(2), 104–110.

Crowley, S. V., Desautel, B., Gazi, I., Kelly, A. L., Huppertz, T., & O'Mahony, J. A. (2015). Rehydration characteristics of milk protein concentrate powders. *Journal of Food Engineering, 149,* 105–113.

Corredig, M., Nair, P.K., Li, Y., Eshpari, H., & Zhao, Z. (2019). Invited review: understanding the behavior of caseins in milk concentrates. *J. Dairy Sci., 102* (6), 4772–4782.

Czulak J, Conochie J, Sutherland BJ, & Van Leeuwen HMJ. (1969). Lactose, lactic acid, and mineral equilibria in Cheddar cheese manufacture. *J Dairy Res 36*, 93–101.

Daniela, D. V., Chevalier, F., Donaghy, J. A., Patterson, M. F., Qian, M. C., & Kelly, A.L. (2012). Effect of high-pressure treatment of milk for cheese manufacture on proteolysis, lipolysis, texture and functionality of Cheddar cheese during ripening. *Innovative Food Science and Emerging Technologies*, *13*, 23-30.

Dixon, S. (2011). Processed cheese plants and equipment: a practical overview. In: Tamime, A.Y. (Ed.), *Processed Cheese and Analogues* (pp. 179–198). West Sussex, UK :Wiley-Blackwell Publishing Ltd.,

Dularia, C., Meena, G. S., Hossain, S., Khetra, Y., & Arora, S. (2023). Effect of emulsifying salts on functional, textural and rheological properties of milk protein concentrate 80 (MPC80) based processed cheese product. *Food Hydrocolloids*, *142*, 108842.

El-Bakry, M., Duggan, E., O'Riordan, E., & O'Sullivan, M. (2011). Effect of chelating salt type on casein hydration and fat emulsification during manufacture and post-manufacture functionality of imitation cheese. *Journal of Food Engineering*, *102*(2), 145–153.

El-Bakry, M., & Mehta, B. M. (2022). *Processed Cheese Science and Technology: Ingredients, Manufacture, Functionality, Quality, and Regulations*. Sawston, Cambridge: Woodhead Publishing Limited.

El-Nour, A.A., Scheurer, G.J., Omar, M.M., Buchheim, W., & Abou-El-Nour, A. (1996). Physicochemical and Rheological Properties of Block Type Processed Cheese Analogue Made From Rennet Casein and Total Milk Protein. *Milchwissenschaft, 51:12* , 684-687.

Food and Drug Administration. (2006). 21 CFR, Part 133.169 to 133.180. Food and Drug Administration. Washington, D.C.: Dept. of Health and Human Services.

Food Data Central. (n.d.). *Retrieved June 25, 2023, from* https://fdc.nal.usda.gov/fdc-app.html#/food-details/171304/nutrients.

Fox, P. F., Guinee, T. P., Cogan, T. M. & McSweeney, P. L. H. (2000). Fundamentals of cheese science, *Aspen Publishers Incorporated*, Maryland, 429-451.

Fox, P.F., & McSweeney, P.L.H. (2003). Advanced Dairy Chemistry, Proteins Part A, Vol. 1 (3) *Kluwer Academic/Plenum Publishers*; New York.

Fox, P.F., Guinee, T.P., Cogan, T.M., & McSweeney, P.L. (2017). *Fundementals of Cheese Science, second ed.* (pp. 589–627), New York: Springer.

Glenn, T. A., C. R. Daubert, B. E. Farkas, & L. A. Stefanski. (2003). A statistical analysis of creaming variables impacting processed cheese melt quality. *J. Food Qual., 26*, 299–321.

Guinee, T. P. (2016). "Cheese: Pasteurized Processed Cheese Products". Reference Module in Food Science 805-813.

Hammam, A. R., Kapoor, R., & Metzger, L. E. (2023). Manufacture of process cheese products without emulsifying salts using acid curd and micellar casein concentrate. *Journal of Dairy Science*, *106*(1), 117–131.

Hanna, S.A.S. & Nader, A.S. (1996). Manufacture of processed cheese from Iraqi white soft cheese. *Journal of the Society of Dairy Technology*, *49*, 57-58.

He, F. J., & MacGregor, G. A. (2010). Reducing Population Salt Intake Worldwide: From Evidence to Implementation. *Progress in Cardiovascular Diseases*, *52*(5), 363–382.

Hennelly, P. J., Dunne, P. G., O'Sullivan, M., & O'Riordan, D. (2005). Increasing the moisture content of imitation cheese: effects on texture, rheology and microstructure. *European Food Research and Technology*, *220*, 415-420.

HMSO. (1974). The Cheese (Amendments) Regulations 1974. Food and Drugs: Composition and Labelling, No.1122. Available at http://www.legislation.gov.uk/uksi/1974/1122/contents/made.

Hoffmann, W., Gärtner, J., Lück, K., Johannsen, N., & Maurer, A. (2012). Effect of emulsifying salts containing potassium on the quality of block-type processed cheese. *International Dairy Journal*, *25*(1), 66–72.

Huppertz, T., & Gazi, I. (2017). Caseins and caseinates. In *Milk For Use In Food And Non–Food Products: From Commodity To Value–Added Ingredients* (pp. 121–144). Burleigh Dodds Science Publishing.

IDF. (2001). - Milk - Determination of nitrogen content - Part 1/2: Determination of nitrogen content using the Kjeldahl method.

IDF. (2008). International Dairy Federation. Milk Determination of fat content - Gerber butyrometers.

İçim Kaşar Peyniri Ürünleri ve Fiyatları. (2023). *Retrieved December 11, 2023, from https://www.icim.com.tr/urunler/icim-kasar-peyniri/.*

Jha, Y.K. & Gupta, S. (1994). Development of processed cheese spread from cow's milk using enzymes and additives. In: *Cheese Yield and Factors Affecting its Control* (pp. 513-519). Brussels, Belgium: International Dairy Federation.

Galpin, A., Kay, Bhaskar, G., Vijaya, Buwalda, R., John, Donk, R., Kathleen, & Harper, S., James. (2017). *Calcium fortified processed cheese without emulsifying salts, and process for preparing same* (Patent No. EP 2 437 614 B1). European Patent Office.

Guinee, T. P. (2004), Salting and role of salt in cheese, *International Journal of Dairy Technology*, *57*(2-3), 99-109.

Guinee, T. P., Carić, M., & Kaláb, M. (2004). Pasteurized processed cheese and substitute/imitation cheese products. *Major Cheese Groups*, 349–394.

Guinee T. P. (2007). *Cheese-like products, in cheese problems solved*. Florida, USA: CRC Press Incorperated.

Gunasekaran, S., & Ak, M.M. (2003)**.** *Cheese rheology and texture*. Florida, USA: CRC Press Boca Raton.

Gupta, V.K., & Reuter, H. (1993). Firmness and melting quality of processed cheese foods with added whey protein concentrates. *Le Lait 73* (4), 381–388.

Kapoor, R., Lehtola, P., & Metzger, L. (2004). Comparison of Pilot-Scale and Rapid Visco Analyzer Process Cheese Manufacture. *Journal of Dairy Science*, *87*(9), 2813–2821.

Kapoor R. & Metzger LE. (2008). Process cheese: Scientific and technological aspects-A review, *Comprehensive Reviews in Food Science and Food Safety*, *7* (2), 194-214.

Kelimu, A., Felix da Silva, D., Geng, X., Ipsen, R., & Hougaard, A. B. (2017). Effects of different dairy ingredients on the rheological behaviour and stability of hot cheese emulsions. *International Dairy Journal*, *71*, 35–42.

Kloss, L., Meyer, J. D., Graeve, L., & Vetter, W. (2015). Sodium intake and its reduction by food reformulation in the European Union — A review. *NFS Journal*, *1*, 9–19.

Kosikowski, F. V. (1977). Cheese and fermented milk foods (2nd ed.). New York: F.V. Kosikowski and Associates. pp. 337–340.

Kosikowski, F. V. and Mistry, V. V. (1997a). *Cheese and fermented milk products*. Wesport, Connecticut, Vol 1, 328-352.

Kosikowski, F. V. and Mistry, V. V. (1997b). *Cheese and Fermented Milk Foods Volume II: Procedures and Analysis*. Wesport, Connecticut. (3rd ed.).

Lee, Buwalda, R.J., Eustan, S.R., Foegeding A. & McKenna, A.B. (2003). Changes in the Rheology and Microstructure of Processed Cheese During Cooking. *Lebensm. Wiss. Technol. 36*, 339-345.

Lee, M. R., Johnson M. E., & Lucey J. A. (2005). Impact of modifications in acid development on the insoluble calcium content and rheological properties of Cheddar cheese. *Journal of Dairy Science, 88,* 3798–3809.

Metin, M. (2012). Süt ve Mamülleri Analiz Yöntemleri. *Ege Üniversitesi Yayınları, 9*, 439.

Metro Chef Süzme Yoğurt 900G | Metro Türkiye. (2023). *Retrieved December 11, 2023, from https://online.metro-tr.com/metro-chef-suzme-yogurt-258730-p-258730*.

Miralles, B., Krause, I., Ramos, M., & Amigo, L. (2006). Comparison of capillary electrophoresis and isoelectric focusing for analysis of casein/caseinate addition in processed cheeses. *International Dairy Journal, 16,* 1448-1453.

Mleko, S. & Foegeding, E. A. (2001). Incorporation of polymerized whey proteins into processed cheese analogs. *Milchwissenschaft Milk Science International*, *56*, 612-615.

Mounsey, J. S. & O'Riordan, E. D. (2007). Characteristics of imitation cheese containing native or modified rice starches, *Food Hydrocolloids*, *22* (6), 1160- 1169.

Mozuraityte, R., Berget, I., Mahdalova, M., Grønsberg, A., Øye, E. R., & Greiff, K. (2019). Sodium reduction in processed cheese spreads and the effect on physicochemical properties. *International Dairy Journal*, *90*, 45–55.

Nogueira, E.B., Costa-Lima, B.R.C., Torres, F., Regazone, A.V., Melo, L., Franco, R.M., & Cortez, M.A.S. (2018). Effect of potassium-based emulsifying salts on the sensory and physicochemical parameters of low-sodium spreadable processed cheese. *Int. J. Dairy Technol., 71* (3), 717–722.

Noronha, N., O'Riordan, D. E. & O'Sullivan, M. (2007). Replacement of fat with functional fibre in imitation cheese. *International Dairy Journal*, *17*, 1073-1082.

O'Connell, J. E., & Flynn, C. (2007). The manufacture and applications of casein e derived ingredients. In *Handbook of food products manufacturing* (pp. 557-591). New Jersey, NJ, USA: John Wiley & Sons Inc.

Oliveira, R. B., Margalho, L. P., Nascimento, J. S., Costa, L. E., Portela, J. B., Cruz, A. G., & Sant'Ana, A. S. (2016). Processed cheese contamination by spore-forming bacteria: A review of sources, routes, fate during processing and control. *Trends in Food Science & Technology*, *57*, 11–19.

Öztürk, R. İ., & Garipağaoğlu, M. (2018). Tuz tüketimi ve sağlık. *Türkiye Klinikleri Sağlık Bilimleri Dergisi*.

Salek, R.N., C'ernikova, M., Pachlova, V., Bubelova, Z., Konecna, V., & Bun'ka, F. (2017) Properties of spreadable processed Mozzarella cheese with divergent compositions of emulsifying salts in relation to the applied cheese storage period. *LWT - Food Sci. Technol., 77*, 30–38.

Salunke, P., & Metzger, L. E. (2022). Functional characteristics of process cheese product as affected by milk protein concentrate and micellar casein concentrate at different usage levels. *International Dairy Journal*, *128*, 105324.

Savello, P.A., Ernstrom, C.A., & Kalab, M. (1989). Micro-structure and meltability of model Process Cheese made with rennet and acid casein. *Journal of Dairy Science*, *72*, 1-11.

Solowiej, B. (2012a). Evaluation of rheological properties of reduced-fat processed cheese analogues. *Zywnosc. Nauka. Technologia. Jakosc, 1*, 60-71.

Sołowiej, B., Cheung, I. W., & Li-Chan, E. C. (2014). Texture, rheology and meltability of processed cheese analogues prepared using rennet or acid casein with or without added whey proteins. *International Dairy Journal*, *37*(2), 87–94.

Sołowiej, B. G., Nastaj, M., Szafrańska, J. O., Muszyński, S., Gustaw, W., Tomczyńska-Mleko, M., & Mleko, S. (2020). Effect of emulsifying salts replacement with polymerised whey protein isolate on textural, rheological and melting properties of acid casein model processed cheeses. *International Dairy Journal*, *105*, 104694.

Souza, A. B., Carlos Gonçalves Costa Júnior, L., Tuler Perrone, T., Stephani, R., & De Freitas Almeida, D. (2014). Parâmetros De Textura Em Queijos Processados: Influência Da Utilização De Concentrados Proteicos De Leite E De Soro. *Revista Do Instituto De Laticínios Cândido Tostes*, *69*(3), 181.

Pamuksuz, T. (2019). *Yüksek ısıl işlem uygulanmış süt ile üretilmiş türk beyaz peynirinde üretim ph'sının kalsiyum dengesi ve peynirin kesilebilirliği üzerine etkisinin incelenmesi* (Yüksek lisans tezi). Sakarya Üniversitesi, SAKARYA.

Pastorino, A. J., Hansen, C. L., & McMahon, D. J. (2003). Effect of salt on structure-function relationship of cheese. *Journal of Dairy Science*, *86*, 60-69.

Pınar Tereyağı. (2023). *Retrieved December 11, 2023, from https://www.pinaronline.com/urun/pinar-tereyagi-1-kg-153106164*.

Piska, I. & Stetina, J. (2004). Influence of Cheese Ripening and Rate of Cooling of the Processed Cheese Mixture on Rheological Properties of Processed Cheese. *Journal of Food Engineering, 61*, 551-555.

Rafiq, S.M., & Ghosh, B.C. (2017). Effect of potato incorporation on the physico-chemical, textural and sensory properties of processed cheese. *J. Food Meas. Charact., 11* (2), 776–780.

Saarentola, Vaino. (2013). *Process cheese and method of preparation* (Patent No. 2014/068187). WIPO.

Shirashoji, N, Jaeggi, J. J. and Lucey, J. A. (2006a), Effect of trisodium citrate concentration and cooking time on the physicochemical properties of pasteurized process cheese, *Journal of Dairy Science, 89*, 15-28

Singh, H. (2009). Protein interactions and functionality of milk protein products. In *Protein interactions and functionality of milk protein products* (pp. 644-674).

Smith, Gary Francis Glenview. (2008). *Processed cheese without emulsifiying salts* (Patent No. EP 2027776A1). European Patent Office.

Smith, G. F., & Rivera, E. (2017). *Processed Cheese Without Emulsifying Salts* (Patent No. US 9,532.584 B2). United States Patent.

WHO. (2023). Sodium reduction. *Retrieved September 14, 2023, from https://www.who.int/news-room/fact-sheets/detail/salt-reduction*.

Suna, G., Ersan, L. (2020). Peynir Benzeri Ürünlerde İnovatif Yaklaşımlar: İmitasyon Peynir. *Türk Bilimsel Derlemeler Dergisi*, *13*(1), 23-31.

Swaminathan, A. V., Lillevang, S. K., & Lucey, J. A. (2023). Measuring insoluble calcium content in curds during cheesemaking. *International Journal of Dairy Technology*, *77*(1), 156–164**.**

Tamime, A.Y. & M.F. Younis, (1991). Production of Processed Cheese Using Cheddar Cheese and Cheese Base. *Milchwissenscaft*, *46*(7), 423-427.

Tamime A.Y. (2011). Processed cheese and analogues, ISBN 978-1-4051-8642-1, *A John Wiley & Sons, Ltd, Publication*, UK.

TFC, (2015). Turkish Food Codex, Cheese Standard, No:2015/6. Available at https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=20523&MevzuatTur=9&MevzuatTertip=5.

Tosun İ. (2021). *Farklı üretim formülasyonları ve depolama sürelerinin blok tip eritme peynirlerinin kalite kriterleri üzerine etkileri* (Doktora Tezi). Uludağ Üniversitesi, BURSA.

Topcu, A., Bulat, T., Ozer, B. (2020). Process design for processed Kashar cheese (a pasta-filata cheese) by means of microbial transglutaminase: Effect on physical properties, yield and proteolysis. *LWT 125*, 109226.

Young, S. (1999). Whey Products in Cold Pack and Pasteurized Processed Cheese Products —Classifications. *US Dairy Export Council*, 1–8.

Walstra, P., Wouters, J. T. M., & Geurts, T. J. (2005). *Dairy Science and Technology (Food Science and Technology)* (2nd ed.). CRC Press.

APPENDICES

APPENDIX A: Meltability measurement scale

APPENDIX B: Sensory analysis forms

APPENDIX A : Meltability measurement scale

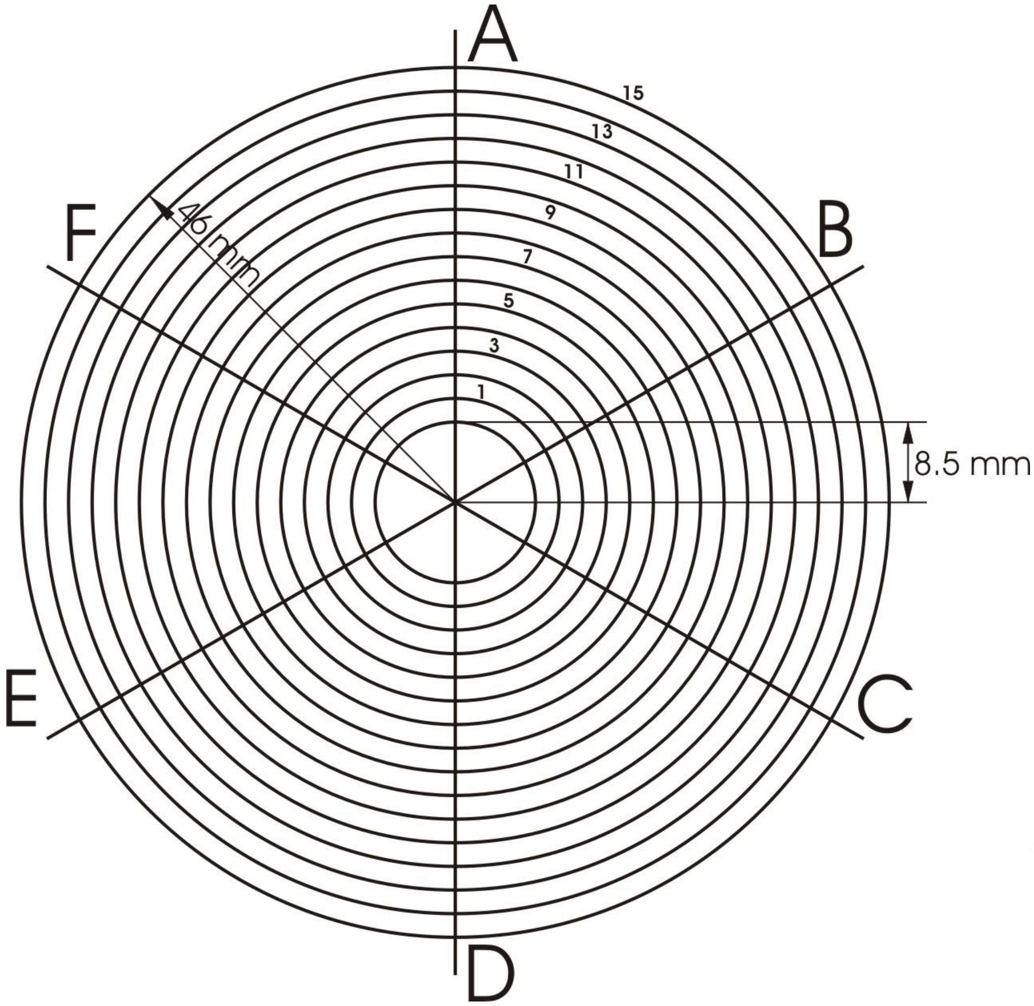


Figure A.1 : Meltability and oiling off scale (Kosikowski, 1977).

APPENDIX B : Sensory analysis forms and results

DESCRIPTIVE SENSORY ANALYSIS

Descriptions: Examine each coded example for the following features. After examining the example, write the code number of the example in the appropriate box on the scale provided. A tile can contain more than one sample code. After tasting a sample, clean your mouth by consuming the crackers and water given to you before moving on to the next sample. Evaluate the control sample first, then evaluate the other samples in the order presented to you.

Table B.1 : The sensory evaluation results.

A) TEXTURAL PROPERTIES				
Feature	**Control Processed Cheese**	**Processed Cheese with 100% MPC**	**Processed Cheese with 50% MPC and 50% WPC**	**Processed Cheese with 100% WPC**
1) Hardness	4.46^{a}	3.46^{b}	2.58^{c}	2.36^{c}
2) Cohesiveness	4.88^{a}	4.42^{a}	2.96^{b}	2.65^{b}
3) Elasticity	4.65^{a}	3.73^{b}	2.72^{c}	2.73^{c}
4) Chewability	4.08^{a}	3.35^{ab}	2.60^{b}	2.77^{b}
5) Cream color	4.46^{a}	4.46^{a}	3.72^{a}	3.85^{a}
6) Dullness	4.54^{a}	4.27^{a}	4.28^{a}	4.23^{a}
7) Crumbliness	1.54^{b}	1.88^{b}	3.85^{a}	4.16^{a}
B) TASTE CHARACTERISTICS				
1) Kaşar cheese flavor	6.19^{a}	4.85^{b}	3.00^{c}	3.19^{c}
2) Sourness	2.85^{a}	2.88^{a}	3.00^{a}	3.23^{a}
3) Sweetness	2.92^{a}	2.92^{a}	2.32^{a}	2.42^{a}
4) Butter flavor	3.31^{a}	3.46^{a}	3.08^{a}	3.39^{a}
5) Saltiness	3.62^{a}	3.00^{a}	3.20^{a}	3.23^{a}
6) Foreign smell to cheese	1.31^{a}	1.39^{a}	1.28^{a}	$1{,}46^{a}$
7) Foreign taste to cheese	1.27^{a}	1.50^{a}	1.44^{a}	1.58^{a}
8) Overall acceptability	5.72^{a}	4.54^{b}	3.40^{c}	3.27^{c}

[1] Values are means (n=15). Means marked by different letters are significantly different ($P < 0.05$).

[2] The scores in the table are the average of the scores given by the panel of 15 people (1 - very little, 7 - very much).

DEFINITIONS OF STRUCTURAL FEATURES

Table B.2 : Definitions of structural features of sensory analysis.

Hardness	The force required to shatter the sample during initial chewing. Cream cheese 1 – Raw carrots 7
Cohesiveness	The degree to which the sample disintegrates (crumbles) before disintegration during chewing. Parmesan cheese 1 – Turkish Delight 7
Elasticity	The degree to which the sample returns to its original shape when light pressure is applied. For example, the degree to which it returns to its original shape (dimensions) after being partially chewed (without breaking into pieces). Cream cheese 1 – Turkish delight 7
Chewability	The number of chews required to make the sample swallowable. Yogurt 1 – Raw carrot 7
Cream color	Milk 1 – Butter 7
Dullness	Oil 1 – Margarine 7
Crumbly texture	Presence of small particles when the sample is crushed by hand. Feeling of solid particles in the mouth, for example when chewing. Cheddar cheese 1 –Parmesan 7

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