

**ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL**

**THE EFFECT OF DIFFERENT STARCH TYPES ON TEXTURE  
PROPERTIES OF WAFER SHEETS**



**M.Sc. THESIS**

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**Department of Food Engineering**

**Food Engineering Programme**

**JUNE 2024**



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**İSTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ**

**FARKLI NİŞASTA ÇEŞİTLERİNİN GOFRET YAPRAKLARININ  
TEKSTÜR ÖZELLİKLERİ ÜZERİNE ETKİSİ**

**YÜKSEK LİSANS TEZİ**

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Gizem SARI ÜNLÜ, a M.Sc. student of İTÜ Graduate School student ID 506191510, successfully defended the thesis entitled “THE EFFECT OF DIFFERENT STARCH TYPES ON TEXTURE PROPERTIES OF WAFER SHEETS”, 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 Family,*



## **FOREWORD**

I would like to express my sincere thanks to my advisor Prof. Dr. Gürbüz GÜNEŞ for his guidance, support and patience during my thesis study.

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## **ABBREVIATIONS**

**PS** : Potato Starch

**RS** : Rice Starch

**WS** : Wheat Starch





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## **THE EFFECT OF DIFFERENT STARCH TYPES ON TEXTURE PROPERTIES OF WAFER SHEETS**

### **SUMMARY**

Wafer sheets are available in many industrially produced snacks with different formulations. Each manufacturer creates different formulations to obtain the optimum texture for their products and consumers. In this study, different starch types were added to the recipe of wafer sheets at different ratios and their effects on the texture of wafer sheets were investigated.

This study focused on investigating how different types and concentrations of starch, specifically potato, wheat, and rice starches at levels of 3%, 6%, and 9%, influence the texture of wafer sheets. At the beginning of the study, characterization analyses were conducted on the starches used. Particle size, water holding capacity, and differential scanning calorimetry analyses were applied to potato, wheat, and rice starches. The results of these analyses were utilized to interpret the effects of starches in wafer sheet recipes. Post-baking moisture content and textural properties of the wafer sheets were examined. Given that the water content in the recipes remained constant, the impact of the starch type and proportion, the sole varying factors, on the residual moisture content after baking was observed. Texture analysis included examination of parameters such as hardness and fracturability.

At the beginning of the shelf life, moisture analysis revealed that wafer sheets containing potato starch had significantly higher moisture content compared to those containing wheat or rice starch. As the proportion of potato starch increased, wafer sheets showed progressively higher moisture levels. Also, hardness and fracturability parameters were analyzed for texture analysis. When evaluated in terms of hardness analysis, wafer sheets containing potato starch exhibited statistically significant higher hardness values compared to waffle sheets containing wheat or rice starch, as well as the control samples. Additionally, wafer sheets containing potato, wheat, and rice starches at 3% concentration showed statistically higher hardness values compared to other starch ratios and the control.

Among all starch types and ratios examined, potato starch showed the most significant differences in hardness, fracturability, and moisture analyses compared to the control samples. High values in hardness and fracturability indicate that wafers containing potato starch are more brittle. Moreover, recipes containing potato starch exhibited the highest moisture levels both at the beginning and end of shelf life, suggesting that wafer sheets with potato starch require better preservation throughout their shelf life.

The properties of wafer sheets may vary according to production efficiencies and textural characteristics preferred by the consumer. There are no appropriate or inappropriate value ranges for the data obtained. In this study, the wafer sheets obtained were compared with each other and their differences were revealed.



## FARKLI NIŞASTA ÇEŞİTLERİNİN GOFRET YAPRAKLARININ TEKSTÜR ÖZELLİKLERİ ÜZERİNE ETKİSİ

### ÖZET

Gofret yaprakları endüstriyel olarak üretimi bulunan pek çok atıştırılmalıkta farklı formatlar ile karşımıza çıkmaktadır. Krema dolgulu gofretler, çikolata kaplamalı gofretler, konik şekillerde dondurma külahları, rulo şeklinde krema dolgulu ürünler gofret yapraklarını en sık gördüğümüz ürün gruplarıdır.

Her üretici, ürünleri ve tüketicileri için ideal tekstürü elde ettiği formülasyonlar oluşturmaktadır. Üreticilerin gofret yaprağı reçeteleri ve kullanım alanları farklılaşsa da, gofret yapraklarının reçeteleri belirli girdilerden oluşmaktadır. Un, su, yağ, emülgatör, kabartıcı ajanlar, tuz gofret yapraklarında kullanılan temel girdilerdir. Enzimler, şeker ve nişasta çeşitleri ise istenilen yapı ve fonksiyonu sağlamak için gofret yaprağı reçetelerine eklenebilir.

Gofret yapraklarının formülasyonlarında kullanılan nişastaların kaynaklarına ve dozajlarına bağlı olarak gofret yapraklarının yapılarına farklı etkilerde bulunduğu düşünülmektedir. Endüstriyel gofret yaprağı üretiminde gofret yapraklarının kullanılacağı üründe hedeflenen yapı ve yeme deneyimine göre farklı nişasta türleri kullanılmaktadır. En yaygın kullanılan nişasta çeşidi patates nişastasası olmakla beraber, buğday ve pirinç nişastalarının da kullanıldığı gözlemlenmektedir.

Bu çalışmada, endüstriyel olarak da kullanımı olan nişasta çeşitlerinin gofret yapraklarının reçetesine farklı oranlarda eklenerek gofret yapraklarının tekstürü üzerine etkileri incelenmiştir. Doğal patates nişastasası, buğday nişastasası ve pirinç nişastasası %3, %6 ve %9 oranlarında formülasyondaki undan azaltılarak reçetelere eklenmiştir. Un-nişasta oranı dışındaki su, yağ, emülgatör ve minör girdilerin oranları tüm reçetelerde sabit tutulmuştur. Kontrol olarak reçetesine nişasta eklenmemiş, sadece buğday unu ile hazırlanan gofret yaprakları kullanılmıştır.

Çalışmanın başlangıcında öncelikle kullanılan nişastaların karakterizasyon analizleri yapılmıştır. Patates, buğday ve pirinç nişastasası için partikül boyutu, su tutma kapasitesi ve diferansiyel taramalı kalorimetri analizleri uygulanmıştır. Uygulanan analizlerin sonuçları, nişastaların gofret yaprağı reçetelerindeki etkilerini yorumlamak için kullanılmıştır. Gofret yaprakları için oluşturulan nişasta içeren ve kontrol reçeteleri, 170 °C'de 100 saniye pişirilmiştir. Ürünler paketlenerek ortam şartlarında ve hızlandırılmış etüv şartlarında 2 aylık raf ömrü boyunca gözlemlenmiştir. 2 aylık raf ömrü takibi boyunca iki haftalık periyotlarda analizler uygulanmıştır. Hızlandırılmış raf ömrü analizinde ürünler 12 saatlik döngülerde 20-38 °C ve %75 bağıl nem içeren etüv ortamında bekletilmiştir.

Elde edilen gofret yapraklarının pişirme sonrası nem oranları ve tekstürel özellikleri incelenmiştir. Reçetelerde kullanılan suyun sabit oranda olması nedeniyle, tek değişken olan nişasta çeşidi ve oranının pişirme sonrası kalan nem miktarı üzerine etkisi gözlemlenmiştir. Tekstür analizi için sertlik ve kırılmalık parametreleri

incelenmiştir. Aynı zamanda kontrol ve %6 oranında nişasta çeşitlerini içeren gofret yapraklarına duyuşsal analiz uygulanmıştır.

Raf ömrü başlangıcında yapılan nem analizlerinde, patates nişastası içeren gofret yapraklarının nem değeri buğday ve pirinç nişastası içeren gofret yapraklarına göre istatistiksel açıdan anlamlı düzeyde yüksek bulunmuştur. Patates nişastasının kullanım oranı arttıkça, gofret yapraklarının nem değeri daha yüksek sonuçlar gözlemlenmiştir. Bu sonucun, patates nişastasının su tutma kapasitesi değeri diğer nişastalara göre çok daha yüksek olmasından kaynaklı olduğu düşünülmektedir. Aynı zamanda, analiz edilen tüm gofret yapraklarında ortam ve hızlandırılmış raf ömrü koşullarında ilk ay içerisinde hızlı bir nem artışı gözlemlenmiş, ilk ay ile ikinci ay arasında istatistiksel olarak anlamlı düzeyde yükselen nem değeri bulunmuştur. Genel olarak gofret yaprakları düşük nem değeri ve yapıları nedeniyle raf ömrü boyunca nem artışı açısından riskli ürünler olarak görülürler. Bu çalışmada yapılan analiz sonuçları da bu verileri doğrulamaktadır. Gofret yapraklarının tümünde geçerli olmak üzere özellikle formülasyonunda patates nişastası içeren gofret yapraklarının nem açısından oldukça korunaklı ambalajlarla paketlenmesi gerekmektedir.

Gofret yaprakları sertlik analizleri açısından değerlendirildiğinde patates nişastası içeren gofret yapraklarının sertlik değeri, buğday ve pirinç nişastası içeren ve kontrol gofret yapraklarına göre istatistiksel olarak anlamlı düzeyde yüksek bulunmuştur. Aynı zamanda patates, buğday ve pirinç nişastalarının %3 oranında kullanıldığı gofret yapraklarının sertlik değeri, diğer nişasta oranlarından ve kontrolden istatistiksel olarak anlamlı düzeyde yüksek bulunmuştur. Nişasta kullanımının literatürde genel olarak gözlemlenen etkisi un miktarından azaltılarak kullanıldığı için proteinleri seyrelterek gluten bağlarının oluşumunu azalttığı, aynı zamanda oluşan gluten bağlarının arasına girerek gluten matriksini zayıflattığı yönündedir. Fakat bazı çalışmalarda düşük oranda nişasta kullanımının, gluten matriksini kırmadan yapıya dahil olarak matriksi güçlendirdiği gözlemlenmiştir. Bu çalışmada %3 oranında nişasta kullanımında sertlik değerinin arttığı gözlemlenmesi de aynı şekilde açıklanabilir.

Analiz sonuçlarına genel olarak bakıldığında, nişasta eklenen gofret yapraklarının kırılma değeri arttığı gözlemlenmiştir. Özellikle patates nişastası kullanılan gofret yapraklarında, buğday ve pirinç nişastası kullanılan ve kontrol gofret yapraklarına göre kırılma değeri istatistiksel açıdan anlamlı düzeyde yüksek bulunmuştur. Bu durumun patates nişastalarının partikül büyüklüğünün daha yüksek olmasından kaynaklı olduğu düşünülebilir. Hızlandırılmış ve ortam raf ömrü boyunca yapılan analizlerde, analiz edilen gofret yapraklarının kırılma değeri farklılık gösterse de raf ömrü süresince istatistiksel açıdan anlamlı düzeyde bir fark bulunmamıştır.

Çalışma kapsamında değerlendirilen gofret yapraklarına tekstür analizlerinin yanında, 18 adet panelist ile duyuşsal analizler uygulanmıştır. Duyuşsal analiz için nişasta içermeyen kontrol gofret yaprağı ile %6 oranında patates, buğday ve pirinç nişastaları içeren gofret yaprakları değerlendirmeye alınmıştır. Duyuşsal değerlendirme için genel beğeni, tat beğenisi, gevreklik, çıtırılık, sertlik ve kırılma skorları ölçümlenmiştir. Analiz sonuçlarına bakıldığında tüm parametreler için kontrol ve nişasta içeren gofret yaprakları arasında istatistiksel olarak anlamlı düzeyde bir fark bulunmamıştır. Değerlendirilen tüm gofret yapraklarının tüketici beklentisini karşıladığı gözlemlenmiştir. Gofret yapraklarının duyuşsal değerlendirmesinde fark algılanmamasının nedeni genellikle gofret yapraklarının arasında bir krema katmanı ile tüketiciye sunulması ve tüketicinin gofret yapraklarını bu formda tüketmeye alışkın

olmaması olabilir. Skorlanan gofret yapraklarının, yaprakların arasına uygun bir krema uygulanarak duysal deęerlendirmeye alınması gelecek alıřmalarda deęerlendirmeye dahil edilebilir.

Endüstriyel olarak üretimi yapılan gofret yapraęı ieren ürünlere bakıldığında, gofret formülasyonları tasarlanan üründe tercih edilen özelliklere göre farklılık gösterebilmektedir. Aynı zamanda gofret yapraklarının reçeteleri, üretim verimliliklerine ve tüketicinin tercih ettięi tekstürel özelliklere göre farklılık gösterebilmektedir.

Ürünlerin tasarım süreçlerinde Ar-Ge alıřmaları ile ortaya ıkan reçetelerin tüketici testleri yapılarak tüketici beklentilerini karşılamaları ölçümlenmektedir. Bu nedenle deęerlendirilen her bileřen, ürünlerde kullanılan dięer bileřenlerle beraber deęerlendirildiğinde belirli bir sonuç ifade etmektedir. Gofret yaprakları için de aynı durum söz konusudur. Gofret yapraęının kullanıldığı ürünlerdeki krema, ikolata kaplama, eřni kombinasyonları gibi dięer bileřenler tüketicinin ürün algısı için benzersiz kombinasyonlar sunmaktadır. Gofret yapraklarının reçetelerinin bu kombinasyonlara uygun hale getirilmesi reçete alıřmalarının temelini oluşturmaktadır. Aynı zamanda endüstriyel olarak üretimi bulunan gofret yapraklarında, üretim verimlilikleri, proses parametrelerinin ve üretim şartlarının optimizasyonu için eřitli reçete alıřmaları yapılabilmektedir. Endüstriyel üretimlerde ürün tasarımlarının yanında proses kořulları da önem kazanmaktadır. Bu nedenle bu alıřmada elde edilen veriler için uygun veya uygun olmayan deęer aralıkları bulunmamaktadır. Bu alıřmada, eřitli niřastaların farklı oranlarda kullanıldığı gofret yaprakları birbiri ile karşılaştırılarak farkları ortaya konmuřtur. alıřma kapsamında incelenen reçete alıřmalarının uygunluęu, hedeflenen ürün ve proses kořullarına göre deęerlendirilmelidir.

İlerleyen alıřmalarda, gofret yapraklarına farklı niřasta eřitleri kombinasyonları uygulanarak tekstürel ve duysal özelliklere etkileri incelenebilir. Elde edilen gofret yaprakları ile endüstriyel denemeler organize edilerek verimlilikleri deęerlendirilebilir. Gofret yaprakları son ürün haline getirilerek tüketiciler tarafından algılanan son ürünlerdeki etkisi incelenebilir.



## **1. INTRODUCTION**

### **1.1 Purpose of Thesis**

Wafer sheets, which we frequently encounter in the snack sector, are low moisture products consisting of water, flour and minor ingredients. Wafers are used as semi-finished or end products in many types of snack products. It is preferred by certain consumer groups due to its unique eating experience and the structure and taste it adds to snack products.

In wafer sheet formulations, the type and amount of ingredients may vary according to the taste or structure targeted in the final product. At the same time, wafer sheet is a product whose structure and eating experience can change considerably with minor changes in the recipe and process. In addition to the changes that can be achieved with the recipe components and ratios in the wafer sheet, different ingredients other than flour can be used to provide differences in texture and taste properties. Starch is one of the ingredients that can be used for this purpose in wafer sheet recipes.

Although it is known that different starch types are used industrially in wafer sheet recipes, there are not many academic studies in this field. With this study, different structures that can be obtained in wafer sheets with three starch types (wheat, potato, rice) will be observed.

Within the scope of this thesis, it is aimed to evaluate the effects of starch on the textural properties of wafer sheets by using different starch types in wafer sheet formulations.

### **1.2 Literature Review**

#### **1.2.1 Wafers**

Wafers are low-moisture, low-fat, ready-to-eat products consisting of water, flour and minor ingredients. They can be shaped as flat wafer sheets, cones, rolls or wafers in different shapes with various molds. Basically, wafer types are divided into two types

based on their content; sugar-free or low-sugar wafers and wafers with high sugar content. Depending on the end product or the desired shape of the wafer, production can be made in a formulation suitable for this classification. Wafers can be consumed without filling or coating, or can be used in various products with cream filling or chocolate coating [20].

## **1.2.2 Recipe ingredients of wafer sheets**

### **1.2.2.1 Flour**

One of the main inputs in wafer batter is flour. Flour is the main source of solids in the dough and must be selected in appropriate quantities and specifications to set the dough structure. Assuming that the flour is of classical quality standards, there are parameters that are particularly important and preferred in wafer batter.

The balance of flour and water affects the rheology of the dough, the baking properties and the structure of the final product. The ratio of flour and water can basically be considered as approximately 1 - 1.4. If a harder and stronger structure is desired in wafer sheets, a lower water ratio can be used. The recipe is adjusted according to the end product target [12,20].

One of the main factors in determining the flour and water ratio is the water absorption property of the flour used in the recipe. Generally, it is preferred that the absorption value of flour is between 50-55%. At higher absorption values, more water will be used in the recipe and more energy will be used. In addition, the use of excess water may make it difficult to obtain the desired moisture content in the final product during cooking and may cause low strength in the wafer sheet structure [10].

One of the effective parameters for wafer dough is the protein value of flour. Since a high protein value in flour indicates a high gluten content and gluten development is desired at a minimum level in wafer doughs, the protein ratio is ideal in the range of 8-11%, the optimum can be considered as 9.5%. High gluten development is not preferred as it will prevent the dough from spreading on the plates. If the protein ratio is low, the development of gluten bonds will not be observed; this may cause the dough to spread too much on the plate and overflow from the plates, increasing production losses; at the same time, it may cause the sheet to have a brittle structure [10,20].

The ash value in flour indicates the amount of mineral matter in the flour. The ash value can be found in the range of 0.45-0.75%, the optimum ratio can be 0.4 - 0.6%. As the amount of ash increases, the brittleness of the wafer sheet will increase. In addition, contamination on the plates also increases as the ash content increases.

The starch in flour swells and gelatinizes by retaining water with its hygroscopic property. Starches are one of the sources of the hollow and airy structure seen in the inner cross-section of the wafer leaf after baking. The proportion of damaged starch is very important for the water holding capacity of flour. Starch granules damaged as a result of mechanical damage during flour milling are more common in finely milled flours obtained from hard wheat. A damaged starch granule can absorb 3 times more water than an undamaged one [6].

The particle size of flour affects the flow properties of the dough and the wafer structure. Large particle size can lead to increased sheet weight and set texture. Fine particle size, on the other hand, increases dough viscosity by increasing the surface to absorb water [20].

The moisture content of flour is usually around 14%. Microbiological problems can be encountered above this moisture content. In addition, flours with high moisture content have an unpleasant odor. Increased moisture content may increase water activity, thus promoting microbial growth [12].

Flours should be stored under controlled temperature conditions before use in the recipe, taking into account that it will also affect the dough temperature.

#### **1.2.2.2 Water**

Water is the main raw material that forms the liquid phase of wafer dough. It is used to dilute the solids in the dough. It is important that the amount of water is sufficient for homogeneous raw material distribution and baking. The properties of the dough and the final product vary depending on the properties and amount of water.

The water to be used in wafer sheets should be of neutral pH and not too high in hardness, as is common in the water supplied for food in food establishments. The use of hard water in wafer batters is a factor that accelerates the contamination of the oven plates. The use of hard water also causes the wafer sheet structure to harden [10].

The amount of water directly affects the viscosity as it generally constitutes the liquid phase of the dough. The viscosity of wafer batters is expressed in s by measuring the flow time of the batter from a 100 mL special measuring cup. While the flow time of doughs with high viscosity is high, the flow time will decrease as the viscosity decreases. Although the flow time of wafer doughs is shown in the literature in the range of 8-25 s, it may vary according to the desired product properties. One of the important effects of viscosity in the process is the spreading of the dough on the plates. Doughs with high viscosity do not spread properly on the plate; after baking, they come out as wafer sheets that do not take the shape of the plate and are missing from the edges and corners. If the viscosity is low, the dough spreads too much and overflows from the edges of the plates, resulting in both lower than targeted wafer weight and increased production losses [12,20].

The water in the wafer batter makes an important contribution to baking by providing heat transfer during baking. The homogeneous distribution of water is one of the critical points of a proper cooking process by ensuring homogeneous heat transfer.

Water in the batter recipe is also important for the gelatinization of the starch in the flour or which can be added separately. The amount of water must be sufficient for starch gelatinization, which results in the characteristic structure and appearance of the wafer sheet. In the absence of sufficient water, the starch may also gelatinize locally, causing inhomogeneous structural differences in the wafer sheet [4].

Water evaporates during baking in wafer sheets, leaving a very low level of moisture in the final product. The moisture content of the dough recipe, which is around 50-60%, decreases to 1-2% after baking. Depending on the end product characteristics, some wafer sheets are conditioned after baking to increase their moisture content to 3-4%. However, it is important to determine the moisture value specific to the product since moisture at lower ratios is sensory perceived and affects the eating quality.

The temperature of the water in the sheet recipe is one of the main parameters affecting the dough temperature, as it is one of the inputs with the highest ratio (other parameters can be considered as flour and equipment temperature). If the temperature of the water is high, the dough temperature will automatically rise. Especially in wafer recipes using enzymes, it is critical that the dough temperature does not increase too much. Therefore, the temperature of the water used must be suitable for the targeted dough

temperature. For wafer dough, a temperature between 20-24 °C is ideal, but it may vary depending on the variety and process [8,20].

The dough temperature, which increases with the water temperature, also affects the structure of the wafer sheets. Gluten development increases in wafer batter at high temperature and affects the process and structure negatively. In addition, according to the literature, as the dough temperature increases, wafer sheet weight increases and hard texture is obtained. At the same time, the fragility of the sheet increases [8].

### **1.2.2.3 Oil**

Oil is used very little amount in wafer batters. In sugar-free flat wafers, oil is generally used at a rate of 0.5-2%. The use of oil in the recipe is effective on the proper separation of the wafer sheet from the plate and melting in the mouth. The oil used in the recipe prevents sticking to the plates by forming a thin film on the intersecting surface with the plate when the dough is poured into the plates. However, as the plate pollution increases, the amount of oil used in the recipe should increase. Increasing the amount of oil used in the recipe also accelerates the contamination of the plates. In this case, an optimum balance must be found between the amount of oil added to the recipe and plate contamination. For this balance, the plates should be cleaned periodically at specified times. It is important to start production with the minimum oil ratio, since the use of too much oil in the recipe will cause the molds to get dirty more quickly. In addition, the increase in oil ratio also affects the shelf life and oxidation stability of the product [12,20].

The properties of the oil used in the wafer recipe directly affect the eating quality and shelf life stability of the wafer sheet. The use of soft oils with a fast melting profile triggers the sensation that the sheet melts rapidly in the mouth during eating. In addition, the use of oils with high oxidative stability will reduce oxidation and rancidity reactions from wafer sheets during shelf life [4].

### **1.2.2.4 Lecithin**

In wafer batters, lecithin is used to keep the high water and low fat phases together and to prevent phase separation. However, it also has many positive contributions. As an emulsifier, lecithin holds the water phase with its hydrophilic ends and the oil phase with its lipophilic ends, allowing these two phases to coexist stably. In addition,

lecithin has a positive contribution during the separation of the sheets from the plate. While its hydrophilic ends adhere to water-loving structures such as starch and gluten, its lipophilic ends adhere to the oil in the form of a thin film between the plate and the surface and contribute to the easy separation of the wafer sheet from the plate [4,20].

It is recommended to mix lecithin with oil at temperatures around 40 °C and add it to the dough as a mixture with oil. In the direct use of lecithin, since it is a dense and sticky raw material, it may not be fully mixed into the dough and may not be distributed homogeneously. Lecithin is a heat-sensitive raw material and at temperatures above 60 °C, color darkening and bitter taste are observed. For this reason, it should be mixed as homogeneously as possible in the dough [10].

#### **1.2.2.5 Salt**

Salt is used in wafer batter because it contributes to both flavor and structure. Generally, a flat, neutral flavor is preferred in unsweetened wafer sheets. This flavor can be enriched by adding salt. In addition, the salt in the wafer sheet can create a contrast with the sweetness of the cream in cream wafers, contributing positively to the overall product taste [4].

As the amount of salt increases, the structure of the wafer hardens and its crispness increases. Thus, wafer sheet strength also increases. However, when used in excessive amounts, it will also increase the amount of mineral matter, promoting brittleness and contributing negatively to the structure [20].

#### **1.2.2.6 Leavening agents**

Sodium Hydrogen Carbonate is a base used as a raising agent. In wafer batter, it is neutralized with the use of acids and contributes to the outgassing and thus to the expansion of the pores in the wafer sheets in terms of number and volume. It also has a positive effect on the spreading of wafer batter in the mold. Increasing the amount of sodium bicarbonate causes the weight of the wafer to decrease, resulting in a lighter structure. In case of excessive use, it weakens the structure more than desired and reduces the strength. The use of sodium bicarbonate contributes to the yellow color of the wafer sheet during baking. Excessive use also adversely affects the color of the sheet. When used above a certain level, its effect on taste should also be checked as it gives a bitter taste [4,12].

SAPP (sodium acid pyrophosphate) is one of the acids used to neutralize sodium hydrogen carbonate and for the formation of leavening gas. It shows a fast effect. For this reason, it is added with flour in the process to dilute it and make it react later. When used in excessive amounts, its unique taste is felt. There is information in the literature that the longer the dough to which SAPP is added waits, the larger the pores in the sheet will be [10].

Ammonium Hydrogen Carbonate is a weak base and soluble in water. It is separated from the structure by evaporating water during the baking of the wafer sheet. Ammonia and carbon dioxide are released from ammonium bicarbonate dissolved in water. The released CO<sub>2</sub> contributes to the swelling. Ammonia forms ammonium salts if there is acid in the environment. When the concentration of ammonium salts increases, a bitter taste can be perceived [20].

#### **1.2.2.7 Starch**

Starch is a raw material that is preferably used in wafer sheet recipes. It is often used for its effects on texture.

Starch can absorb half as much water due to its hydrophilic nature. When used instead of flour in formulas, the amount of water needs to be regulated as it has lower absorption than flour [2].

The size of starch granules varies according to their source. Different types of starch can be used to contribute to the desired texture in the wafer sheet. In addition, since the use of starch also dilutes the amount of flour, it can negatively affect gluten development and contribute to achieving the desired structure in the wafer sheet. More detailed information on this subject will be given in the following sections [20].

#### **1.2.2.8 Albumin**

The use of albumin is important for the structure of wafer sheets. Albumin increases the strength of the sheets. Especially in sugary wafer recipes, it contributes to color formation with Maillard reaction due to its protein structure [10].

#### **1.2.2.9 Enzyme**

Protease and xylanase enzymes can be used to regulate gluten development, water holding capacity of flour and dough rheology in wafer batters. In case of enzyme use,

the enzyme should first be mixed with flour and water and the dough mixture should be continued after the mixture has been kept for a suitable period of time to work. Attention should also be paid to the optimum temperature at which the enzyme activates. The use of enzymes allows to reduce the amount of water in the wafer sheet batter. Thus, energy gain is also achieved. It is also known that the use of enzymes has a positive effect on the spreading of the wafer batter on the plate [4,20].

### **1.2.3 The effects of starch usage in wafer recipes**

The natural consequence of using starch by reducing the amount of flour in the recipe is that it has a direct effect on the formation of gluten bonds by diluting the flour particles. However, it also directly affects the gluten matrix.

In a study published in 2020, gluten and starch were added to wheat flour and dough properties were investigated. As a result of this study, it was observed that the dough with added wheat starch was stronger. Starch showed a strengthening effect in the gluten matrix, especially in doughs with low protein content [6].

A review article published in 2021 tried to explain this effect. In this article, the effect of wheat starch in wheat flour on the gluten matrix is discussed. This effect, which varies according to the size and properties of starch granules, suggests that structural differences can be achieved by affecting the gluten matrix by adding additional starch from outside [18].

In a study conducted in 2018, the gluten-starch interaction of starches obtained from 5 different sources (wheat, corn, potato, sweet potato, tapioca) in dough was investigated. As a result of this study, the starch with the highest interaction with the gluten matrix was wheat starch and the lowest starch was potato starch [22].

In a study published in 2019 with adlay starch, the effect of this starch on gluten-starch gel was investigated. It was observed that the viscoelastic structure of the gluten gel improved and a more continuous gel was obtained. In this study, it was observed that as the starch ratio increased, the structure was more continuous but more regular micro cavities were obtained [5].

## **2. MATERIAL AND METHOD**

### **2.1 Materials**

Wheat flour (with 14% moisture, 11% protein, 1% ash); water, salt, sodium bicarbonate, sodium acid pyrophosphate, ammonium bicarbonate, palm oil, lecithin and starch varieties are used for wafer sheet batter preparation. Materials were obtained from Ülker Bisküvi.

### **2.2 Methods**

#### **2.2.1 Starch characterization analyses**

##### **2.2.1.1 DSC analyses**

Gelatinization temperatures of starches were measured using differential scanning calorimetry (Mettler Toledo). A 1:3 starch-distilled water solution was prepared. The mixtures were stirred for 1 hour. Aluminum pans were filled with 10 grams each and hermetically sealed. The samples were scanned from 25 to 180 °C at a heating rate of 10 °C/min. The temperature at which gelatinization started ( $T_0$ ), the peak temperature ( $T_p$ ) and the conclusion temperature at which gelatinization ended ( $T_c$ ) were measured [21].

##### **2.2.1.2 Water absorption analyses**

Starch samples were weighed into centrifuge tubes. Distilled water was added and vortexed for 5 minutes. Rested for 30 min at room conditions. The mixtures were centrifuged at 3000 rpm for 10 minutes. The gel formed after centrifugation was weighed [14].

##### **2.2.1.3 Particle size analyses**

The particle sizes of the starches were measured on a CAMSIZER X2 optical analyzer (Retsch GmbH, Haan, Germany) with a detection range of 0.8-8000  $\mu\text{m}$  and a 50 kPa

compressed air dispersion module. The average particle size was calculated using image analysis [13].

## **2.2.2 Wafer sheets preparation**

### **2.2.2.1 Batter preparation**

The starch ratios to be used in the wafer sheet recipes were reduced from flour and applied to the recipe. In order to observe the effect of starches on batter rheology, the amount of all ingredients except starch and flour was kept the same in all formulations.

Wheat, potato and rice starches were added to the recipes at 3%, 6% and 9% and these amounts were balanced with the amount of flour in the formulation. The recipe for wafer sheets is as shown in the table 2.1.

**Table 2.1 : Recipes of wafer sheets.**

Parameters	Potato Starch Recipes			Wheat Starch Recipes			Rice Starch Recipes			Control
	3%	6%	9%	3%	6%	9%	3%	6%	9%	0%
WHEAT FLOUR	34.89	31.89	28.89	34.89	31.89	28.89	34.89	31.89	28.89	37.89
POTATO STARCH	3.00	6.00	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WHEAT STARCH	0.00	0.00	0.00	3.00	6.00	9.00	0.00	0.00	0.00	0.00
RICE STARCH	0.00	0.00	0.00	0.00	0.00	0.00	3.00	6.00	9.00	0.00
WATER	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00
PALM OIL	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
SOYA LESITIN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SODIUM BICARBONATE-E500	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
AMMONIUM BICARBONATE-E503	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
SODIUM ACID POLYPHOSPHATE-SAPP-E450	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
SALT	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
<b>TOTAL</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>

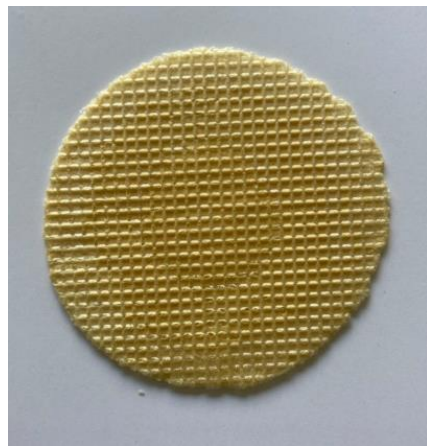
During the preparation of the recipes, water was first added and the salt and leavening agents were dissolved in water for 10 seconds. Water was added at 22 °C. Then flour and starch mixtures were added to the mixture. Finally, lecithin was mixed with oil and added to the mixture. Mixing time was applied for 3 minutes. The mixtures were made with a hand mixer by creating a vortex in the center axis of the mixing bowl. The final dough temperature was kept at  $25 \pm 2$  °C [10,12].

### **2.2.2.2 Baking**

To encourage air bubbles to rise to the top, the mixture was allowed to sit at room temperature for 5 mins before baking. The purpose of this aeration procedure is to prevent changes in batter density throughout production, which could have an impact on the wafer sheets final weight.

The wafer sheets were prepared using a laboratory-type cooking machine as shown in Figure 2.1 (HEBENSTREIT, Mörfelden-Walldorf, Germany).

The top and bottom plate temperatures were set to 170 °C.  $4 \pm 0.2$  g of wafer batter was deposited in the center of the bottom plate and the top plate was closed and locked. The cooking time was 100 seconds for all formulations.



**Figure 2.1 :** Wafer sheet.

### **2.2.2.3 Packaging**

The wafer sheets were packaged within 1 minute after cooking. Packaging material containing "15 $\mu$  BOPP (213E) // 30  $\mu$  Metalized BOPP (7514)" layers was used. Wafer sheets were packaged by heat sealing in a manual packaging machine. The wafer sheets were packaged using a laboratory-type heat sealing machine as shown in Figure 2.2.



**Figure 2.2 :** Packaged wafer sheet.

#### **2.2.2.4 Storage**

Wafer sheets were packaged and shelf life studies were carried out in two different environments.

During the ambient shelf life applied in the laboratory environment, the wafers were kept in the 18-20 °C. In accelerated shelf life studies, a stove environment was used to expose packaged wafer sheets to extreme conditions. The temperature was varied between 20-38 C every 12 hours and the relative humidity was maintained at 75% during 8 weeks of shelf life in the stove.

#### **2.2.3 Analyses of wafer sheets**

##### **2.2.3.1 Moisture analyses of wafer sheets**

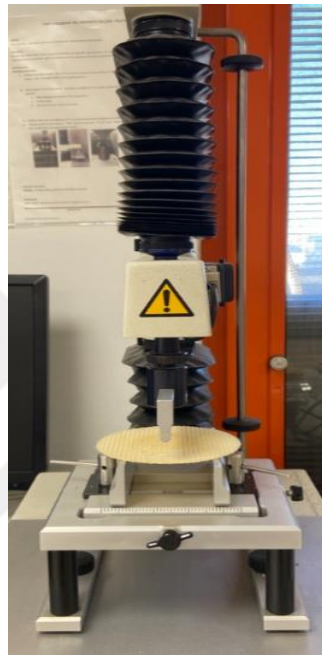
The moisture analysis of the wafer sheets was analyzed with a moisture analyzer (Mettler Toledo HE73, Switzerland). After grinding and homogeneous mixing of the wafer sheets, 1 gram sample was taken and moisture analysis was measured. Analyses were performed in three replicates.

##### **2.2.3.2 Texture analyses of wafer sheets**

Texture analysis of wafer sheets was analysed with Texture Analyser (Stable Micro Systems TA XT plus) as shown in Figure 2.3. Analyses were applied using a three point bend rig. Fracturability and hardness parameters of wafer sheets were analyzed. The fracturability of the wafer sheets was determined by measuring the force (g-force/mm) required to break them in particular distance. The bending length of the wafer sheet provides information about its flexibility, while the maximum force given

to break it provides information about its hardness. Hardness is expressed in terms of measuring the force (g-force).

During the measurements, trigger force 100.0 g, pre-test speed 1.0 mm/sec, test speed 3.0 mm/sec, post-test speed 10.0 mm/sec, rupture distance 10 mm were set. The wafer sheets obtained after the baking process were analyzed by placing the probes exactly at the midpoint of the probes in the same direction for all wafer sheet samples. Analyses were performed in three repetitions [10,12,20].



**Figure 2.3 :** Texture analyser.

### **2.2.3.3 Sensory analyses of wafer sheets**

For sensory analysis, scores were obtained on 6 parameters: overall liking, taste, crunchiness, crispiness, hardness and fracturability. Sensory scores were obtained from 18 people, 9 women and 9 men, with the form shown below as Figure 2.4.

5-point liking scale (1- I don't like it, 5-I like it very much) was used for overall liking and taste parameters. For the crunchiness, crispiness, hardness and fracturability parameters, a "just about right" assessment was made. In this scale, data were taken according to the values "1-Less than i prefer, 3- Just about right, 5-More than i prefer".

Sensory analyses were performed on control wafer sheets (no added starch) and wafer sheets containing 6% potato, wheat and rice starch [15]. The percentage of meeting expectations over a score of 3 (just about right) was calculated by subtracting the received scores from the desired score of 3 and expressing it as a percentage [9,15].

**Sample Code:**

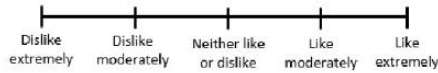
**SENSORY EVALUATION FORM**

This form was prepared to evaluate the sensory analysis scores of wafer sheets prepared with different recipes by the consumer. The results will be evaluated within the scope of the master's thesis of Istanbul Technical University, Department of Food Engineering.

After tasting the wafer sheets, score them according to the following parameters.

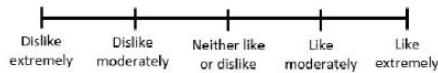
**Overall Liking**

Considering all the factors, score your level of liking for the wafer sheet you tasted.



**Taste**

Score how much you like the taste of the wafer sheet you taste.



**Crunchiness**

The force required to bite a wafer sheet.



**Crispiness**

Crunching sound when biting a wafer sheet.



**Hardness**

Resistance while biting a wafer sheet.



**Fracturability**

Resistance to break a wafer sheet when you bite into it.



**Figure 2.4 :** The scorecard for sensory evaluation of wafer sheets.

#### **2.2.4 Statistical analyses**

The effects of different starch types and ratios on the hardness, fracturability and moisture properties of wafer sheets were analyzed by ANOVA ( $p \leq 0.05$ ) with Minitab 16, and any significant difference between the values was examined and evaluated. Tukey test was applied to the results where differences were detected. The same method was also applied to the results of starch characterization and sensory analyses.



### 3. RESULTS AND DISCUSSION

#### 3.1 The Results of Starch Characterization Analyses

##### 3.1.1 The results of particle size analyses

The average results obtained in particle size analyses performed as part of starch characterization analyses are shown in the Table 3.1. In addition to the average results, the particle sizes of potato starch were measured in the range of 20-71, wheat starch in the range of 16-92, rice starch in the range of 8-44. The data obtained are in accordance with the data stated in the literature. However, the sizes of starches may vary according to the various grinding processes applied during their production.

Anova analysis of the measured results showed a statistically significant difference between the sizes of the three starch varieties ( $p < 0.05$ ).

**Table 3.1 :** Results of the starch characterization analyses.

Parameters	Potato Starch	Wheat Starch	Rice Starch
DSC - Onset Temperature (°C)	119.32 <sup>b</sup>	122.02 <sup>a</sup>	107.69 <sup>c</sup>
DSC - Peak Temperature (°C)	123.91 <sup>b</sup>	132.78 <sup>a</sup>	108.23 <sup>c</sup>
DSC - Conclusion Temperature (°C)	134.22 <sup>b</sup>	147.47 <sup>a</sup>	109.49 <sup>c</sup>
Water Absorption Capacity (%)	99.83 <sup>a</sup>	32.83 <sup>c</sup>	51.00 <sup>b</sup>
Particle Size - average (µm)	41.36 <sup>a</sup>	30.70 <sup>b</sup>	18.60 <sup>c</sup>

##### 3.1.2 The results of DSC analyses

The results of DSC analysis to examine the gelatinization temperatures of starches are shown in the Table 3.1. A significant difference was found between the initial temperatures (T<sub>0</sub>), peak temperatures (T<sub>p</sub>) and conclusion temperatures (T<sub>c</sub>) of all three starches ( $p < 0.05$ ). In this analysis, T<sub>0</sub> is the first temperature at which gelatinization of starch starts, T<sub>p</sub> is the highest temperature at which starch molecules are filled with water and crystalline region starts to decrease, and T<sub>c</sub> is the temperature at which gelatinization of starch is completed. According to the obtained measurement temperatures, gelatinization of rice starch is completed at a lower temperature compared to other starch types, while that of wheat starch is completed at a higher

temperature compared to other starches. Knowing these data can give an idea for the optimization of cooking temperatures of wafer sheet recipes using related starch varieties.

### **3.1.3 The results of water absorption analyses**

The results of the measurement of the water absorption capacity of the starches are shown in the Table 3.1. According to the results, the water absorption capacities of potato, wheat and rice starches were significantly different from each other. While the water absorption capacity of potato starch was the highest, that of wheat starch was the lowest.

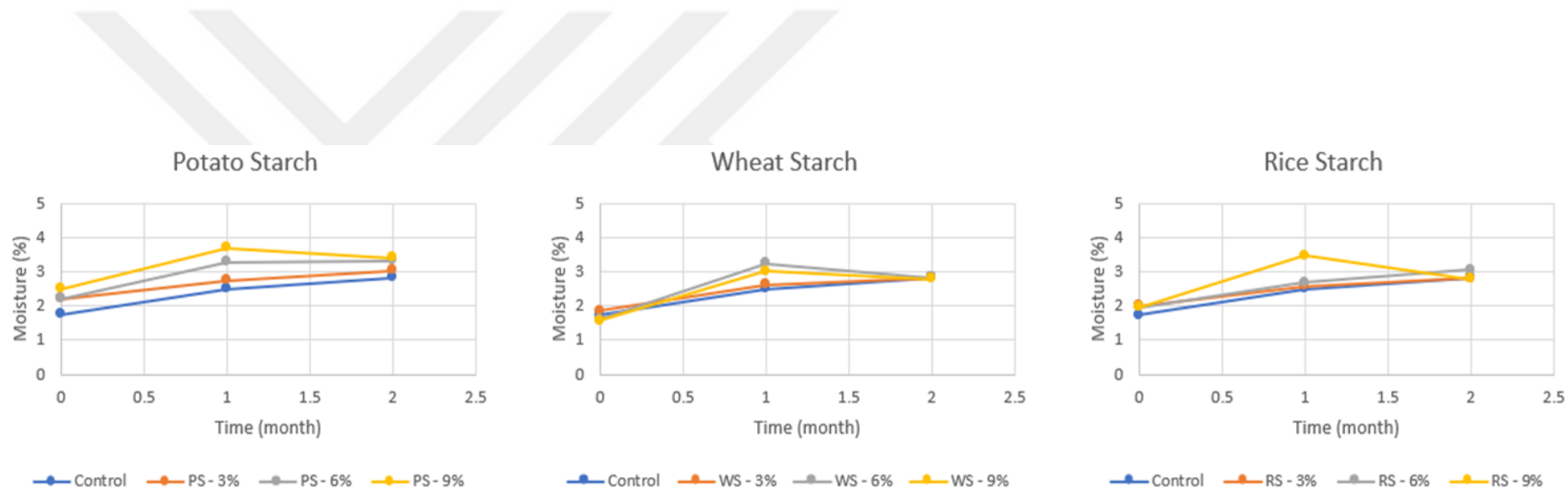
The results of this analysis can give an idea at the design stage of wafer sheet recipes containing related starches. In order not to increase the variability in the recipes applied in this thesis study, the amount of water was kept constant in all recipes. However, as further studies, the amount of water in the recipes can be optimized in accordance with the water absorption capacity of starches and their effects on dough rheology can be examined.

## **3.2 The Effect of Different Starch Types on Moisture of Wafer Sheets During Ambient and Accelerated Shelf Life**

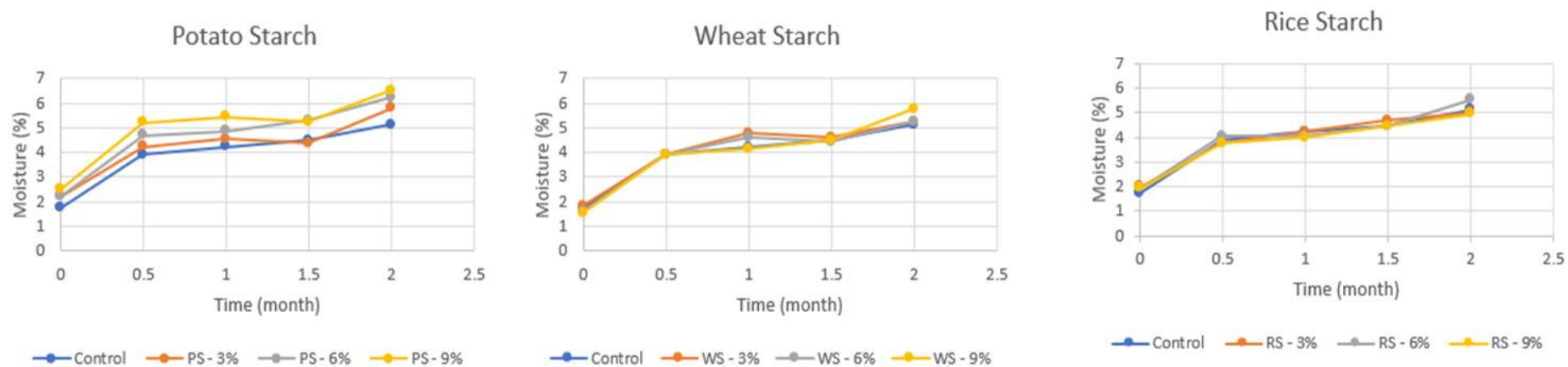
The moisture data obtained by observing the products prepared with different starch types under ambient and accelerated conditions are shown in the Figure 3.1. and Figure 3.2. in comparison with the control.

When the wafer sheets containing starch varieties were analyzed, the wafer sheets containing potato starch had significantly the highest moisture value compared to the other starches. During the 2 months of ambient shelf life observed, the humidity value was statistically significantly higher in the first month after onset, but did not increase at the same rate between the first and second month. Compared to the control, the moisture values of wafer sheets to which starch was added were statistically higher.

The type and ratio of starch may have an impact on the moisture content of wafer sheets after baking, as evidenced by the fact that all wafer sheet recipes examined had the identical ratios of water to dry matter and that the only variations were in the starch-to-flour ratios.



**Figure 3.1 :** Changes in the moisture content of wafer sheets containin different starch during ambient shelf life test.



**Figure 3.2 :** Changes in the moisture content of wafer sheets containin different starch during accelerated shelf life test.

When we examine the accelerated shelf life, the recipes to which potato starch was added showed higher moisture values than the control wafer sheet to which starch was higher than the moisture values of wafer sheets with wheat and rice starch. As can be seen in the tables, as the potato starch content in the recipe increased, the moisture content also increased and the same situation continued throughout the shelf life period. No statistically significant difference was observed between the moisture content of wheat and rice starch wafer sheets.

When the overall results of all wafer leaves were analyzed, it was observed that the moisture value increased significantly in almost every measurement made every two weeks under accelerated shelf life conditions. Only between weeks four and six, no statistically significant increase was observed. Afterwards, this increase continued throughout the shelf life, although not at the same rate. The recipes with wheat and rice starches did not show a regular and dosage-dependent increase throughout the shelf life like the recipes with potato starch. Also, the moisture content of starch-containing wafer sheets was significantly higher than that of control wafer sheets during the accelerated shelf-life conditions.

In the recipes with 3% starch added, there was a continuous increase in moisture content as expected throughout the shelf life. During the accelerated shelf life, the moisture content of different starch types was not significantly different within the same period. In addition, when we examined the recipes with 6% and 9% starch, the moisture content of the wafer sheets with potato starch was significantly higher than the moisture content of the wafer sheets with wheat and rice starch.

### **3.3 The Effect of Different Starch Types on Texture Properties of Wafer Sheets During Ambient and Accelerated Shelf Life**

#### **3.3.1 Hardness results**

The hardness values obtained by observing the products prepared with different starch types under ambient and accelerated conditions are shown in the Figure 3.3. and Figure 3.4. in comparison with the control.

When the wafer sheets containing starch types were examined, the hardness value of the wafer sheets containing potato starch was found to be significantly higher than the

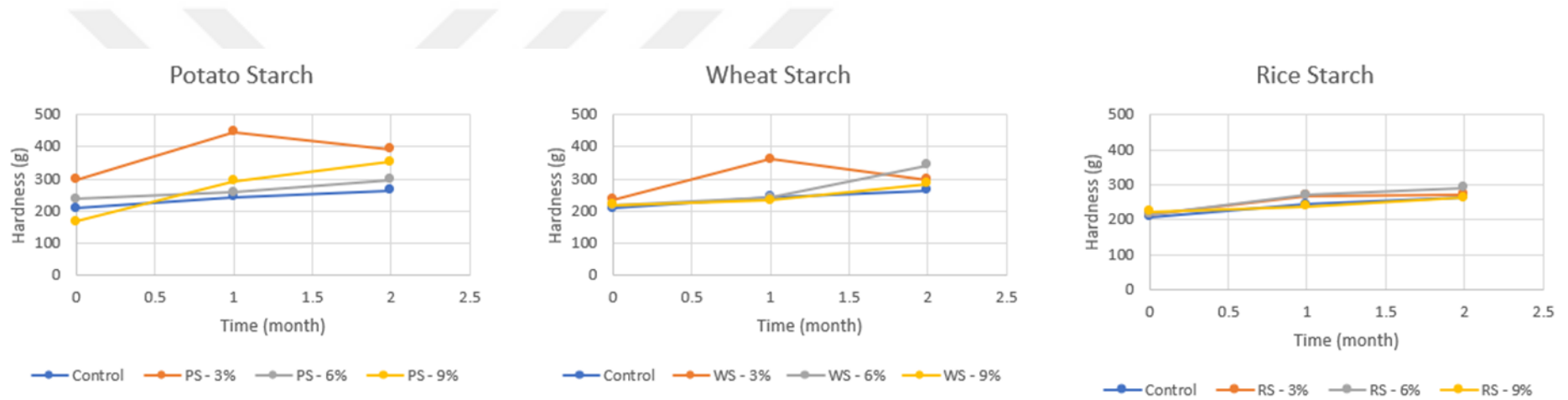
other starches. Although the hardness values of wafer sheets containing wheat and rice starch differed when examined in detail, but in total no significant difference was observed in terms of hardness value between wafer sheets containing two starch types.

During the ambient shelf life, the hardness value of starch-containing wafer sheets increased significantly as time progressed. When hardness was evaluated on the basis of starch ratios, the hardness values of wafer sheets containing control (0%), 6% and 9% starch did not differ significantly. However, the hardness value of wafer sheets containing 3% starch was significantly higher than the other wafer sheets.

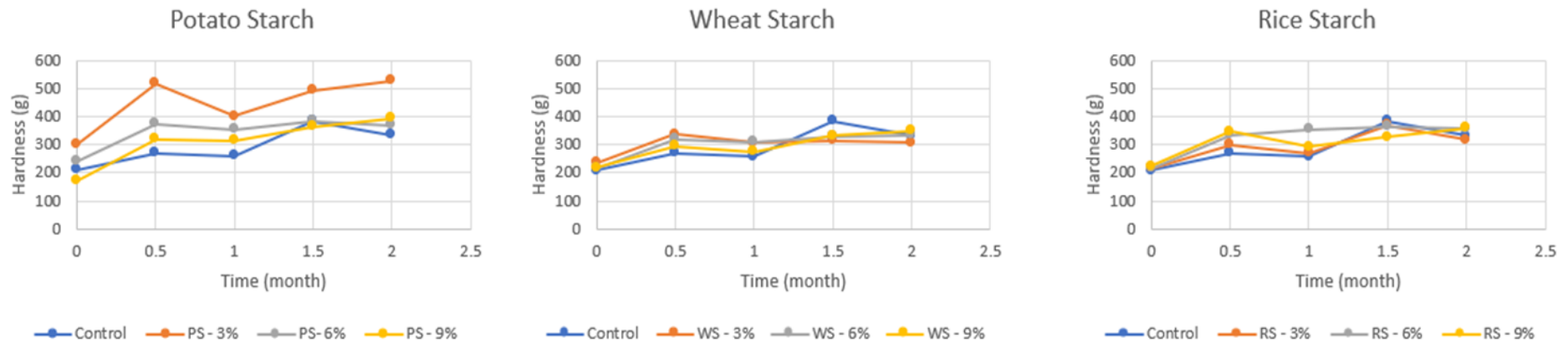
When all the results were analyzed, the hardness value of potato starch wafer sheets was found to be higher than wheat and rice starches under accelerated shelf life conditions. Also, in the analyses performed during the shelf life, it was observed that the hardness value increased over time. Wafer sheets with 3% potato starch were observed to have higher hardness values than the control and other starch types during the shelf life. However, the hardness values of wafer sheets with 6% and 9% potato starch were generally higher than the control but much lower than the 3% starch recipe.

In the case of wheat starch and rice starch, the hardness value of almost all wafer sheets with added starch was higher than the control. In this case, it can be stated that wheat and rice starches increase the hardness of the wafer sheets. This situation, which was not observed in recipes with 6% and 9% potato starch, may be due to the lower particle size of wheat and rice starch compared to potato starch.

In wafer sheets to which 3% starch was added, the hardness value of those to which potato starch was added was found to be the highest. The hardness values of wafers to which 6% potato starch was added were higher than those to which wheat starch was added and similar to those to which rice starch was added. In the recipes with 9% starch added; the hardness value of the wafer sheet with potato starch added at the beginning of the shelf life was the lowest, while it was higher than the others from the 2nd week onwards. It should be noted that the wafer sheets with 9% potato starch also had the highest moisture data during the shelf life. To evaluate the hardness data in general; the hardness value of the control wafer sheets was significantly lower than that of the wafer sheets containing starch. When starch-containing wafer sheets were examined, the hardness value of wafer sheets containing 3% starch was significantly higher than the others.



**Figure 3.3 :** Changes in the hardness result of wafer sheets containing different starch during ambient shelf life test.



**Figure 3.4 :** Changes in the hardness result of wafer sheets containing different starch during accelerated shelf life test.

### 3.3.2 Fracturability results

The fracturability values obtained by observing the products prepared with different starch types under ambient and accelerated conditions are shown in the Figure 3.5. and Figure 3.6. in comparison with the control.

When the wafer sheets containing starch types were examined, the fracturability value of potato starch wafer sheets was found to be significantly higher than the other starches. Although the fracturability values of wheat and rice starches differed when examined in detail, but in total no significant difference was observed in terms of fracturability value between the wafer sheets containing the two starch types.

During the ambient shelf life, the result of fracturability measurements in the first and second months was significantly higher than at the beginning. However, no significant difference was observed between the first and second months.

Under accelerated shelf life conditions, the fracturability of wafer sheets containing potato starch was significantly higher than those containing wheat and rice starch. In general, the fracturability value first increased and then decreased during the accelerated shelf life of 8 weeks. However, at the end of the shelf life, the fracturability value was higher than at the beginning. Fracturability value was significantly higher in wafer sheets with 3% starch compared to the control. Especially in wafer sheets to which potato starch was added, the fracturability value was significantly higher than in wafer sheets to which starch was not added.

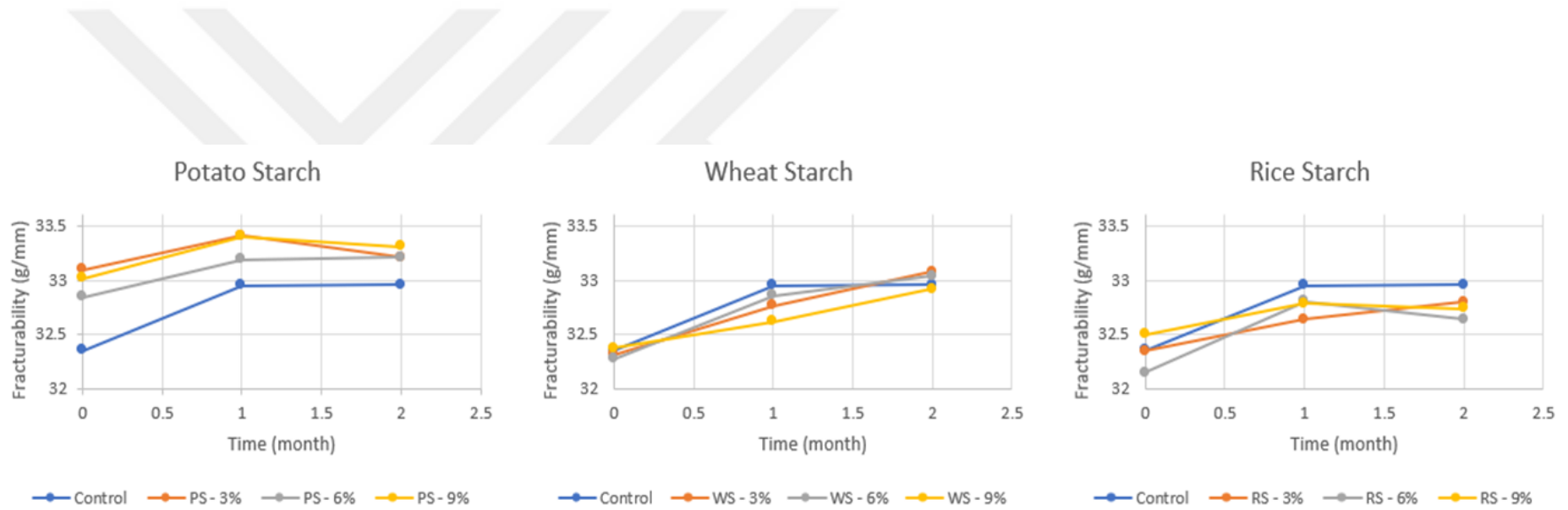
In the results observed up to week 8 of the accelerated shelf life, it was observed that the fracturability values of wafer sheets with 3% and 9% potato starch were higher than those with 6% potato starch. In the recipes with wheat starch added, the fracturability value decreased in the recipes with 3% and 6% starch added until the 6th week, but it was higher than the control in the recipe with 9% starch added.

During the shelf life of the recipes with added rice starch, the fracturability values increased compared to the initial values and the biggest difference compared to the control was observed in the recipes with 9% starch.

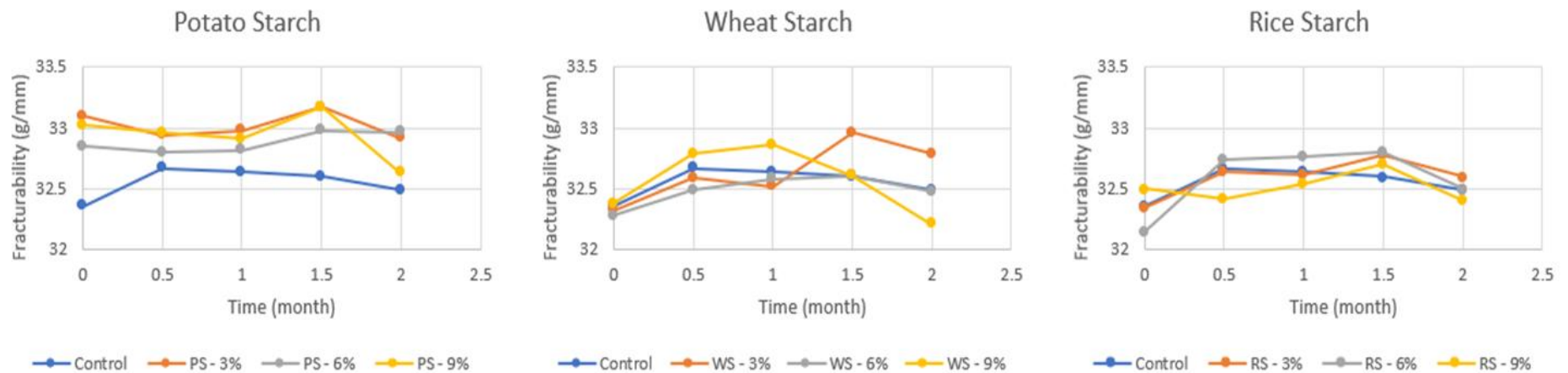
Especially in wafer sheets to which potato starch was added, the fracturability value was significantly higher than in wafer sheets to which starch was not added. Especially

in wafer sheets with 3% starch added, a significant difference is observed in potato starch added wafer sheets compared to wheat and rice starch added wafer sheets.





**Figure 3.5 :** Changes in the fracturability result of wafer sheets containing different starch during ambient shelf life.



**Figure 3.6 :** Changes in the fracturability result of wafer sheets containing different starch during accelerated shelf life.

### 3.4 Effect of Different Starch Types on Sensory Analyses

In the sensory analysis, scores were obtained for overall liking, taste, crispiness, crunchiness, hardness and fracturability parameters. During the sensory analysis tests, personal preferences, ambient temperature and other parameters that may affect the taste were neglected. When the scores were evaluated by Anova, no statistical difference was observed between the results of all parameters as seen in Table 3.2. and Table 3.3. However, the main reason for this situation may be due to the insufficient sample size in the test applied to 18 people.

**Table 3.2 :** Averages of liking scores.

Parameters	Potato Starch Containing- Wafers	Wheat Starch Containing- Wafers	Rice Starch Containing- Wafers	Control (No added starch)
Overall Liking	3.77 <sup>a</sup>	3.5 <sup>a</sup>	3.89 <sup>a</sup>	3.94 <sup>a</sup>
Taste	3.66 <sup>a</sup>	3.27 <sup>a</sup>	3.72 <sup>a</sup>	3.66 <sup>a</sup>

\* Scores are rated on a scale of 5.

**Table 3.3 :** Averages of “just about right” scores.

Parameters	Potato Starch Containing- Wafers	Wheat Starch Containing- Wafers	Rice Starch Containing- Wafers	Control (No added starch)
Crunchiness	2.50 <sup>a</sup>	2.72 <sup>a</sup>	2.72 <sup>a</sup>	2.55 <sup>a</sup>
Crispiness	2.44 <sup>a</sup>	2.44 <sup>a</sup>	2.50 <sup>a</sup>	2.72 <sup>a</sup>
Hardness	2.33 <sup>a</sup>	2.55 <sup>a</sup>	2.50 <sup>a</sup>	2.72 <sup>a</sup>
Fracturability	2.44 <sup>a</sup>	2.61 <sup>a</sup>	2.55 <sup>a</sup>	2.66 <sup>a</sup>

\* Scores are rated on a scale of 3.

In addition to the Anova analysis, the rates of scores meeting consumer expectations were also evaluated. The evaluation results are shown in Table 3.4.

**Table 3.4 :** Percentages of parameters meeting consumer expectations.

Parameters	Potato Starch Containing- Wafers	Wheat Starch Containing- Wafers	Rice Starch Containing- Wafers	Control (No added starch)
Overall Liking	75.5%	70.0%	77.8%	78.9%
Taste	73.3%	65.5%	74.4%	73.3%
Crispiness	81.5%	81.5%	83.3%	90.7%
Crunchiness	83.3%	90.7%	90.7%	85.0%
Hardness	77.8%	85.2%	83.3%	90.7%
Fracturability	81.5%	87.0%	85.2%	88.9%

In this evaluation, the average scores obtained were compared to the highest score and the percentages of meeting consumer expectations were determined. The wafer sheet containing wheat starch was the lowest scoring variety among the overall liking scores. Potato and rice starch-containing wafer sheets and starch-free control wafer sheets had similar percentages for meeting consumer expectations for overall liking. In terms of taste scores, the percentage of wafer sheets containing wheat starch meeting consumer expectations was lower than the other varieties. The results of overall liking and taste scores were parallel to each other and the ANOVA analysis showed that there was a correlation between them ( $p < 0.05$ ).

In terms of crispiness, crunchiness, hardness and fracturability scores, almost all starch-containing wafer sheets and the control met the consumer expectation above 80%. Only the hardness value of the wafer sheet containing potato starch was found to be lower than the others. In the hardness values determined by texture analyses, higher values were observed for potato starch compared to other varieties, but they were not scored in the same way by consumers.

It should be noted that although wafer sheets are tasted directly for sensory analysis in these reviews, wafer sheets are usually presented to the consumer together with a cream. Since the eating experience of wafer sheets combined with different creams and other inputs will vary, the scores may also differ depending on the product type.



#### **4. CONCLUSION AND RECOMMENDATIONS**

When all starch types and ratios were examined, potato starch was the starch type that showed the most difference in hardness, fracturability and moisture analyzes compared to the control samples. Obtaining high results in hardness and fracturability analyses indicates that wafers containing potato starch are more brittle. Additionally, since the highest moisture values were observed in recipes containing potato starch both at the beginning and end of shelf life, it can be concluded that wafer sheets containing potato starch need better preservation throughout their shelf life.

In terms of moisture ratios, the moisture values of the samples containing potato starch were measured higher after baking. Considering that there is the same liquid input in the formulations, this may be directly related to the ratio of starch-flour mixture. The granule size of the potato starch may have triggered higher moisture retention in the wafer sheet after baking. When we examined the other starch types, we found similar moisture values within themselves and with the control recipe, but statistically significant differences were also obtained. The cooling process is also very effective on the moisture content since the moisture content is stabilized during cooling in the environment after baking. Although all wafer sheets were allowed to cool in the same time and environment in this study, there is a possibility that minor changes in the environment may also affect the moisture values to some extent. In addition to measuring the moisture content, the sensory sensation of staling in the wafer sheets should also be evaluated.

In terms of hardness values, statistically significantly different hardness values were obtained when potato starch was used in different ratios. The hardness values of other starch types were measured at values parallel to the formulation with 6% potato starch. This may be due to the lower granule size of wheat and rice starches compared to potato starch, which may affect the gluten matrix to a certain extent, but does not break the matrix significantly. The larger granule size of the potato starch and its ability to interfere with more gluten matrix, weakening the gluten matrix formation, may explain the more brittle structure as the utilization rate increases. For large-scale production

facilities, processing wafer sheets that are too hard or too soft may cause problems, but there is no optimized range for this value. Hardness should be evaluated from a sensory point of view, based on product and consumer needs.

In terms of production efficiency, wafer sheets with high fracturability have negative effects; therefore, wafer sheets with high fracturability values are not preferred. When the fracturability of the examined wafer sheets was evaluated in terms of fracturability, the highest value was measured statistically significantly for the wafer sheets with 3% potato starch. When we examine the hardness data, the highest value was again observed in wafer sheets with 3% potato starch. In this case, high hardness may have triggered fracturability. When the other wafer sheets were analyzed in terms of fracturability, similar values were obtained in general. The fracturability value of the wafer sheets using 6% rice starch was statistically significantly lower compared to the others. The fracturability value may vary depending on the other raw materials in the formulation and their interactions, as well as baking parameters, homogeneous heat transfer and surface contamination of the oven plates.

In future studies, combinations of different starch types at different ratios can be applied and their effects on the texture properties of wafer sheets can be investigated. The use of starches with different granule sizes together can be studied to improve the processability and structure of wafer sheets.

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