SEPTEMBER 2021

M.Sc. in Food Engineering

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REPUBLIC OF TURKEY

GAZİANTEP UNIVERSITY

GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES

THE EFFECT OF ULTRASOUND ON WAFER

M.Sc. THESIS

IN

FOOD ENGINEERING

BY

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SEPTEMBER 2021

THE EFFECT OF ULTRASOUND ON WAFER

M.Sc. Thesis

in

Food Engineering

Gaziantep University

Supervisor

Prof. Dr. Mustafa BAYRAM

by

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September 2021

THE EFFECT OF ULTRASOUND ON WAFER

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ABSTRACT

THE EFFECT OF ULTRASOUND ON WAFER

KARATAŞ, Dilan
M.Sc. in Food Engineering
Supervisor: Prof. Dr. Mustafa BAYRAM
September 2021
107 pages

The use of ultrasound has recently received significant attention in the food industry due to consumers' conscious and healthy food preferences, developing and changing consumption habits and especially new trends towards functional foods. The aim of this study of the improving the qualitative properties of the wafer sheets and providing the desired structure using ultrasound in wafer batters. Specifically, the aim of this project was to increase the porous texture with the necessary processing and quality properties by observing the effects of different ultrasound frequencies applied in the wafer sheets batter on the baked wafer sheet's structure and thus to obtain a high porous texture with a physical method. In this the study, it was observed that ultrasound application at 25 and 40 kHz changed the wafer properties. While this application caused to decrease in wafer weight with different time (15, 30, 45 and 60 min), batter showed different viscosity value. Applied 40 kHz ultrasound shown better result for stringy-batter texture by the way undesired gluten formation. On the other hand, the hardness of wafer sheet decreased as generally for two different ultrasound applications.

Key Words: Ultrasound, Wafer, Batter (Dough), Frequency, Functional Food.

ÖZET

ULTRASESİN GOFRETE ETKİSİ

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Eylül 2021
107 sayfa

Ultrases kullanımı, tüketicilerin bilinçli ve sağlıklı gıda tercih etmeleri, gelişen ve değişen tüketim alışkanlıkları ve özellikle fonksiyonel gıdalara yönelik yeni eğilimleri nedeniyle son zamanlarda gıda endüstrisinde önemli bir ilgi görmüştür. Bu çalışmanın amacı; gofret tabakalarının kalitatif özelliklerinin iyileştirilmesi ve gofret hamurlarında ultrason kullanılarak istenilen yapının sağlanmasıdır. Ultrases uygulaması ile gofret hamuruna uygulanan farklı ultrason frekanslarının fırınlanmış gofret yaprağının yapısı üzerindeki etkilerini gözlemleyerek gerekli işleme ve kalite özellikleri ile gözenekli dokuyu arttırmak ve böylece yüksek gözenekli bir doku elde edilmek istendi. Bu çalışmada 25 ve 40 kHz ultrason uygulamasının gofret özelliklerini değiştirdiği görüldü. Bu çalışmada, ultrason uygulamasının gofret özelliklerini değiştirdiği gözlemlendi. Bu uygulama gofret ağırlığında azalmaya neden olurken, aynı zamanda hamurda farklı sürelerle farklı viskozite değerleri gösterdi. 40 kHz ultrases uygulaması, istenmeyen glüten oluşumu ile lifli hamur dokusu için daha iyi bir önleyici özelllik gösterirken, öte yandan gofret tabakasının sertliği genel olarak iki farklı ultrason uygulamasında da azaldı.

Anahtar Kelimeler: Ultrases, Gofret, Hamur, Frekans, Fonksiyonel Gıda.

"Dedicated to my family"

ACKNOWLEDGEMENTS

I would like to to thank my supervisor, Prof. Dr. Mustafa Bayram for his guidance, support throughout the study. I am thankful for his encouragement and motivation.

At the same time, I would like to express my deepest gratitude to my dear teacher Bülent Belibağlı, who always motivates and supports me with his support. Rest in peace dear Bülent Belibağlı.

My grateful thanks to my friend Merve Koçak for her help and support.

I would like to thank ŞÖLEN, this work is supported by ŞÖLEN ÇİKOLATA GIDA SAN. VE TİC. A.Ş.

Finally, my deepest gratitude for my family, my mother Süphan Koç, my father Ömer Faruk Koç and my lovely husband Yusuf Karataş for their endless support, encouragement and love. Any word can exactly express my love and appreciation to them. I dedicate this work to my beloved family.

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LIST OF ABBREVIATIONS

AACC	American Association of Cereal Chemists
AOAC	Association of Official Agricultural Chemists
CNR	Child Nutrition and WIC Reauthorization
GI	Gluten Index
gr	Gram
hZ	Hertz
kHz	Kilohertz
min.	Minute
mm	Millimeter
NMR	Nucleic Magnetic Resonance
SFC	Solid fat content
TPA	Texture Profile Analysis
TS	Türk Standartları
TSE	Türk Standartları Enstitüsü
US	Ultrasound

CHAPTER I

INTRODUCTION

1.1 General Information

Ultrasound is defined as frequency (20 Hz to ~20 kHz) of waves that exceeds the hearing of human ear limit. These waves are produced by the transformation of electrical energy to mechanical energy and formation of oscillations. Ultrasound is a kind of energy form, and this energy is generated by acoustic waves can be used to different form of matter as solid, liquid and gas (Welti-Chanes et al., 2017).

Ultrasound has major advantage over other technique in food industry because of the safe, non-toxic and green energy features (Feng et al., 2011). For this reason, this technique can be used to many areas in food industry.

Wafer is a confectionery-bakery product that containing some raw materials like flour, water, emulsifier, sugar, salt and vegetable oil (Manley, 2000). The main quality parameters of wafer are raw materials quality, color, taste and texture. The most important property of wafer texture is crispiness

In food technology, wafer has two different meanings. One of them is thin, light and crispy food obtained from baked batter. Another one is generally used in the United States that is thin and crisp cookies (biscuits) (Tiefenbacher, 2017).

1.2 Wafer

Wafer is defined as prepared in accordance with the technology by adding or not wafer filling matter between the wafer sheets or filling depending on the type of wafer or by coating them It is claimed that the wafer was found by the clergy. Allegedly, the monks made product called holy bread by using iron plate the symbols symbols of the orders.

However, the modern wafer was made by the Dutch using the special hinged tongs in the mid-19th century. Wafer ovens were established after the First World War. However, mass production of wafers started only after 1950 (Mert, 2014). According to another source, in a painting made in the 17th century, products resembling wafers are drawn Figure 1.1.

Figure 1.1 Lubin Baugin, Le Dessert de gaufrettes, 1630/1635. (Original: Musee du Louvre, Paris, 2016).

1.2.1 Wafer Sheet

Wafer sheet is defined as a product a crispy and porous structure obtained by cooking the batter that prepared of wheat flour, drinking water, and if necessary, sugar, salt and vegetable oil mixture and one or more additives [50].

Special equipments are required for making wafer sheets. They are heated metal plates that are fastened together with hinges like two covers of a book, on which different patterns can be engraved. Batter is baked between two plates and obtain

Proportions and quality of flour, water and other ingredients are very important to obtain high quality wafer sheets. Additionally, mixing and cooking time and

temperature of batter and temperature of wafer plates should be considered during production (Dogan, 2006).

1.2.2 The Characteristic of Wafer Sheets

Confectionary wafers are baked with hot metal plates and obtained different shapes like; sheets, hollow figures and wafer cones. Wafers are generally very thin, crisp and light texture. There are 2 basic types of wafers. They are classified to their sugar amount on a flour base. One of them is no/low sugar wafer and another one is sugar wafers that contain more than 10% sugars on a flour base. No/low sugar wafer is containing zero to a few percent sucrose or other sugars on a flour base. Wheat flour is the main ingredient for 2 types of wafers. Wafers are manufactured at industrial area is classified in bakery products and have a long shelf-life term (Tiefenbacher, 2017).

Confectionary wafers that are generally baked on two hot plates can be sweet, crisp and flat, and its recipe consist of mainly from flour, water, additionally sugar and salt, emulsifier, leavening agents such as sodium bicarbonate, ammonium bicarbonate or enzyme. All ingredients are according to consumer or sensory requests. While flat wafer is generally used as confectionary wafer product; rolled wafer is used as ice cream wafer cones. Both of them have different baking conditions and recipe requirement. On the other hand, wafers are aerated structure, which baked between two hot plates (Verma, 2019).

1.2.3 Wafer Production in Turkey

The production of wafer in Turkey, has high capacity and was produced in too many companies. Every company, produce it with different taste, structure, appearance and technology. Manufacturer is lean to produce more and different wafer due to the technological changes and consumer attractive to more healthy and different products.

1.2.4 Global Wafer Markets

Annual Compound Growth Rate (CAGR) of market of the global wafer is expected an increase of 4.3% growth rate. European market region has the biggest global

wafer market like biscuit market. European global biscuit market has 31 percent in wafer market. The reason of that is the presence of too many suppliers and high living standards. North America has the 2nd biggest market region along with the US leaders. On the other hand, wafer consumption decreases because of the increasing of the healthy product consumption request of consumers. Fasted growing market is expected from Asia-Pacific region. Important market regions are China and India in this region (CNR Food İstanbul, 2021).

1.2.5 Ingredients Used in Wafer Sheet Production

There are different raw materials used in the wafer production. These are flour, water, emulsifiers, egg products, salt, sugar, enzyme, flavors, vegetable oils and some other additives. Ingredients are determined to consumer request and process requirement. Cocoa wafer, chocolate wafer, flavored wafer and plain wafer are some of the wafer varieties. Tiefenbacher (2002) are listed to required ingredients that making wafer at Table 1.1 (Tiefenbacher, 2017).

Table 1.1 Ingredients affecting in wafer sheet quality, derived from Tiefenbacher, 2002.

Ingredients	Specification	Comments	Influence on wafer
Wheat flour	Protein below 10%, moisture below 14.5%	Low absorption Use low shear mixer not to develop gluten	Provides bulk and structure
Starch, native	Potato, tapioca preferable to corn, wheat	Increases dry matter Reduces gluten problems	Increased stability, more homogenous structure
Water	Potable, Preferable below 60°F	Dissolve water soluble components, disperse flour	Weight+stability decrease; water hardness increases wafer hardness slightly
Baking Soda	Food grade Sodium bicarbonate	Improves spread in baking mould	Less weight and stability More color

*Table 1.1 (cont.)

Ingredients*	**Specification***	**Comments***	**Influence on wafer***
Sugar	Sucrose, Granular	Dissolve sugar completely	Improves taste, texture; Increases wafer color + residues on baking moulds
Oil/Fat	Coconut, palm kernel; partially hardened oils; No di-, polyunsaturates	Reduces viscosity; Add in liquid form or powder	Improves release, texture; if too high: cloudiness, incomplete structure details
Lecithin	Lecithin (liquid); or carrier bound powder, deoiled powder	Reduces viscosity; mix with oil; If powder add before flour	Improves release, texture; increases residues on baking plates, color

1.2.5.1 Water

Water is a main ingredient for wafer structure and quality. Water is classified as soft and hard water. For the wafer production, hard water can be preferred for the process requirement.

Hard water increases both texture hardness and brittleness. The force, which is needs to bite and break to wafer is related with the hardness. In this point, wafer brittleness related with the bending angle to access the break point. Hard water decreases the bending angle and wafer will be less flexible (Tiefenbacher, 2017).

1.2.5.2 Flour

Flour is another main ingredient for wafer production. Most of the quality parameters of wafer are related to the flour. Depending on the structure of flour (soft or hard flour) wheat flour is giving different application result. Soft wheat flour is mostly preferred for wafer production in some countries due to low gluten content to obtain sufficient texture (Tiefenbacher, 2017).

For a wafer with the desired quality parameter is gluten strength is very important, in

this point flour type is important. Gluten content in the flour should be adequate to obtain required wafer texture. Particle size distribution of flour is also another important factor to determine the quality of wafer. Small particle size of flour creates less dense, soft and high brittle wafer sheets (Dogan, 2006).

1.2.5.2.1 Wheat Flour

The first agriculture began at nearly 10,000 years ago at Middle East with huge consumption of cereal grains. Wheat is the one of the cereal grains, which was cultivated and planted at firstly (Figoni, 2010). Wheat flour has unique properties when mixed with water, it causes elastic structure because of its protein components and ability to hold gas properties during baking (Hazelton et al., 2003). Wheat has a really important nutritional value. Flour, semolina and other similar products are produced by wheat grain and most of them are preserved to main nutrient source to human at world. Wheat products are used as an ingredient in bakery products such as pasta and bakery products like bread, biscuit e.g. (Šramková et al., 2009). When wheat flour is mixed with water, glutenin and gliadin are formed as gluten formed protein that affect the structure of quality of bakery products. Generally, some flour consists of 12% protein, 14% moisture, 2% gums, 1% lipids, 5% ash and 71% starch components. Moisture of flour ranges between 11 -14 percent. Flour should be storage at suitable conditions, because when moisture content is increasing the normal range, flour is susceptible to spoilage (Figoni, 2010). Wheat flour can be soft, medium or hard according to its textural properties by millers. Softer wheats have less starch-protein complexes, this causes the less starch deterioration and less water absorption. Generally, soft wheat has less protein and resistance. Because of its properties, more elasticity batter can be produced. This kind of ‘weak’ flours are more suitable to produce biscuit like products (Hazelton et al., 2003).

1.2.5.3 Vegetable Oil

Vegetable oil is another important ingredient of wafer. Mostly, it is used for to prevent sticking of wafer batter on hot plates. Also, it is a recipe requirement for other quality parameters. Fat tenderizes the texture of final product. In bakery product, shortenings give a moisture mouth feel, transfer the heat and support to stronger the structure (Stauffer, 2005).

The most of preferred oils that used for wafer production are native palm kernel olein and native palm olein. These vegetable oils give advantages that being liquid form in media, this is important for easy dosage and it gives well stability during thermal process (Tiefenbacher, 2017).

1.2.5.4 Emulsifier

Lecithin (E322) is a natural emulsifier. Generally, soy lecithin is suitable for wafer production. Soy lecithin is used to prevent for sticking wafer batter on hot plates and also, it is a recipe requirement for other quality parameters similar to vegetable oils. Emulsifiers are generally known as surface active agents. These agents supply uniform quality and also increase the shelf life of final product. Emulsifiers that used in the batter formation cause the increasing of gas cell during fermentation process. It provides the improving of elasticity of batter structure (Krog, 2018).

Soy lecithin is a kind of emulsifier that used in the baked goods. On the other hand, lecithin improves the organoleptic properties of baked goods. It also improves the viscosity of batter of bakery product (Riaz, 1999).

1.2.5.5 Salt

Salt is mainly flavor or enhancer however it provides the control of fermentation of batter gives toughness to batter by interaction with gluten (Lai and Lin, 2006). Sodium chloride is generally referred as terms of salt in baking process. Salt has too many functions in baking process. Salt has too many functions in baking procedures beside of to be flavor enhancer. It stabilizes the rate of yeast fermentation, enhance to batter, increases taste of final product and increase the mixing time of batter during process (Miller and Hoseney, 2008). To give taste and improve the structural properties in wafer, salt is used and generally referred salt is sodium chloride. Salt is strengthening the batter with increasing mixing time. But mostly it is used as flavor enhancer (Miller and Hoseney, 2008).

1.2.5.6 Raising Agent

Beside of the increase enhance flavor of final product, leavening agent helps to improve the technological properties of batter in bakery products. These sodium

additives control the fermentation rate in products which is contain yeast and it helps to provide the water absorption (Vetter, 1980).

1.2.6 Process of Wafer Production

The process steps of wafer sheet production are represented in Figure 1.2.

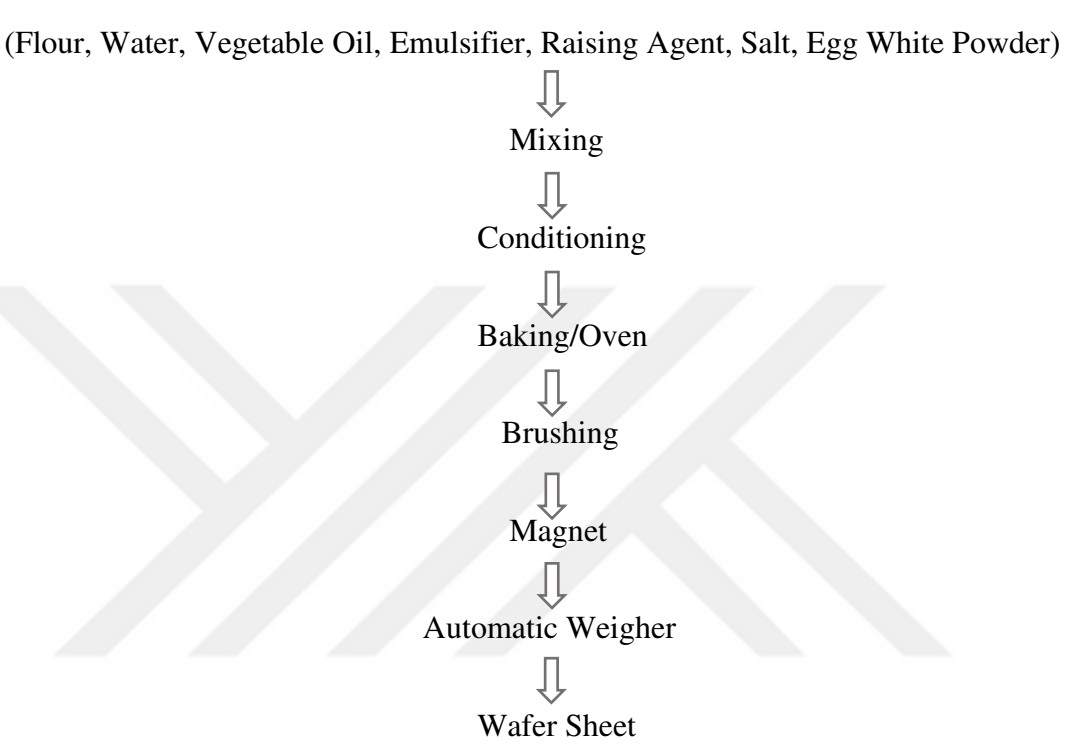

Figure 1.2 Wafer sheet production steps

Initially, all materials are weighted according to the determined recipe with precise measure. Firstly, liquid ones are poured into vessel to avoid hardly mixing process. After that, other ingredients are poured into vessel.

All raw materials are mixed in a vessel to obtain wafer batter. Water temperature should be as much as cold between 10-15 ^{o}C. The mixing process is continued until a homogeneous structure is obtained. The duration may vary depending on raw material and process requirements.

Batter is waited at a vessel with certain temperature and time. The reason of the conditioning step is to obtain desired consistency of batter and ready to process. In this step, batter is generally waited between 10-15 ^{o}C nearly for 20 min.

For a high-quality wafer sheet, the beside of the quality and amount of flour and water in recipe; mixing time, batter temperature, mold temperature and cooking time determine the quality of wafer (Dogan, 2006).

After that for molding stage, the batter that has the consistency is poured into molds. Wafer is shaped by using metal molds. To avoid any adhesion of batter, molds should be sprayed with oil before the pouring. Oven is working with direct cooking process and batter is cooked that is poured between two metal plates by compressing with heat conduction transfer. Temperature of oven and cooking time are settled while depend on poured batter amount and final product requirements. Temperature is generally changed between 150-190 ^{o}C.

The time for baking the wafer batter is around 2 min. at range of 180 ^{o}C. When wafer sheets turn the light, homogenous foamed structure is come true under pressure with conversion of high moisture ratio to steam during cooking process (Tiefenbacher, 2017).

The baked wafer sheets are brushed to get rid of batter residue and possible wafer dust created during the cooking time. According to the downstream process and final product requirements, the wafer sheets are weighed.

1.3 Effect of Ultrasound on Foods

1.3.1 Food and Technology

Food is one of the main necessities for human life. With the developing and changing consumption habits of people, technology has gained a different dimension with these changes. These changes led to different technological discoveries. At this point, in the industrial field, these technological changes are being used in need. At this point, ultrasound has been one of the methods to meet these changes in food industry.

Food technologies have evolved and changed in many places with a variety of climate, crop and food choices. While China uses salt to dry beef for military food, salt was used to preserve food in Japan. Weather conditions is helping to develop the food processing technique, people preserve food at winter months (Fellows, 2009).

From the past to the present, people have always found a way to preserve their basic need as food and develop to them according to their needs

1.3.2 Ultrasound

Ultrasound is a kind of mechanical energy that obtained by frequency of sound wave that are audibled by human ear (16–18 kHz) (Jayasooriya et al., 2004).

The classification of ultrasound of frequency wave range is shown in Figure 1.3.

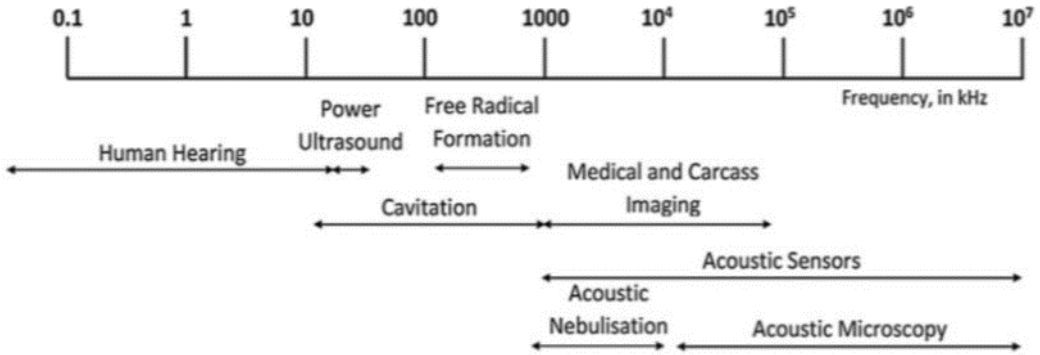

Figure 1.3 The classification of ultrasound waves range (Kentish, 2017).

When ultrasound is dispersed through a biological structure, it causes the compression and collapsing of medium particles and also, it can give high energy. In dependence of the amplitude of frequency waves, ultrasound technique gives physical, chemical and biochemical effects. Additionally, ultrasound is used too many different areas like civil engineering and medicine (Dolatowski et al., 2007). When ultrasound is classified the most important factor is energy amounts of produced sound areas. Sound power (W) is related with sounds intensity (W/m^2) and sound energy intensity (Ws/m^3).

1.3.3 Ultrasound and Food Processes

Ultrasound is used too many food processing areas like pasteurization, sterilization, generation of emulsion, cell disruption performing of chemical reactions and crystallization (Chemat et al., 2004).

Ultrasound technique is used for food analysis and food processing applications for many years. Analytical ultrasound applications are applied low intensity ultrasound

range in 5-10 MHz frequency. Texture, composition and rheological behavior are determined by this technique. In this point, low intensity ultrasound frequencies do not cause the chemical or physical changes during the analytical applications. On the other hand, food processing applications are applied high intensity ultrasound range in 20-100 kHz and generally used for cleaning and cutting process. However, when high intensity ultrasound frequency is applied to liquid form foods, there is a mainly changes in food materials; cavitation occurs (Tiwari and Mason, 2012).

Ultrasound is used also mechanical and physical food processing operations. For example, it provides to shorter cooking times and better cooking because of its improved heat transfer (Tiwari and Mason, 2012). Ultrasound reduces the soaking and cooking time of chickpeas when different ultrasound frequency waves are used (Yildirim et al., 2013). For frozen and soft foods, ultrasonic vibrations can be used for cutting process. Also, ultrasound is used for production of emulsions like sauce and mayonnaise. Beside these, ultrasound is also used for pickling, marination, drying, filtration, extraction, freezing and defoaming operations in food industry (Tiwari and Mason, 2012). It has also been used for oxidation and reduction reactions, inactivation of enzymes and pasteurization process (Soria and Villamiel 2010). The idea of the using ultrasound system in industrial area is begun at 1980 years and it has continued to be used in a wide variety to present day. Ultrasound wave is applied in medicine, measuring, determination of area and length, dental process, jewelry cleaning, equipment cleaning of industrial area, metallic and plastic adhesive process, treatment of water, antibacterial processing, food treatment and food process improvement etc. at present. Principally, ultrasound is basically composed of 2 parts; generator and transducer. When generator creates the ultrasound waves; transducer is transformed the electrical signal to mechanical signals (Yildirim et al., 2013).

1.3.4 Working Principle of Ultrasound System

Ultrasound consists of a series of high frequency sound waves. When sound propagated to a medium like air, liquid or solid area by a source, the sound radiates in as simple harmonic motion (as sinusoidal waves). Medium gives a react to this propagation of waves and also assist them by vibrating elastically (Feng et al., 2010).

During sonication process, when ultrasound waves meet a liquid form, it causes alternative compression and expansion areas. This pressure changes areas cause the cavitation and gas bubbles are formed in medium (Dolatowski et al., 2007). These bubbles have bigger surface area during the expansion and therefore it causes the expansion of bubbles while it increases diffusion of gas and principle of cavitation is illustrated Figure 1.4.

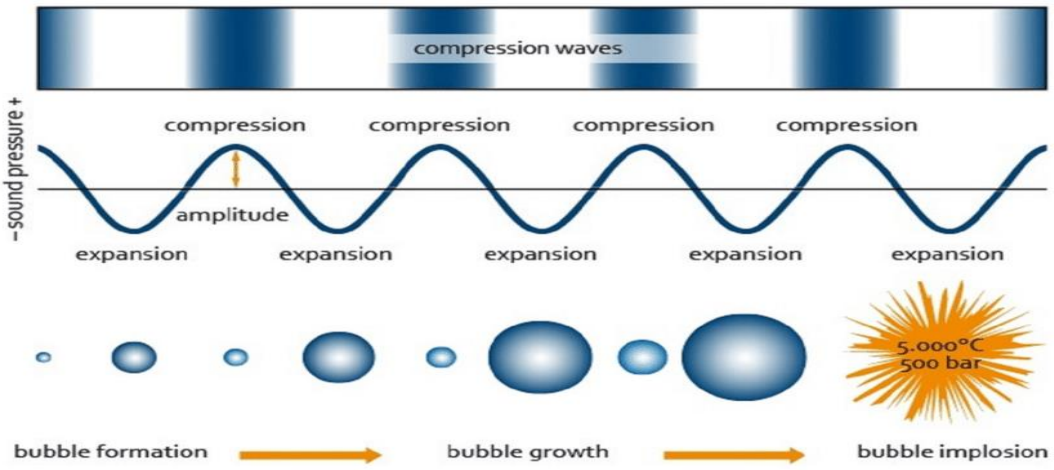

Figure 1.4 Principle of ultrasound cavitation (Johansson et al., 26).

Ultrasound energy spreads in the form of waves. There are various types of waves; however mostly 'longitudinal waves' are used in the most of applications. The particles in the medium oscillate back and forth around their balance states. In this way, energy is transported into the environment in a direction parallel to the vibrations of its particles. Ultrasound is the vibration of atoms or molecules around their balance position. Therefore, ultrasound is mechanical energy (Duran et al., 2006). High pressure and low-pressure waves can occur in the liquid that is applied high intensity ultrasonication. During low pressure wave generation, ultrasonic waves create small vacuum bubbles, and when these bubbles reach a volume that cannot absorb more energy, high pressure wave formation occurs and burst inward. This phenomenon is called cavitation and Figure 1.5 shows formation of cavitation (Johansson et al., 2017).

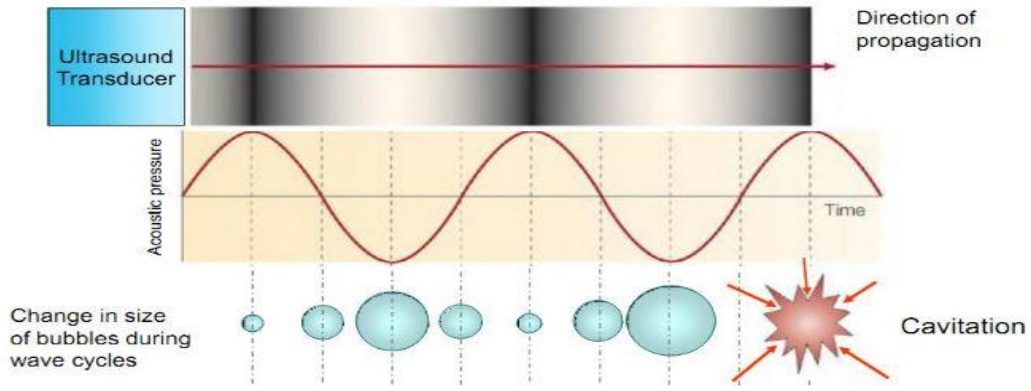

Figure 1.5 Formation of cavitation (Johansson et al., 2017).

The order of occurrence of cavitation is as follows and illustrated in Figure 1.6:

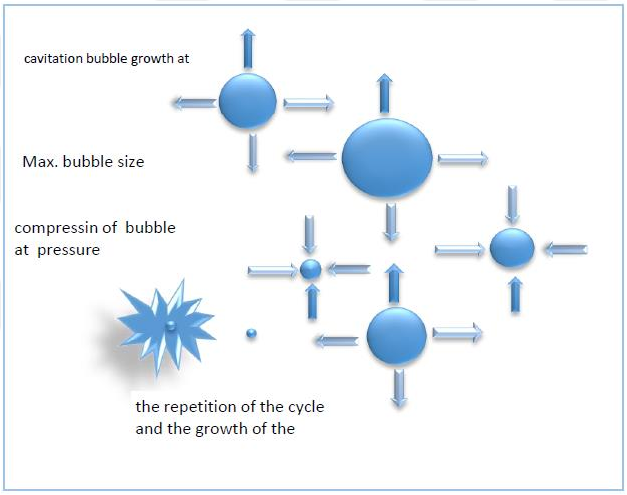

Figure 1.6 Illustration of occurrence of cavitation (Johansson et al., 2017).

1-There is a gap-shaped interruption in the dilution phase of the ultrasound waves. This space is filled with the saturated vapor of the supplied liquid.

2-In the compression phase, the vapor condenses and the cavity decays as a result of falling under the effect of increasing pressure.

3-When the compression ends, second shock waves occur in the surrounding liquid that evaporates rapidly in the environment.

4-As a result of this phenomenon called cavitation, a pressure over 1000 atm and a great energy is released. This energy heats the area where the bubbles are located and causes chemical (Johansson et al., 2017).

1.3.5 Physical Effects of Ultrasound System

As generally, ultrasound is described as a pressure wave that high frequency. When this pressure waves are passed from the medium, it causes the high and low pressure areas. These pressure changes called as pressure wave amplitude or acoustic pressure. These are directly proportional with energy amount. This wave will distribute the energy as viscously even it is air or water. This is called as "steady streaming'' (Feng et al., 2011).

Talked about as before, cavitation is a kind of bubble formation process. The lowest acoustic pressure is called as cavitation or Blake threshold, PB. It is function of vapor pressure solution P_v (Pa), the surface tension (σ) (N/m), radius of initial bubble (R_0) (μm) and system pressure (P_0) (Pa) (Feng et al., 2011). The equation is shown as follow:

$$P_b = P_0 - P_V + \frac{4}{3}\sigma \sqrt{\frac{2\sigma}{3\left(P_0+2\frac{\sigma}{R_0}-P_V\right)R_0^3}} \qquad (1.1)$$

1.3.6 Literature Review of Ultrasound Systems on Foods

In a study which was made by Lee et al., it was observed that on liquid whole eggs, foaming and emulsion features of the samples shown important some structural changes when the sample is treated with high hydrostatic pressure and ultrasound (Lee et al., 2003). They suggest that there is a heat labile protein denaturation due to increasing of L-value (color) with ultrasound and high hydrostatic pressure (Lee et al., 2003). To inactivate the *Eschericha coli* in water supply, performance of the squeeze film is examined with using ultrasound system. The setting of the optimal thickness of squeeze film to be 2 mm with using the ultrasound system, inactivation of *E. coli* cells was observed by researchers (Fruta et al., 2004).

To evaluate the effect of soaking and ultrasound on chickpea, texture of chickpea is increased during soaking and different ultrasound treatment and power of ultrasounds also effect the texture of chickpeas as significantly. Applied ultrasound treatment decreased the soaking and cooking time (Yildirim et al., 2013).

There are too many examples about using of ultrasound on increase the production of foods that increase the cell efficiency without disturbing cell walls. For example, using of low power ultrasonic activation in liquid nutrient media, aimed to rate of growth of alga cells. Essentially, this causes the increasing of protein and it represents different potential of production of foodstuffs (Mason et al., 1996).

1.4 The Aim of The Study

The aim of this study was to determine the effects of ultrasound at different frequencies 25 and 40 kHz and for 15, 30, 45 and 60 min. treatment on the properties of wafer dough and the texture of wafer after baking. In addition to textural effects, this study was also aimed about possibility of the utilization of ultrasound in the wafer production at industrial scale.

CHAPTER II

MATERIALS AND METHODS

2.1 Methods

Wafer sheet samples were prepared using water, flour, vegetable oil, soy lecithin, sodium bicarbonate, salt and egg white powder (Table 2.1). The wafer batter prepared according to the recipe was cooked in wafer baking machine (Franz Haas Waffel, A-2100, Leobendorf, 2011, Austria) and a control group was formed primarily as a batter and wafer sheet. Then, the wafer batter was baked by using a wafer baking equipment (Franz Haas Waffel, A-2100, Leobendorf, 2011, Austria) with subjecting it to ultrasound operating (Intersonik, Turkey) at different time intervals (15, 30, 45 and 60 min.) and different frequencies (25 and 40 kHz). Thus, the batter samples and wafer layers formed as control group and test group were subjected to different analyzes. Distilled water was used in all analyses.

2.1.1 Chemicals

Acetic acid (CH_3COOH) n-hexane (1:1 ratio) (Merck KGaA, Germany), diethyl ether $(C_2H_5)_2O$ (1:1) (Merck KGaA, Germany), chloroform acetic acid $C_3H_5Cl_3O_2$ (2:3 ratio) (Merck KGaA, Germany), lactic acid ($C_3H_6O_3$) (Merck KGaA, Germany), phenol (C_6H_6O) (Merck KGaA, Germany), potassium hydroxide solution in ethanol (KOH; 0,1N) (Merck KGaA, Germany), potassium iodide (KI) (Merck KGaA, Germany), sodium thiosulfate solution ($Na_2S_2O_3$ $5H_2O$; 0,1N) (Merck KGaA, Germany), sulfuric acid (H_2SO_4, 95-97%) (Merck KGaA, Germany), starch (d= 1,5 g/cm³) (Merck KGaA, Germany), Kjeldahl tablets (without addition of SE and Hg, 5g/tablet) (Merck KGaA, Germany), Wijs solution (contains acetic acid) (Merck KGaA, Germany) were used. All chemicals were analytical grades.

2.1.2 Instrumentation

Ultrasonic system at 25 and 40 kHz (Intersonik, Turkey) was used for the experiements. (Figure 2.1)

Figure 2.1 Illustration of ultrasonic devices

A digital micrometer (Mitutoyo, Japan) was used to determine the diameters of wafer batter. An analytical balance was used (with a sensitivity of ± 0.0001, Sartorius Weighing Technology, Germany and Swock Weight ±0.1).

To obtain wafer batter, the raw materials were mixed by using a mixer (Moulinex, France). The texture of the samples was measured by using TA.XT.plus Texture Analyser (Stable Micro Systems, Ltd., Godalming, Surrey, UK).

The solid fat content was measured by using a NMR analyzer (the minispec mq20 NMR analyzer, Bruker). The protein content was determined by using a protein analyzer (BUCHI, KjelMaster K-375, Switzerland).

Water lifting, kneading, gluten, viscosity, amylase and retrogradation of wheat flour used in the batter were measured with Mixolab analyzer (Chopin Technologies, Version 4.1.2.7, France). Gluten index was determined by using Gluten Index Analyzer (Perten Glutomatic 2200, Sweden; Perten Glutork 2020, Sweden).

The color and moisture content of the samples were measured by using a color meter Hunter Lab Colorflex, USA) and a moisture analyzer (Ohaus MB45, Switzerland), respectively. The moisture analysis of soy lecithin was measured by using a Karl Fischer Titration device (Methrom, 841 Titrando, Switzerland).

Rheometer (Brookfield eng labs inc., USA) was used to determine the rheological properties of the samples. The pH of the samples was measured by using a pH meter

(Mettler-Toleda AQ, Switzerland). The sedimentation value was determined with a sedimentation device (SDM 2013-22353 Tekpa Sedimentasyon, Turkey). The ash analysis was performed by using an ash oven (Thermo Heraeus Scientific M110, Germany). The wafer porosity was observed with light magnifying mechanism (Electro-mag, C722). The cooking of wafer sheets was made by using a wafer plate (Franz Haas Waffel, A-2100, Leobendorf, 2011, Austria) (Figure 2.2).

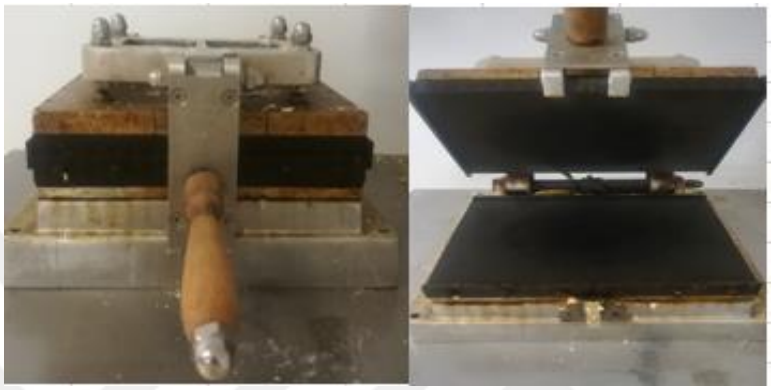

Figure 2.2 Laboratory-type wafer sheet baking plates

2.2 Experimental Methods

2.2.1 Experimental Set-up

The experimental set-up is given in Figure 2.3. Three experimental groups used such as control, 25 and 40 kHz US applied. For 25 and 40 kHz ultrasound applications, for 15, 30, 45 and 60 min. ultrasound periods were used for the wafer dough. Then, the doughs were used for baking/wafering stage.

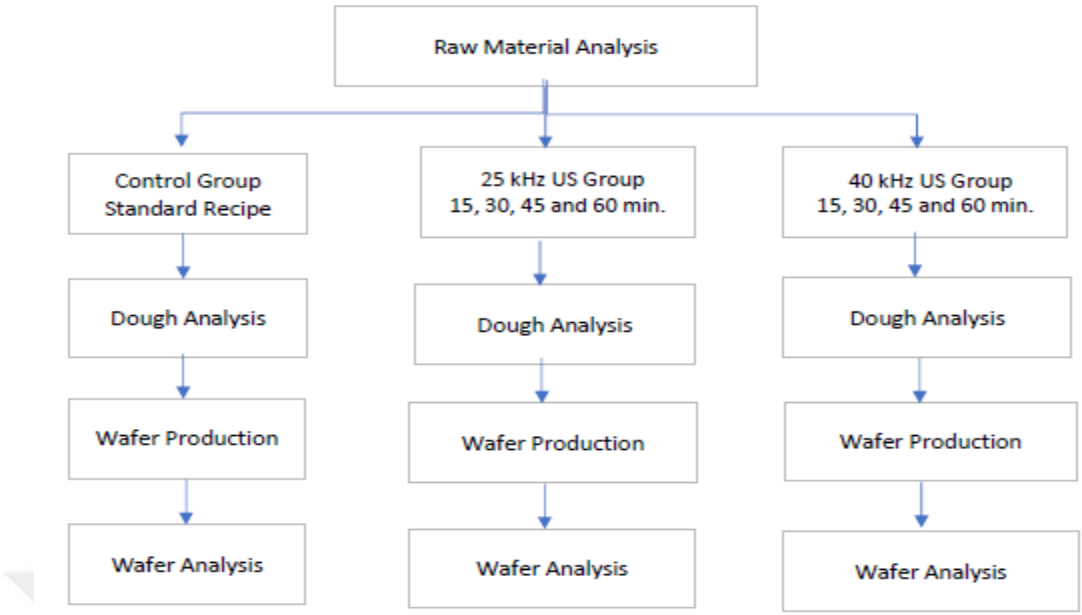

Figure 2.3 Experimental set-up (US: Ultrasound)

2.2.1.1 Batter (Dough) Preparation

Ingredients that used in the wafer batter are given in Table 2.1. Water was added at around 15-16 ^{o}C to prevent the agglomeration into a laboratory type of dough mixer (Moulinex, France). Other ingredients were gently added into the mixer. Mixing time was 4-5 minutes to obtain homogeneous batter. After that, the batter was waited at nearly 8 ^{o}C to allow air bubbles to rise to top. The temperature of batter was kept at 15 ^{o}C during the study.

For the ultrasound application, cold distilled water (minimum. 9-10 ^{o}C) was put into an ultrasound device to a certain level to tolerate the heat generation and heat-up of bath due to ultrasound. The operation temperature was fixed around 15-16 ^{o}C. Then, a plastic beaker containing wafer batter was placed inside the ultrasound device. At the same time, a graduated cylinder containing 25 ml of wafer batter was placed into device to observe the volume changes (Figure 2.4). The distilled water in the device should be above the batter level in the beaker and graduated cylinder. Therefore, distilled water covered the batter in the beaker and graduated cylinder. Before the device was switched on, the temperature of the batter and the distilled water were recorded. In addition, the volume of the batter in the graduated cylinder was recorded as 25 ml. The device was started and batter was subjected to the ultrasound

frequency at specified durations (15, 30, 45 and 60 min.).

Since the heat released during the ultrasound, the water of the device was changed with cold water or ice from time to time in order to prevent the increasing of temperature of the water by measuring and controlling the temperature during the ultrasound application. After duration time was over, the device was turned off. The final temperature of the water and batter in the device was recorded as quickly. At the same time, the change in the volume of the dough in the graduated cylinder was measured.

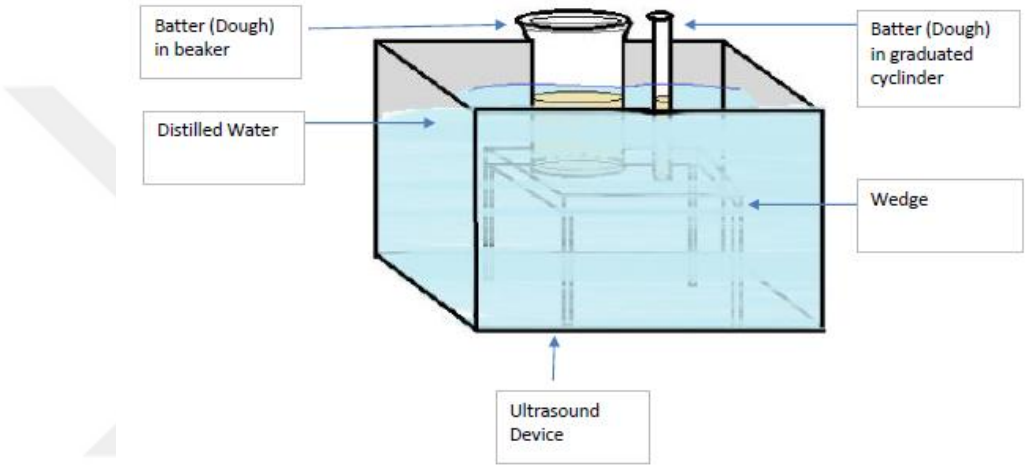

Figure 2.4 Ultrasound application on batter samples

Table 2.1 Wafer batter formula

Ingredients	**Amount (mass %)**
Water	55.2
Wheat flour	42.9
Vegetable oil (palm)	1.0
Salt	0.4
Soy lecithin	0.3
Egg white powder	0.1
Sodium bicarbonate	0.1

2.2.1.2 Baking Process

Laboratory-type wafer sheet baking plates (Figure 2.2) was used to obtain wafer sheets. All wafer sheets are 28.8 mm x 22.8 mm rectangular shape and 0.4 mm

thickness due to standard dimension of the device's plates. The temperature of baking plates was nearly 140-150 ^{o}C and every batter amount to feed to center of lower plate was 150 ml. After the pouring of batter into the plate, the upper plate was closed quickly and locked the lid. After cooking for about one and a half minutes, it was carefully removed from the plate. To prevent any sticking or dusting, the plates was sprayed by negligible amounts of spray oil before the feeding batter.

2.2.2 Raw Materials, Wafer Sheet and Wafer Batter (Dough) Analysis

The analysis made in the raw materials, wafer sheets and wafer batter (dough) are given in Tables 2.2 and 2.3 (signed as ''X''):

Table 2.2 Raw Material Analysis

Raw Material Analysis Parameters	**Salt**	**Egg White Powder**	**Sodium Bicarbonate**	**Soy Lecithin**	**Wheat Flour**	**Vegetable Oil**
Moisture Analysis	X	X		X	X	
pH Analysis		X	X			
Free Fatty Acid Analysis				X		X
Peroxide Analysis				X		X
Iodine Analysis						X
Colour Analysis					X	X
Solid Fat Content Analysis						X
Ash Analysis					X	
Sedimentation Analysis					X	
Delayed Sedimentation					X	
Gluten Analysis					X	
Protein Analysis					X	
Mixolab Analysis					X	

Table 2.3 Wafer Sheets and Wafer Batter Analysis

Analysis Parameters	Wafer Batter (Dough) Analysis	Wafer Sheet Analysis
Weight	X	X
Colour L*,a*,b*	X	X
Glass Analysis	X	
Falling Number	X	
pH	X	
Viscosity	X	
Plastic Viscosity	X	
Yield Stress	X	
Texture	X	X
Moisture		X
Porosity		X
Sensory		X

2.2.2.1 Moisture Analysis

The moisture content for wafer sheet, salt, egg white powder and wheat flour were measured by using the method of AOAC 925.10, (1997).

2.2.2.2 Karl Fischer Titration Analysis

The moisture content of soy lecithin was measured by using AOAC 977.10, (1979) method with a Karl Fischer Titration device (Methrom, 841 Titrando, Switzerland) .

2.2.2.3 pH Analysis

pH is scale to measure of acidity of substances when dissolve in water. The pH of egg white powder and sodium bicarbonate were determined by using TS 3263 method (1999) [50]. Ten grams of sample and 90 ml distilled water was added to beaker and mixed until homogeneous sample obtaining, then the pH was measured.

2.2.2.4 Free Fatty Acid Content Analysis

It was made for soy lecithin and vegetable oil to determine the free fatty acid content by using TS 894 method (1970) [50]. Five grams sample was weighted and 30 ml of diethyl ether (1:1 ratio) mixture were added onto the weighed sample. It was shaken

with a magnetic stirrer for 1 minute to dissolve fat and fatty acids with mixing. Three or four drops of phenolphthalein were added as indicator. After that, titration was performed with 0.1 N ethanolized potassium hydroxide until a permanent color change (pink) was obtained. The consumption of 0.1 N ethanolized potassium hydroxide was recorded. Free fatty acid content was calculated according to oleic acid with following equation (Eq. 2.1).

Calculation of Free Fatty Acids:

$$\%\ Free\ fatty\ acid\ \left(\%\ oleic\ acid, \frac{g}{ml}\right) = \frac{Consumption\ (ml)}{Sample\ Weight\ (gr)}\ x\ 2.82 \qquad (2.1)$$

2.2.2.5 Peroxide Analysis

Peroxide values of soy lecithin and vegetable oil were determined by using TS 4964 (1986) [50] and AOAC 965.33 (1969) methods. Three grams sample was weighted and 35 ml of chloroform acetic acid (2:3 ratio) solution and 1 ml potassium iodide was added onto the weighed sample and then quickly mixed. Erlenmeyer was placed into a dark room for 5 minutes. After 5 minutes, 75 ml distilled water and 1 ml starch were added. After this process, if there is no darkening, there was no peroxide. If there is a darkening, titration was performed with sodium thiosulfate until a permanent color change (white) was obtained. The consumption is recorded. Equation 2.2 was used.

$$Peroxide\ Value\ (meq) = \frac{(Vx2xF)}{M} \qquad (2.2)$$

F = 0.002N $Na_2S_2O_3.5H_2O$ *Factor*
M = amount of sample, g
V= consumption of sodium thiosulfate, mL

2.2.2.6 Iodine Number Analysis

The iodine of vegetable oil was determined by using AOAC 920.159, (2000) method. 0.7 g sample was weighted and 25 ml Wijs solution and 20 ml acetic acid n-hexane (1:1 ratio) were added onto the weighed sample and quickly mixed. Tightly closed Erlenmeyer was placed into a dark room for 1 hour. After 1 hour, 90 ml distilled

water and 10 gr potassium iodide mix were added. After this process, 150 ml distilled water was added and titration was performed with 0.1 M sodium thiosulfate until a permanent color change (white) was obtained. The consumption was recorded. A blank reference analysis was performed, with no samples added in parallel with same procedures. The iodine number was calculated by using Eq. 2.3.

Calculation of Iodine Number:

$$Iodine\ Number, I = \frac{(B\ x\ C)}{m}\ x\ 1.269 \qquad (2.3)$$

I= iodine number

B=blank consumption, mL

C=consumption, mL

m=sample weight, g

2.2.2.7 Color Analysis

It was made for vegetable oil, wheat flour and wafer sheets to determine the color parameters of samples. The color measurement was made by Hunter Lab colormeter (Colorflex, USA).

L* is lightness coordinate. L*=0 shows black; L*=100 shows white. a* is red/green coordinate. +a*=+60 shows red; -a*=-60 shows green. b* is yellow/blue coordinate. +b*=+60 shows yellow; -b*=-60 shows blue. Illuminance value was D65/10^{o}.

2.2.2.8 Solid Fat Content (SFC) Analysis

NMR (nuclear magnetic resonance) device was used to determine Solid Fat Content (SFC). The international standards (ISO 8292-2, (2008)) were used to determine the solid fat content of fats and oils with NMR method (ISO, 2008). Ratio of liquid and solid parts of the samples was obtained by NMR to determine the solid fat (Process NMR Associates, 2021).

The solid fat content of vegetable oil was measured by using following procedure. Ten sample tubes were prepared. For determination of solid fat content, 3 ml sample was poured to each tube. Tubes were first kept in water bath at 60 ^{o}C degree for 30 minutes and then kept at 0 ^{o}C degree for another 30 minutes. After that, the tubes

were waited as 2 parallels at 10, 20, 25, 30 and 35 ºC for 30 minutes and the tubes were placed into NMR device (the minispec mq20 NMR analyzer, Bruker) and the results were recorded.

2.2.2.9 Ash Analysis

The ash content of wheat flour was determined according to AOAC 923.03 method, (1999). Following equation was used to determine the ash content. The ash content was calculated according to Eq. 2.4.

$$Ash\ (\%, dry\ basis) = \frac{Weight\ of\ ash\ (g)}{Weight\ of\ dry\ sample\ (g)}\ x\ 100 \qquad (2.4)$$

2.2.2.10 Sedimentation and Delayed Sedimentation Analysis

It was made for wheat flour to determine the sedimentation and delayed sedimentation properties of flour to. Firstly, 3.20 g flour and 50 ml phenol were poured into sedimentation tubes and mixed gently. After that, the tubes were placed onto a sedimentation device and shaken 5 minutes. After 5 minutes, 25 ml lactic acid solution was added into the tubes and shaken 5 minutes more in device. The tubes were settled on a flat and waited 5 minutes and precipitation was observed as ml.

In delayed sedimentation, after 5 minutes shaking of sample and phenol solutions, the tubes were waited nearly 2 hours. After 2 hours, same procedures were repeated as adding lactic acid and value was read after 5 minutes.

2.2.2.11 Gluten Analysis

The gluten content and index were determined by using AOAC 2018.15 method, (2018). Ten grams sample was placed in batter bowl and 2.8 ml of 2% salty water was added for kneading. After that, batter was separated as wet and decay batter in device. The following equation was used to determine the gluten index.

$$Gluten\ index\ (\%) = \frac{(Wet\ (g) x\ Decay\ (g))}{Wet\ (g)}\ x\ 100 \qquad (2.5)$$

2.2.2.12 Protein Analysis

Protein analysis was made for wheat flour according to AOAC 920.87, (1999) method. One gram sample and 20 ml sulfuric acid were poured into a tub. Two Kjeldahl tablets were added on it. The tubes were placed in burning unit system and preheating was applied at 8 ^{o}C by through 10 minutes. After 10 minutes, temperature was increased to 10 ^{o}C and burned for 60 minutes. After 1 hours, the tubes were left to cool and the value was read on device.

2.2.2.13 Mixolab Analysis

Mixolab analysis was made for wheat flour to determine water lifting, kneading, gluten, viscosity, amylase and retrogradation of wheat flour. The analysis was made according to AACC Method 54-60.01, (2010).

2.2.2.14 Dough Flowability and Rheology Analysis

The consistency measurement of foods is usually carried out by viscosity measurements. The studies carried out so far are in this direction, but the rheological properties of a food cannot be determined by viscosity alone. In general, rheology studies the flow and deformation of fluids under the influence of mechanical forces. In the food industry, liquid or semi-fluid foods are used in all or some of the production stages such as evaporation, pasteurization and pumping. It is aimed to know the physical change and rheological behavior of the food in the face of the conditions it is exposed to at every stage to select the processing equipment with the appropriate features and to increase the yield. In this study, it is aimed to determine the rheological changes that may occur based on the shear time with this analysis (Bıldır et al., 2018).

One of the other important quality criteria of wafer sheets are related with rheological properties of wafer batter. Using with dough flowability, internal friction and resistance of the fluid was determined. A teaspoon of batter (3g ±1) was poured on a smooth glass surface angled at 30 degrees and it was observed how long time it takes to take the specified distance (for example 5 cm; 10 cm). The analysis is shown in Figure 2.5.

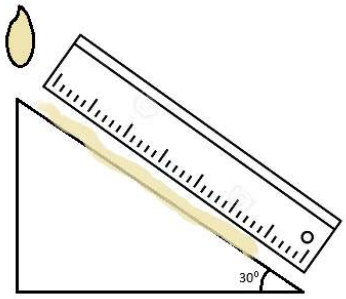

Figure 2.5 Illustration of glass analysis system

2.2.2.15 Rheology of Wafer Batter with Falling Number Analysis

Falling number for wafer batter was measured to determine the viscosity and firmness of wafer batter. A special measurement method was developed (Figure 2.6).

Batter was poured into a graduated cylinder as possible as long and a material like a ball was dropped into graduated cylinder. Therefore, it was observed how long the ball collapses to the bottom. A falling number system was used and is shown in Figure 2.6.

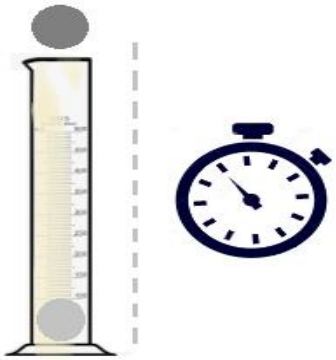

Figure 2.6 Illustration of homemade falling number analysis system

2.2.2.16 Rheology (Viscosity) Analysis with Brookfield

Rheology is the study of deformation and flow of food matters to determine the important properties of food systems with different factors. Flow, textural properties and changes of matters can be measured by using rheometers (Windhab, 1995). All liquids and soft solids have viscous values. Viscosity can be explained by resistance of substance when apply a certain stress. It can be expressed as thickness. If substance have high viscosity value, it is thicker when compare the less viscosity substance. For example, honey is thicker than water; so that honey has high viscosity

value. Viscosity of substance depends on temperature. Some foodstuffs like béchamel sauce can be more flowy (low viscosity) when its temperature is high however it gets thicker as it cools (Food Crumbles, 2021).

The viscosity of wafer batter was measured by using Brookfield rheometer (Brookfield eng labs inc., USA) at 22 ^{o}C. Capillary tubes, cone plate concentric cylinder apparatuses were used. Batter samples were poured into rheometer tubes (it should not overflow) and cylinder were placed into batter. Viscosity (cP) versus time (s) and plastic viscosity and yield stress were determined. All rheological experiments were repeated twice and their average values were recorded on data.

2.2.2.17 Texture Profile Analysis

Texture is a quality criterion by using structural, mechanical and surface properties foods determining with kinesthetic way, vision, hearing and touching. Textural characters divided into three as mechanical properties, geometric properties and oil-water content related to the mechanical and geometric properties. Mechanical characters are related with deformation of foods. These mechanical characters divided into 2 groups as primary mechanical characters like stiffness, adherence, elasticity, stickiness, consistency, viscosity and secondary mechanical characters like friability, chewability and softness (Ertaş et al., 2010).

It was made for wafer sheets and wafer batter to determine the textural properties of samples. Texture of wafer sheet and wafer batter samples were measured by using TA. XT2i Texture Analyzer (Stable Microsystems Ltd., Godalming, Surrey, UK) with the Texture Expert programmers. Texture parameters are given in Table 2.4 for wafer batter and wafer sheets.

Table 2.4 Texture profile analysis parameters of wafer batter and wafer sheet samples

Parameters	**Wafer Batter Samples**	**Wafer Sheet Samples**
Probe	25 mm Cyclinder Probe	Three Point Bending Rig
Compression Force Mode	On	On
Pre-Test Speed (mm/s)	1.0	1.0
Test Speed (mm/s)	2.0	3.0
Post Test Speed (mm/s)	10.0	10.0
Distance (mm)	2	5
Trigger Force	Auto-20g	Auto-50g
Tare Mode	Auto	Auto
Sample Dimension (mm*mm)	-	70*70 ±5
Measured Parameters	Stringness	Hardness

The force (g) versus time (t) (Figure 2.7) shows force peak resulting of each compression cycle as clearly, force-distance graph shows better the sample's response to application and stress relief. TPA is performed by compressing standard sized samples of food two times action. The resulting of two bites compression, force vs time graphic gives different textural properties like brittleness, hardness, chewiness, gumminess and cohesiveness of a sample. First peak of compression curve gives hardness and springiness is equal to length 2 over length 1. Chewiness is defined as the product of multiply of gumminess and springiness which equal to multiply of 3 parameters: hardness, cohesiveness and springiness (Özkaleli and Kaya, 2015).

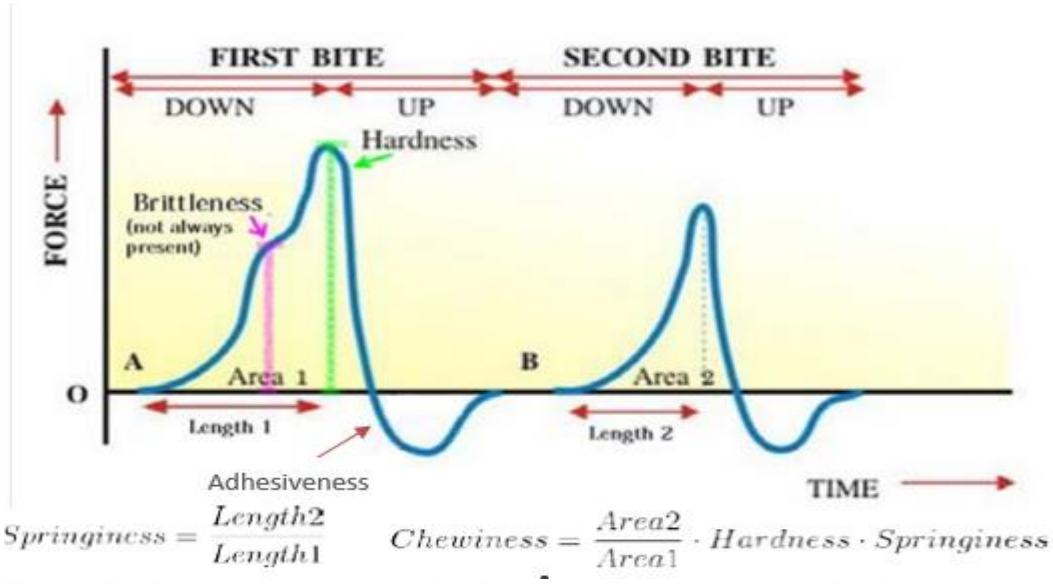

Figure 2.7 Illustration of General Presentation of Texture Profile Analysis (Friday et al., 2016).

2.2.2.18 Wafer Sheet Porosity Analysis

The wafer sheets were cut into pieces as small as possible to make them thin. These small parts were placed on the light magnifying mechanism (Electro-mag, C722, Türkiye). At the same time, a small measurement unit was added on the magnifying glass together with the wafer in order to make a real scaling. Light was adjusted to obtain perfect appearance. Photographs was taken by capturing the appropriate angle for the pores. Image analyses were done with software (AutoCAD, 2014, USA). Pores were measured by AutoCAD areas, which were calculated by dividing the real area for each image.

Figure 2.8 Electro-mag, C722 Magnifying glass

2.2.3 Sensory Analysis

The sensory analysis of wafer sheets was performed by using scoring test method by 10 trained panelists. Five-point ranking scale was used in the test. From 1 to 5 ranking scale describes as: 1= Dislike extremely, 2= Dislike, 3= Neither like nor dislike, 4=Like and 5=Like extremely. The samples are separated as control wafer groups, 25 kHz wafer sheet samples and 40 kHz wafer sheet samples with different US time ranges. The product evaluation panel form sample is given in Table 2.5.

Table 2.5 Sensory evaluation chart

Scoring
From 1 to 5

		SAMPLES				
		K	**15**	**30**	**45**	**60**
Evaluated Parameters	Brittleness					
	Chewiness					
	Porous Structure					

1	Dislike extremely
2	Dislike
3	Neither like nor dislike
4	Like
5	Like extremely

2.3 Statistical Analysis

Analysis of variance (ANOVA) was performed with the effect of time and ultrasound frequency power using SPSS software (v. 27.0.1.0, USA) and significant difference was determined as α=0.05 level. The data were analyzed with two-way ANOVA. Duncan's test was applied as post-Hoc test. The experiments were replicated. The analysis was duplicated.

CHAPTER III

RESULT AND DISCUSSION

3.1 The Properties of Raw Materials

3.1.1 Moisture Content Analysis Results

Moisture content analysis can be one of the most important analysis in food sectors. For the wafer, moisture is critical to obtain the desired texture and porosity.

Moisture content affects the workability, shelf life, usability and quality of a product. Therefore, determining moisture correctly plays a fundamental role in ensuring quality in many industries, including food, pharmaceuticals and chemicals. In addition, the maximum permissible moisture content in certain products may be subject to legislation (e.g., national food regulations). The analysis result for salt, egg white powder and wheat flour are given in Table 3.1.

Table 3.1 Salt, egg white powder and wheat flour moisture analysis results

	Moisture Content (%, wb, g/g)		
Raw Materials	**Result 1**	**Result 2**	**Average**
Salt	0.11	0.12	0.115 ± 0.007
Egg white powder	6.39	6.34	6.365 ±0.03
Wheat flour	11.74	11.72	11.73 ±0.01

3.1.2 Karl Fischer Titration Analysis Results

Karl Fischer titration is a kind of method to determine the water content of samples. This is preferred in industrial quality control area. Basically, it mainly occurs in the oxidation of sulfur dioxide in presence of water. This oxidation process takes place in a buffered solution.

Alcohols are generally used as solvent. Amount of water is determined as indirectly because of conversions of water as stoichiometrically (Schöffski and Strohm, 2006). The moisture content of soy lecithin was 0.80-0.79 % (g/g) range.

3.1.3 pH Analysis Results

Analysis result for egg white powder and sodium bicarbonate are given in Table 3.2.

Table 3.2 pH analysis result of egg white powder and sodium bicarbonate

	pH		
Raw Materials	**Result 1**	**Result 2**	**Average**
Egg white powder	6.39	6.34	6.365 ± 0.03
Sodium bicarbonate	8.53	8.50	8.515 ± 0.02

3.1.4 Free Fatty Acid Content Analysis Results

Titratable acidity features of foods are important for organoleptic properties of foods like flavor, taste, odor and color while it also affects the microbiological control of food products. For this reason, it is important as quality control parameter. Total acid content is called as titratable acidity. Total free fatty acid content that is called as acid values are evaluated as quality parameter. When the vegetable oil is contact with air, quality of oil is decreased because of releasing of free fatty acids. For this reason, acidity analysis is another important parameter for foodstuff (Kotani et al., 2019). The analysis results for soy lecithin and vegetable oil are given in Table 3.3.

Table 3.3 Free fatty acid content analysis results of soy lecithin and vegetable oil

	Free fatty acid content (%, g/ml oleic acid)		
Raw Materials	**Result 1**	**Result 2**	**Average**
Soy Lecithin	1.35	1.46	1.405±0.07
Vegetable oil	0.16	0.16	0.16±0.00

3.1.5 Peroxide Analysis Results

Peroxide value is used to determine the rancidity of vegetable oils. It is used as oxidation indicator of vegetable oils and fats. Toxins, off-odors and off-flavors can be reason of (Dermiş et al., 2012). There is not any color change of soy lecithin and vegetable oil during the analysis of peroxide. Peroxide value was found as 0.0 % (m_{eq}/kg) for each analysis group of vegetable oil.

3.1.6 Iodine Number Analysis

Iodine number of vegetable oil was found as 54.2 and 54.5 g/g (average is 54.35±0.212 g/g) values with different two results.

.

3.1.7 Color Analysis

The color of the foods is the other most important organoleptic factor and quality criteria. Acceptance of foodstuff by consumer is comes true at first sight of appearance due to its appearance before consumed. The analysis results for wheat flour and vegetable oil are given in Table 3.4.

Table 3.4 Analysis results for wheat flour and vegetable oil.

Color Analysis			
Vegetable oil	**L_1***	**L_2***	**L* Average**
	6.82	7.06	6.94±0.169
	a_1*	**a_2***	**a* Average**
	-0.93	-0.88	-0.905±0.03
	b_1*	**b_2***	**b* Average**
	2.28	2.35	2.315±0.04
Wheat flour	**L_1***	**L_2***	**L* Average**
	93.38	93.44	93.41±0.04
	a_1*	**a_2***	**a* Average**
	0.29	0.29	0.29±0.00
	b_1*	**b_2***	**b* Average**
	9.08	9.13	9.105±0.03

3.1.8 Solid Fat Content

The analysis results for vegetable oil are given in Table 3.5.

Table 3.5 SFC Analysis Result for vegetable oil

		Solid Fat Content (%)		
Raw Materials	**Temperature ºC**	**Result 1**	**Result 2**	**Average**
Vegetable oil	10	52.49	52.95	52.72±0.32
	25	27.43	27.94	27.68±0.36
	25	19.08	19.13	19.10±0.03
	30	12.88	12.37	12.62±0.36
	35	9.91	9.7	9.8±0.14

3.1.9 Ash Analysis

Ash is inorganic residue that remaining after ignition of organic acids or oxidation of sample as completely. Ash is a quality criterion for nutritional parameters of foods. Additionally, ash content shows amount of bran in bakery and cereal products. The ash analysis result of wheat flour was 1.19±0.005 % with dry basis (g/g).

3.1.10 Sedimentation and Delayed Sedimentation Analysis Results

The amount of protein and its quality with carbohydrate-amylase complex situation is important for food process like milling and baking, which related with technological quality of wheat. This is determined by degree of starch damage and amylase content. Quality of the protein is determined by sedimentation values. These parameters are very important for process quality of bakery (Hrušková et al., 2004). Sedimentation analysis results were 26.0±0.00 ml while delayed sedimentation analysis results were 22.0±0.00 ml.

3.1.11 Gluten Analysis Results

Wheat contains complex protein and wheat flour has viscoelastic structure when mixed with water. When starch is washed with water in batter, viscoelastic residue remains and this water insoluble protein residue is called as gluten. It gives an idea about gluten quality as strength, weak and normal and plays important role to

determine baking process. Gluten index (GI) is a method to determine the gluten content and quality of wheat samples. When gluten index is smaller than 30%, the quality of gluten is weak; between the 30 and 80% it is normal quality range; if bigger than 80%, gluten quality is strong (Oikonomou et al., 2015).
Gluten index of wheat flour was found as 95.435±0.000 %.

3.1.12 Protein Analysis Results

Protein is one of the other quality parameters for wheat flour. It plays important role of batter structure in bakery products. Protein gives an idea about process requirements because of batter's viscoelastic gluten structure. It is not only parameters to characterize the flour, but it is an important tool for quality and process requirements in bakery products (Başlar et.al., 2011). Protein analysis result was found as 8.90±0.20 with two different results.

3.2 Wafer Batter (Dough) Properties

3.2.1 The Weight Variation of Dough Samples

The change in the weight of dough samples was determined during the ultrasonic operation at 25 and 40 kHz (Figure 3.1). In the dough samples that exposed to 40 kHz ultrasonic frequency, a decrease and difference in dough weight was observed, especially at the 15 and 60 minutes ultrasound application according to Figure 3.1.

According to Table A13, the batter weight significantly changed ($p \leq 0.05$) with time and ultrasound levels. The change in the weight can be explained by the local temperature that inside the graduated cylinder may have increased despite keeping the temperature constant. This situation may have caused a decrease in dough weight with evaporation.

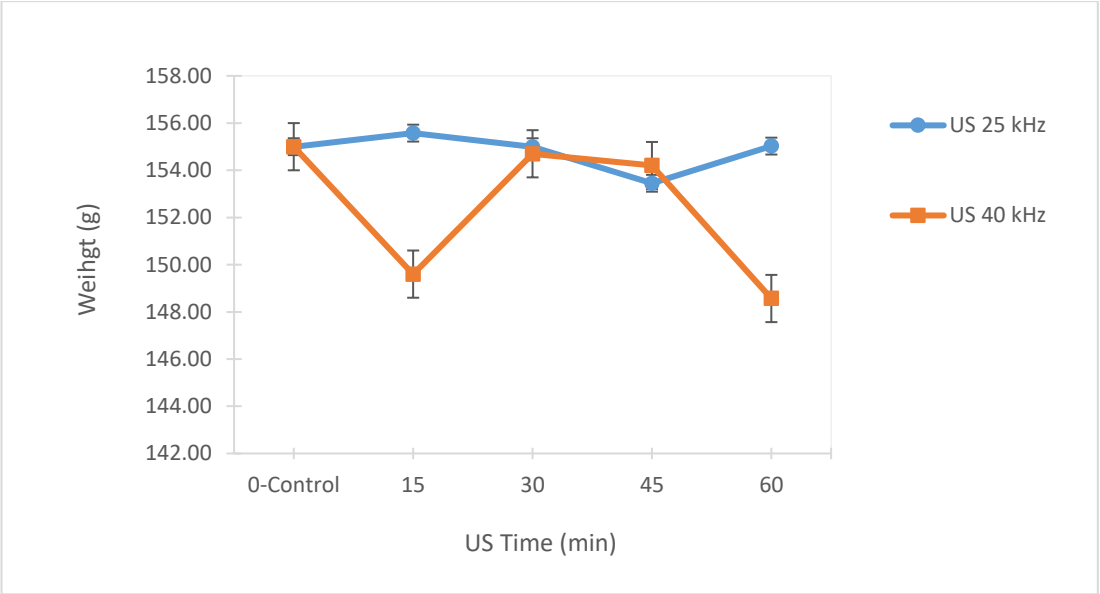

Figure 3.1 The weight variation of dough samples exposed to different ultrasound frequencies by different ultrasound time

3.2.2 Effects of Ultrasound on the Color of Wafer Batter

In the study, the color of wafer batter was determined by using L*, a* and b* values. In the determination of color, L* values indicate the lightness and darkness of the samples. The effect of ultrasound frequency by different time intervals on L* color values are also presented in Figure 3.2. For 25 and 40 kHz, there was a general decrease in the L* values of dough with increasing time exposed to ultrasound with compared to initial value. For 40 kHz, it also increased at 60 minutes ultrasound application. However, there was observed a regular decrease for 25 kHz. At this point, it can be said that 15, 30 and 45 min time duration of 40 kHz ultrasound application was decreased in the L* value of batter; means that the color of the dough was darker than other time intervals and an increase was observed for 60 min ultrasound application. For 25 kHz ultrasound application, the color of the dough gets darker as ultrasound was applied according to Figure 3.2. Tiwari et al., found that ultrasound technology changes the orange juice color with different ultrasound time applications (Tiwari et al., 2008). Same situation was observed for apple cider with increasing of L* was found by Ugarte-Romero et al., (Ugarte-Romero et al., 2006). According to Table A13, while the time and the interaction between time and ultrasound significantly ($p \leq 0.05$) changed to the L* value of the dough; there was not

statistically significant (p>0.05) change in the L* value of the dough only in the ultrasound application.

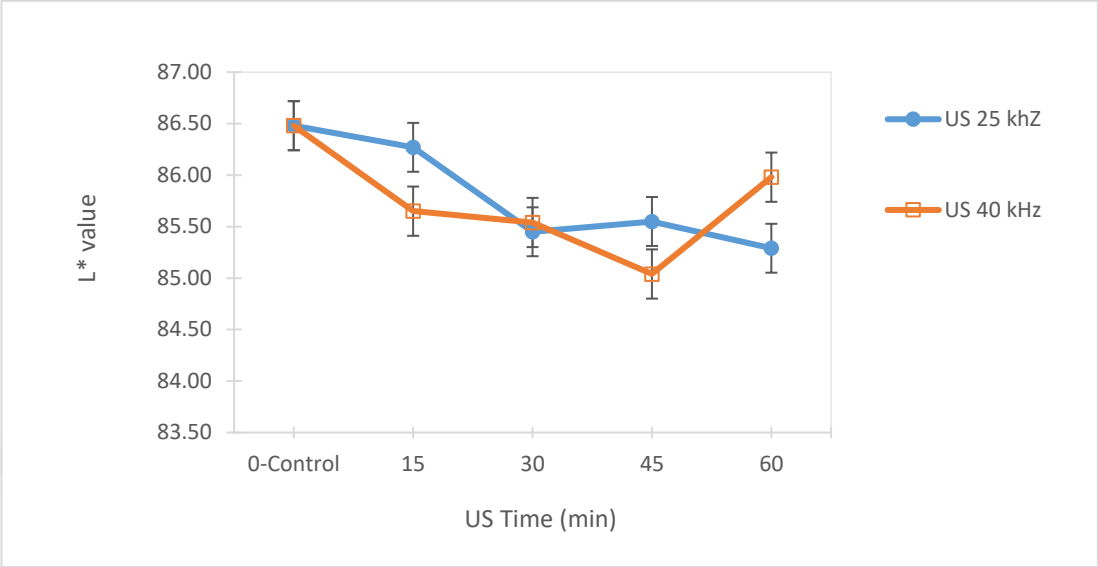

Figure 3.2 L* value of dough during the ultrasonic application

The a* value indicates the redness/greenness of the samples. The effect of ultrasound frequency with different time intervals on the a* value is presented in Figure 3.3. The a* value increased at 15 min and 25 kHz ultrasound application and decreased other time intervals. Even that, there was not any change was observed for 30, 45 and 60 min ultrasound application times. At the same time, the a* value of the samples increased during 15, 30 and 45 min ultrasound applications and again a slight decrease was observed at 60 min ultrasound application. When Figure 3.3 is examined, 60 min ultrasound application was same with control group for both ultrasound frequency applications. At this point, it can be said that 60 min ultrasound application was not effective for changing of the a* value of the batter samples. According to Table A13, the a* value of the batter changed significantly ($p \leq 0.05$). When ultrasound and time were significantly changed ($p \leq 0.05$); only time was not effective to change the a* value of batter as significantly ($p > 0.05$).

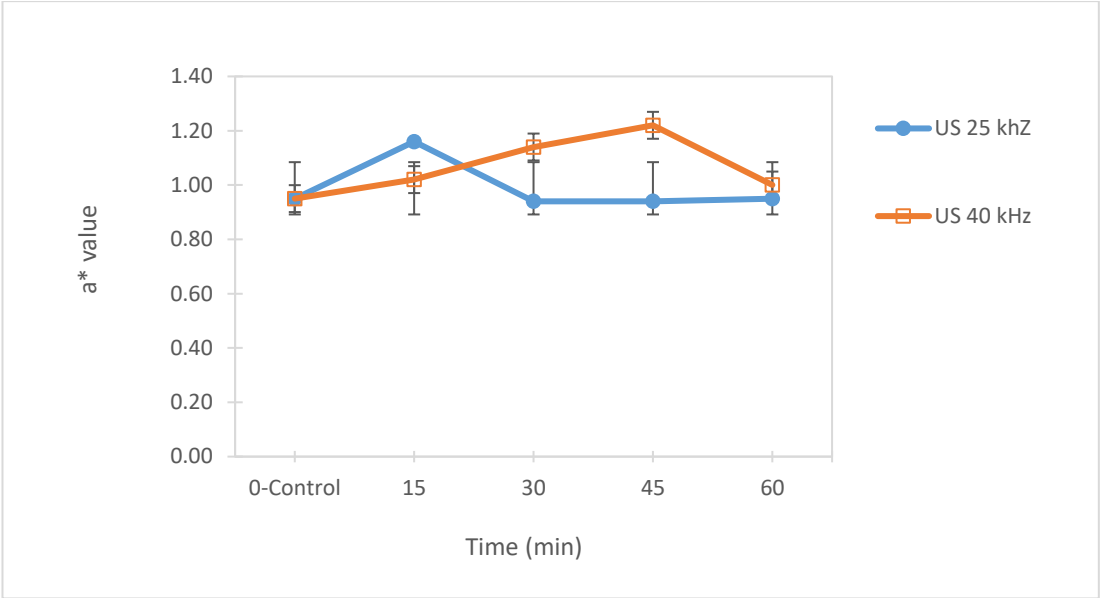

Figure 3.3 a* value of dough during the ultrasonic application.

The b* value indicates the blue/yellow of the samples. The effect of ultrasound frequency by different time intervals on the b* values are presented in Figure 3.4. It was found that the in the samples applied 40 kHz ultrasound frequency had a higher b* values than 25 kHz ultrasound frequency. Huang et al., was observed that ultrasound technology improved the color of products in dried foods (Huang et al., 2020). According to Table A13, while interaction of ultrasound and time was not significantly changed ($p>0.05$) of b* value of batter, only ultrasound or only time changed as significantly ($p\leq0.05$).

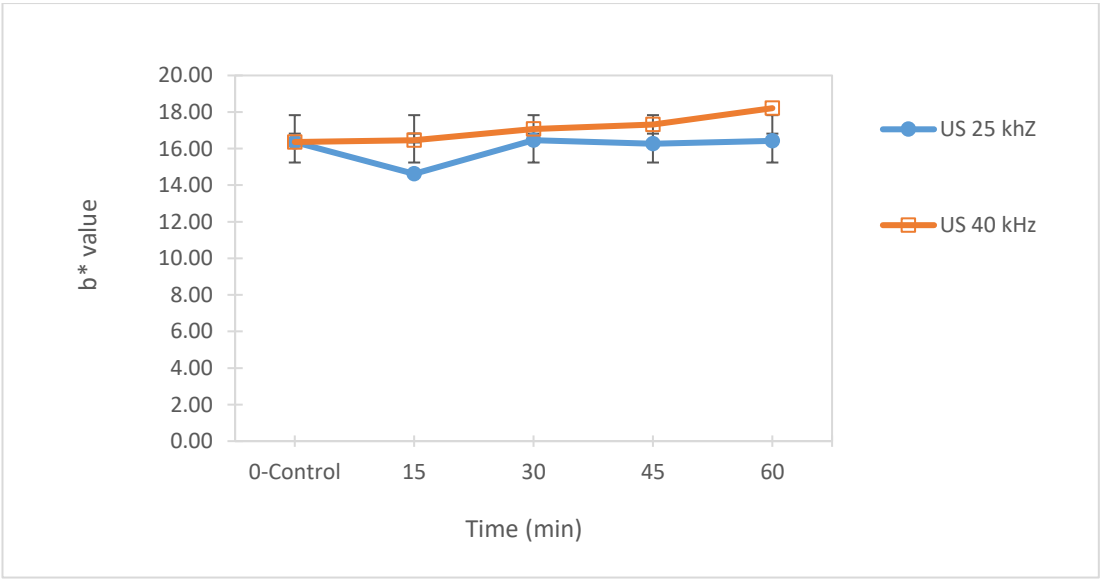

Figure 3.4 b* value of dough during the ultrasonic application

3.2.3 Rheology (flowability) of Wafer Batter with Glass Analysis

As mentioned before, one of the other important quality criteria of wafer sheets are related to the rheological properties of wafer batter. Using with glass analysis, internal friction and resistance of the fluid was determined. According to Table A13, ultrasound, time and the interaction of was significantly ($p \leq 0.05$) different to change the flowability of wafer batter. According to Figure 3.5 and 3.6, the lines of the 25 kHz and 40 kHz showed nearly same increase and decrease. According to the graphs, the time required to cross the 5 and 10 cm distances increased with increasing ultrasound time except 60 min ultrasound frequency. At this point, contrary to other time intervals, 60 min ultrasound application reduced the flow rate and so it can be said that adequate amount of ultrasound application was showed better flowability. While Gallo et al., observed that an ultrasound application that applied for the filtration process, the ultrasound technology has an improving effect on the flow (Gallo et al., 2018).

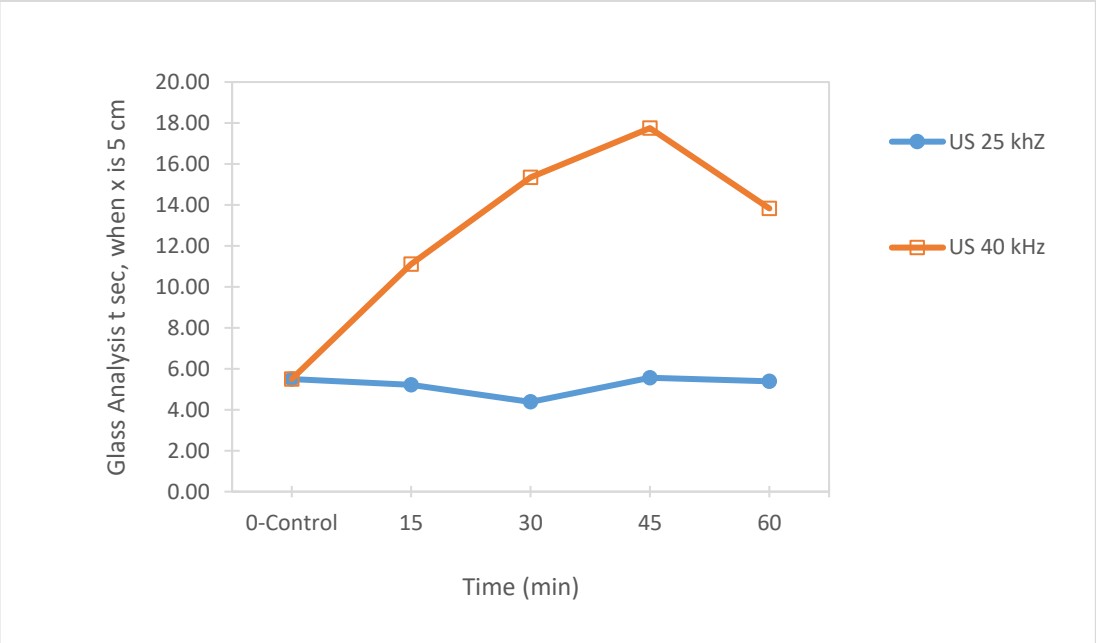

Figure 3.5 Effect of ultrasound on the rheology (flowability) of wafer batter with glass analysis when distance is 5 cm.

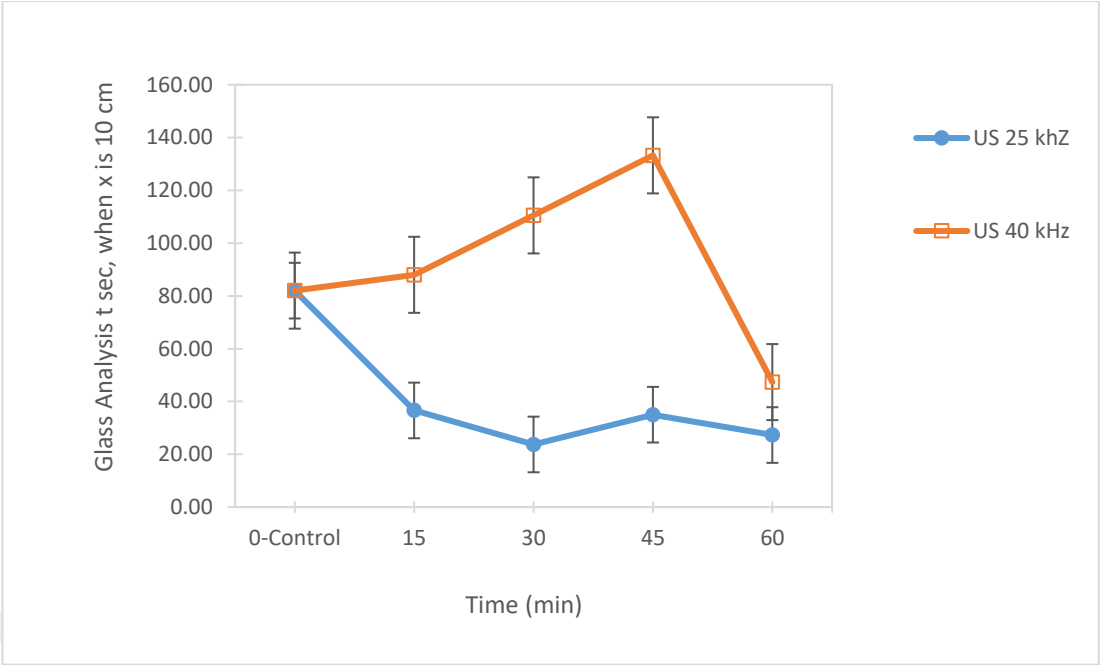

Figure 3.6 Effect of ultrasound on the rheology (flowability) of wafer batter with glass analysis when distance is 10 cm.

3.2.4 Flowability of Wafer Batter with Falling Number Analysis

According to Figure 3.7, a decrease was observed in time that need to it takes for the ball to collapse to the bottom of the graduated cylinder at 15 the 30 minutes for both 25 and 40 kHz ultrasound applications. While this decreasing was continued on other time intervals for 25 kHz; an increase was observed for 45 min 40 kHz ultrasound application and again a decrease was observed for 60 min 40 kHz ultrasound application. According to Table A13, ultrasound, time and the interactions was significantly different ($p \leq 0.05$) to change the falling number time of wafer batter. Gallo et al., observed that an ultrasound application applied for the filtration process facilitates the passage of liquid or smaller particle structures through the filtration (Gallo et al., 2018). According to Figure 3.7 and the study of Gallo et al., it can be said that ultrasound technology can increase the flowability of dough. Because, as the dough becomes more fluid, it will be faster for the ball to sink to the bottom (Gallo et al., 2018).

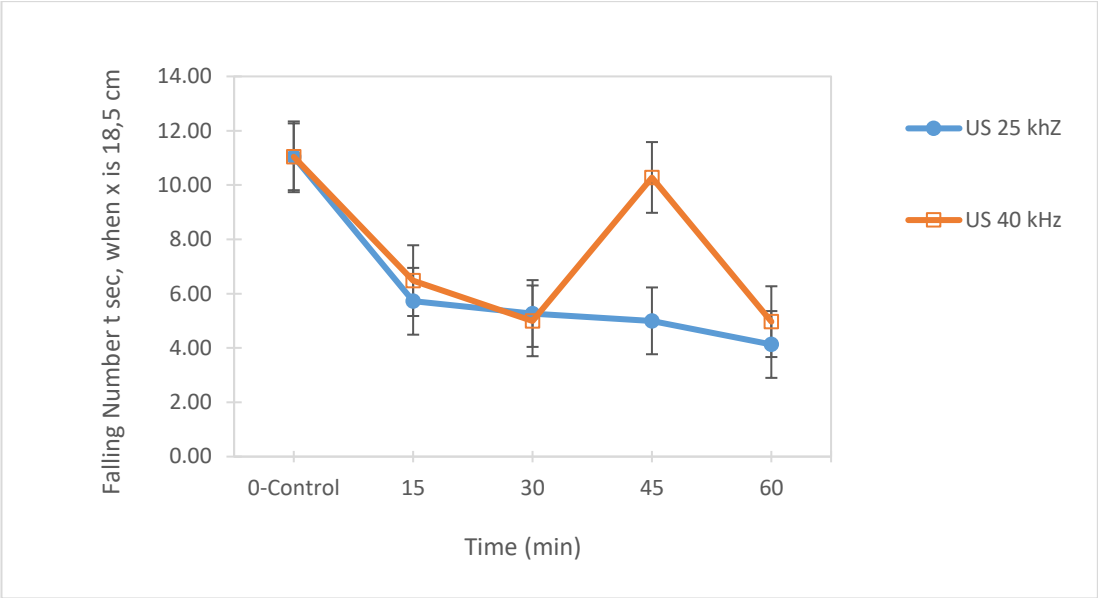

Figure 3.7 The effects of different ultrasound application on wafer batter by measuring falling number analysis.

3.2.5 Effect of Ultrasound on the Rheological Properties of Wafer Batter

Viscosity is a texture property, and it is the measure of resistance of fluid that related with shear stress and tensile stress. This resistance happens because of the friction between molecules when liquid layers slide over each other. If flow resistance is low, liquid is thin and increasing of the flow resistance, viscosity increases. The meaning of the higher viscosity is low flow (Tiefenbacher, 2017).

According to Figure 3.9, a regular decrease was observed by increasing ultrasound time of viscosity. While the control group was higher viscosity value; 15, 30, 45 and 60 min ultrasound application decreased the viscosity of samples for both 25 and 40 kHz ultrasound frequencies. According to Table A13, the rheological properties of batter changed significantly ($p \leq 0.05$) during the ultrasound application. However, the increase in frequency was not cause any significant change ($p > 0.05$).

Liquids are made up of molecules, when they begin to move, molecules are forced to slide over each other. Due to internal friction, these molecules create resistance to flow. At this point, it can be said that ultrasound technique can make vibrations by sound waves and the flow rate of the dough was increased with increasing ultrasound time due to this vibrations effect. Because these vibrations can increase interaction of

time the intermolecular.

Decreasing or preventing gluten formation is desired for a better batter viscosity. According to Figure 3.8, this decrease appears as clearly. At this point, it can be said that the reason for this decrease was that the ultrasound application caused an increase in the intermolecular frequency and thus reduce the viscosity. The increase in the viscosity of the dough is one of the signs of gluten formation (Tiefenbacher, 2017).

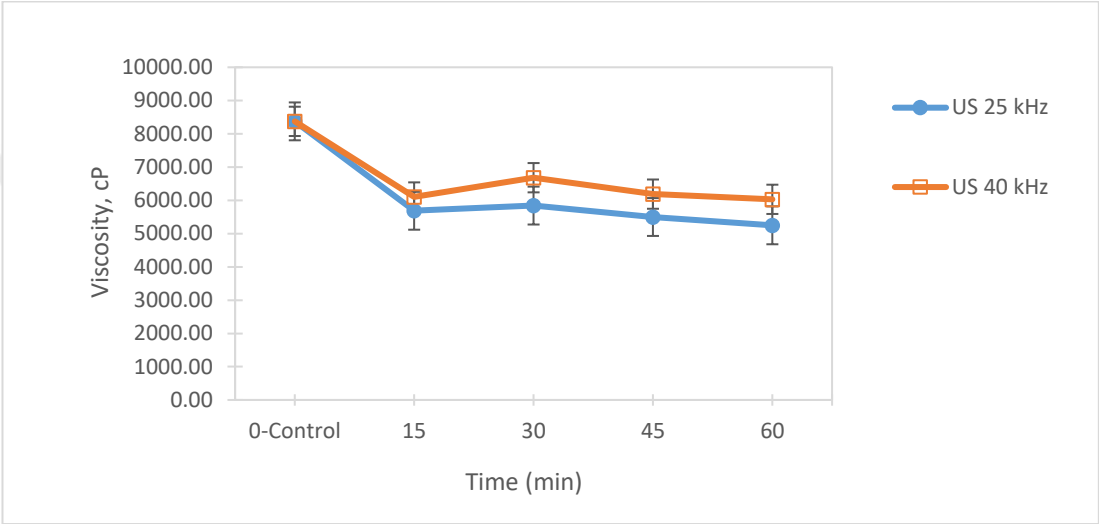

Figure 3.8 Effect of different ultrasound applications on the viscosity properties of wafer batter

Batter showed different viscosity value with different ultrasound times. Non-Newtonian behavior may explain this difference. Because of, if viscosity changes with different parameters, it can show non-Newtonian behavior. On the other hand, it should not be overlooked that soy lecithin emulsifier is used in the recipe to keep the dough flowing freely.

According to Figures 3.8-3.10, the batter samples showed pseudoplastic behavior. This type of behavior of flow in fluids whose viscosity decreases with the increase of shear stress. Viscosity is inversely proportional to shear rate. It has no threshold value; its viscosity cannot be expressed with a single point (Nakayama, 2018).

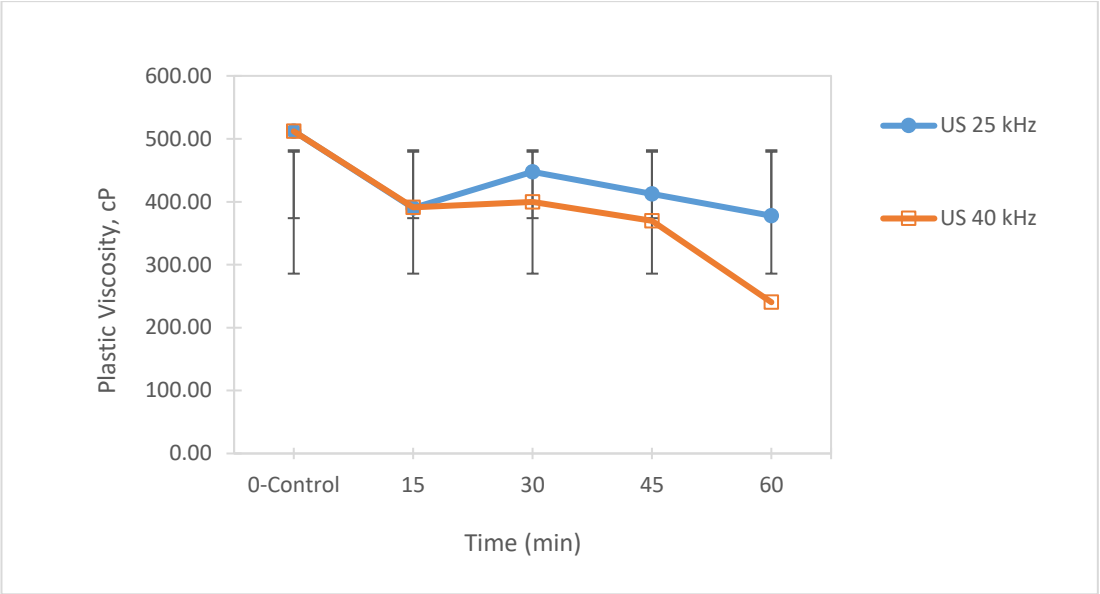

Figure 3.9 Effect of different ultrasound applications on the plastic viscosity properties of wafer batter

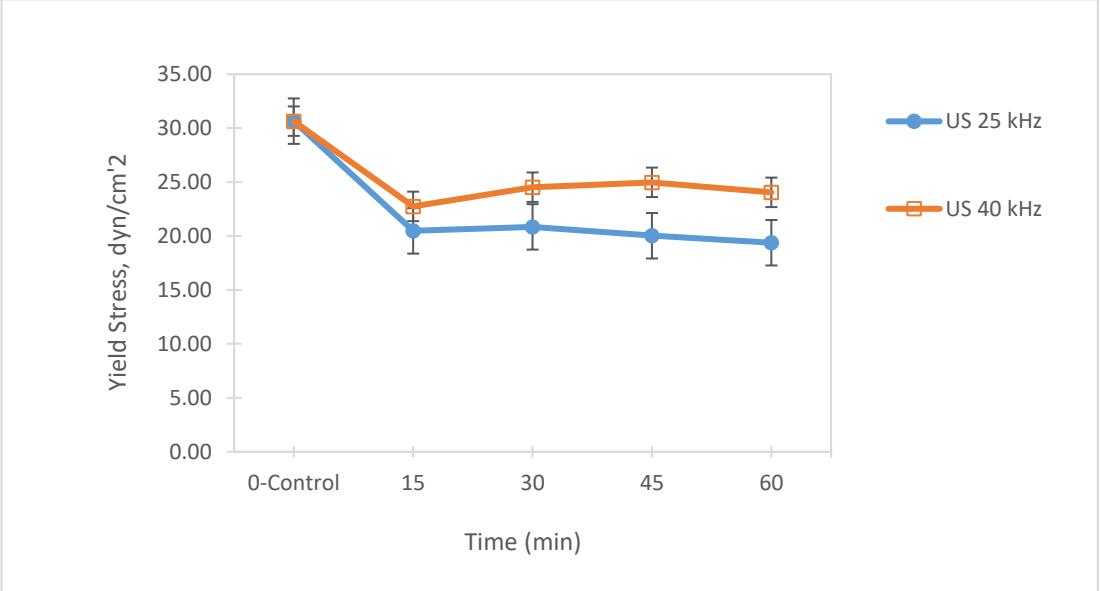

Figure 3.10 Effect of different ultrasound applications on the yield stress of wafer batter

3.2.6 Effect of Ultrasound on the pH of Wafer Batter

A typical wafer batter pH range is around 6.5 and 7.5. The pH value is affecting the quality and sensory properties of wafer sheets and it is also related with the acidity of samples. When acidity increases odor and taste is more intense (Tiefenbacher, 2017). According to Table A13, the pH of batter changed significantly ($p \leq 0.05$) during the

ultrasound application as generally. Also, while the interaction of ultrasound and time was significantly changing the pH of batter; only ultrasound frequency was not effective to change the pH of batter as significantly. However, the increase in frequency was not cause any significant change ($p>0.05$).

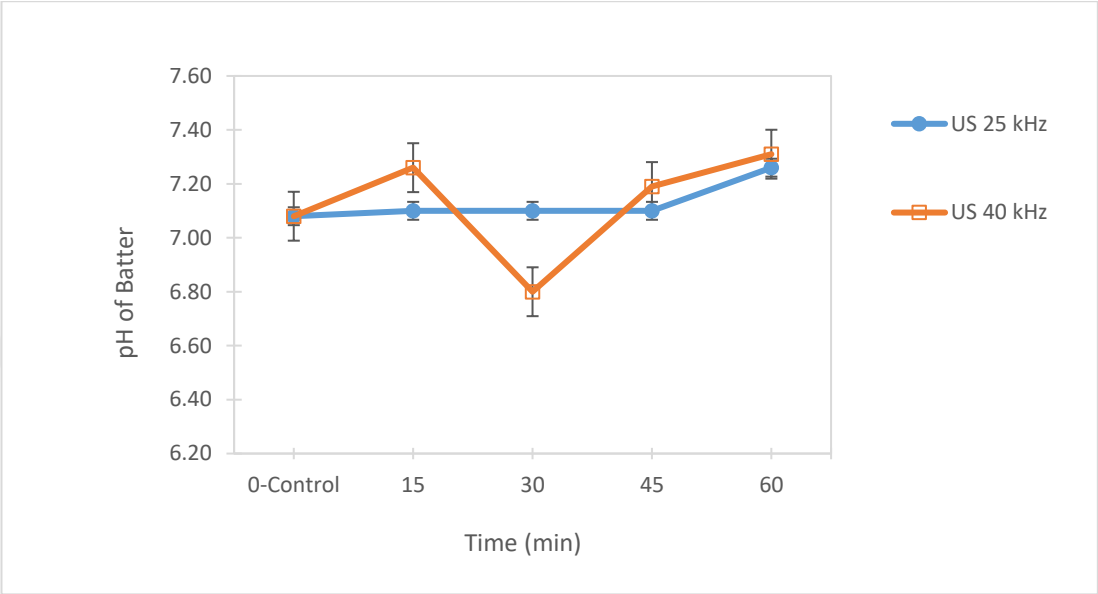

Figure 3.11 The effect of ultrasound frequency by different time intervals with pH value

3.2.7 Textural Properties of Wafer Batter

The aim of the wafer batter preparation is generally to suspend and hydrate of the flour particles without any gluten formation. Generally, gluten network causes the stringy-batter texture. The formation of gluten strings causes some process problems like clogging of depositors, improperly filling of wafer baking molds. At this point, better idea to prevent intense gluten formation (Tiefenbacher, 2017).

The effect of different ultrasound frequency on the textural properties of wafer batters is presented in Figure 3.12. The stringiness of the wafer batters was quantified by measuring force (g force). According to Figure 3.12, while a decrease was observed in the stringiness texture structure of the samples exposed to ultrasound that (applied 25 and 40 kHz for 15 minutes), an increase was observed in the stringiness texture structure of the dough samples that were applied at 40 kHz for 30 min. Although there was a general decrease according to the graph curves for 40 kHz ultrasound application, an excessively decreasing of stringiness of batter samples was

observed at 60 min for 40 kHz. According to Figure 3.12, it was observed that the ultrasound frequency applied at 40 kHz was better gluten formation preventative. According to Table A13, the texture properties of batter was changed significantly ($p \leq 0.05$) during the ultrasound application as generally. At the same time, it can be said that different ultrasound frequency was significantly ($p \leq 0.05$) changed textural properties of wafer batter. Especially, the stringiness of wafer batter decreased with 40 kHz ultrasound frequency as significantly ($p \leq 0.05$).

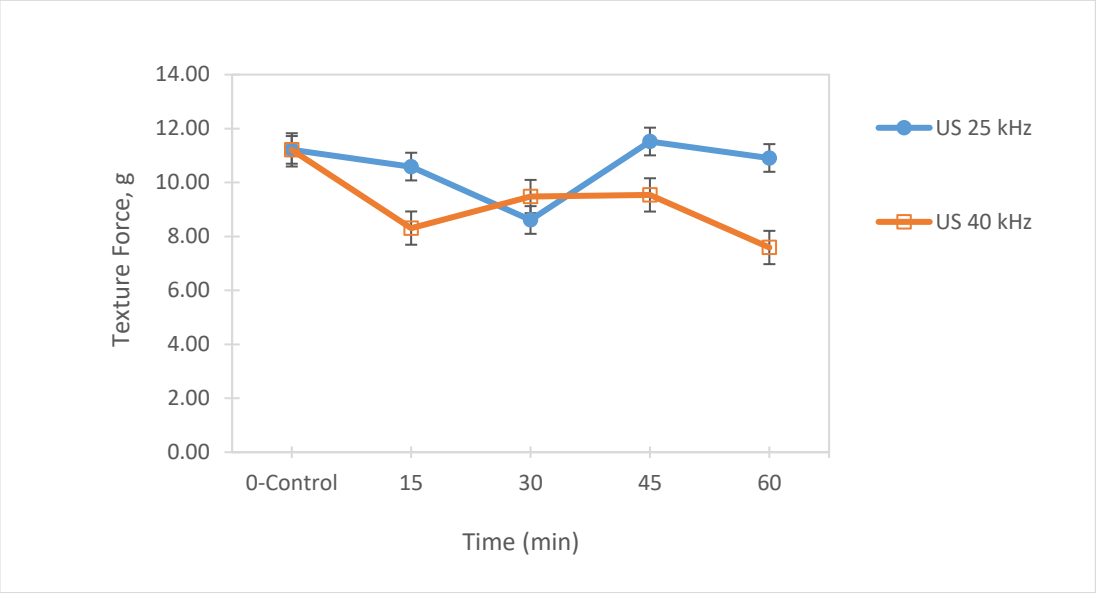

Figure 3.12 The effects of different ultrasound frequency on textural properties of wafer batter

3.3 Wafer Sheets Properties

3.3.1 The Weight and Moisture Content of Wafer Sheet Samples

Wafer sheet weight is generally related to wafer batter weight, cooking time and temperature and all of them indirectly affect the sensory properties of wafer texture parameters (Dogan, 2006). The effect of different ultrasound frequency on the weight of wafer sheets is presented in Figure 3.13. According to Figure 3.13, the wafer sheets weight decreased by increasing ultrasound periods. For both ultrasound frequencies, weight of the wafer sheets was observed to approach each other for 30 min ultrasound frequency. The most obvious difference was obtained at 40 kHz ultrasound application for 15 minutes. When it was compared the wafer batter and wafer sheet weights, the reduction curves in the wafer sheet paralleled the reduction

curves in the wafer dough (Figure 3.1) for 15, 30 and 45 min ultrasound application. For 40 kHz at 60 min ultrasound application a slight increase was observed in wafer sheet weight. At the same time, according to Table A14 as statistically, the increasing ultrasound frequency was significantly ($p \leq 0.05$) changed weight of wafer sheet samples. The change in the biomass of the raw materials, which may be caused by ultrasound, may have caused a decrease in the wafer weight.

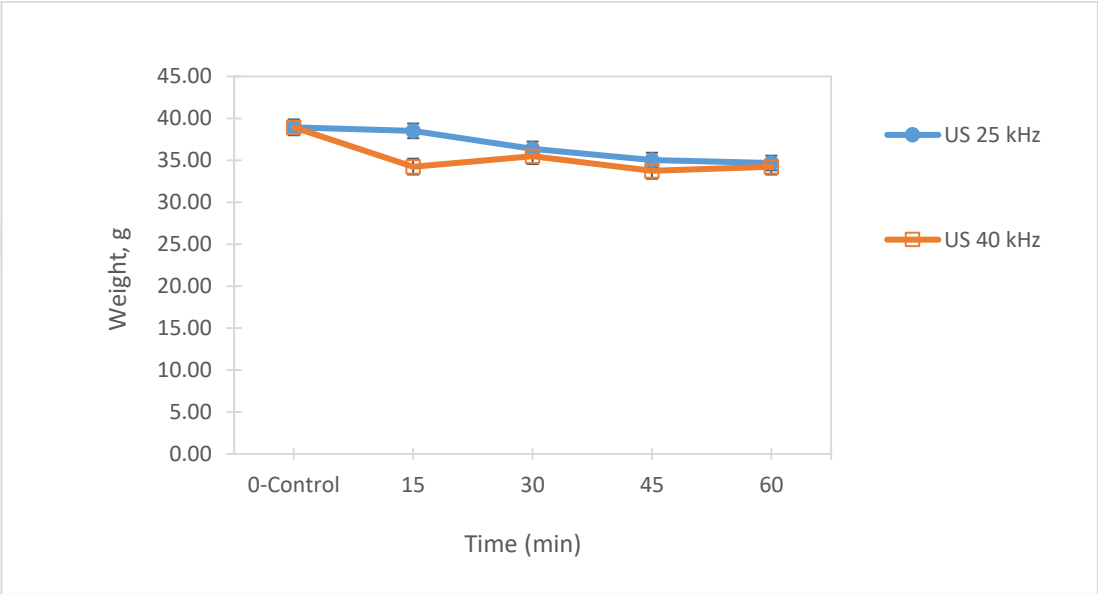

Figure 3.13 The effects of different ultrasound frequency on weight of wafer sheets

The decrease in the weight of the ultrasound applied samples over time indicates that the wafer samples are getting lighter. Physically, as known, a wafer is referred to as a highly aerated gel or foam. At this point, it can be said that ultrasound helps aeration and can help provide a lighter weight wafer structure.

On the other hand, other important quality parameter is moisture content of wafer sheet. It is related with texture and shelf life of wafer sheet samples. The level of moisture affects the wafer texture by softening of starch-protein matrix (Katz and Labuza, 1981). In wafer baking, both starch and protein of flour are denaturized. The gelatinization of starch changes of water binding properties of wheat flour. In batter, starch is wetted with water before the cooking. Little fraction on polysaccharides that is non starch, bind water nearly 6-10 times that of their weight. Therefore, most of the water is bind (Tiefenbacher, 2017). The applied ultrasound frequencies may have

affected water, which is concentrated in the recipe at this point. The effect of different ultrasound frequency on moisture of wafer sheets is presented in Figure 3.14.

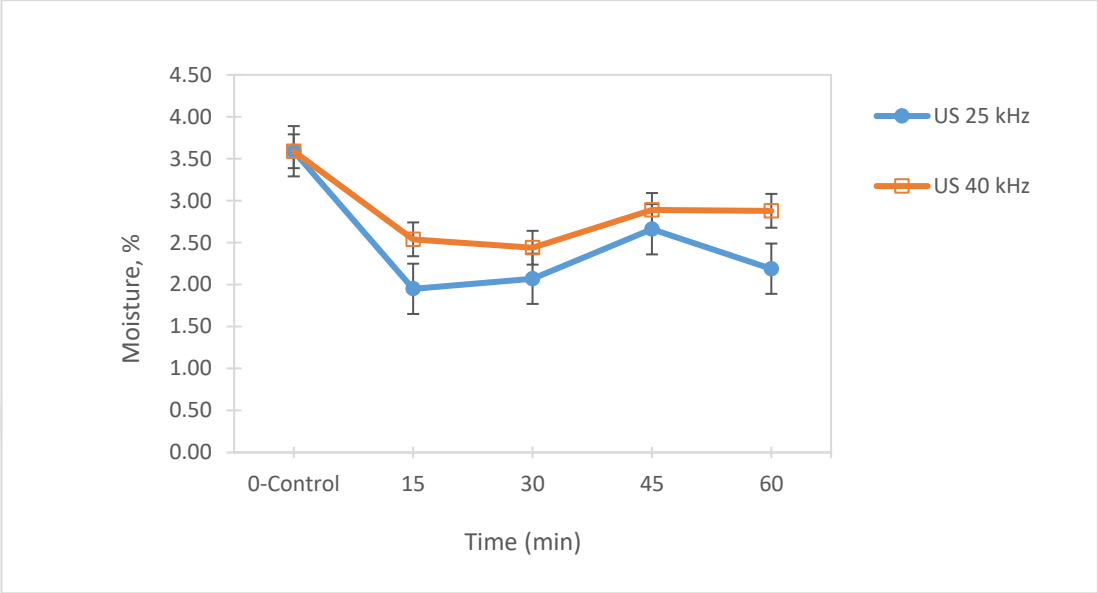

Figure 3.14 The effects of different ultrasound frequency on moisture of wafer sheets

While the current wafer moisture value was around 3.5%, the differences were observed in the samples exposed to different ultrasound frequencies by time. According to Figure 3.14, 25 and 40 kHz ultrasound frequency applied for 15 minutes was reduced the moisture value of the wafer sheets. After applying ultrasound for 45 minutes at both 25 and 40 kHz, an increase in moisture values was observed again, but it was still not close to the control group. According to Table A14 as statistically, increasing of ultrasound frequency was significantly changed ($p \leq 0.05$) of moisture content of wafer sheet samples. Fuente-Blanco et al., were observed that the cavitation that occurs during the ultrasound process can be a powerful factor for removing moisture in vegetable and fruits (De La Fuente-Blanco et al., 2006). According to moisture analyses results of wafer sheets were decreased with ultrasound application. At this point, it would not be wrong to say that ultrasound is a good practice to reduce the moisture value for such light bakery products.

3.3.2 Color Properties of Wafer Sheet Samples

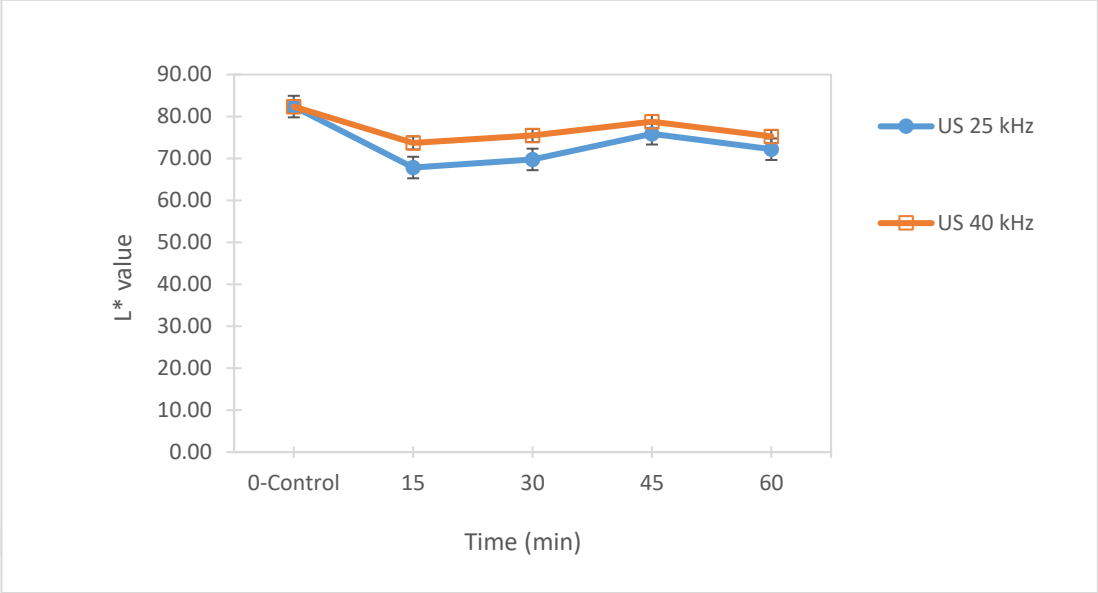

Figure 3.15 The effects of different ultrasound frequency on color L* value of wafer sheets

The color of wafer sheet samples was analyzed by using the L*, a* and b* values. The effect of ultrasound frequency by different time intervals on the L* values are presented in Figure 3.15.

As generally, according to Figure 3.15, the L* value of the wafer sheet samples decreases with exposure to ultrasound frequency application compared to control group. This is related to their lightness appearance. It should not be overlooked that the L* values are quite close to each other in the ultrasound samples applied for 45 minutes for both 25 and 40 kHz ultrasound groups. According to Table A14, the L* value of wafer sheets was not significantly changed ($p>0.05$) with interaction of ultrasound and time. Dogan., was observed that the wafer sheets color can change with water level and baking temperature (Dogan, 2006). Especially, he observed that water level is more effective to changing of color of wafer sheets and it cause the higher L* value. According to Figure 3.14, it was mentioned that the moisture content of the wafer sheets decreased with the application of ultrasound. At this point, decreasing L* value of wafer sheets was also supported of working of Dogan (Dogan, 2006).

The a* value is related to red/green color parameters of wafer sheets samples. The effect of ultrasound frequency by different time intervals on the a* values is presented in Figure 3.16.

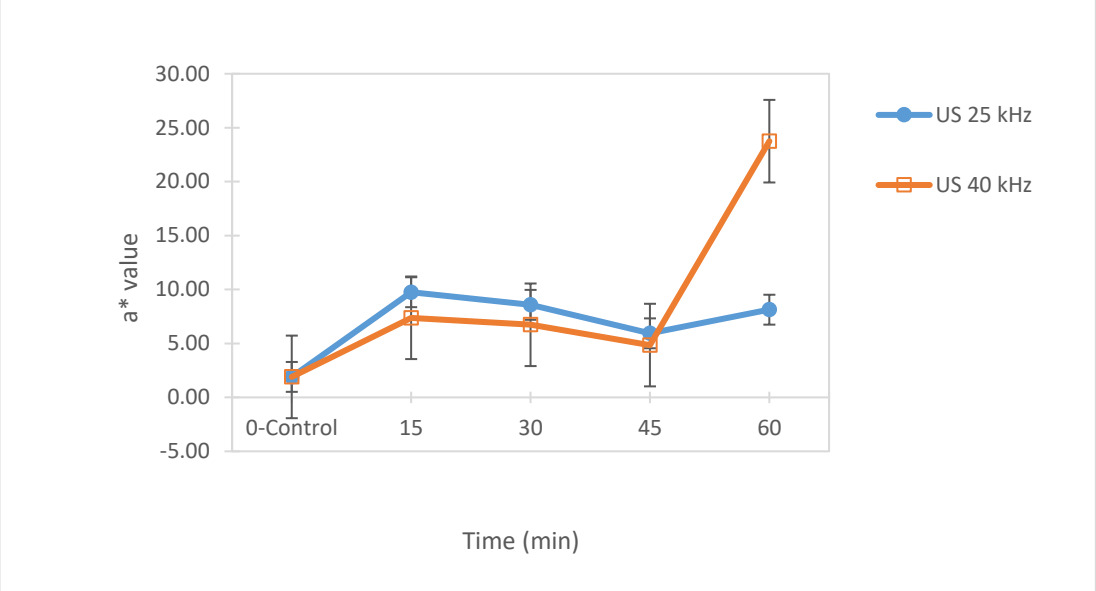

Figure 3.16 The effects of different ultrasound frequency on color a* value of wafer sheets

According to Figure 3.16, the a* values of the wafer sheet samples increase with exposure to ultrasound compared to the control group. This is related to their red/green color appearance. An increase in the color a parameter was observed during the 15 minutes for both ultrasound (25 and 40 kHz) applied groups. Then, from two sample groups showing a slow declined for 45 min. ultrasound application, a large increase was observed in the 40 kHz experimental group after 60 min. exposure. According to Table A14, the a* value of wafer sheets did not significantly change ($p>0.05$) with interaction of ultrasound and time, as statistically.

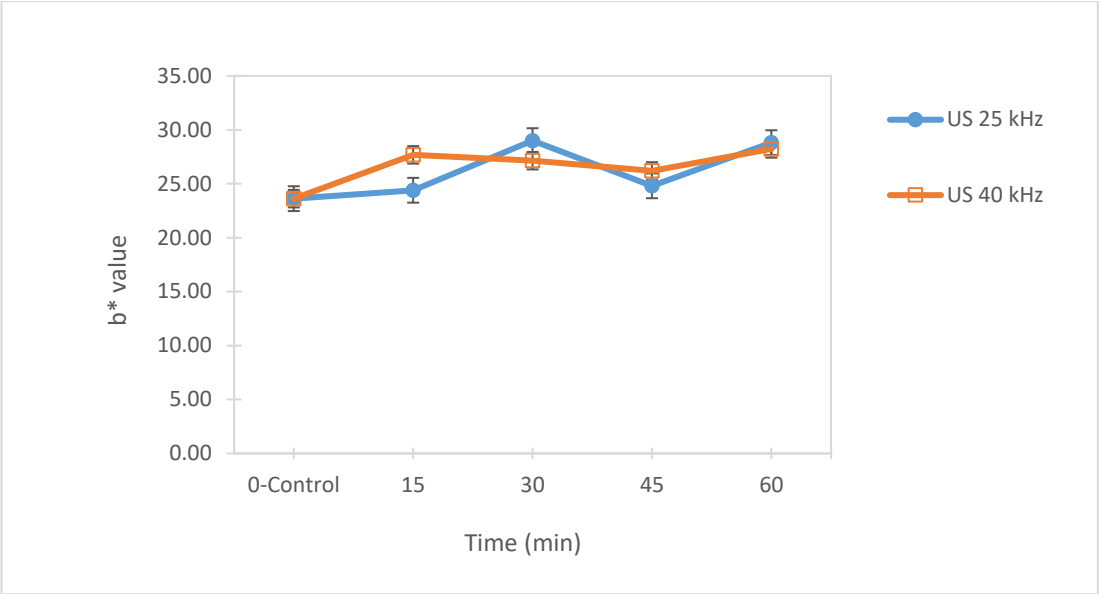

Figure 3.17 The effects of different ultrasound frequency on color b* value of wafer sheets

In determination of color, the b* values related with yellow/blue color parameters of wafer sheets samples. The effect of ultrasound frequency by different time intervals on the b* values is presented in Figure 3.17. According to the graph, there was no linear decrease or increase in the b* value. According to Table A14, the b* value of wafer sheets did not significantly change ($p>0.05$) with interaction of ultrasound and time, as statistically.

In general, due to the manufacturing conditions of the wafer sheet, ultrasound application may not be the only variable for color change. This may be because of the time of exposure the batter into the cooking molds. Since baking under laboratory conditions was done manually, the time to remove the wafer sheet from the layers was also manual.

3.3.3 Textural Properties of Wafer Sheet Samples

Texture is the most important factor at the first bite by consumers. Hardness and crunchy terms meet customer requirements. Hardness of wafer sheets was measured by measuring force (g force). The effect of different ultrasound frequency on textural properties of wafer sheets is presented in Figure 3.18.

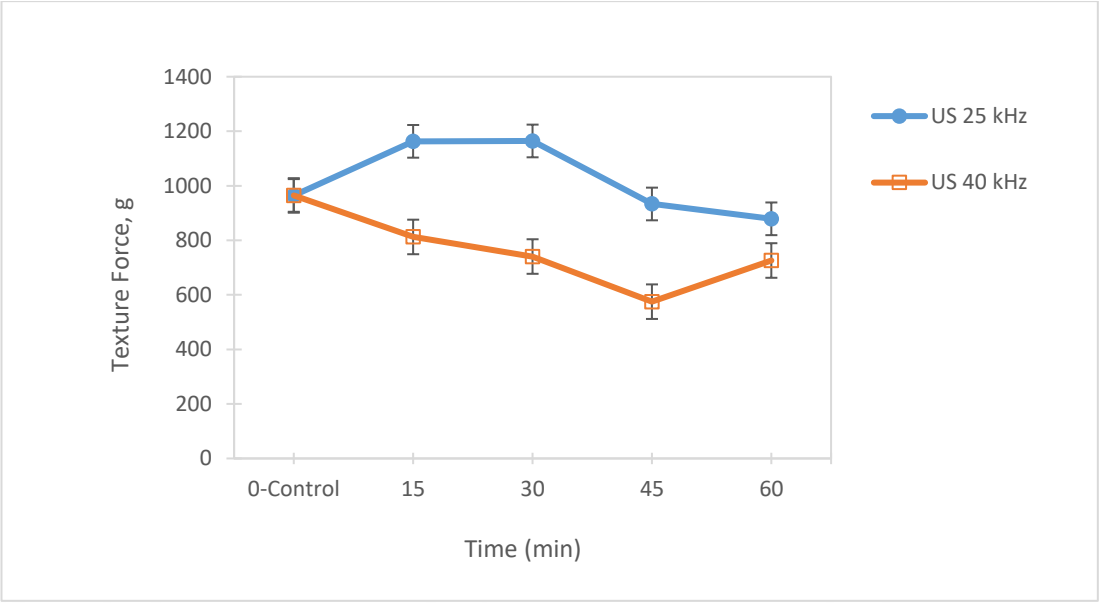

Figure 3.18 The effects of different ultrasound frequency on hardness parameter of wafer sheets

According to Figure 3.18, the hardness parameter was showed differences in the wafer sheet samples that applied 25 and 40 kHz ultrasound frequencies at different times. While the 25 kHz wafer samples show a harder structure among the wafers formed with dough samples that were subjected to 15 minutes of ultrasound, the situation was the opposite for the samples that applied 40 kHz ultrasound frequency. For samples that applied 40 kHz ultrasound, there was a general decrease in the hardness structure according to the graph. On the other hand, hardness gradually decreased as it was exposed to ultrasound for 15, 30 and 45 minutes, respectively. This situation showed an increase again for the sample exposed to ultrasound for 60 min., albeit less than the control group. According to Table A14, increasing ultrasound frequency, the hardness of wafer sheets significantly changed ($p \leq 0.05$), as statistically. For 25 kHz, according to the Figure 3.18, while an increase was observed in the hardness of the wafer, which was applied ultrasound for 15, 30 minutes. It was observed that there is a decrease in wafer hardness in the samples applied for 45 and 60 minutes. Dogan was observed that less water decreases the hardness of wafer texture (Dogan, 2006). According to Figure 3.14, the moisture content of the wafer sheets especially decreased at 25 kHz ultrasound application. This decrease in wafer sheets moisture content supports the increase in the hardness of the wafer sheets (Figure 3.18).

3.3.4 Effects of Ultrasound Frequency on Porous of Wafer Sheet Samples

The cross section images of wafer sheets are presented in Figure 3.19 and the effects of different ultrasound frequency on the number of pore and the porous area of wafer sheets are presented in Figures 3.20 and 3.21. According to Figures 3.20 and 3.21, although there was not a very intense change in the porosity quantity in the wafer sheet samples applied at 25 kHz, the same was true in the pore areas. For the wafer sheet samples applied at 40 kHz, the number of pores increased as the ultrasound exposure time increased. A decrease in the wafer pore area was observed along with an increase in the wafer pore number. At the same time, Elmehdi et al., was mentioned that the air bubbles in the dough are changed by ultrasound velocity depending on the wave frequency (Elhemdi et al., 2003).

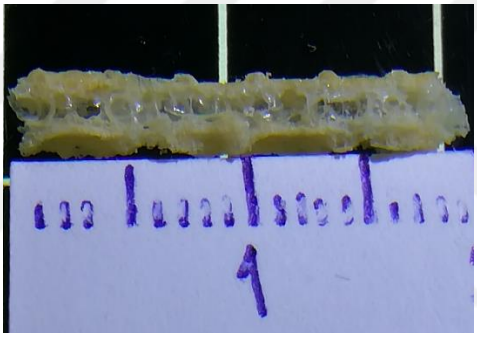

Figure 3.19 Imagination of pore image from the side section of wafer sheet sample, mean of 1 is 1 cm.

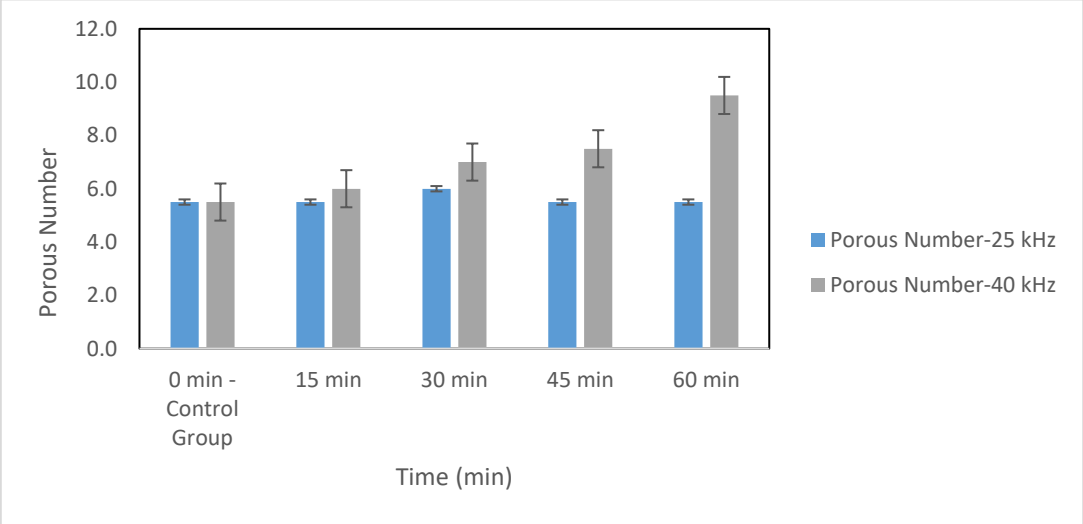

Figure 3.20 The effects of different ultrasound frequency on porous number of wafer sheets

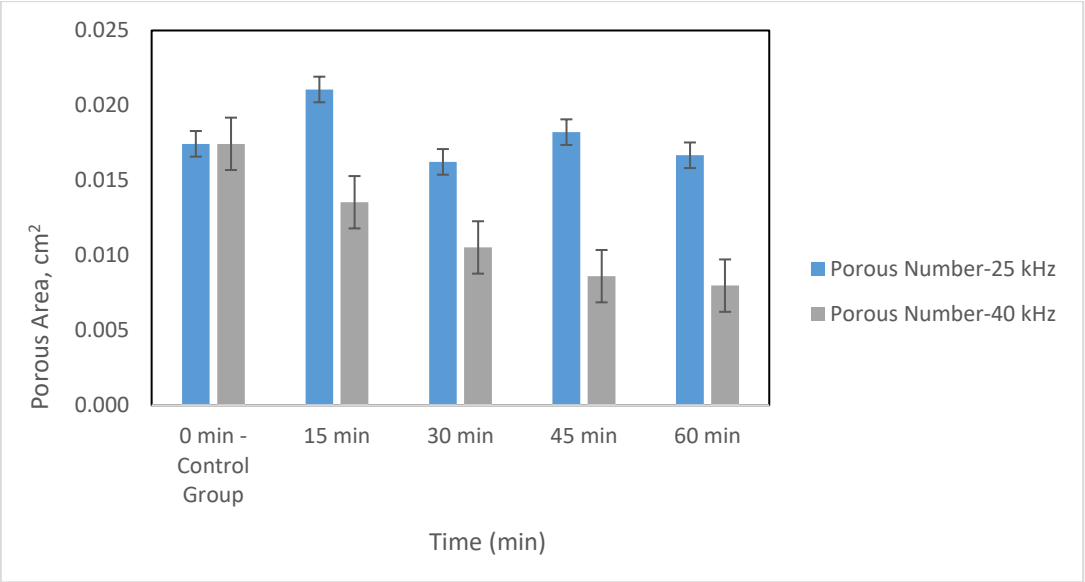

Figure 3.21 The effects of different ultrasound frequency on porous area of wafer sheets

3.4 Sensory Evaluation Properties of Wafer Sheet Samples

For food acceptability, the sensory analysis was performed according to scoring test method. During the analysis, higher score represents higher acceptability. Brittleness, chewiness and porous structure of samples were investigated by the panelists for the sensory evaluation. Figures 3.22 and 3.23 show the acceptability score of samples of 25 and 40 kHz ultrasound samples with different time intervals.

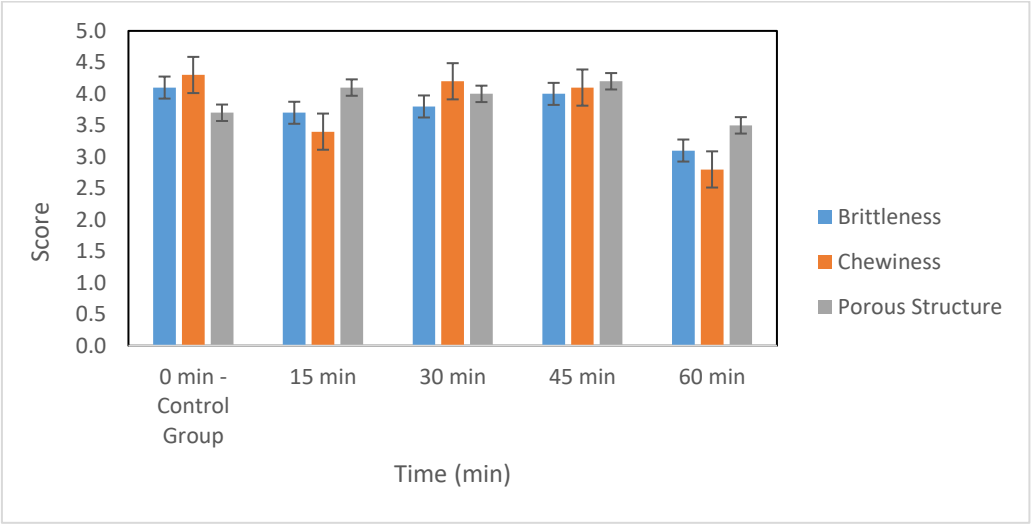

Figure 3.22 The acceptability score of samples of 25 kHz ultrasound samples with different time intervals

According to Figure 3.22, the sample in which ultrasound was applied for 60 minutes was the most disliked sample for 25 kHz ultrasound application. It was lower than the others, especially in chewiness. Among the 25 kHz samples, the most admired group was selected from the samples that underwent ultrasound for 45 minutes.

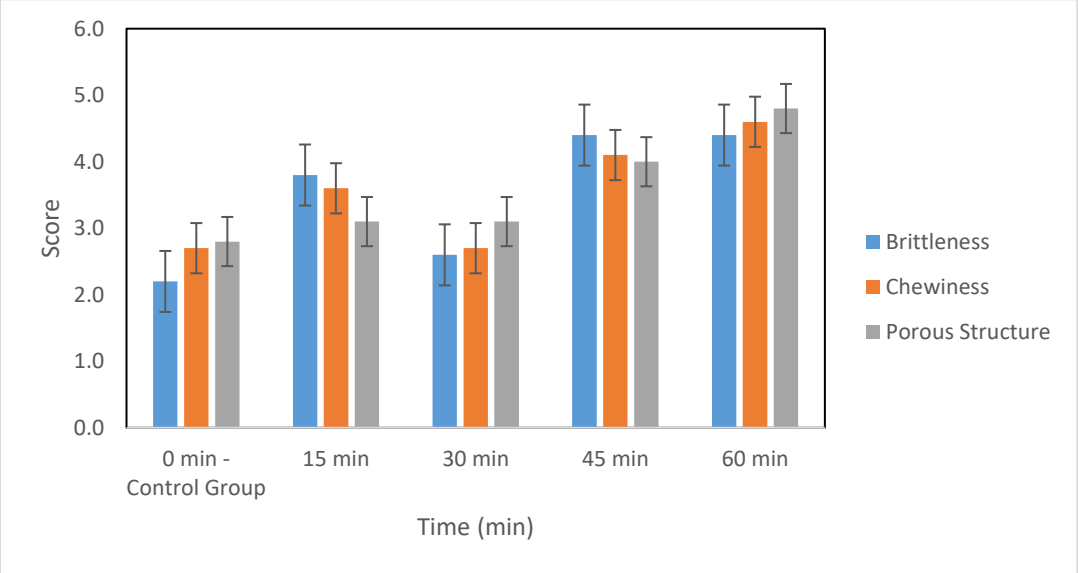

Figure 3.23 The acceptability score of samples of 40 kHz ultrasound samples with different time intervals.

According to Figure 3.23, the sample in which control group was the most disliked sample. It is scored lower than the others, especially in brittleness. Among the 40 kHz samples, the most admired group was selected from the samples that underwent ultrasound for 45 and 60 minutes.

CHAPTER IV

CONCLUSION AND RECOMMENDATION

As can be seen from the analysis results throughout the study, the ultrasound application changes properties of the wafer sheet. Wafer batter weight decreased when 40 kHz ultrasound was applied, especially at 15 min. and 60 min. So, it can be said that the increasing ultrasound frequency significantly changed ($p \leq 0.05$) of wafer batter. At the same time, the weight of wafer sheet was observed to decrease at 40 kHz for 15 min. The change in the weight occurred due to increasing ultrasound frequency with time.

The color of wafer batter changed as significantly with applied ultrasound frequency with different times. For 25 and 40 kHz, there was a general decrease in the L* values of dough with increasing time exposed to ultrasound with compared to initial value. This caused dark color. As generally, a significant change ($p \leq 0.05$) was observed in the L* value of wafer batter with increasing ultrasound frequency. By the way, the L* value of wafer sheets did not significantly change ($p > 0.05$) with interaction of ultrasound and time. The a* value of wafer batter increased with 15 min and 25 kHz ultrasound application and decreased other time intervals. Even that, a change did not observe for 30, 45 and 60 min ultrasound application times. As generally, the a* value of wafer batter and wafer sheets did not significantly change ($p > 0.05$) with interaction of ultrasound and time. As generally, b* value of wafer batter and wafer sheet samples were not significantly change with increasing ultrasound application with time. It can be said that it is effective in changing the color of the wafer layers in the baking time and temperature of the wafer. Ultrasound alone is not a factor for color change. After all, the applied process is manual and human influence should also be considered.

Rheology and flowability of wafer batter have different behaviors for both 25 and 40

kHz ultrasound applications. Especially, in the samples applied 40 kHz ultrasound frequency for 45 minutes, difficulty in flowability was observed.

However, 60 minutes ultrasound application reduced the flow rate and so it can be said that adequate amount of ultrasound application was showed better flowability. While Gallo et al., (2018) observing that an ultrasound application that applied for the filtration process, the ultrasound technology has an improving effect on the flow (Gallo et al., 2018). It can be said that ultrasound application can affect the molecules of samples and it affected the resistance of flow of batter. During the ultrasound application with different time, the batter showed different viscosity value. Non-Newtonian behavior may explain these changes. As generally, wafer batter was showed more fluid structure by using ultrasound application. Decreasing viscosity of wafer batter showed the desired gluten formation.

While interaction of ultrasound and time was significantly changing the pH of batter; only ultrasound frequency was not effective to change the pH of batter as significantly. However, the increase in frequency was not cause any significant change.

Significant textural change was observed for both 25 and 40 kHz ultrasound applications. The stringiness of wafer batter decreased with different ultrasound duration as generally for both 25 and 40 kHz ultrasound applications. But 40 kHz ultrasound application show better preventative for stringy-batter texture by the way undesired gluten formation. On the other hand, the hardness of wafer sheet was decreased as generally for two different ultrasound applications.

The number of wafer pores increased with 40 kHz ultrasound exposure time. It was also observed that the area of the pores decreased as the number of pores increased for 40 kHz ultrasound application.

According to sensory analysis results, while the most disliked sample was 60 minutes for 25 kHz ultrasound application; the most admired group was 45 minutes and 25 kHz ultrasound application for people. On the other hand, the most disliked sample was control group for 40 kHz ultrasound application. The most liked group was 60 minutes and 40 kHz ultrasound application by people. At this point, it can be said

that ultrasound application can also be effective to improve the sensory analysis of that foodstuff. In this study, the experiment conditions may be a guide for improve the other ultrasound application or wafer studies.

Further studies are needed to determine the effect of ultrasound on wafer sheet samples. At the same time, the raising agents can be removed from the wafer sheet recipe and a comparison with the standard recipe can be made. Also, the results of this study may be helpful to the manufacturers of industrial wafer/confectionary products.

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APPENDIX

Table A1. Control group wafer batter and wafer sheet analysis results.

			Control group batter 1		Control group batter 2		Control groups	
			1st parallel		2nd parallel		Average Results	
	Analysis Paremeter	Unit	Result 1	Result 2	Result 1	Result 2	Average	sdt-dev
Batter	Weight	g	155.00	155.00	155.00	155.00	155.0	0.00
	Volume	ml	150.00	150.00	150.00	150.00	155.0	0.00
	Color	L*	86.49	86.47	86.48	86.48	86.48	0.01
		a*	0.94	0.93	0.97	0.95	0.95	0.02
		b*	16.40	16.35	16.43	16.25	16.36	0.08
	Glass Analysis	x: 5 cm-t, sec	7.00	4.00	7.00	4.00	5.50	1.73
		x: 10 cm-t, sec	96.00	68.00	96.00	68.00	82.00	16.17
	Falling Number Analysis	t, sec	11.64	10.62	10.95	10.93	11.04	0.43
	pH		7.05	7.05	7.1	7.1	7.08	0.03
	Viscosity	(cP)	9750.0	9750.0	7000.0	7000.0	8375.00	1587.71
	Plastic Viscosity	(cP)	482.0	482.0	542.0	542.0	512	34.64
	Yield Stress	dyn/cm^2	36.8	36.8	24.5	24.5	30.65	7.10
	Texture	g	11.011	11.092	11.330	11.397	11.21	0.19
Wafer	Moisture at 130°C	%	3.79	3.50	3.62	3.46	3.59	0.15
	Color	L*	82.90	82.95	81.81	81.82	82.37	0.64
		a*	1.45	1.38	2.39	2.39	1.90	0.56
		b*	22.71	23.79	23.97	23.99	23.62	0.61
	Weight	g	39.7	38.4	38.3	39.3	38.93	0.68
	Texture	g	1024.0	1024.0	905.268	905.268	964.63	68.55

x mean is distance.

Table A2. 15 min. US application analysis results for 25 kHz

			1st parallel		2nd parallel		Average Results	
	Analysis Parameter	Unit	Result 1	Result 2	Result 1	Result 2	Average	sdt-dev
Batter	Weight	g	155.3	154.6	156.4	156.0	155.58	0.79
	Volume	ml	150	150	150	150	150	0
	Color	L*	86.48	86.48	86.07	86.04	86.27	0.25
		a*	1.35	1.35	0.97	0.95	1.16	0.23
		b*	12.43	13.59	16.21	16.25	14.62	1.92
	Glass Analysis	x: 5 cm-t, sec	5.46	4.2	5.49	5.72	5.22	0.69
		x: 10 cm-t, sec	39.4	36.12	35.17	35.75	36.61	1.9
	Falling Number Analysis	t, sec	5.72	5.73	5.74	5.7	5.72	0.02
	pH		7.1	7.1	7.1	7.1	7.1	0
	Viscosity	(cP)	4500	4500	6750	7000	5687.5	1375
	Plastic Viscosity	(cP)	407	386	384	382.6	389.9	11.49
	Yield Stress	dyn/cm^2	13.8	15.1	25.8	27.2	20.48	7
	Texture	g	9.857	10.772	10.920	10.805	10.59	0.49
Wafer	Moisture at 130°C	%	2	1.89	1.86	2.06	1.95	0.09
	Color	L*	67.43	67.43	68.24	68.25	67.84	0.47
		a*	9.85	9.85	9.65	9.64	9.75	0.12
		b*	18.45	18.43	30.33	30.37	24.4	6.88
	Weight	g	38.2	38.2	38.84	38.81	38.51	0.36
	Texture	g	1145.6	1149.4	1179.6	1177.5	1163.03	18.01

Table A3. 30 min. US application analysis results for 25 kHz

			1st parallel		2nd parallel		Average Results	
	Analysis Parameter	Unit	Result 1	Result 2	Result 1	Result 2	Average	sdt-dev
Batter	Weight	g	154	155	156	155	155	0.82
	Volume	ml	150	150	150	150	150	0
	Color	L*	85.38	85.38	85.54	85.48	85.45	0.08
		a*	1.04	1.04	0.84	0.83	0.94	0.12
		b*	16.75	16.77	16.1	16.2	16.46	0.35
	Glass Analysis	x: 5 cm-t, sec	4.1	4.1	4.2	5.12	4.38	0.5
		x: 10 cm-t, sec	21.56	24.48	22.35	26.5	23.72	2.22
	Falling Number Analysis	t, sec	5.21	5.25	5.27	5.36	5.27	0.06
	pH		7.09	7.09	7.1	7.1	7.1	0.01
	Viscosity	(cP)	6000	5000	5875	6500	5843.75	623.96
	Plastic Viscosity	(cP)	423	440	419.8	507	447.45	40.68
	Yield Stress	dyn/cm^2	20.1	18.1	21.9	23.3	20.85	2.25
	Texture	g	8.390	8.720	8.667	8.665	8.61	0.15
Wafer	Moisture at 130°C	%	2.52	2.57	1.48	1.69	2.07	0.56
	Color	L*	74.84	74.84	64.69	64.69	69.77	5.86
		a*	6.53	6.58	10.6	10.6	8.58	2.34
		b*	27.82	27.73	30.19	30.25	29	1.41
	Weight	g	35.7	35.7	37	37	36.36	0.74
	Texture	g	1103.602	1109.364	1323.526	1066.00	1164.38	139.100

Table A4. 45 min. US application analysis results for 25 kHz.

			1st parallel		2nd parallel		Average Results	
	Analysis Parameter	Unit	Result 1	Result 2	Result 1	Result 2	Average	sdt-dev
Batter	Weight	g	152	153	154.4	154.4	153.45	1.17
	Volume	ml	150	150	150	150	150	0
	Color	L*	85.85	85.85	85.23	85.28	85.55	0.34
		a*	1.07	1.08	0,81	0.79	0.94	0.16
		b*	16.38	16.39	16,17	16.12	16.27	0.14
	Glass Analysis	x: 5 cm-t, sec	5.1	6.2	6,20	4.72	5.56	0.76
		x: 10 cm-t, sec	35	37.6	36.23	31.18	35	2.76
	Falling Number Analysis	t, sec	5.12	5.33	5.39	4.16	5	0.57
	pH		7.09	7.1	7.09	7.1	7.1	0.01
	Viscosity	(cP)	6000	5250	5500	5250	5500	353.55
	Plastic Viscosity	(cP)	392.8	442	405.8	409	412.4	20.94
	Yield Stress	dyn/cm^2	22.4	19.5	20.2	18	20.03	1.83
	Texture	g	10.180	12.070	11.967	11.876	11.52	0.9
Wafer	Moisture at 130ºC	%	3.58	3.6	1.67	1.8	2.66	1.07
	Color	L*	83.88	82.86	68.42	68.39	75.89	8.65
		a*	2.06	2.58	9.59	9.54	5.94	4.19
		b*	19.19	20.73	29.61	29.7	24.81	5.63
	Weight	g	34.55	34.55	35.5	35.5	35.03	0.55
	Texture	g	951.669	960.756	910.056	910.745	933.31	26.71

Table A5. 60 min. US application analysis results for 25 kHz.

			1st parallel		2nd parallel		Average Results	
	Analysis Parameter	Unit	Result 1	Result 2	Result 1	Result 2	Average	sdt-dev
Batter	Weight	g	156.1	155	154,5	154.5	155.03	0.75
	Volume	ml	150	150	150	150	150	0
	Color	L*	85.25	85.22	85.35	85.32	85.29	0.06
		a*	1	1.06	0.84	0.91	0.95	0.1
		b*	16.73	16.74	16.12	16.12	16.43	0.36
	Glass Analysis	x: 5 cm-t, sec	5.58	6.43	4.02	5.48	5.38	1
		x: 10 cm-t, sec	24.92	28.27	28.58	27.39	27.29	1.66
	Falling Number Analysis	t, sec	4.12	4.42	4	3.98	4.13	0.2
	pH		7.26	7.26	7.26	7.26	7.26	0
	Viscosity	(cP)	5500	5875	5250	4375	5250	637.38
	Plastic Viscosity	(cP)	400	385.3	358	367.7	377.75	18.65
	Yield Stress	dyn/cm^2	21.3	22.4	18.8	15	19.38	3.28
	Texture	g	10.383	11.182	11.068	10.998	10.91	0.36
Wafer	Moisture at 130ºC	%	2.24	2.39	2	2.12	2.19	0.17
	Color	L*	73.38	73.38	71.03	71.01	72.2	1.36
		a*	7.59	7.57	8.66	8.7	8.13	0.64
		b*	28.47	28.46	29.17	29.15	28.81	0.4
	Weight	g	34.74	34.73	34.62	34.62	34.68	0.07
	Texture	g	834.91	809.665	874.604	996.465	878.91	82.8

Table A6. 15 min. US application analysis results for 40 kHz

			1st parallel		2nd parallel		Average Results	
	Analysis Parameter	Unit	Result 1	Result 2	Result 1	Result 2	Average	sdt-dev
Batter	Weight	g	147.7	148.9	151.2	150.6	149.6	1.6
	Volume	ml	150	150	150	150	150	0
	Color	L*	85.66	85.63	85.66	85.62	85.64	0.02
		a*	0.99	1.02	1.01	1.04	1.02	0.02
		b*	16.46	16.49	16.44	16.46	16.46	0.02
	Glass Analysis	x: 5 cm-t, sec	11.13	12.2	10	11.1	11.11	0.9
		x: 10 cm-t, sec	93	95	74	90	88	9.56
	Falling Number Analysis	t, sec	6.3	6.7	6.4	6.5	6.48	0.17
	pH		7.48	7.48	7.07	7	7.26	0.26
	Viscosity	(cP)	6500	6530	5625	5750	6101.25	480.63
	Plastic Viscosity	(cP)	387.7	390.4	398	388	391.03	4.8
	Yield Stress	dyn/cm^2	25	25.3	20.6	20.1	22.75	2.78
	Texture	g	8.356	8.187	8.403	8,278	8.31	0.09
Wafer	Moisture at 130^{o}C	%	2.52	2.53	2.56	2.56	2.54	0.02
	Color	L*	72.14	72.14	75.27	75,26	73.7	1.8
		a*	8.31	8.3	6.46	6.44	7.38	1.07
		b*	29.09	29.4	26.12	26.12	27.68	1.81
	Weight	g	34	34	34.5	34.5	34.25	0.29
	Texture	g	748.564	723.934	893.756	883.269	812.38	88.59

Table A7. 30 min. US application analysis results for 40 kHz

			1st parallel		2nd parallel		Average Results	
	Analysis Parameter	Unit	Result 1	Result 2	Result 1	Result 2	Average	sdt-dev
Batter	Weight	g	153.9	154.9	155	155	154.7	0.54
	Volume	ml	150	150	150	150	150	0
	Color	L*	85.54	85.51	85.55	85.54	85.54	0.02
		a*	1.12	1.13	1.14	1.17	1.14	0.02
		b*	17.07	17.13	17.04	17.04	17.07	0.04
	Glass Analysis	x: 5 cm-t, sec	15.2	15.28	15.4	15.49	15.34	0.13
		x: 10 cm-t, sec	105	108	110	119	110.5	6.03
	Falling Number Analysis	t, sec	9.76	9.8	10.4	10.58	10.14	0.42
	pH		6.58	6.58	7.01	7.01	6.8	0.25
	Viscosity	(cP)	6500	7000	6625	6600	6681.25	219.26
	Plastic Viscosity	(cP)	389.4	300	454.9	455	399.83	73.37
	Yield Stress	dyn/cm^2	25.1	24.5	25.1	23.4	24.53	0.8
	Texture	g	9.805	9.903	8.495	9.701	9.48	0.66
Wafer	Moisture at 130°C	%	2.06	2.26	2.71	2.73	2.44	0.33
	Color	L*	78.04	78.02	72.91	72.9	75.47	2.96
		a*	5.34	5.36	8.09	8.11	6.73	1.59
		b*	25.44	25.49	28.79	28.82	27.14	1.93
	Weight	g	34	34	37	37	35.5	1.73
	Texture	g	810.9	825	647.6	678.6	740.54	90.46

Table A8. 45 min. US application analysis results for 40 kHz

			1st parallel		2nd parallel		Average Results	
	Analysis Parameter	Unit	Result 1	Result 2	Result 1	Result 2	Average	sdt-dev
Batter	Weight	g	152.8	153	155	156	154.2	1.56
	Volume	ml	150	150	150	150	150	0
	Color	L*	85.08	85.02	85.03	85.01	85.04	0.03
		a*	1.21	1.22	1.23	1.22	1,22	0.01
		b*	17.3	17.32	17.3	17.31	17.31	0.01
	Glass Analysis	x: 5 cm-t, sec	17.45	17.41	18.09	18.05	17.75	0.37
		x: 10 cm-t, sec	139	135	130	129	133.25	4.65
	Falling Number Analysis	t, sec	10.13	10.2	10.66	10.11	10.28	0.26
	pH		7.17	7.17	7.21	7.21	7.19	0.02
	Viscosity	(cP)	6625	6500	5875	5750	6187.5	438.99
	Plastic Viscosity	(cP)	397.7	315	385	382	369.93	37.24
	Yield Stress	dyn/cm^2	23.9	26	22.4	27.6	24.98	2.29
	Texture	g	7.527	8.301	10.487	11.842	9.54	1.98
Wafer	Moisture at 130^{o}C	%	2.62	3.14	3.01	2.79	2.89	0.23
	Color	L*	77.47	77.45	80.13	80.13	78.8	1.54
		a*	5.83	5.81	3.86	3.89	4.85	1.12
		b*	26.95	27.02	25.42	25.38	26.19	0.92
	Weight	g	33.5	33.2	34	34.3	33.75	0.49
	Texture	g	534.379	516.343	693.008	556.401	575.03	80.34

Table A9. 60 min. US application analysis results for 40 kHz

			1st parallel		2nd parallel		Average Results	
	Analysis Parameter	Unit	Result 1	Result 2	Result 1	Result 2	Average	sdt-dev
Batter	Weight	g	149.3	150	147.7	148	148.5	1.25
	Volume	ml	150	150	150	150	150	0
	Color	L*	86.06	86.04	85.92	85.89	85.98	0.09
		a*	1.02	1.02	0.97	1.00	1.00	0.02
		b*	18.27	18.24	18.15	18.16	18.21	0.06
	Glass Analysis	x: 5 cm-t, sec	11.02	15.03	14.09	15.19	13.83	1.94
		x: 10 cm-t, sec	47.17	48.16	45.06	49.02	47.35	1.71
	Falling Number Analysis	t, sec	4.38	5	5.33	5.16	4.97	0.41
	pH		7.31	7.31	7.3	7.3	7.31	0.01
	Viscosity	(cP)	6750	6625	4875	5875	6031.25	862.26
	Plastic Viscosity	(cP)	272.8	28.98	343.2	316.3	240.32	143.85
	Yield Stress	dyn/cm^2	31.4	27	15.7	22.1	24.05	6.74
	Texture	g	9.519	8.107	6.046	6.695	7.59	1.55
Wafer	Moisture at 130°C	%	2.87	2.75	2.96	2.95	2.88	0.1
	Color	L*	73.89	73.86	76.59	76.58	75.23	1.56
		a*	7.51	75,10	6.09	6.29	23.75	34.24
		b*	28.4	28.6	27.96	27.94	28.23	0.33
	Weight	g	34	34	34,50	34,50	34.25	0.29
	Texture	g	885.14	763.834	626.464	628.616	726.01	124.03

Table A10. Sensory analysis results for 25 kHz.

US-25 kHz	Brittleness	Chewiness	Porous Structure
0 min - Control Group	4.1	4.3	3.7
15 min	3.7	3.4	4.1
30 min	3.8	4.2	4.0
45 min	4.0	4.1	4.2
60 min	3.1	2.8	3.5

Table A11. Sensory analysis results for 40 kHz.

US-40 kHz	Brittleness	Chewiness	Porous Structure
0 min - Control Group	2.2	2.7	2.8
15 min	3.8	3.6	3.1
30 min	2.6	2.7	3.1
45 min	4.4	4.1	4.0
60 min	4.4	4.6	4.8

TABLE A.12 ANOVA RESULTS

Between-Subjects Factors

		N
Samples	Control	4
	US2515	4
	US2530	4
	US2545	4
	US2560	4
	US4015	4
	US4030	4
	US4045	4
	US4060	4
Frequency	0	4
	25	16
	40	16
Time	0	4
	15	8
	30	8
	45	8
	60	8

Table A13. ANOVA results for wafer batter

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Batter Weight

F	df1	df2	Sig.
4.606	8	27	.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Time + Ultrasound + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Batter Weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	203.327[a]	8	25.416	23.635	<.001
Intercept	750239.445	1	750239.445	697656.794	<.001
Time	41.443	3	13.814	12.846	<.001
Ultrasound	69.620	1	69.620	64.740	<.001
Ultrasound * Time	81.838	3	27.279	25.367	<.001
Error	29.035	27	1.075		
Total	848227.780	36			
Corrected Total	232.362	35			

a. R Squared = .875 (Adjusted R Squared = .838)

Post Hoc Test
US Frequency
Homogeneous subset

Batter Weight

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
40	16	151.8125	
25	16		154.7625
0	4		155.0000
Sig.		1.000	.651

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 1.075.
a. Uses Harmonic Mean Sample Size = 8.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Batter Weight

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
40	16	151.8125	
25	16		154.7625
0	4		155.0000
Sig.		1.000	.651

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 1.075.
a. Uses Harmonic Mean Sample Size = 8.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Batter L* value

F	df1	df2	Sig.
177.097	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Ultrasound + Time + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Batter L* value

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6.954[a]	8	.869	39.585	<.001
Intercept	233830.274	1	233830.274	1064836.000	<.001
Ultrasound	.065	1	.065	2.951	.097
Time	1.861	3	.620	28.254	<.001
Ultrasound * Time	2.227	3	.742	33.811	<.001
Error	.593	27	.022		
Total	264354.342	36			
Corrected Total	7.547	35			

a. R Squared = .921 (Adjusted R Squared = .898)

Post Hoc Test
US Frequency
Homogeneous subset

Batter L* value

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
40	16	85.5475	
25	16	85.6375	
0	4		86.4800
Sig.		.235	1.000

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .022.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Batter L* value

Duncan[a,b,c]

Time	N	Subset 1	2	3	4
45	8	85.2938			
30	8		85.4900		
60	8		85.6313		
15	8			85.9550	
0	4				86.4800
Sig.		1.000	.093	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .022.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Batter a* value

F	df1	df2	Sig.
78.122	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Time + Ultrasound + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Batter a* value

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.378[a]	8	.047	4.200	.002
Intercept	33.246	1	33.246	2952.987	<.001
Time	.059	3	.020	1.737	.183
Ultrasound	.078	1	.078	6.929	.014
Ultrasound * Time	.208	3	.069	6.153	.003
Error	.304	27	.011		
Total	39.184	36			
Corrected Total	.682	35			

a. R Squared = .554 (Adjusted R Squared = .422)

Post Hoc Test
US Frequency
Homogeneous subset

Batter a* value

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
0	4	.9475	
25	16	.9956	.9956
40	16		1.0944
Sig.		.372	.074

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .011.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
US Time
Homogeneous subset

Batter a* value

Duncan[a,b,c]

Time	N	Subset 1	Subset 2
0	4	.9475	
60	8	.9775	.9775
30	8	1.0388	1.0388
45	8		1.0787
15	8		1.0850
Sig.		.149	.101

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .011.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Batter b* value

F	df1	df2	Sig.
41.294	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Ultrasound * Time + Ultrasound + Time

Tests of Between-Subjects Effects

Dependent Variable: Batter b* value

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29.811[a]	8	3.726	8.460	<.001
Intercept	8697.767	1	8697.767	19746.708	<.001
Ultrasound * Time	2.113	3	.704	1.599	.213
Ultrasound	13.926	1	13.926	31.616	<.001
Time	13.560	3	4.520	10.262	<.001
Error	11.893	27	.440		
Total	9931.343	36			
Corrected Total	41.703	35			

a. R Squared = .715 (Adjusted R Squared = .630)

Post Hoc Test
US Frequency
Homogeneous subset

Batter b* value

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
25	16	15.9419	
0	4	16.3575	
40	16		17.2613
Sig.		.221	1.000

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .440.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Batter b* value

Duncan[a,b,c]

Time	N	Subset 1	2	3
15	8	15.5413		
0	4		16.3575	
30	8		16.7625	16.7625
45	8		16.7863	16.7863
60	8			17.3163
Sig.		1.000	.276	.161

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .440.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Batter Flowability time when distance is 5cm (Glass Analysis)

F	df1	df2	Sig.
3.845	8	27	.004

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Ultrasound + Time + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Batter Flowability time when distance is 5cm (Glass Analysis)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	865.738[a]	8	108.217	97.297	<.001
Intercept	2485.249	1	2485.249	2234.454	<.001
Ultrasound	703.219	1	703.219	632.255	<.001
Time	49.226	3	16.409	14.753	<.001
Ultrasound * Time	46.928	3	15.643	14.064	<.001
Error	30.030	27	1.112		
Total	4036.437	36			
Corrected Total	895.769	35			

a. R Squared = .966 (Adjusted R Squared = .957)

Post Hoc Test
US Frequency
Homogeneous subset

Batter Flowability time when distance is 5cm (Glass Analysis)

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
25	16	5.1325	
0	4	5.5000	
40	16		14.5081
Sig.		.492	1.000

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = 1.112.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = ,05.

Post Hoc Test
Time
Homogeneous subset

Batter Flowability time when distance is 5cm (Glass Analysis)

Duncan[a,b,c]

		Subset			
Time	N	1	2	3	4
0	4	5.5000			
15	8		8.1625		
60	8			9.6050	
30	8			9.8613	
45	8				11.6525
Sig.		1.000	1.000	.661	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 1.112.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Batter Flowability time when distance is 10cm (Glass Analysis)

F	df1	df2	Sig.
6.936	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Time + Ultrasound + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Batter Flowability time when distance is 10cm (Glass Analysis)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	58481.500[a]	8	7310.188	40.904	<.001
Intercept	150428.680	1	150428.680	84.729	<.001
Time	10101.159	3	3367.053	18.840	<.001
Ultrasound	37668.949	1	37668.949	210.778	<.001
Ultrasound * Time	9679.715	3	3226.572	18.054	<.001
Error	4825.274	27	178.714		
Total	224229.434	36			
Corrected Total	63306.774	35			

a. R Squared = .924 (Adjusted R Squared = .901)

Post Hoc Test
US Frequency
Homogeneous subset

Batter Flowability time when distance is 10cm (Glass Analysis)

Duncan[a,b,c]

US Frequency	N	Subset 1	2	3
25	16	30.6563		
0	4		82.0000	
40	16			99.2756
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = 178.714.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Batter Flowability time when distance is 10cm (Glass Analysis)

Duncan[a,b,c]

		Subset		
Time	N	1	2	3
60	8	37.3213		
15	8		62.3050	
30	8		76.1113	76.1113
0	4			82.0000
45	8			84.1263
Sig.		1.000	.070	.311

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 178.714.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Batter Falling number time

F	df1	df2	Sig.
2.770	8	27	.022

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Time + Ultrasound + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Batter Falling number time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	232.380[a]	8	29.047	261.477	<.001
Intercept	1797.413	1	1797.413	16179.819	<.001
Time	53.690	3	17.897	161.101	<.001
Ultrasound	68.767	1	68.767	619.023	<.001
Ultrasound * Time	36.707	3	12.236	110.143	<.001
Error	2.999	27	.111		
Total	2000.079	36			
Corrected Total	235.379	35			

a. R Squared = .987 (Adjusted R Squared = .983)

Post Hoc Test
US Frequency
Homogeneous subset

Batter Falling number time

Duncan[a,b,c]

US Frequency	N	Subset 1	2	3
25	16	5.0312		
40	16		7.9631	
0	4			11.0350
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .111.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Batter Falling number time

Duncan[a,b,c]

		Subset			
Time	N	1	2	3	4
60	8	4.5487			
15	8		6.0988		
45	8			7.6375	
30	8			7.7038	
0	4				11.0350
Sig.		1.000	1.000	.720	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .111.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Batter pH

F	df1	df2	Sig.
382.026	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Time + Ultrasound + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Batter pH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.744[a]	8	.093	6.442	<.001
Intercept	1611,913	1	1611.913	111658.395	<.001
Time	.478	3	.159	11.048	<.001
Ultrasound	3.125E-6	1	3.125E-6	.000	.988
Ultrasound * Time	.252	3	.084	5.812	.003
Error	,390	27	.014		
Total	1831.405	36			
Corrected Total	1.134	35			

a. R Squared = .656 (Adjusted R Squared = .554)

Post Hoc Test
US Frequency
Homogeneous subset

Batter pH

Duncan[a,b,c]

US Frequency	N	Subset 1
0	4	7.0750
40	16	7.1369
25	16	7.1375
Sig.		.336

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = ,014.
a. Uses Harmonic Mean Sample Size = 8,000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = ,05.

Post Hoc Test
Time
Homogeneous subset

Batter pH

Duncan[a,b,c]

Time	N	Subset 1	2	3
30	8	6.9450		
0	4	7.0750	7.0750	
45	8		7.1425	7.1425
15	8		7.1788	7.1788
60	8			7.2825
Sig.		.059	.147	.053

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .014.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Batter Viscosity

F	df1	df2	Sig.
11.587	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Ultrasound + Time + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Batter Viscosity

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	27121700.000[a]	8	3390212.500	4.660	.001
Intercept	1328569363.843	1	1328569363.843	1826.266	<.001
Ultrasound	3699200.000	1	3699200.000	5.085	.032
Time	1611615.625	3	537205.208	.738	.538
Ultrasound * Time	212006.250	3	70668.750	.097	.961
Error	19641925.000	27	727478.704		
Total	1423544650.000	36			
Corrected Total	46763625.000	35			

a. R Squared = .580 (Adjusted R Squared = .456)

Post Hoc Test
US Frequency
Homogeneous subset

Batter Viscosity

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
25	16	5570.3125	
40	16	6250.3125	
0	4		8375.0000
Sig.		.122	1.000

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = 727478.704.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Batter Viscosity

Duncan[a,b,c]

Time	N	Subset 1	Subset 2
60	8	5640.6250	
45	8	5843.7500	
15	8	5894.3750	
30	8	6262.5000	
0	4		8375.0000
Sig.		.235	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 727478.704.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha =.05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Batter Texture (Stringness)

F	df1	df2	Sig.
8.421	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Ultrasound + Time + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Batter Texture (Stringness)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	61.893[a]	8	7.737	8.707	<.001
Intercept	3137.660	1	3137.660	3531.167	<.001
Ultrasound	22.559	1	22.559	25.388	<.001
Time	10.553	3	3.518	3.959	.018
Ultrasound * Time	19.223	3	6.408	7.211	.001
Error	23.991	27	.889		
Total	3508.173	36			
Corrected Total	85.884	35			

a. R Squared = .721 (Adjusted R Squared = .638)

Post Hoc Test
US Frequency
Homogeneous subset

Batter Texture (Stringness)

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
40	16	8.7283	
25	16		10.4075
0	4		11.2075
Sig.		1.000	.101

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = ,889.

a. Uses Harmonic Mean Sample Size = 8,000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Batter Texture (Stringness)

Duncan[a,b,c]

		Subset	
Time	N	1	2
30	8	9.0432	
60	8	9.2497	
15	8	9.4473	
45	8		10.5313
0	4		11.2075
Sig.		.468	.201

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .889.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Table A14. ANOVA results for wafer sheet

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Wafer Sheet Weight

F	df1	df2	Sig.
107.278	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Time + Ultrasound + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Wafer Sheet Weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	113.126[a]	8	14.141	26.089	<.001
Intercept	41424.831	1	41424.831	76427.749	<.001
Time	24.730	3	8.243	15.209	<.001
Ultrasound	23.222	1	23.222	42.844	<.001
Ultrasound * Time	18.177	3	6.059	11.179	<.001
Error	14.634	27	.542		
Total	45992.266	36			
Corrected Total	127.760	35			

a. R Squared = .885 (Adjusted R Squared = .852)

Post Hoc Test
US Frequency
Homogeneous subset

Wafer Sheet Weight

Duncan[a,b,c]

Frequency	N	Subset 1	2	3
40	16	34.4375		
25	16		36.1413	
0	4			38.9250
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .542.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Wafer Sheet Weight

Duncan[a,b,c]

Time	N	Subset 1	2	3
45	8	34.3875		
60	8	34.4638		
30	8		35.9250	
15	8		36.3813	
0	4			38.9250
Sig.		.851	.268	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .542.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Wafer Moisture Content

F	df1	df2	Sig.
76.020	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Ultrasound + Time + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Wafer Sheet Moisture Content

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8.214[a]	8	1.027	5.443	<.001
Intercept	233.340	1	233.340	1236.940	<.001
Ultrasound	1.781	1	1.781	9.443	.005
Time	1.549	3	.516	2.737	.063
Ultrasound * Time	.266	3	.089	.469	.706
Error	5.093	27	.189		
Total	252.835	36			
Corrected Total	13.308	35			

a. R Squared = .617 (Adjusted R Squared = .504)

Post Hoc Test
US Frequency
Homogeneous subset

Wafer Sheet Moisture Content

Duncan[a,b,c]

US Frequency	N	Subset 1	2	3
25	16	2.2169		
40	16		2.6888	
0	4			3.5925
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .189.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Wafer Sheet Moisture Content

Duncan[a,b,c]

		Subset	
Time	N	1	2
15	8	2.2475	
30	8	2.2525	
60	8	2.5350	
45	8	2.7762	
0	4		3.5925
Sig.		.050	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .189.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Wafer Sheet Texture (Hardness)

F	df1	df2	Sig.
2.596	8	27	.030

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Ultrasound * Time + Ultrasound + Time

Tests of Between-Subjects Effects

Dependent Variable: Wafer Sheet Texture (Hardness)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1216297.451[a]	8	15203.181	21.339	<.001
Intercept	25349709.945	1	25349709.945	3557.913	<.001
Ultrasound * Time	76865.777	3	25621.926	3.596	.026
Ultrasound	808988.820	1	808988.820	113.544	<.001
Time	300239.155	3	100079.718	14.047	<.001
Error	192371.819	27	7124.882		
Total	29458950.986	36			
Corrected Total	1408669.269	35			

a. R Squared = .863 (Adjusted R Squared = .823)

Post Hoc Test
US Frequency
Homogeneous subset

Wafer Sheet Texture (Hardness)

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
40	16	713.4681	
0	4		964.6350
25	16		1031.4675
Sig.		1.000	.125

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = 7124.882.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Wafer Sheet Texture (Hardness)

Duncan[a,b,c]

		Subset	
Time	N	1	2
45	8	754.1263	
60	8	802.4625	
30	8		945.5800
0	4		964.6350
15	8		987.7025
Sig.		.305	.398

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 7124.882.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Wafer Sheet L* value

F	df1	df2	Sig.
11.057	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Ultrasound + Time + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Wafer Sheet L* value

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	724.033[a]	8	90.504	3.768	.004
Intercept	185407.748	1	185407.748	7718.568	<.001
Ultrasound	112.575	1	112.575	4.687	.039
Time	173.379	3	57.793	2.406	.089
Ultrasound * Time	12.002	3	4.001	.167	.918
Error	648.567	27	24.021		
Total	204626.300	36			
Corrected Total	1372.600	35			

a. R Squared = .527 (Adjusted R Squared = .387)

Post Hoc Test
US Frequency
Homogeneous subset

Wafer Sheet L* value

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
25	16	72.0475	
40	16	75.7988	
0	4		84.8700
Sig.		.137	1.000

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = 24.021.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Wafer Sheet L* value

Duncan[a,b,c]

Time	N	Subset 1	2	3
15	8	70.7700		
60	8	73.7150	73.7150	
30	8	73.8663	73.8663	
45	8		77.3413	
0	4			84.8700
Sig.		.286	.213	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 24.021.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Wafer Sheet a* value

F	df1	df2	Sig.
758.260	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Ultrasound + Time + Ultrasound * Time

Tests of Between-Subjects Effects

Dependent Variable: Wafer sheet a* value

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	169.426[a]	8	21.178	6.517	<.001
Intercept	1167.278	1	1167.278	359.178	<.001
Ultrasound	21.764	1	21.764	6.697	.015
Time	43.039	3	14.346	4.414	.012
Ultrasound * Time	2.009	3	.670	.206	.891
Error	87.746	27	3.250		
Total	1862.510	36			
Corrected Total	257.172	35			

a. R Squared = .659 (Adjusted R Squared = .558)

Post Hoc Test
US Frequency
Homogeneous subset

Wafer sheet a* value

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
0	4	1.9025	
40	16		6.4500
25	16		8.0994
Sig.		1.000	.078

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = 3.250.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Wafer sheet a* value

Duncan[a,b,c]

Time	N	Subset 1	2	3
0	4	1.9025		
45	8		5.3950	
60	8			7.4900
30	8			7.6512
15	8			8.5625
Sig.		1.000	1.000	.315

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 3.250.
a. Uses Harmonic Mean Sample Size = 6.667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Wafer sheet color b* value

F	df1	df2	Sig.
293.950	8	27	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Ultrasound * Time + Ultrasound + Time

Tests of Between-Subjects Effects

Dependent Variable: Wafer sheet color b* value

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	127.478[a]	8	15.935	1.603	.171
Intercept	21906.556	1	21906.556	2203.513	<.001
Ultrasound * Time	30.610	3	10.203	1.026	.397
Ultrasound	2.470	1	2.470	.248	.622
Time	52.909	3	17.636	1.774	.176
Error	268.425	27	9.942		
Total	25966.577	36			
Corrected Total	395.902	35			

a. R Squared = .322 (Adjusted R Squared = ,121)

Post Hoc Test
US Frequency
Homogeneous subset

Wafer sheet color b* value

Duncan[a,b,c]

US Frequency	N	Subset 1	Subset 2
0	4	23.6150	
25	16	26.7531	26.7531
40	16		27.3088
Sig.		.057	.727

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = 9.942.

a. Uses Harmonic Mean Sample Size = 8.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Post Hoc Test
Time
Homogeneous subset

Wafer sheet color b* value

Duncan[a,b,c]

Time	N	Subset 1	Subset 2
0	4	23.6150	
45	8	25.5000	25.5000
15	8	26.0388	26.0388
30	8		28.0662
60	8		28.5188
Sig.		.196	.120

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 9.942.
a. Uses Harmonic Mean Sample Size = 6,667.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = ,05.

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