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THE EFFECT OF ULTRASOUND PRETREATMENT ON OIL ABSORPTION AND QUALITY OF DEEP-FRIED CHICKEN SCHNITZELS

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ABSTRACT
Although deep-fried products are enjoyed by consumers of different age groups, they contain large amounts of oil, which affects product quality and cannot fail to meet the demand for a healthy diet. In this study, the effect of ultrasound pretreatment on the oil absorption and quality of deep-fried chicken schnitzels was investigated. For this purpose, chicken schnitzel samples were subjected to ultrasound pretreatment at different amplitudes (32 and 64%) and times (10, 20, and 30 min) and then deep-fried at 180 °C. Ultrasound pretreatment improved the crispness by reducing the hardness of schnitzel samples and also reduced oil absorption by 36-53%. According to the findings obtained from SEM analysis, ultrasound pretreatment caused collapses and deformations in the microstructure of the schnitzel samples, leading to the formation of many microscopic channels. Also, ultrasound pretreatment kept the original sensory properties of the schnitzel samples. These results show that ultrasound pretreatment has greatly improved the quality of chicken schnitzels.
Keywords: Ultrasound, schnitzel, deep-frying, oil absorption

ULTRASON ÖN İŞLEM UYGULAMASININ DERİN YAĞDA KIZARTILMIŞ TAVUK ŞNİTZELLERİN YAĞ EMİLİMİNE VE KALİTESİNE ETKİSİ

ÖZ
Derin yağda kızartılmış ürünler, farklı yaş grubundaki tüketiciler tarafından sevilse de ürün kalitesini etkileyen ve sağlıklı bir diyet talebini karşılayamayan fazla miktarda yağ içerirler. Bu çalışmada, ultrason ön işlem uygulamasının derin yağda kızartılmış tavuk şnitzellerin yağ emilimi ve kalitesi üzerine etkisi araştırılmıştır. Bu amaçla tavuk şnitzel örnekleri farklı genlik (%32 ve 64) ve sürelerde (10, 20 ve 30 dk) ultrason ön işlemine tabi tutulmuş ve daha sonra 180 °C'de derin yağda kızartılmıştır. Ultrason ön işlemi şnitzel örneklerinin sertliğini azaltarak gevrekliği iyileştirmiş ve yağ emilimini de %36-53 oranında azaltmıştır. SEM analizinden elde edilen bulgulara göre, ultrason ön işlemi şnitzel örneklerinin mikro yapısında çökmelere ve deformasyonlara neden olarak birçok mikroskobik kanalın oluşmasına yol açmıştır. Aynı zamanda, ultrason ön işlemi şnitzel örneklerinin orijinal duyusal özelliklerini de korumuştur. Bu sonuçlar, ultrason ön işleminin tavuk şnitzellerin kalitesini önemli ölçüde iyileştirdiğini göstermektedir.
Anahtar kelimeler: Ultrason, şnitzel, derin yağda kızartma, yağ emme

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INTRODUCTION

Chicken schnitzel is an important industrial chicken meat product classified within the scope of coated products and consumed by deep-frying (Anonymous, 2021). Fried foods have widespread popularity worldwide and are enjoyed by people of all ages due to their attractive flavor, desirable color, and crispy texture that cannot be developed with other cooking techniques (Choe and Min, 2007; Ananey-Obiri et al., 2020; Zhang et al., 2021a, b). Frying is a process that involves simultaneous heat and mass transfer, in which frying oil is the medium of heat transfer into the food, while moisture migrates out and oil is absorbed into the food (Oke et al., 2018; Cozain Montiel et al., 2022). As a result of oil absorption, there is a significant increase in the amount of fat and, consequently, the calorie value of fried foods. In some cases, the amount of fat reaches up to one-third of the total food product's weight (Myers and Brannan, 2012; Zeng et al., 2016; Cozain Montiel et al., 2022). Eating foods with such high levels of fat can make it hard to follow the recommendation of less than 35% of one's daily calories being contributed from fat and to meet consumers' demand to maintain a healthier diet (Myers and Brannan, 2012). There are many reports that the consumption of high-fat food has adverse effects on health and might lead to diseases such as cardiovascular, hypertension, obesity, and cancers (Varela and Fiszman, 2011; Ananey-Obiri et al., 2020; Chayawat and Rumpagaporn, 2020; Zhang et al., 2021a, b).

Recently, many researchers have been studying different methods to reduce the fat content and improve the quality of fried products. Oil absorption is a complex and surface-oriented phenomenon resulting from the competition between drainage and absorption during frying (Bouchon et al., 2001; Cozain Montiel et al., 2022). Oil enters fried food as a direct result of water loss and oil absorption during frying, and this process is particularly affected by voids and pores near the surface (Rice and Gamble, 1989; Cozain Montiel et al., 2022). Pretreatment methods play a key role in reducing oil absorption of fried foods and are classified into two groups as traditional and innovative techniques (Zhang et al., 2021a). Traditional methods are based on common and old methods used for frying foods. These consist of different applications such as hot air drying (Dehghanny et al., 2016; Zhang and Fan, 2021), blanching (Sobukola et al., 2008; Ngobese and Workneh, 2018), coating (Ananey-Obiri et al., 2018), osmotic dehydration (Karizaki et al., 2013; Piyalungka et al., 2019) and freezing (Albertos et al., 2016). However, these traditional pretreatment methods have some disadvantages, such as high energy consumption, long process time, and low efficiency (Oladejo et al., 2018; Zhang et al., 2021a). Therefore, innovative methods are needed to reduce oil absorption.

Ultrasound, an innovative non-thermal technique, has been widely researched in recent years due to its economic benefits, environmentally friendly impact, efficiency, and ability to preserve nutritional components (Oladejo et al., 2018; Piyalungka et al., 2019; Zhang et al., 2021a; Yu et al., 2021). Ultrasound is a type of vibrational energy that operates with frequencies above 20 kHz. Two important parameters of ultrasonic processes are frequency and power, which can determine process conditions and application areas of ultrasound (Yu et al., 2021). Ultrasound technology may be an effective application in improving the quality and reducing oil absorption of fried foods.

The effect of ultrasound pretreatment or the combination of ultrasound and other technologies on oil absorption and product quality has been examined in limited studies on vegetable products such as potato (Karizaki et al., 2013; Dehghanny et al., 2016), corn tortilla chips (Janve et al., 2015), potato chips (Zhang and Fan, 2021; Zhang et al., 2021a, b) and sweet potato (Oladejo et al., 2017a, b). There is no study in the literature on the effect of this pretreatment on fat absorption and other quality characteristics in muscle foods such as schnitzel. Chicken meat differs from plant foods in terms of chemical composition and structural properties, which may affect oil absorption during deep-frying through a different mechanism. For this reason, innovative techniques need to be studied in animal foods in order to make coated chicken products, which have widespread consumption potential, healthier and deliver them to consumers, thus providing economic benefits to producers by reducing oil absorption. The primary aims of this study planned in this context were: i) to determine the effect of ultrasound pretreatment on quality characteristics such as oil absorption, texture and color of deep-fried chicken schnitzels and ii) to reveal the potential of breaded chicken products to benefit consumers by making them healthier.

MATERIAL AND METHOD

Materials

Fresh chicken breasts (Şen Piliç, Sakarya, Turkey) used in this study were obtained from a local butcher shop (Samsun, Turkey) and kept in a refrigerator at 4 °C until the ultrasound pretreatment procedure (~30 min). The materials including wheat flour (Misun Un, Amasya, Turkey), breadcrumbs (Bahartat Baharat, Samsun, Turkey), egg, and salt (Billur Tuz, İzmir, Turkey) used in preparing chicken schnitzels and sunflower oil (Karadenizbirlik, Amasya, Turkey) used as frying media were purchased from a local supermarket (Samsun, Turkey). All reagents were of analytical grade unless otherwise stated.

Ultrasound pretreatment process

For the ultrasound pretreatment process, chicken breasts were sliced 6 cm x 10 cm x 1 cm (~50 g) using a knife, and 3 slices of chicken breast were placed in an 800 mL glass beaker containing 450 mL of distilled water. A titanium probe with a diameter of 1.3 cm of the ultrasonic processor (VCX 750, Sonics & Materials, Inc., USA) was immersed in a depth of approximately 2.5 cm in distilled water to create acoustic cavitation, and slices were pretreated with 20 kHz ultrasound at two different amplitudes (32 and 64%) and at three different times (10, 20, and 30 min). Slices without ultrasound pretreatment served as control. During the ultrasonic pretreatment processes, ice was placed on the outside of the glass beaker, and thus the water temperature was kept constant at 25 ± 1 ºC. The experimental design of ultrasound pretreatment process is given in Table 1.

Table 1. Experimental design of ultrasound pretreatment process

Ultrasound pretreatment conditions		
Amplitude (%)	Time (min)	Abbreviations
-	-	Control
32	10	UP32-10
32	20	UP32-20
32	30	UP32-30
64	10	UP64-10
64	20	UP64-20
64	30	UP64-30

Preparation and deep-frying of chicken schnitzels

After the ultrasound pretreatment process, the chicken breast slices were dried with absorbent paper and rubbed thoroughly by adding 1.5% salt. The salted slices were dipped in wheat flour and then in a mixture containing egg yolk and white. Lastly, the slices were gently dipped in breadcrumbs, and all their surfaces were evenly coated with breadcrumbs. The resulting coated slices were deep-fried in sunflower oil at 180 °C for 5 min using a deep fryer (Remta R90, Istanbul, Turkey). The oil temperature was constant during frying, and the experiment was always performed with fresh oil. After frying, schnitzel samples were removed from the deep fryer and placed on a wire mesh at room temperature for about 10 min to remove excess surface oil. All pretreatments and frying processes were performed in triplicate.

Moisture and total fat analysis

The moisture content of chicken schnitzel samples was determined by drying in an oven at 105 ºC until constant weight (AOAC, 2000). The total fat content of samples (dry basis, g/g) was determined quantitatively using the Soxhlet extraction method with diethyl ether as a solvent (AOAC, 2000).

Oil absorption
The oil absorption was calculated using the oil content of the sample before and after frying as follows (Ananey-Obiri et al., 2020):

$$\text{Oil absorption (\%)} = \frac{OC_{af} - OC_{bf}}{OC_{bf}} \times 100 \qquad (1)$$

Here, OCaf and OCbf represent the oil content of the sample after and before frying (g), respectively.

Hardness analysis
The hardness of fried chicken schnitzels with a mean of 50 mm diameter and 10 mm thickness was analyzed using a Texture Analyzer (TA-XT Plus, Stable Micro Systems, Surrey, UK) with a 50 mm aluminum cylindrical probe (model P/50R) and a 2 kg load cell. Measurements were made on chicken schnitzels cooled to room temperature (20±2 °C) after deep-frying at a compression/test speed of 5 mm/s and 60% strain.

Color analysis
The surface color of chicken schnitzels was measured at three different locations of each sample using a colorimeter (Chroma meter CR 400, Minolta, Japan) according to the CIELAB color system. The colorimeter was calibrated using white and black standard tiles, illuminate D65, and a 10° standard observer before testing. The color of the chicken schnitzels was expressed as *L** (lightness/brightness), *a** (redness/greenness), and *b** (yellowness/blueness) values. In addition, the total color change between the fried sample and raw sample was calculated as total color difference (Δ*E**) as follows (Zhang et al., 2021a):

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \qquad (2)$$

Scanning electron microscopy (SEM) analysis
The microscopic structure of deep-fried chicken schnitzels was visualized by JSM-7001F Jeol (Japan) scanning electron microscope (SEM). Before visualization, deep-fried chicken schnitzels were defatted by the Soxhlet extraction method mentioned in the "Moisture and total fat analysis" section and dried using a freeze dryer (Christ Alpha 1-2 LD Plus, France). The dried samples were coated with gold-palladium (Quorum SC7620, Laughton, UK). Then these samples were visualized at 10 kV, and photographs were taken at magnifications of 500, 1000, and 1500.

Sensory evaluation
The sensory evaluation of deep-fried chicken schnitzels was conducted by an experienced panelist group of 30 members from the staff and graduate students of the Department of Food Engineering, Ondokuz Mayis University, Turkey. The evaluation was done in a well-lit and ventilated sensory evaluation room, and samples were presented to panelists on white plates coded with 3-digit numbers. The panelists were instructed to cleanse their palates with provided drinking water between tastings. The overall appearance, surface color, internal color, flavor, oiliness, and juiciness of the fried chicken schnitzels were evaluated using a nine-point hedonic scale (1= dislike extremely, 9= like extremely). The overall acceptability scores were also calculated from the arithmetic mean of the scores of all sensory characteristics (Turhan et al., 2014).

Statistical analysis
The experiments were triplicated independently, and the data were expressed as means ± standard deviations (SD). Statistical analyses of the results were performed using one-way analysis of variance and a Duncan multiple range test at a 5% significance level using the SPSS 21 statistical software (IBM, Chicago, IL, USA).

RESULTS AND DISCUSSION

Moisture, total fat and oil absorption of deep-fried chicken schnitzels
The moisture content of deep-fried chicken schnitzels varied from 32.26 to 52.54% (Table 2), and the effect of ultrasound pretreatment on the moisture content of the chicken schnitzels was significant (P <0.01). The lowest moisture content was determined in the control sample without ultrasound pretreatment, and all the ultrasound-pretreated samples exhibited higher moisture values than the control (P <0.05). Depending on the amplitude and time parameters

of the ultrasound pretreatment, some differences were also observed between the moisture contents of the fried schnitzel samples. For example, the UP32-10 sample showed a lower moisture value than all other ultrasound-pretreated samples (P <0.05).

Table 2. Effect of ultrasound pretreatment on moisture, total fat, oil absorption and hardness of deep-fried chicken schnitzels

Samples	Moisture (%)	Total fat (%)	Oil absorption (%)	Hardness (N)
Control	32.26±0.78^{e}	29.79±0.24^{a}	22.15±2.11^{a}	241.78±66.20^{a}
UP32-10	44.06±1.03^{d}	25.02±0.96^{c}	14.11±1.03^{b}	162.48±46.92^{b}
UP32-20	46.95±1.46^{c}	26.77±0.07^{b}	11.19±1.21^{bc}	81.28±40.79^{c}
UP32-30	48.22±0.09^{bc}	25.65±1.03^{bc}	14.21±1.54^{b}	12.23±3.53^{d}
UP64-10	52.54±1.22^{a}	23.07±0.07^{d}	13.06±0.55^{bc}	23.75±17.88^{d}
UP64-20	47.87±0.92^{bc}	26.15±0.86^{bc}	10.38±0.14^{c}	14.35±9.92^{d}
UP64-30	49.36±0.38^{b}	22.71±0.38^{d}	12.50±1.20^{bc}	15.89±3.61^{d}
Significance	**	**	**	**

Values are presented as means ± SD from triplicate experiments. The different superscript letters in column indicate significant differences among samples at P <0.05 as assessed by Duncan's multiple range test. **P <0.01. Control, sample without ultrasound pretreatment; UP32-10, ultrasound pretreated sample at 32% amplitude for 10 min; UP32-20, ultrasound pretreated sample at 32% amplitude for 20 min; UP32-30, ultrasound pretreated sample at 32% amplitude for 30 min; UP64-10, ultrasound pretreated sample at 64% amplitude for 10 min; UP64-20, ultrasound pretreated sample at 64% amplitude for 20 min; UP64-30, ultrasound pretreated sample at 64% amplitude for 30 min.

One of the most critical problems in the consumption of coated products is the amount of absorbed oil during frying, and it is essential to keep the oil absorption at a minimum level during the frying of such products (Gökçe et al., 2016). As with the moisture content, the effect of ultrasound pretreatment on the total fat content of chicken schnitzels was also significant (P <0.01), and the highest value was found in the control sample, with 29.79% (P <0.05) (Table 2). Depending on the amplitude and time parameters of the ultrasound pretreatment, some differences were also observed between the total fat contents of the fried schnitzel samples. For example, while the UP64-30 and UP64-10 samples showed lower total fat contents than the other ultrasound-pretreated samples (P <0.05), the differences between the total fat contents of the UP32-10, UP32-30, and UP64-20 samples were not significant (P >0.05). The amount of oil absorbed by the chicken schnitzel samples during frying was generally parallel with the amount of total fat, and all the ultrasound pretreated samples absorbed less oil than the control sample (P <0.05) (Table 2). However, all ultrasound pretreated schnitzel samples generally absorbed oil in similar amounts during frying. Accordingly, ultrasound pretreatment significantly reduced the oil absorption during frying, and this decrease was calculated as the lowest in the UP32-10 and UP32-30 samples, with 36%, and the highest in the UP64-20 sample, with 53%.

Oil absorption in fried breaded and battered foods can be explained by three mechanisms, including water replacement, a cooling-phase effect, and the surfactant theory of frying. All three mechanisms describe the strong dependence of oil absorption on the microstructure and surface properties of fried foods (Zeng et al., 2016; Cui et al., 2022). According to the water replacement mechanism, the moisture in the food goes out through the pores during frying, and then large pores formed by moisture evaporation are filled with oil; thus, the product's amount of oil increases (Cui et al., 2022). The fact that ultrasound pretreatment reduces the total oil content and oil absorption of chicken schnitzel samples could be explained by the changes in microstructure during ultrasound pretreatment and the water replacement mechanism of oil uptake during frying (Dehghannya et al., 2016; Zhang et al., 2021a, b). Because during deep-frying, heat is transferred by convection from the oil to the surface of the food and then into the core by conduction. The moisture from the food escapes through weak crevices and forcefully dug pores created by water pressure. Although some oil may replace some removed water, the overpressure development during frying prevents substantial oil absorption (Oke et al., 2018). Accordingly, some pores, voids, and cracks formed in the schnitzel samples after the ultrasound pretreatment may have caused a decrease in the total amount of oil by creating vapor pressure with the evaporation of water during frying, preventing the oil from being absorbed into the product (Ghaderi et al., 2018; Zhang et al., 2021a).

Different researchers have studied the reduction of oil absorption of foods by ultrasound pretreatment or the combination of ultrasound and other technology and have generally reported similar results. For example, Karizaki et al. (2013) stated that ultrasound-assisted osmotic dehydration as a pretreatment before frying reduced the oil content of fried potatoes by 12.5 % (dry basis) compared to untreated samples. In another study, it was examined the simultaneous effect of ultrasound and pre-drying on the oil uptake of fried potato strips and reported that pretreatment with both ultrasound and drying significantly decreased the oil uptake of samples compared to the control (Dehghannya et al., 2016). In the study performed by Oladejo et al. (2017a), the possibility of ultrasound-assisted pretreatments of sweet potato to lower the moisture content and oil uptake during deep fat frying and its effects on the mass transfer rate was investigated. The lowest moisture content was found in fried samples pretreated in ultrasound-assisted osmotic dehydration and osmotic dehydration without ultrasound, while the lowest oil uptake was obtained in fried samples pretreated in ultrasound, having 65.11 and 71.47% oil reduction at temperatures of 150 and 170 °C, respectively, compared to the untreated sample. Finally, Zhang et al. (2021a) studied the effect of ultrasound pretreatment on the quality and oil absorption of fried potato chips and reported that ultrasound pretreatment (360 W, 60 min) decreased penetrated surface oil content of potato chips, causing a 27.66% decrease in total oil content.

Hardness of deep-fried chicken schnitzels

Crispness, a textural property, is a substantial and important index of fried products, and it is closely related to rapid fracture under stress at small strains. It refers to the quality of brittle materials that rapidly fracture under stress at small strains. The maximum force achieved before the fracture is also defined as hardness (Zhang and Fan, 2021). Many studies showed that hardness was negatively related to crispiness (Zhang et al., 2021a; Zhang and Fan, 2021). The highest hardness value was determined in the control schnitzels with 241.78 N, and ultrasound pretreatment reduced the hardness values of the schnitzel samples ($P < 0.05$) (Table 2). The fact that ultrasound pretreatment reduces the hardness value of the samples can be explained by the cavitation and "sponge effect" of ultrasound. This effect creates additional microchannels in the product and reduces the breaking force by producing higher vapor pressure during frying (Zhang et al., 2021a). Accordingly, ultrasound pretreatment contributed to increasing the evaporation rate of water by creating pores, cracks, and microchannels in schnitzel samples. As a result, chicken schnitzels subjected to ultrasound pretreatment exhibited lower hardness values, and ultrasound pretreatment improved the crispness of fried samples.

Depending on the amplitude and time parameters of the ultrasound pretreatment, some differences were also observed between the hardness values of the fried schnitzel samples. For example, while the UP32-10 sample showed higher hardness values than the other ultrasound-pretreated samples ($P < 0.05$), the differences between the hardness values of the UP32-30, UP64-10, UP64-20, and UP64-30 samples were not significant ($P > 0.05$). As in the present study, it was also reported by some researchers that ultrasound and some other pretreatments combined with ultrasound affected the hardness value of deep-fried foods. As in our findings, most of these studies indicated that ultrasound pretreatment reduced the product's hardness. For example, Zhang et al. (2021a) reported that potatoes subjected to ultrasound pretreatment showed a lower hardness value compared to the control sample ($P < 0.05$) and that pretreatment at 600 W was more effective than 360 W (*P* <0.05). In another study, it was reported that the hardness value of potato chips with the same water content was lower in those subjected to air drying combined with ultrasound before frying than in those subjected to air drying alone. This decrease was calculated as 21.48% in potato chips containing 80% water and 16.54% in potato chips containing 50% water (Zhang and Fan, 2021). Findings obtained by Karizaki et al. (2013) also supported the results of the current study. Researchers reported that the pretreatment of potato slices before frying affected the hardness values, and both osmotic dehydration and ultrasound-assisted osmotic dehydration pretreatment caused softening in texture. Accordingly, the results of the present study indicate that ultrasound pretreatment before frying can reduce the hardness and improve the crispness of fried foods.

Color parameters of deep-fried chicken schnitzels

Color is one of the most important appearance characteristics affecting consumer acceptance of fried foods (Zhang et al., 2021a). Generally, the end of the frying process is determined by using color. The final color of fried products is influenced by the Maillard reaction that occurs between reducing sugars and protein sources, and the amount of absorbed oil (Karizaki et al., 2013). The *L** values of the control sample without ultrasound pretreatment and the samples subjected to ultrasound pretreatment at different amplitudes and times ranged from 50.74 to 53.91, *a** values from 15.25 to 17.33, and *b** values from 27.86 to 32.16 (Table 3). Uyarcan et al. (2022) reported similar color values in chicken breast meats coated with different cereal sources (buckwheat, chickpea, and rice flours) and deep-fried, while Ananey-Obiri et al. (2020) reported different color values in chicken drumstick coated with different concentrations of chicken protein and deep-fried. These different results could be attributed to various factors such as product type, composition of the coating material, cooking temperature, cooking time, and properties of the frying oil.

Table 3. Effect of ultrasound pretreatment on color of deep-fried chicken schnitzels

Samples	*L**	*a**	*b**	Δ*E**
Control	52.97±4.90	17.33±1.38^{a}	31.56±5.69^{a}	-
UP32-10	53.91±6.54	15.71±2.38^{bc}	32.16±7.21^{a}	11.12±7.16
UP32-20	53.48±5.54	15.93±1.85^{bc}	31.95±6.11^{a}	9.85±5.67
UP32-30	52.90±4.86	16.06±2.57^{bc}	30.30±5.89^{ab}	9.35±5.66
UP64-10	52.80±5.51	16.48±1.93^{ab}	29.79±6.26^{ab}	9.56±5.60
UP64-20	53.17±5.98	15.25±2.16^{c}	30.95±6.85^{a}	12.25±7.50
UP64-30	50.74±5.10	16.30±1.96^{b}	27.86±5.84^{b}	10.08±6.01
Significance	ns	**	*	ns

Values are presented as means ± SD from triplicate experiments. The different superscript letters in column indicate significant differences among samples at *P* < 0.05 as assessed by Duncan's multiple range test. ns: not significant (*P* >0.05); **P* <0.05; ***P* <0.01. Control, sample without ultrasound pretreatment; UP32-10, ultrasound pretreated sample at 32% amplitude for 10 min; UP32-20, ultrasound pretreated sample at 32% amplitude for 20 min; UP32-30, ultrasound pretreated sample at 32% amplitude for 30 min; UP64-10, ultrasound pretreated sample at 64% amplitude for 10 min; UP64-20, ultrasound pretreated sample at 64% amplitude for 20 min; UP64-30, ultrasound pretreated sample at 64% amplitude for 30 min.

While the effect of ultrasound pretreatment on the *L** and Δ*E** values of schnitzel samples was not significant (*P* >0.05), its effect on *a** and *b** values was significant at 1% and 5% levels, respectively (Table 3). The highest *a** value of 17.33 was determined in the control schnitzels, and all samples with ultrasound pretreatment, except for the UP64-10 sample, showed lower *a** values than the control sample (*P* <0.05). The lowest *a** value was determined in the UP64-20 sample, but the differences between *a** value of this sample and *a** values of the UP32-10, UP32-

20, and UP32-30 samples were not significant (*P* >0.05). The golden-yellow color is desired in deep-fried foods and is considered an important quality parameter (Oladejo et al., 2018). Except for the UP64-30 sample, all other ultrasound-pretreated samples exhibited a yellowness (*b**) value similar to the control sample (*P* >0.05). The results of color reveal that ultrasound pretreatment has a partial effect on the color of chicken schnitzels.

There are limited studies on the effect of ultrasound and some other pretreatments combined with ultrasound on the color values of deep-fried foods. In one of these studies, Zhang et al. (2021a) reported that *L**, *a**, *b**, and Δ*E** values of ultrasound pretreated and deep-fried potato chips were between 66.75 and 67.49, 1.43 and 1.68, 26.90 and 28.33, and 22.10 and 25.12, respectively, but these differences were not significant (*P* >0.05). In another study, it was shown that air drying pretreatment combined with ultrasound increased the *L** and *a** values of deep-fried potato chips but had no significant effect on b* values (Zhang and Fan, 2021). Finally, Oladejo et al. (2017b) reported that ultrasound pretreatment increased the brightness (*L**) and decreased redness (*a**) of sweet potatoes, while ultrasound-assisted osmotic dehydration pretreatment enhanced the yellowness (*b**) in sweet potatoes.

Microstructure of deep-fried chicken schnitzels

Observation of microstructural changes during the processing of foods greatly assists in understanding the mechanisms involved and their modeling. In recent years, extensive research has been conducted on the use of SEM images to understand better the changes that occur in the structural properties of foods during processing (Karizaki et al., 2013). The microstructural changes of ultrasound-pretreated at different amplitudes and times and deep-fried chicken schnitzels were visualized with SEM, and the images are presented in Figure 1.

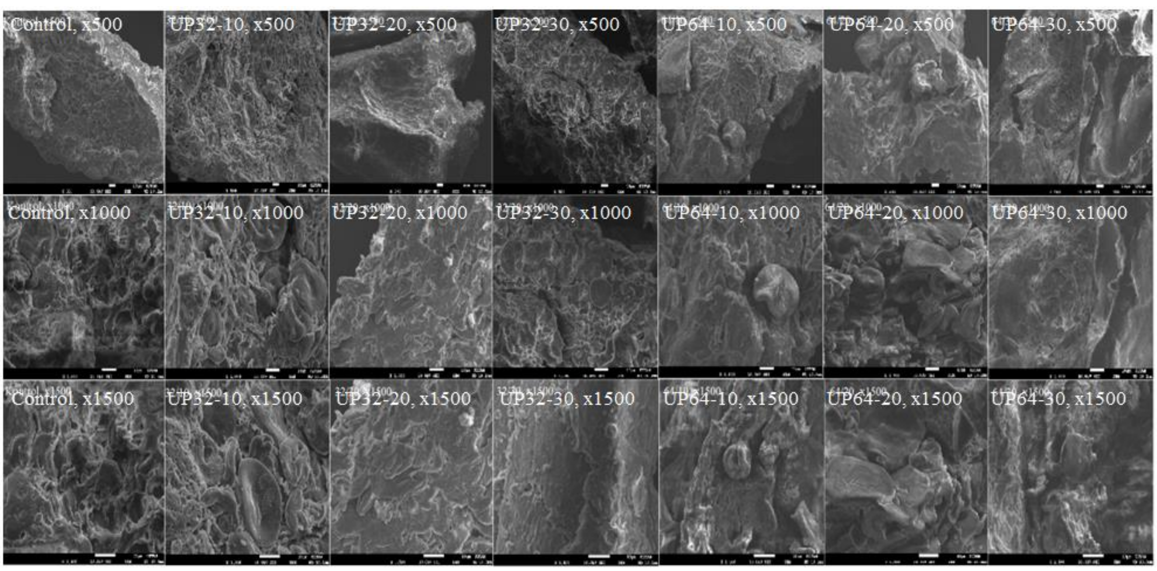

Figure 1. SEM images of ultrasound-pretreated and deep-fried chicken schnitzels. Control, sample without ultrasound pretreatment; UP32-10, ultrasound pretreated sample at 32% amplitude for 10 min; UP32-20, ultrasound pretreated sample at 32% amplitude for 20 min; UP32-30, ultrasound pretreated sample at 32% amplitude for 30 min; UP64-10, ultrasound pretreated sample at 64% amplitude for 10 min; UP64-20, ultrasound pretreated sample at 64% amplitude for 20 min; UP64-30, ultrasound pretreated sample at 64% amplitude for 30 min.

The SEM images showed that there was no noticeable change in the microstructure of the control samples, while ultrasound pretreatment caused collapses and deformations in the microstructure of the schnitzel samples, leading to the formation of many microscopic channels, including pores and cracks. These noticeable changes in the microstructure of ultrasound-pretreated schnitzels can be explained by the cavitation effect of ultrasound waves (Zhang et al., 2021a). These physical collapses and deformations at the cellular level, in response to acoustic cavitation, are the main reasons for the low oil absorption (Oladejo et al., 2017a). As mentioned above, pores and cracks formed in the schnitzel samples after the ultrasound pretreatment may have caused a decrease in the total amount of oil by creating vapor pressure with the evaporation of water during frying, preventing the oil from being absorbed into the product (Ghaderi et al., 2018; Zhang et al., 2021a).

Collapse and deformations in the microstructure of potatoes pretreated-ultrasound were also reported by some researchers. For example, Zhang et al. (2021a) reported that progressive collapses of cell structure were observed in pretreated ultrasound samples and that this disruption of the cell walls and deformation of the cell tissues were more in the samples with the pretreatment at 600 W for 60 min. Similar results were reported by Miano et al. (2019), and they demonstrated ultrasound caused surface erosion and the formation of micro-channels in potato tissue (especially after 60 min of pretreatment). In another study, the characterization of microstructural changes of ultrasound-combined convective air-drying pretreated potato chips at the frying temperature of 180 °C was observed with SEM, and it was reported that ultrasound-combined convective air-drying pretreatment resulted in more pores and microscopic channels (Zhang and Fan, 2021). The effect of ultrasound on microstructure has also been studied in animal foods. Inguglia et al. (2021) showed the formation of micro-channels on the meat surface when processed using ultrasound compared to untreated meat.

Sensory evaluation of deep-fried chicken schnitzels

Sensory evaluation (overall appearance, surface color, internal color, flavor, oiliness, juiciness, and overall acceptability) results of ultrasound-pretreated at different amplitudes and times and deep-fried chicken schnitzels are presented in Figure 2. While the effect of ultrasound pretreatment on the flavor, oiliness, and overall acceptability scores of schnitzel samples was significant ($P < 0.05$), its effect on overall appearance, surface color, internal color, and juiciness scores was not significant ($P > 0.05$). The lowest flavor score was given by the panelists to the control sample with 6.07, and all other pretreated schnitzel samples were evaluated with a higher score than the control sample ($P < 0.05$). Ultrasound pretreatment caused schnitzel samples to be generally more liked in terms of oiliness and overall acceptability. This liking was higher in the UP32-20, UP32-30, UP64-20, and UP64-30 samples in terms of oiliness and only in the UP32-20 sample in terms of overall acceptability than the control sample ($P < 0.05$). The fact that ultrasound-pretreated schnitzel samples are generally more liked in terms of flavor, oiliness, and overall acceptability could be explained by the better hardness attribute and lower fat content of these samples. These results indicate that ultrasound pretreatment can keep the original sensory properties of chicken schnitzel samples and even improve their flavor, oiliness, and overall acceptability.

Similar results were also reported by Zhang et al. (2021a), and they demonstrated that ultrasound pretreatment did not cause a significant change in the color scores of potato chips ($P < 0.05$), but it increased the overall acceptability scores, and the highest acceptability scores were determined in those pretreated at 360 W for 60 min. Similarly, Janve et al. (2015) reported no negative effect of processing methods (power ultrasound-assisted nixtamalization and traditional nixtamalization) on the final acceptability and quality of tortilla chips. In contrast, Bao et al. (2022) stated that ultrasound-assisted processing improved the tenderness and quality of the dry-cured yak meat but negatively affected the color and smell scores, and overall, 300 W ultrasonic power was more suitable.

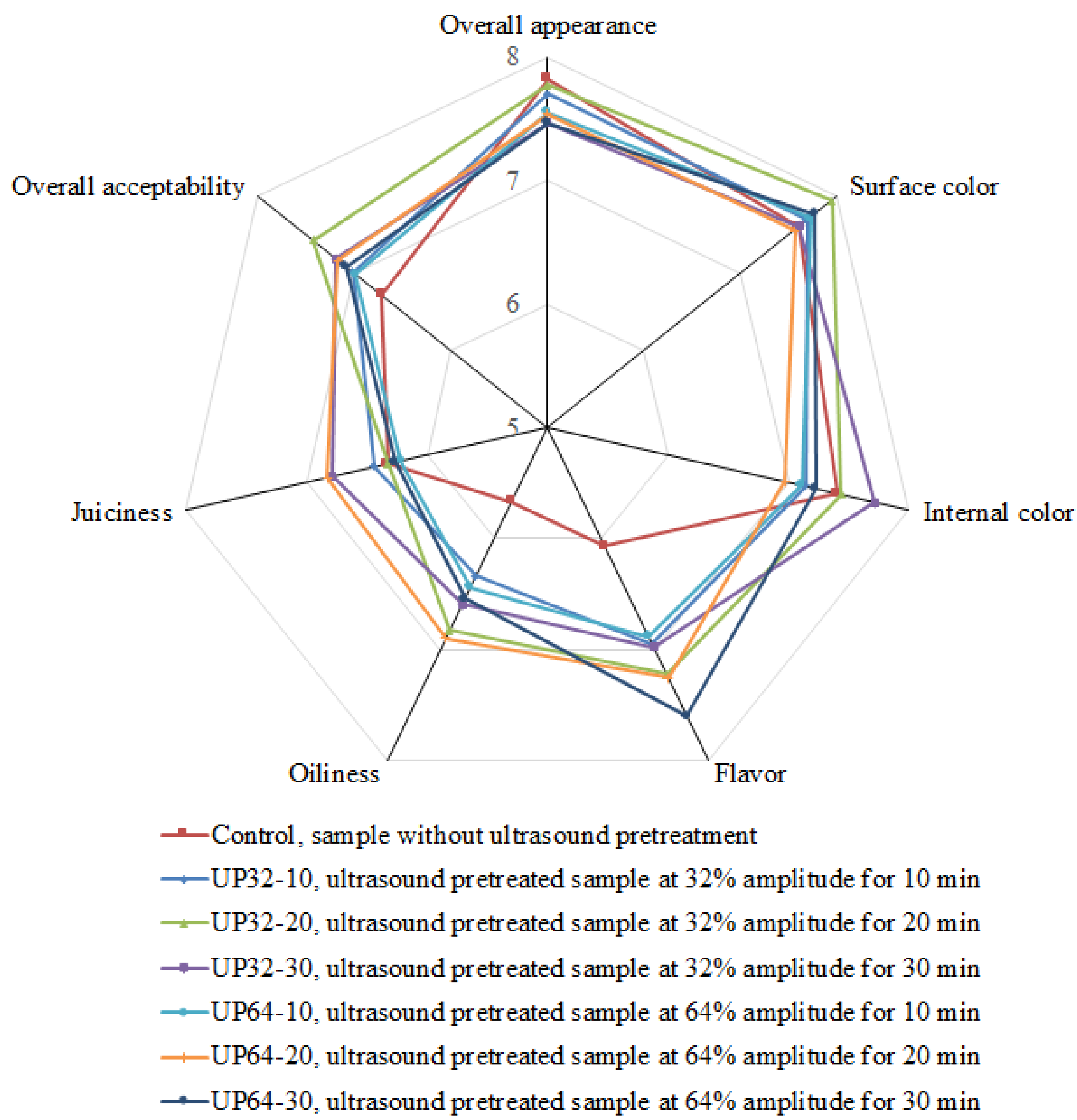

Figure 2. Sensory scores of ultrasound-pretreated and deep-fried chicken schnitzels

CONCLUSION

Results obtained in the present study showed that ultrasound pretreatment at 32 and 64% amplitudes for 10, 20, and 30 min hindered the oil absorption during frying. Compared to the control sample, the fat content of samples pretreated with ultrasound decreased by 36-53%. Hardness and color results indicated that ultrasound pretreatment improved the crispness and had a partial effect on the color of the samples. Ultrasound pretreatment kept the original sensory properties of samples and even enhanced their flavor, oiliness, and overall acceptability. Moreover, ultrasound pretreatment at 32% amplitude for 10 or 20 min of all the pretreatments produced the lowest oil absorption into fried chicken schnitzels. In conclusion, ultrasound pretreatment could be considered in future research as a promising approach to reduce oil absorption and improve the other quality properties of fried products.

CONFLICT OF INTEREST

There are no possible conflicts of interest between the authors.

AUTHOR CONTRIBUTION

This study was derived from Anahi Guadalupe Cozain Montiel's master's thesis. Sadettin Turhan contributed as the thesis supervisor in conducting analyses, statistical analyses of data, writing the article, and writing-review-proofreading-publishing procedures. The thesis student, Anahi Guadalupe Cozain Montiel, carried out the preparation of samples, analyses, reporting, and writing and correction of literature sources. Hilal Soyocak also assisted in conducting analyses and writing-review-proofreading-publishing procedures. The authors have read and approved the final version of the article.

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REFERENCES

Albertos, I., Martin-Diana, A. B., Sanz, M. A., Barat, J. M., Diez, A. M., Jaime, I., Rico, D. (2016). Effect of high pressure processing or freezing technologies as pretreatment in vacuum fried carrot snacks. *Innovative Food Science and Emerging Technologies* 33: 115-122, doi: 10.1016/ j.ifset.2015.11.004.

Ananey-Obiri, D., Matthews, L., Tahergorabi, R. (2020). Chicken processing by-product: A source of protein for fat uptake reduction in deep-fried chicken. *Food Hydrocolloids* 101: 105500, doi: 10.1016/j.foodhyd.2019.105500.

Anonymous (2021). *Erzincan ili dondurulmuş tavuk ürünleri üretim tesisi ön fizibilite raporu*. T.C Sanayi ve Teknoloji Bakanlığı, Kuzey Doğu Anadolu Kalkınma Ajansı. Erzincan, Türkiye, 41 s.

AOAC (2000). *Official methods of analysis* (16th ed.). Association of Official Analytical Chemists, Arlington, VA, USA.

Bao, G., Niu, J., Li, S., Zihang, L., Luo, Y. (2022). Effects of ultrasound pretreatment on the quality, nutrients and volatile compounds of dry-cured yak meat. *Ultrasonics Sonochemistry* 82: 105864, doi: 10.1016/j.ultsonch.2021.105864.

Bouchon, P., Hollins, P., Pearson, M., Pyle, D. L., Tobin, M. J. (2001). Oil distribution in fried potatoes monitored by infrared microspectroscopy. *Journal of Food Science* 66(7): 918-923, doi: 10.1111/j.1365-2621.2001.tb08212.x.

Chayawat, J., Rumpagaporn, P. (2020). Reducing chicken nugget oil content with fortified defatted rice bran in batter. *Food Science and Biotechnology* 29(10): 1355-1363, doi: 10.1007/s10068-020-00782-y.

Choe, E., Min, D. B. (2007). Chemistry of deep-fat frying oils. *Journal of Food Science* 72: R77-86, doi: 10.1111/j.1750-3841.2007.00352.x.

Cozain Montiel, A. G., Tombuloğlu, H., Turhan, S. (2022). A nonthermal emerging technology for reducing the oil absorption in deep-fried foods: Ultrasound. 4th International Conference on Advanced Engineering Technologies, 28-30 September 2022, Bayburt, Türkiye, 1001 p.

Cui, L., Chen, J., Zhai, J., Peng, L., Hayes, D. G. (2022). Oil penetration of batter-breaded fish nuggets during deep-fat frying: effect of frying oils. *Foods* 11: 3369, doi: 10.3390/foods11213369.

Dehghannya, J., Naghavi, E. A., Ghanbarzadeh, B. (2016). Frying of potato strips pretreated by ultrasound-assisted air-drying. *Journal of Food Processing and Preservation* 40(4): 583-592, doi: 10.1111/jfpp.12636.

Ghaderi, A., Dehghannya, J., Ghanbarzadeh, B. (2018). Momentum, heat and mass transfer enhancement during deep-fat frying process of potato strips: Influence of convective oil temperature. *International Journal of Thermal Sciences* 134: 485-499, doi: 10.1016/ j.ijthermalsci.2018.08.035.

Gökçe, R., Akgün, A. A., Ergezer, H., Akcan, T. (2016). Farklı kaplama bileşenleriyle kaplamanın derin yağda kızartılan piliç nuggetların bazı kalite karakteristikleri üzerine etkileri. *Journal of Agricultural Sciences* 22(3): 331-338, doi: 10.1501/Tarimbil_0000001391.

Inguglia, E. S., Granato, D., Kerry, J. P., Tiwari, B. K., Burgess, C. M. (2021). Ultrasound for meat processing: Effects of salt reduction and storage on meat quality parameters. *Applied Sciences* 11: 117, doi: 10.3390/app11010117.

Janve, B., Yang, W., Sims, C. (2015). Sensory and quality evaluation of traditional compared with power ultrasound processed corn (*Zea mays*) tortilla chips. *Journal of Food Science* 80(6): S1368-S1376, doi: 10.1111/1750-3841.12892.

Karizaki, V. M., Sahin, S., Sumnu, G., Mosavian, M. T. H., Luca, A. (2013). Effect of ultrasound-assisted osmotic dehydration as a pretreatment on deep fat frying of potatoes. *Food and Bioprocess Technology* 6(12): 3554-3563, doi: 10.1007/s11947-012-1012-5.

Miano, A. C., Rojas, M. L., Augusto, P. E. D. (2019). Structural changes caused by ultrasound pretreatment: Direct and indirect demonstration in potato cylinders. *Ultrasonics Sonochemistry* 52: 176-183, doi: 10.1016/j.ultsonch.2018.11.015.

Myers, A. S., Brannan, R. G. (2012). Efficacy of fresh and dried egg white on inhibition of oil absorption during deep fat frying. *Journal of Food Quality* 35(4): 239-246, doi: 10.1111/j.1745-4557.2012.00454.x.

Ngobese, N. Z., Workneh, T. S. (2018). Potato (*Solanum tuberosum* L.) nutritional changes associated with French fry processing: Comparison of low-temperature long time and high-temperature short-time blanching and frying treatments. *LWT-Food Science and Technology* 97: 448-455, doi: 10.1016/j.lwt.2018.07.039.

Oke, E. K., Idowu, M. A., Sobukola, O. P., Adeyeye, S. A. O., Akinsola, A. O. (2018). Frying of food: A critical review. *Journal of Culinary Science & Technology* 16(2): 107-127, doi: 10.1080/15428052.2017.1333936.

Oladejo, A. O., Ma, H., Qu, W., Zhou, C., Wu, B., Yang, X., Onwudeb, D. I. (2017a). Effects of ultrasound pretreatments on the kinetics of moisture loss and oil uptake during deep fat frying of sweet potato (*Ipomea batatas*). *Innovative Food Science & Emerging Technologies* 43: 7-17, doi: 10.1016/j.ifset.2017.07.019.

Oladejo, A. O., Ma, H., Qu, W., Zhou, C., Wu, B., Yang, X. (2017b). Influence of ultrasound pretreatments on diffusion coefficients, texture and colour of osmodehydrated sweet potato (*Ipomea batatas*). *International Journal of Food Science and Technology* 52: 888-896, doi: 10.1111/ijfs.13352.

Oladejo, A. O., Ma, H., Qu, W., Zhou, C., Wu, B., Uzoejinwa, B. B., Yang, X. (2018). Application of pretreatment methods on agricultural products prior to frying: A review. *Journal of the Science of Food and Agriculture* 98(2): 456-466, doi: 10.1002/jsfa.8502.

Piyalungka, P., Sadiq, M. B., Assavarachan, R., Nguyen, L. T. (2019). Effects of osmotic pretreatment and frying conditions on quality and storage stability of vacuum-fried pumpkin chips. *International Journal of Food Science and Technology* 54: 2963-2972, doi: 10.1111/ijfs.14209.

Rice, P., Gamble, M. H. (1989). Modeling moisture loss during potato slice frying. *International Journal of Food Science Technology* 24: 183-187, doi: 10.1111/j.1365-2621.1989.tb00632.x.

Sobukola, O. P., Awonorin, S. O., Sanni, L. O., Bamiro, F. O. (2008). Optimization of blanching conditions prior to deep fat frying of yam slices. *International Journal of Food Properties* 11: 379-391, doi: 10.1080/10942910701409294.

Turhan, S., Yazici, F., Saricaoglu, F. T., Mortas, M., Genccelep, H. (2014). Evaluation of the nutritional and storage quality of meatballs formulated with bee pollen. *Korean Journal for Food Science of Animal Resources* 34(4): 423-433, doi: 10.5851/kosfa.2014.34.4.423.

Uyarcan, M., Yayla, E., Akgül, D., İşseven, D. (2022). Development of healthier gluten-free chicken products coated with different cereal sources. *British Food Journal* 124(4): 1301-1313, doi: 10.1108/BFJ-03-2021-0284.

Varela, P., Fiszman, S. M. (2011). Hydrocolloids in fried foods. A review. *Food Hydrocolloids* 25: 1801-1812, doi: 10.1016/j.foodhyd.2011.01.016.

Yu, Z., Su, Y., Zhang, Y., Zhu, P., Mei, Z., Zhou, X., Yu, H. (2021). Potential use of ultrasound to promote fermentation, maturation, and properties of fermented foods: A review. *Food Chemistry* 357: 129805, doi: 10.1016/j.foodchem.2021.129805.

Zeng, H., Chen, J., Zhai, J., Wang, H., Xia, W., Xiong, Y. L. (2016). Reduction of the fat content of battered and breaded fish balls during deep-fat frying using fermented bamboo shoot dietary fiber. *LWT-Food Science and Technology* 73: 425-431, doi: 10.1016/j.lwt.2016.06.052.

Zhang, J., Fan, L. (2021). Effects of preliminary treatment by ultrasonic and convective air drying on the properties and oil absorption of potato chips. *Ultrasonics Sonochemistry* 74: 105548, doi: 10.1016/j.ultsonch.2021.105548.

Zhang, J., Xie, T., Fan, L. (2021a). Improving the quality and reducing oil absorption of fried potato chips by ultrasound pretreatment. *LWT-Food Science and Technology* 148: 111763, doi: 10.1016/j.lwt.2021.111763.

Zhang, J., Yu, P., Fan, L., Sun, Y. (2021b). Effects of ultrasound treatment on the starch properties and oil absorption of potato chips. *Ultrasonics Sonochemistry* 70: 105347, doi: 10.1016/ j.ultsonch.2020.105347.