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Changes in Quality Parameters of Deep Fat Fried Carrot Slices Under the Effect of Ultrasound Assisted Pre-drying Process

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Abstract: Oil absorption is partially associated to the initial moisture content of frying material, thus controlling the moisture level could result in decreased oil absorption during frying with accompanying changes in other physical properties. As a result, in the current study, in order to figure out the changes in moisture and oil contents of fried carrot slices, the effects of process parameters of ultrasound (U/S) assisted pre-drying was examined. As process conditions of U/S, power levels of 30%, 50%, and 70%, temperature levels of 30 and 50 °C, and time periods of 5, 10 and 15 min were studied. Additionally texture and color preferences were studied. Any reduction in oil absorption was achieved by U/S-predrying, whereas it was observed that there was an increase in brightness (L*) value of carrot slices as well as generally a decrease in a* values compared to the control group (directly deep-fat-fried 4mm-carrot slices at 160°C for 120 seconds). Effect of temperature was found to be significant over a* and L* values for all power levels. Additionally, no statistically significant change was observed for the textural properties with applied ultrasound power levels.

Keywords: frying; food drying; texture; oils; color.

1. Introduction

Frying is a common cooking method with a wide range of applications all over the world. In the frying process, product is immersed in pre-heated oil at certain temperature level being far above the boiling point of water. Thus, water movement throughout the solid matrix occurs with accompanying oil absorption and product is removed from oil, when color and textural characteristics meet the sensorial expectations (Gupta, 2005; Dueik et al., 2010; Medina et al., 2015; Esturk et al., 2000). This oil absorption is crucial parameter, since high amount of fat intake is known to potentially cause disorders such as coronary heart disease, diabetes (Saguy and Dana, 2003). Therefore, people are willing to consume low-fat products (Esturk et al., 2000). Studies show that reduction in moisture content encourages positively oil absorption and final product has high oil content which could be potentially hazard for health (Pedreschi and Moyano, 2005; Krokida et al., 2001; Moreira et al., 1999; Vitrac, 2000; Lamberg et al., 1990; Moreira et al., 1997). Consequently, many techniques to apply before frying have been developed in food industry such as; drying (Pedreschi and Moyano, 2005), microwave drying (Gamble and Rice, 1987), vacuum assisted microwave drying (Song et al., 2007), vacuum frying (Dueik et al., 2010), osmotic dehydration (Ikoko and Kuri, 2007), application of coating material (García et al., 2004; Esturk et al., 2000; Lalam et al., 2013).

In literature there are a plenty number of research works about potato chips being pre-dried with different techniques before frying. However, there is no any literature focusing on the ultrasound assisted hot air pre-drying prior to deep fat frying for fried carrot slice manufacturing.

In reported studies, improvements in drying characteristics of different plant materials have been achieved by ultrasound assisted drying technique as a result of the sponge effect occurring in micro channels (Garcia-Perez et al., 2007;

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Ortuño et al., 2010; Nowacka et al., 2012). Therefore, with sonication, it was supposed to achieve a reduction in moisture content and also oil absorption.

In this study, it was aimed to facilitate drying characteristics by means of the effect of ultrasound application, as a result, to achieve the encouraged moisture movement throughout the carrot slices during drying. Additionally, the influences of ultrasound assisted pre-drying and frying of carrot slices on the quality parameters like color and texture values were examined.

2. Material and Method

2.1. Sample preparation

Carrots (Daucus carota L. subsp. Sativus, Nanco) were purchased five days after the harvest from a local market in Isparta, Turkey, and were stored in a polyethylene bags in a refrigerator at 4°C before use. Initial moisture content of carrot samples were determined as 897.0 ± 2.0g.kg^{-1}, which was coincidence with the range (873 – 910g.kg^{-1}) reported by Gichuhi et al. (2009). Before the analyses, carrot was washed, cleaned and peeled. Peeled carrots were sliced at 4 mm thickness using an industrial type slicer (Arisco, HBS-200, Turkey). Carrot slices having diameter of 2.5±0.5 cm were selected for remaining process steps. Afterwards, carrot slices were subjected to blanching for 90 s in a hot water at 85°C and then cooled down using tap water for 120 seconds. Excess surface water was removed using absorbent paper.

2.2. Ultrasound pretreatments and hot air drying

Boiled carrot slices have been immersed in a beaker filled with distilled water. Sonication was conducted by using an ultrasonic probe having ultrasonic frequency of 20 kHz and density of 500 W.m^{-2} (Ultrasonic-Homogenizer, Cy-500, Spain). The ratio of sample in water for all groups was adjusted 1: 4 (w/v) in order to avoid environment effect on sonication influence (Fernandes et al., 2006). Ultrasonic treatments were carried out at power levels of 30%, 50%, and 70% under temperature levels of 30 and 50 °C for time periods of 5, 10 and 15 min. All conducted trials and relevant process conditions were given in Table 1.

A bunch of carrot slices (~50 g) of previously pretreated by ultrasound (at different temperature, time and power) were arranged as a single layer on a tray and dried in a convectional hot air dryer (Mikrotest, MKD, Turkey) at air flow rate of 1.3 ± 0.02 m s^{-1}. Temperature and weight loss during drying were set according to optimal drying conditions (63.4°C for drying temperature, 16% for weight loss during drying) determined in our previous study (Karacabey et al., 2016).

Table 1. Ultrasonic Pretreatments

Label	Power (%)	Temperature (°C)	Time (min)
A	50	30	5
B	50	30	10
C	50	30	15
D	50	50	5
E	50	50	10
F	50	50	15
G	30	30	15
H	50	30	15
I	70	30	15

2.3. Deep fat frying

When the target weight loss on samples was attained, frying was conducted using 3 L of sunflower oil (Marsa Oil Industry Co. Ltd., İstanbul, Turkey) in an industrial type fryer (Remta Co. Ltd, İstanbul, Turkey) under specified optimal conditions determined as 152°C for frying temperature, and 207 s for frying time (Karacabey et al., 2016).

After frying, the fried carrot slices were removed from the oil and drained for about 300 s over a wire screen to drain the most of the surface oil, and then the slices were transferred to an absorbent towel. Frying oil was replaced with fresh one, after each run was completed. In order to determine the reference values for untreated samples, one group of carrot slices were directly fried after blanching without pre-treatment steps. Oil content, moisture content, breaking force, and L*, a*, b* value were measured in these fried slices. Temperature (160°C) and time (120 sec.) were the corresponding values of directly deep-fat-frying process which was determined according to our previous study. In that study, sensory analysis was conducted to determine the process conditions, fried carrot slices (4 mm thickness) at which took the highest score. Texture values, L*, a*, and b*, oil content and moisture content of control group is shown in Table 2.

2.4. Analyses of samples

Moisture content

The method of Fan, Zhang was used (Fan et al., 2005). Carrot slices were ground after frying. Five gram of ground samples were used for moisture content ($g.kg^{-1}$). Ground samples were dried in an oven (FN300, Nuve, Turkey) at 105 ± 0.5°C, until no weight change was attained. Test was performed in duplicate.

Table 2. The Results of Control Group

MC,%	OC*,%	CV			TP	
		L*	a*	b*	H, g force	BF, g force
48	32.50	50.3	30.4	41.8	462.8	549.0

*Oil content (%) is calculated based on the dry weight. MC: moisture content; OC: Oil content; CV: Color values; TP: Texture properties; H: Hardness; BF: Breaking force

Oil content

The oil determination method reported by Sulaeman et al. (2001) was used with modification. Briefly, oil extraction was performed in a Soxhlet extractor (Büchi Universal Extraction System B-811, Germany) using hexane as a solvent to determine the oil content of fried carrot slices. Before extraction, fried samples (5 g) were dried in a vacuum oven and then ground (James, 1998). Oil content (g.kg-1) was calculated as wet bases. The test was performed in duplicate.

Surface Color

Color parameters (L*, a*, and b*) were measured using a colorimeter (NH310, 3nh Tech. Co., Ltd. China) (Robertson, 1977). The equipment was standardized each time with white and black references. Five carrot slices and at five different locations for each slice were used for color measurements and mean values were reported.

Texture Values

Texture analysis was conducted by a texture analyzer (TA.XT Plus, Stable Micro System Co. Ltd., Godalming, UK). The PS / 30 probe and LKB probe were used to measure the slice hardness and firmness, respectively. PS / 30 probe movement speed was 1×10^{-3} m s^{-1} and initial distance from the platform was set as 50×10^{-3} m. LKB probe movement speed was 1×10^{-3} m s^{-1} and initial distance from the platform was set as 25×10^{-3} m. The result for each trial was given as a mean of 5 measurements.

3. Results and Discussion

The results of texture, surface color, moisture and oil content of fried carrot slices previously ultrasound assisted pre-dried were given in Table 3.

3.1. Texture

As can be seen in Table 3, the hardness values of ultrasound-assisted pre-dried and fried carrot slices were lower than the control group in case of almost all treatments, except for B and D, but this reduction in the slice hardness was not enormous, instead, limited. Statistical analysis has also supported this fact by indicating that the differences in control and pretreated carrot slices as none significant almost for all cases ($p>0.05$) (Table 3). In order to analyses the effects of process variables of ultrasound assisted pre-drying, temperature and treatment time were statistically analyzed and the results were given in Table 4.

Table 3. Results of texture, color and moisture and oil content of fried carrot slices pretreated by ultrasound-assisted pre-drying

Groups	Hardness, g force	Firmness, g force	L*	a*	b*	Moisture Content, %	Oil Content, %
A	409.58±282.57[a,b]	569.95±227.38[a]	53.34±3.46[f]	23.41±2.91[c]	44.55±4.01[d]	51.36±0.85[c,d]	33.57±0.58[c]
B	538.35±345.76[a]	499.41±188.81[a,b]	56.80±3.10[b,c]	28.42±3.00[b]	50.64±3.20[a,b]	58.03±1.02[a,b]	33.60±1.58[c]
C	154.31±242.74[b]	239.01±143.40[c]	54.83±1.80[d,e]	30.65±1.92[a]	49.89±2.42[a,b]	47.05±0.27[d,e,f]	40.64±1.80[b]
D	485.86±517.51[a,b]	225.44±116.68[c]	51.19±2.21[g]	31.19±1.73[a]	47.95±3.91[c]	44.19±6.21[e,f]	34.72±2.04[c]
E	141.47±190.80[b]	368.23±178.03[a,b,c]	57.35±3.17[b]	24.16±3.81[c]	51.19±2.24[a]	42.00±0.72[f]	47.11±0.81[a]
F	308.15±183.80[a,b]	290.04±142.78[c]	63.52±1.36[a]	18.64±3.04[d]	49.52±2.75[b]	51.29±1.02[c,d]	39.97±5.51[b]
G	410.80±283.89[a,b]	329.43±216.45[b,c]	54.34±1.22[e,f]	28.43±1.46[b]	46.53±2.03[c]	53.47±2.72[b,c]	34.44±1.67[c]
H	358.49±416.32[a,b]	511.17±275.01[a,b]	55.65±1.30[c,d]	28.59±1.55[b]	47.40±2.78[c]	46.67±2.11[d,e,f]	36.22±0.83[b,c]
I	181.29±222.14[b]	542.60±188.97[a]	57.64±1.16[b]	30.61±1.35[a]	47.67±1.38[c]	59.72±0.43[a]	32.19±0.06[c]
Control	462.75±443.18[a,b]	549.02±231.48[a]	50.25±2.86[g]	30.35±1.43[a]	41.76±3.21[e]	48.00±0.70[c,d,e]	32.50±1.35[c]

Different letters in the same column indicate a significant difference ($p \leq 0.05$)

Table 4. Effects of temperatures and time of the ultrasound assisted pre-drying on the hardness of fried carrot slices

Hardness (g, force)		Temperature (ºC) 30	50
Time (min)	5	409.58±282.57[A,a,b]	485.86±517.51[A,a]
	10	538.35±345.76[A,a]	141.47±190.80[B,b]
	15	154.31±242.74[A,b]	308.15±183.80[A,a,b]

Different capital letters in the same row indicate a significant difference in terms of application temperatures ($p \leq 0.05$) Different lowercase letters in the same column indicate a significant difference in terms of application time ($p \leq 0.05$)

The difference among the application time of the ultrasonic pre-treatment carried out for 10 and 15 minutes at 30°C were significant ($p \leq 0.05$). Hardness of carrot slices were only changed with temperature rise from 30°C to 50°C, when the ultrasound assisted pre-drying was performed for 10 min (Table 4).

Similar to the hardness values of carrot slices, it was seen that treatments C, D, F, and G caused significant changes in firmness value compared to that of control group ($p \leq 0.05$). Remaining ones were found to be statistically same as control (Table 3). Change in firmness of fried carrot slices depending on the process conditions of pre-dried by ultrasound assisted drying technique were displayed in Table 5. The influence of temperature increasing from 30 ºC to 50 ºC was only found to be significant when pretreatment was applied for 5 min ($p \leq 0.05$). Treatment time caused any significant change in firmness of carrot slices, when it was performed at 10 min and 15 min ($p > 0.05$). For both temperature levels, it was seen that the firmness decreased with increasing time (Table 5).

Table 5. Effects of temperatures and time of the ultrasound assisted pre-drying on the firmness of fried carrot slices

Firmness (g. force)		Temperature (ºC) 30	50
Time (min)	5	569.95±227.38[A,a]	225.44±116.68[B,b]
	10	499.41±188.81[A,a]	368.23±178.03[A,a]
	15	239.01±143.40[A,b]	290.04±142.78[A,a,b]

Different capital letters in the same row indicate a significant difference in terms of application temperatures ($p \leq 0.05$). Different lowercase letters in the same column indicate a significant difference in terms of application time ($p \leq 0.05$)

Table 6. The effects different intensity ultrasound power on textural properties of fried carrot slices

Experiments	Power (%)	Hardness, g force	Firmness, g force
G	30	410.80±283.89[a]	329.43±216.45[a]
H	50	358.49±416.32[a]	511.17±275.01[a]
I	70	181.29±222.14[a]	542.60±188.97[a]

Different letters in the same column indicate a significant difference ($p \leq 0.05$)

According to the results given in Table 6, it is seen that there is no any significant change in hardness or firmness values of fried carrot slices with changing ultrasound power ($p > 0.05$). Brncic et al. (2010) studied the ultrasound assisted drying at different ultrasound power and reported the absence of significant effect on the textural properties or a limited effect. In another study conducted by Dujmić et al. (2013), increasing ultrasound power was found to cause a decrease in hardness values but noted that this effect was not statistically significant. These results are coincidence with the finding in this current study.

3.2. Surface Color Values

As can be seen in Table 3, L* values, representing surface brightness of fried carrot slices pre-dried by ultrasound assisted drying technique, displayed that the nearest brightness value to control group was achieved for the carrot slices processed at the conditions coded as D among all experiments. Besides to D group, L* values of remaining ones are shown to be higher than control group (Table 3). Color change from green to red is defined with a* value. The results indicated that the general trend in a* value was a decrease compared to control group ($p \le 0.05$), but few exceptions being coded treatments of C, D, and I ($p > 0.05$). b* value is another surface color parameter measured in current study. Table 3 shows that compared to b* value of control group, there is an increase in this color parameter of fried carrot slices if they were pretreated by ultrasound assisted drying technique before frying ($p \le 0.05$). Ultrasound parameters (temperature and time) were also investigated to figure out their influences on L*, a* and b* values. Figure 1, Figure 2 and Figure 3 display the change in surface color parameters with temperature and time as well as their statistical differences. It is seen that at constant temperature level, increasing sonication time caused an increase in L* value and this is more apparent when medium temperature was 50°C (Figure 1). The temperature was found not to create any certain effect on L* value of fried carrot slices as seen from Figure 1. For 5 min treatment, as changing temperature value from 30°C to 50°C lowered the L*value. On the other hand, an increase in brightness was seen with increasing temperature, when sonication was 15 min (Figure 1). No statistically significant change was observed with temperature for 10 min treatment. The temperature significantly affected a* value for all treatment durations ($p \le 0.05$), but this effect was different in between 5 min and 10 or 15 min treatments. There was an increase in a* value for 5 min treatment, whereas a* value decreased for the treatments of 10 min and 15 min (Figure 2). This may be related to the effect of temperature-time on carotenoid content of carrot slices. Because, for short term application, carotenoids may turn to free form with effects of temperature and ultrasound, but further increase in process time resulted in adverse effect of temperature like that was seen for treatments of 10 min and 15 min and carotenoids degraded and a* value partially decreased. As can be seen from Figure 2 that an increase in a* value was seen with increasing sonication time from 5 min to 15 min at 30°C, but this influence was reversed and increasing process time caused a decrease for sonication processes carried at 50°C. Another color parameter b* was also studied and temperature and process time were found to affect it in limited extent (Figure 3). Except for 5 min treatment ($p \le 0.05$), b* value did not change with temperature ($p > 0.05$). There was also no change in b* value with time when sonication was at 30 °C. However, time affected b* value ($p \le 0.05$) when sonication temperature was increased to 50°C, but this effect did not have a clear trend, instead fluctuated.

Ultrasound power was another process variable controlled in this study and the effect of its change was investigated in terms of surface color. The results were shown in Figure 4. An increase in ultrasound power was seen to increase brightness (L* value) and redness (a* value) of carrot slices ($p \le 0.05$), but no significant change in b* value was detected ($p > 0.05$) (Figure 4). An increase in L* value was continued throughout the power levels. Power change was effective for a* value after it was shifted from 30% to 70% ($p \le 0.05$), there was no difference between a* values measured for samples processed at 30% and 50% power levels ($p > 0.05$) (Figure 4). The change in color may be attributed to the cavitation occurred as a result of ultrasound. Tiwari et al. (2008) have reported change in color parameters after ultrasound application and they have associated these changes with the effects of ultrasound. An intensification in a* value may also be attributed to the isomerization of carotenoids and reduction in degradation of β-carotene (Chen et al., 1995; Sun et al., 2010).

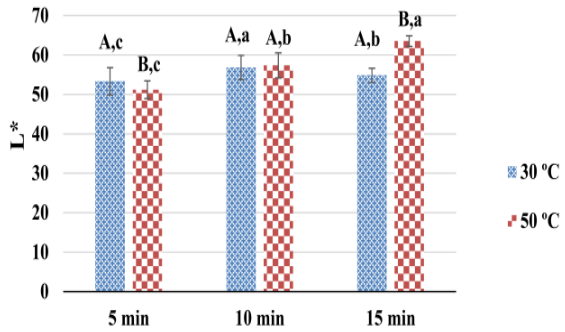

Figure 1. Effects of temperatures and time of the ultrasound assisted pre-drying on the brightness of fried carrot slices

Different lowercase letters indicate a significant difference in terms of ultrasound application time separately for each temperature (*p≤0.05*)

Different capital letters in the per column indicate a significant difference in terms of application temperatures for each time (*p≤0.05*)

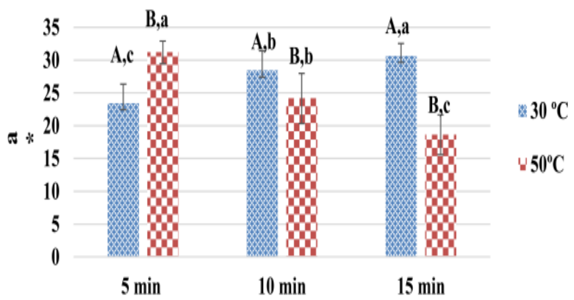

Figure 2. Effects of temperatures and time of the ultrasound assisted pre-drying on the a* values of fried carrot slices

Different lowercase letters indicate a significant difference in terms of ultrasound application time separately for each temperature (*p≤0.05*)

Different capital letters in the per column indicate a significant difference in terms of application temperatures for each time (*p≤0.05*)

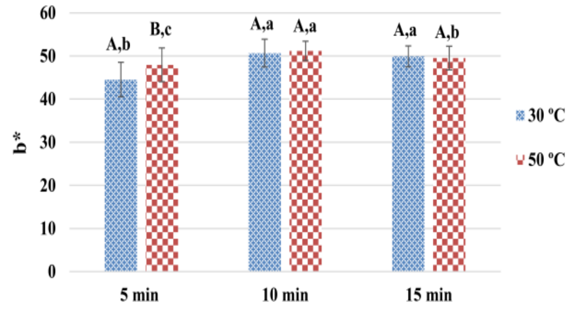

Figure 3. Effects of temperatures and time of the ultrasound assisted pre-drying on the b* values of fried carrot slices

Different lowercase letters indicate a significant difference in terms of ultrasound application time separately for each temperature (*p≤0.05*)

Different capital letters in the per column indicate a significant difference in terms of application temperatures for each time (*p≤0.05*)

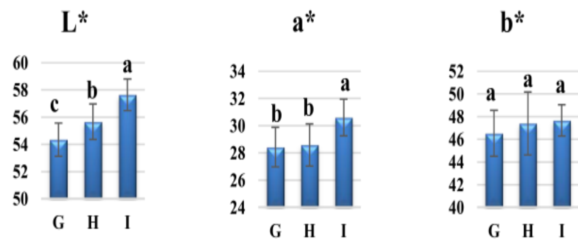

Figure 4. The effects of ultrasound power on surface color of fried carrot slices

Different letters indicate a significant difference for each color parameters separately (*p≤0.05*)

3.3. Moisture Content

Compared to control group, the moisture content of fried carrot slices differed depending on the conditions of ultrasound applications (*p≤0.05*) (Table 3). Change in moisture content of final product occurred as a decrease or an increase. Thus, the influence of sonication conditions on moisture content of fried carrots was also investigated and temperature and time effects were analyzed in Table 7.

Table 7. Effects of temperatures and time of the ultrasound assisted pre-drying on the moisture content of fried carrot slices

Moisture Content (%)		Temperature (ºC) 30	50
Time (min)	5	51.36±0.85^{A,b}	44.19±6.21^{A,a}
	10	58.03±1.02^{A,a}	42.00±0.72^{B,a}
	15	47.05±0.27^{A,c}	51.29±1.02^{B,a}

Different capital letters in the same row indicate a significant difference in terms of application temperatures (*p≤0.05*)
Different lowercase letters in the same column indicate a significant difference in terms of application time (*p≤0.05*)

Tabulated results indicated that temperature elevation was only effective on moisture content, when application time was higher than 10 minutes (*p≤0.05*), in other words there was no change in moisture content with sonication temperature for 5 min- treatment (*p>0.05*). Process time was also considered and it was found to cause a change in moisture content only application temperature was 30°C (*p≤0.05*). Although moisture content increased especially after treatment time of 10 min, this change did not occur at significant level when sonication was conducted at the temperature level of 50°C. The last parameter of ultrasound application was power level and the influence of different sonication power in the fix time and temperature applications was shown in Figure 5. A decrease in moisture content at certain level was seen with increasing ultrasound power from 30% to 50%, but further increase up to 70% caused an increase in moisture content again. This variation in moisture content under the effect of power level was found to be statistically significant (*p≤0.05*). Gallego-Juárez et al. (2007) reported that increasing the ultrasonic power raised the diffusion coefficient and accordingly it was supposed that the amount of moisture away from the product was increased by rising the ultrasound power. In this study similar effect was seen for power level of 30% and 50% and this effect was thought to be relevant to the occurrence of micro channels in solid matrix and thus moisture level decreased. However, at 70% power there was an increase in moisture content. This increase occurring in moisture content of product was attributed to the failure to remove moisture from the structure due to the collapses in the micro channel with the high ultrasonic effect, at 70% level (Figure 5).

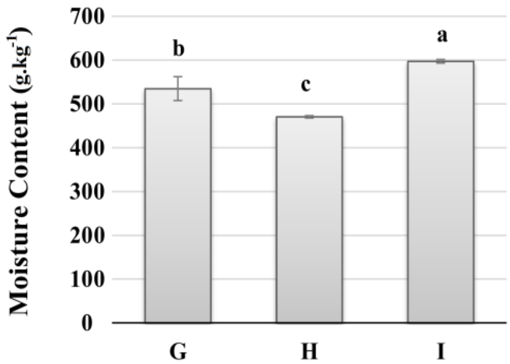

Figure 5. The effects different intensity ultrasound power on moisture content of fried carrot slices
Different letters indicate a significant difference (*p≤0.05*)

3.4. Oil Content

Oil content of ultrasound assisted dried and fried carrot slices were tabulated in Table 3. Oil content of final fried carrot slices were generally higher than that measured for control group samples (*p≤0.05*). This may be explained with the effects of ultrasound on structure of carrot slices, since the cavitation occurred as a result of sonication caused mechanical effects on layers close to surface and this accelerates the mass transfer throughout/ into the solid matrix. Thus, oil absorption increased during frying as well that occurred for moisture transfer out of solid. Temperature and time effects on oil absorption of fried carrot slices were given in Table 8 where it was seen that both variables caused significant changes in oil content (*p≤0.05*). At constant temperature level, in general manner, an increase in process time resulted in an increase in oil content. Temperature change was found only to affect oil content for 10 min treatment (Table 8).

Table 8. Effects of temperatures and time of the ultrasound assisted pre-drying on the oil content of fried carrot slices

Oil Content		Temperature (ºC) 30	50
Time (min)	5	33.57±0.58^{A,b}	34.72±2.0^{A,b}
	10	33.60±1.58^{A,b}	47.11±0.81^{B,a}
	15	40.64±1.80^{A,a}	39.97±5.51^{A,a,b}

Different capital letters in the same row indicate a significant difference in terms of application temperatures (*p≤0.05*)
Different lowercase letters in the same column indicate a significant difference in terms of application time (*p≤0.05*)

Power level of sonication was another variable and its effect on oil content of fried carrot slices were seen in Figure 6. Increased power level of sonication was found to create statistically significant difference for 50% power level compared to 30% and 70% power levels (Figure 6). When oil absorption was taken into account, it was compatible with that observed for moisture content change in general trend (Figure 6).

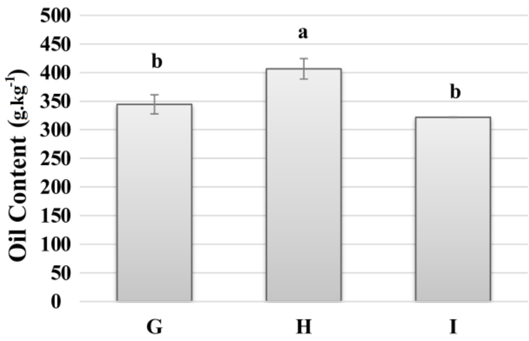

Figure 6. The effects different intensity ultrasound power on oil content of fried carrot slices
Different letters indicate a significant difference (*p≤0.05*)

Conclusion

The effect of ultrasound applied during drying was found not to change the oil absorption in the studied conditions. However, there are some differences in other investigated properties including color. As a result, although ultrasound application in drying have been reported to provide some changes in drying characteristics being relevant to the textural variations, these changes were not enough to affect the oil absorption taking place during frying process being contrast to expectations. Briefly, it could be said that further studies including different process conditions are required to evaluate the effect of ultrasound application on oil absorption.

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