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INVESTIGATION OF CONVENTIONAL AND MICROWAVE COMBINED ROASTING EFFECT ON THE PHYSICOCHEMICAL, TEXTURAL AND SENSORY PROPERTIES OF SUNFLOWER SEED

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ABSTRACT

In this study, conventional, microwave, and also a combination of these two methods were applied to compare the quality properties of sunflower seeds. Alternative to conventional roasting at 160°C, microwave roasting at two different powers (300W and 600W) and also microwave with conventional roasting treatment (300 W+160°C, 600 W+160°C) were applied to raw sunflower seeds during 5 and 10 min. for each group. The moisture content of roasted seeds was found to be lower than 6%. The results show that the highest protein and fat content were found in the group of combined methods as 21.09±6.64 and 40.55±0.345% respectively. Additionally, the color values were found to be higher, and hardness and sensory characteristics were protected better after roasting compared to the control (unroasted) group. Roasting of microwave at 600W power for 5 min at 160°C was found to be advantageous for the roasting process of sunflower seed via these properties.

Keywords: Hardness, microwave roasting, quality, roasting, sunflower seed

AYÇEKİRDEĞİNİN FİZİKOKİMYASAL, TEKSTÜREL VE DUYUSAL ÖZELLİKLERİ ÜZERİNE KONVANSİYONEL VE MİKRODALGA KOMBİNE KAVURMA ETKİSİNİN İNCELENMESİ

ÖZ

Bu çalışmada ayçiçeği tohumlarının kalite özelliklerinin karşılaştırılması amacıyla konvansiyonel, mikrodalga ve bu iki yöntemin kombinasyonu uygulanmıştır. Ayçekirdekleri 160°C'de geleneksel kavurmaya alternatif olarak iki farklı güçte (300W ve 600W) mikrodalgada kavurma ve ayrıca geleneksel kavurma işlemiyle (300 geleneksel kavurma işlemiyle (300 W+160°C, 600 W+160°C) mikrodalgada her grup için 5 ve 10 dk uygulanmıştır. Kavrulmuş tohumların nem içeriği % 6'dan düşük bulunmuştur. Sonuçlar, en yüksek protein ve yağ içeriğinin sırasıyla %21.09±6.64 ve %40.55±0.345 ile kombine yöntem grubunda bulunduğunu göstermektedir. Ayrıca kavurma sonrasında renk değerlerinin kontrol (kavrulmamış) grubuna göre daha yüksek olduğu, sertlik ve duyusal özelliklerin daha iyi korunduğu belirlenmiştir. Bu özellikleri nedeniyle ayçiçeği çekirdeğinin kavurma işleminde 600W gücündeki mikrodalga fırında 160°C'de 5 dakika kavurmanın avantajlı olduğu bulunmuştur.

Anahtar kelimeler: Sertlik, mikrodalga kavurma, kalite, kavurma, ayçekirdeği

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INTRODUCTION

Sunflower (*Helianthus annuus L.*) is one of the main crops in the world (Kaya et al. 2012; Seilar and Jan 2010). On a worldwide scale, the sunflower crop is ranked the fourth most important oilseed crops, following soybeans, rapeseed and safflower, as the most economically significant oilseed crop (Adeleke and Babalola, 2020). Also it is largely consumed as confectionery type product and variety of pies and cakes (Jie et al. 2023; Özcan et al. 2024). Sunflower seeds supply several components including unsaturated fats, protein, polyphenols (Guo et al. 2020). Furthermore, sunflower seeds contain high amounts of vitamins and minerals such as vitamine B and E, folate, niacin, phosphorous, sodium, zinc, calcium, iron, magnesium, copper and manganese (Adeleke and Babalola 2020). This high nutritional quality makes it a suitable option for a healthy diet. It is known that it has antioxidant, anti-inflammatory, antihypertensive, antidaibetic and antimicrobial properties (Paji et al. 2011; Guo et al. 2017). It is reported that nutritional profiles provide anti-inflammatory effects against certain chronic diseases (Khan et al. 2015; Al-Kuraieef, 2021).

Roasting is a time-temperature-dependent method for food processing used to cook the product with dry heat (Clarke1987; Das et al. 2023). It uses the heating principle to cook the food uniformly and improve the sensory qualities, palatability, and digestibility while modifying the matrix of food and desired structural characteristics (Sruthi 2021). Roasting is used and preferred as a pretreatment method before milling of plant seeds commonly and also a good way to prepare the seeds for snacks or long-term storage. (Guo et al. 2020). The aim of this process is the enhance the preferability of this product by changing color, texture, flavor and favoredness. Maillard reaction (non-enzymatic browning) can provide these positive changes (Soleimmanieh et al. 2015; Nikzadeh and Sedagha 2008; Robertson et al. 1985). Roasting can greatly enhance flavor by causing the maillard reaction and caramelization on the food product's surface. The need for fortified roasted products is growing, and worries about food safety have sparked interest in innovative roasting processes as a potential replacement for traditional methods. For instance, microwave roasting provides more efficiency in terms of energy and time and also preferred products rather than hot- air roasting due to volumetric heating mechanism (Yin et al. 2023). The impact of microwave energy on the nutrients of the food also differs significantly from conventional method due to the mechanism of direct microwave-material interaction whichdiffers from conventional heating that needs heat from the outer heat sources (Yoshida et al. 2001). During microwave roasting with the effect of penetration of microwaves directly inside of the seeds, the process is intensified throughout the core of the material (Nebesny and Budryn 2006; Bölek and Özdemir 2017). Microwaves oftenly used for roasting of plant seeds and researchers obtain non-negligible results. For example Jogihalli et al. (2017) studied with chickpea seed, Bolek and Özdemir, (2017) studied roasting of Pistacia terebinthus beans, hazelnut was studied by Uysal et al. (2009), sesame seed was evaluated by Yin et al. (2023) and Ahmed et al. (2023), Raigar et al. (2017) used microwave roasting for peanuts, and Hojjati et al. (2015) measured the impact on pistachios.

Sunflower seed was roasted with microwave technology by several researchers (Yoshida et al. 2001; Goszkiewicz et al. 2020; Soleimanieh et al. 2015; Anjum et al. 2006; Mohammed et al. 2017; Shorstkii et al. 2019; Guo et al. 2019; Mosayebi et al. 2018), but in most of these studies the methods compared seperately and characteristics of sunflower oils were examined. Additionally there is no study in the literature using the conventional and microwave roasting method together.

Therefore in this study, it was aimed to investigate the synergistic effects of conventional and microwave roasting methods and to compare them with the methods individually applied in terms of some quality characteristics of sunflower seed. The pysicochemical (moisture, protein, fat, ash), textural (hardness), sensorial (color, texture, odor, general appeal) and color (L*, a* and b*) values were determined at two different microwave powers (300 and 600W) and times (5 and 10 min.).

MATERIALS AND METHODS

Materials

Raw sunflower seeds (*Helianthus annuus L.*) were purchased from a local producer in İzmir Turkey. The initial moisture content of unroasted seed was determined as 9.32 ± 0.83% (wet basis). All chemicals used in this study were analytical grade and from either Merck (Darmstadt, Germany) or Sigma-Aldrich (Buchs, Switzerland).

Methods

Before roasting samples were cleaned and deshelled. Then, they were kept at 4°C until using in experiment. Three different roasting methods (conventional roasting, microwave roasting, and microwave roasting+conventional roasting) were carried with an oven (ArclikKMF 833, Istanbul, Turkey) which can be used as both conventional and microwave at the same time. Samples (50 g each) were subjected to conventional roasting treatment for 5 and 10 min at 160 °C; to microwave roasting treatment for 5 and 10 min at 300 and 600 W; and to microwave roasting + conventional roasting treatment for 5 and 10 min at 300 W + 160 °C, and 600 W + 160 °C, respectively. Samples groups were coded as 1 :160 ºC, 5 min, conventional roasting, 2: 160 °C, 10 min, conventional roasting, 3: 300 W, 5 min, microwave roasting, 4: 300 W, 10 min, microwave roasting, 5: 600 W, 5 min, microwave roasting, 6: 600 W, 10 min, microwave roasting, 7: 300 W, 160 ºC, 5 min, microwave roasting+conventional roasting, 8: 300 W, 160 ºC, 10 min, microwave roasting+conventional roasting, 9: 300 W, 160 ºC, 5 min, microwave roasting+conventional roasting, 10:600 W, 160 ºC, 10 min, microwave roasting+conventional roasting. Production was done in 2 repetitions and analysis in 3 parallels.

Roasting conditions were determined according to literature and also pretreatments taking into account the burning of samples above the selected temperature, time and microwave power (Anjum et al. 2006; Darvishi et al. 2013).

Chemical Characteristics

Composition of sunflower seeds

Moisture, protein, fat and ash contents of samples were measured according to AACC (2000).

Color value

Konica Minolta Chroma Meter (CR-400, Japonya) was used to measure the colour values of the samples. Calibration of the tool was made with standard white line (Y = 93.9, x = 0.313, y = 0.321) for the values of $L*$ (lightness), $a*$ (redness/greenness), and $b*$ (yellowness/blueness). Also total color differences (ΔE) of the treatment groups were calculated based on the values of control group given in the Equation 1.

$$.\ \Delta E = \sqrt{\left[\left(L^* - L^*_{ref}\right)^2 + \left(a^* - a^*_{ref}\right)^2 + \left(b^* - b^*_{ref}\right)^2\right]} \quad \text{(Eq. 1)}$$

Texture Analysis

Hardness is an important charactersitic and defined as the required force over compression test. TA.XT Plus Texture Analyzer (Stable Micro System Co. Ltd., Surrey, UK) with a load cell of 250 N. The diameter of 32 mm, a speed of 5 mm/min, and a penetration index of the (P/36R) probe 50% of the thickness (Mosayabi et al. 2018; Soleimanieh et al. 2015) was used for textural analysis of the sunflower seeds. 10 sunflower seeds were used for measurements.

Sensory analysis

8 trained panelists for the 10 different samples performed the sensory tests. Panelists put in order their liking of the samples for color, texture, odor and general appeal in a 10-point hedonic scale ranging from 1 (dislike extremely) to 10 (like extremely). The mean values and standart deviations were calculated (Altuğ and Elmacı, 2005).

Statistical analysis

Data obtained from the research were analyzed with the Duncan test, One-way ANOVA technique in statistical software (Version 20, SPSS Inc., Chicago, IL, USA) at a least significant difference of P-value≤0.05.

RESULTS AND DISCUSSION

Evaluation of Proximate Composition

Moisture, protein, fat and ash contents of control and roasted samples were given in the Table 1.

Moisture content was found as 4.18±0.01 % in the control group. In the conventional roasted samples, time significantly effected the moisture content (*P*≤0.05). The minumum moisture ratio was found to be as 2.11±0.08 in the 300 W, 160 ºC and 10 min. group. Also the power of microwave was found statistically significant on the moistures (*P*≤0.05). The decreases were seen in moisture contents due to increase in roasting time and power of microwave. Mohammed et al. (2017), confirmed that the moisture content of the unroasted sunflower seed was 5.69 %. In another study, seeds of sunflower were processed with microwaves for 6, 12, 20 or 30 min at a frequency of 2450 MHz., and it was found the roasting time was parallel to the rate of the weight loss of the seeds at the end of roasting (Yoshida et al. 2001). In accordance with these results, Ahmed et al. (2020), also indicated that microwave roasting significantly decreased the moisture content of sesame seeds due to the water evaporation from the seeds by the generated heat and supported this conditon by similar studies.

Table 1. Proximate Composition of Control and Roasted Sunflower Seed Samples

Sample	Power (W)	Temperature (ºC)	Time (min.)	Moisture (%, w.b.)	Protein (%)	Fat (%)	Ash (%)
Control	-	-	-	4.18±0.01^{a,b}	17.60±0.01^{a,b}	36.33±0.35^{a}	3.14±0.01^{a}
1	-	160	5	4.30±0.07^{a}	10.66±2.21^{d}	35.52±0.423^{b}	2.81±0.02^{b}
2	-	160	10	3.55±0.03^{d}	15.36±5.66^{b,c}	36.43±0.444^{b,c}	2.88±0.07^{b}
	300	-	5	3.19±0.04 ^{d}	10.95±1.71^{c,d}	35.12±0.330^{b,c}	2.83±0.11^{b}
4	300	-	10	2.97±0.99^{e,f}	14.01±1.69 ^{b,c}	38.25±0.420^{c}	2.80±0.04^{b}
5	600	-	5	3.68±0.23^{c,d}	12.71±1.51^{b,c,d}	37.52±0.300^{c}	2.80±0.07^{b}
6	600	-	10	2.93±0.05^{e,f}	13.86±1.64^{b,c,d}	37.33±0.350^{c}	2.87±0.01^{b}
7	300	160	5	3.28±0.05^{d,e}	12.84±1.73^{b,c,d}	36.49±0.314^{b}	2.82±0.01^{b}
8	300	160	10	2.11±0.08^{g}	12.87±0.89^{b,c,d}	39.33±0.327^{d}	2.91±0.21^{b}
9	600	160	5	2.68±0.02^{f}	21.09±6.64^{a}	40.55±0.345 ^{d}	2.76±0.05^{b}
10	600	160	10	2.92±0.14^{e,f}	18.43±1.56^{a,b}	41.40±0.296 ^{d}	2.86±0.03^{b}

$^{a-e}$ Means in the same coloumn with different superscripts are significantly different (P≤0.05).

Protein content was determined in the control (unroasted seed) sample as 17.60% .whereas the highest protein content was found in the combined group of 600W- 5min-160ºC. The lowest value of protein was found in the group of conventional roasting 160ºC- 5 min. as 10.66±2.21. The microwave power also found to be significant at a stable time and temperature (*P*≤0.05). Mohammed et al. (2017), determined the protein content of unroasted sunflower seeds as 24.2%. They also found that roasting by microwave was not effective on the fiber, ash, and protein contents of seeds significantly (*P*≤0.05).

There is a disagreement between the previous researchers. Some of researches showed that application of roasting did not effect the protein content and amino acid composition of sunflower seed, although the concentration of lysine was found higher in raw rather than in roasted samples (Sarrazin et al. 2003). They also expressed that glutamic acid was the most dominant amino acid in sunflower seed, followed by aspartate and arginine. In contrast to this, Lao et al. (2023) studied the pre-roasting of yellow pea proteins and found that other studies suggest that roasting under moderate conditions has a positive effect on protein solubility and emulsification. They also noted that higher temperatures (150ºC) and longer roasting times (10, 20, and 30 minutes) could potentially alter the protein structures and consequently affect the protein content. Inversely, Ji et al. (2023), determined that better quality sunflower seed oil was obtained when roasted at 160- 180ºC for about 20 min (e.g., 160ºC for 20–25 min or 180ºC for 15–20 min).

But they found after roasting at 160, 180 and 200ºC for 25 min, the total amount of amino acids decreased to 49.09, 47.51, and 40.86%, respectively. Among the 17 amino acids detected, cysteine, lysine, arginine, and serine decreased more significantly than others.

Fat content was found to be as 36.33±0.35 in the unroasted samples whereas in the combined groups this value increases to 39.33-41.40%. The effect of methods was found to be significant on the fat contents of seeds (*P*≤0.05). In the other researches it was claimed that roasting slightly effected fatty acid profiles of sunflower seeds e.g. in a previous study, they designated that fatty acid concentrations of sunflower seeds did not change which was autoclaved at 127ºC for up to 30 min. (Sarrazin et al. 2003). Jie et al. (2023), specified that seed roasting has been widely used to improve oil recovery and oxidative stability, coagulate proteins, and most importantly to impart special flavor and aromas to oils through the Maillard reaction.

Ash content was not changed significantly via the roasting method (*P*>0.05). The ash amounts were found between 2.76-2.91%. Ash values of the samples increased parallel with the time when the power was constant but this increase was not found statistically significant (*P*>0.05). Accordingly, Ahmed et al. (2020), exclaimed that roasting effect on ash content was not statistically significant in sesame seeds.

Evaluation of color

In roasted products color is an important quality characteristic and showed by quantitative data as *L*, a*, b** (Mosayebi et al. 2018). These parameters were measured and showed in the Table 2. Also total color difference (ΔE) were given in the same table. *L** (brightness) value was found as 79.00±0.59 in the control group and the change was found statistically significant when compared to the combination groups (*P*≤0.05). In a combination group (300W, 160ºC, 5 min.), *L** has the highest value as 77.47±0.57. *a** value found at most in the 600W, 160ºC 5 min. group. Redness value was important for the roasted samples. *b** value was found most in the 300 W, 160ºC, 10 min as 23.97±1.24. Time affected significantly the color of the samples at a constant power level (*P*≤0.05). The color parameters increased parallel with the increase in time. Also, total color differences showed that both treatments were statistically significant effect on the color values (P≤0.05). The results showed that, combination groups changed the color values positively.

Table 2. Color Values and Hardness of Control and Roasted Sunflower Seeds

Sample	Power (W)	Temperature (ºC)	Time (min.)	*L**	*a**	*b**	ΔE	Hardness (g)
Control	-	-	-	79.00±0.59^{a}	2.50±0.30^{a}	20.20±0.48^{a}		13657.36±7853.71^{a}
1	-	160	5	78.42±0.69^{a,b}	1.50±0.24^{c}	17.30±0.82^{e}	2.84±0.02^{a}	6972.14±7124.50^{b}
2	-	160	10	78.47±0.42^{a}	1.54±0.21^{c}	17.58±0.62^{d,e}	2.96±0.10^{a}	7472.14±8024.50^{c}
3	300	-	5	77.99±0.69^{a,b,c}	1.80±0.21^{c}	17.63±0.50^{d,e}	2.42±0.03^{a}	9380.84±4806.81^{a}
4	300	-	10	77.91±1.54^{a,b,c}	1.63±0.53^{c}	18.15±2.26^{d,e}	2.52±0.02^{a}	7691.45±6618.66 ^{c}
5	600	-	5	77.54±0.77^{b,c}	1.70±0.25^{c}	18.34±0.96^{d}	2.43±0.00^{a}	6670.93±7844.52^{b}
6	600	-	10	77.43±0.95^{c}	1.71±0.41^{c}	18.52±0.89^{c}	1.93±0.04^{a}	9840.33±7116.31^{a}
7	300	160	5	77.47±0.57^{c}	1.56±0.28^{c}	19.56±0.62^{d}	6.92±0.03^{a}	4966.77±3568.27^{d}
8	300	160	10	73.20±1.15^{f}	2.60±0.33^{b}	23.97±1.24^{a}	5.04±0.02^{a}	4457.01±4238.66^{d}
9	600	160	5	74.02±1.39^{e}	3.11±0.48^{a}	20.68±0.57^{b}	3.90±0.00^{a}	5791.45±6015.56^{d}
10	600	160	10	75.21±1.30^{d}	2.42±0.48^{b}	21.11±1.29^{b}	2.96±0.10^{a}	6847.94±4723.96^{b}

$^{a\text{-}e}$ Means in the same coloumn with different superscripts are significantly different (P≤0.05).

In another study the sufflower was roasted at 180°C for 15 min. After Maillard reaction the color of the products was increased (Taha and Matthäus 2018). Some quality criterias such as color, total phenolic contents of the oil, and the antioxidant activity of seeds oil influenced by higher temperatures (Taha and Matthäus 2018). Similarly in microwave roasting of chickpea lightness decreased while *a** and *b** value increased with roasting (Jogihalli et al. 2017). Additioanally, Mohammed et al. (2017), roasted sunflower seeds at 700 MHz at 130ºC in microwave oven and found the *a** value between 1.1 and 1.6 during 8 to 20 min roasting respectively.

Hojjati et al.(2015), roasted the pistachios and found the *L** value as 57.32 and 57.68 for 640 and 480 W during 4 min. respectively whereas the hot air roasting samples had this value as 54.51. The raw material has *L** value of 61.88. They also added that generally, when the roasting time increased at a constant MW power, a decrease in the *L** values of nuts was observed. Nevertheless, the ower of MW did not significantly effect lightness compared to control group (P>0.05). Pistachios became darker due to browning, when the MW roasting time and power increased the *a** values also increased; but also they concluded that the differences were not bigger than 2 units, so this could not create a problem for the consumers. They also determined that *b** value did not effected by MW time and power.

Evaluation of texture

Hardness is the measure of a material's resistance to deformation or collapse. In the context of food, hardness typically refers to the force required to break the material, often felt during the initial bite with the molars. Control sample had the hardness value of 13657.36±7853.71 (g). Hardness values differed significantly between the combined group and the other groups (P≤0.05). In the group of 300 W-5 in hardness was found as 9380 (g) and in the 600 W-10 min treatments as 9380 (g) which were not statistically significant from the control group (P>0.05). Minumum hardness value was determined as 4457.01 (g) in the 600 W-160ºC-10 min. In this study, it was observed that breaking force decreased with the microwave technology and also increase in roasting time and power, the samples became softer when compared with the unroasted one. As previously mentioned in a different study, The breaking force of P. terebinthus beans was adversely affected from the roasting power and roasting time increasing (Bölek and Özdemir 2017). In another study, maximum hardness of roasted sunflower seed was 1962 NS in treatment of 401 W, 121°C, 3.6 min. and minumum value was 256.9 NS in treatment of 401 W, 158°C, 3.6 min. During the roasting process at high temperatures, the decrease in moisture content of the kernels led to them becoming crispier and more fragile, requiring less force to break. Consequently, the hardness decreased (Mosayebi et al. 2018).

Similar to our study, time increase significantly effect the hardness value but not parallel with the increase in time or power. They investigated the effect of both methods of microwave and convection in sunflower seeds and used the temperature of 180°C for 5, 15, 20 and 25 min. The other groups were exposed to microwave radiation for 4, 6, and 8 minutes at microwave powers of 500, 600, and 800 W. The hardness value was found to be 22165.42 ± 3173.61 (g) in the control group and 21164.47 ± 2433.15 (g) in the 5-minute group during conventional roasting. While in MW roasting hardness was found to be as 21572.76± 1324.88 (g) in 500 W – 4 min; 19689.76± 1732.59 (g) in 500 W 6 min. group, and as 20226.33±2012.56 (g) in the group of 500 W 8 min. In the 600W group at 4 min. this value was 21097.56± 1533.23 (g); for 6 min. as 21574.66± 2246.01 (g); and for 8 min as 19670.44± 1295.45 (g) (Goszkiewicz et al. 2020).

In an earlier research investigation, the firmness of roasted sunflower seeds fell between 28.31 and 55.83 Newtons (N) (Costell et al. 2010; Joyner, 2019). Yin et al. (2023) conducted a study on sesame seeds and found that the judicious use of microwave technology offered distinct benefits compared to traditional hot-air roasting. They observed a significant improvement in the extraction rate of sesame seeds following microwave treatment, attributed to the enhanced porosity and disruption of cell structure within the seeds. So it can be effective on the texture (hardness) of tissues. Similar results were observed for roasted peanuts, where it was shown that hardness exhibited a linear relationship with both roasting time and microwave (MW) power. Additionally, the quadratic effect of MW power significantly impacted the hardness of the samples. The hardness of peanuts tended to decrease with increasing roasting time and MW power, attributed to the rise in brittleness resulting from moisture loss. This phenomenon suggests a slightly softer and crisper texture in the roasted peanuts (Kahyaoglu and Kaya, 2006). The ideal hardness for peanuts was achieved at 4528.34 grams, with a roasting time of 201.17 seconds and a microwave (MW) power of 898.57 watts, according to Raigar et al. (2017).

Evaluation of sensory analysis

Color, texture, odor and general appeal of roasted sunflower seeds scored by panelists (Table 3). The impact of various roasting conditions on the sensory evaluation of both control and roasted sunflower seeds is illustrated in Figure 1. There was a significant difference between the scores of panelists to color values of combination groups between the other groups ($P \leq 0.05$). Texture, odor and general appeal scores were decreased in the combined groups compared to the conventional and microwave roasting methods when they seperately applied. However, these decreases not showed statistically significant effects between the groups ($P > 0.05$).

Table 3. Sensorial Analysis of Control and Roasted Sunflower Seeds

Sample	Power (W)	Temperature (°C)	Time (min)	Color	Texture	Odor	General Appeal
Control	-	-	-	8.25 ± 0.86^{a}	7.37 ± 1.63^{a}	8.00 ± 1.03^{a}	8.00 ± 0.73^{a}
1	-	160	5	$8.00 \pm 1.03^{a,b}$	7.00 ± 1.59^{a}	$7.37 \pm 1.15^{a,b}$	$7.56 \pm 1.03^{a,b}$
2	-	160	10	$6.81 \pm 1.68^{b,c}$	$6.62 \pm 2.22^{a,b,c}$	$7.06 \pm 1.29^{a,b,c}$	$6.94 \pm 1.29^{a,b,c}$
3	300	-	5	$7.37 \pm 1.36^{a,b,c}$	$6.75 \pm 1.84^{a,b}$	$6.56 \pm 1.67^{b,c,d,e}$	$6.81 \pm 1.17^{b,c}$
4	300	-	10	$7.44 \pm 1.03^{a,b,c}$	$6.62 \pm 2.28^{a,b,c}$	$6.69 \pm 1.14^{b,c,d,e}$	$6.75 \pm 1.29^{b,c}$
5	600	-	5	$7.56 \pm 1.46^{a,b,c}$	$5.75 \pm 2.86^{a,b,c}$	$6.69 \pm 1.40^{b,c,d,e}$	$6.50 \pm 1.41^{b,c}$
6	600	-	10	$6.56 \pm 2.30^{c,d}$	7.19 ± 1.33^{a}	$6.75 \pm 1.44^{b,c,d}$	$6.50 \pm 1.63^{b,c}$
7	300	160	5	$6.94 \pm 1.61^{b,c}$	7.44 ± 1.46^{a}	$6.56 \pm 2.10^{b,c,d,e}$	$6.69 \pm 2.33^{b,c}$
8	300	160	10	5.56 ± 1.75^{d}	$6.06 \pm 1.88^{a,b,c}$	$5.75 \pm 1.77^{d,e}$	5.81 ± 1.33^{c}
9	600	160	5	$6.81 \pm 1.80^{b,c}$	5.06 ± 2.52^{c}	$5.81 \pm 1.64^{c,d,e}$	5.81 ± 1.51^{c}
10	600	160	10	$6.31 \pm 1.92^{c,d}$	$5.12 \pm 2.45^{b,c}$	5.44 ± 2.22^{e}	5.75 ± 1.80^{c}

$^{a-e}$ Means in the same coloumn with different superscripts are significantly different ($P \leq 0.05$).

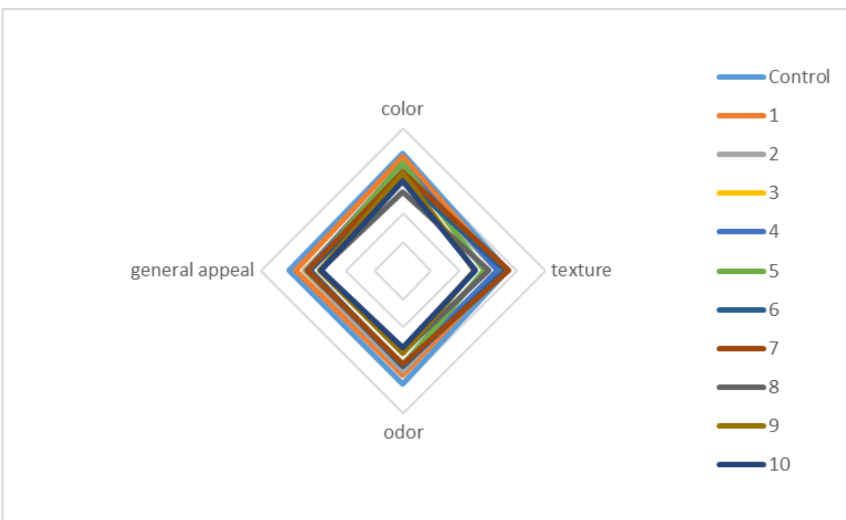

Fig 1. Effects of different roasting conditions on the sensory analysis of control and roasted sunflower seeds.

In line with these findings, Goszkiewicz et al. (2020) discovered that conventional roasting notably enhanced the aromas and flavors of seeds. However, they did not observe significant differences in consumer preference between microwave and conventional treatment methods. Goszkiewicz et al. (2020) further noted that the assessment of unroasted, microwave, and conventionally roasted samples demonstrated a heightened intensity of aroma and taste with convective roasting. However, microwave roasting did not compromise the sensory quality of the product, as evidenced by overall consumer preference. Additionally, the utilization of convection roasting was found to increase the textural hardness value.

The earlier researchers also elucidated that texture parameters exhibited a positive correlation with sensorial hardness and a negative correlation with total acceptance. Hence, it can be inferred that lower textural values corresponded to higher consumer acceptance scores and overall acceptability. From the consumers' perspective, the samples garnered moderate total acceptance. This observation may be attributed to the novel color and flavor profiles of the samples (Mohammadi-Moghadda, 2021). In agreement to these results in this study also it can be said that it is very difficult to choose the newly processed food product instead of the usual consumed ones, so it is normal to be that the scores was not significantly changed ($P>0.05$).

The sensory evaluation of roasted sunflower seeds revealed a moderate level of overall acceptance among consumers, potentially attributed to the novel color and flavor profiles of the samples. Goszkiewicz et al. (2020) observed that the aroma and taste of sunflower seeds roasted using the conventional method were predominantly preferred, hypothesizing that this preference might stem from the higher convection roasting temperature, with the sample temperature averaging at 75°C post-roasting. Importantly, the roasting methods employed did not have adverse effects on the structure of the sunflower seeds. These findings align with the results of studies by Mosayebi et al. (2018) and Soleimanieh et al. (2015), which indicated a decrease in moisture content of the seeds and an associated increase in crispiness.

Laemont and Sheryl Barringer (2023) noted that unlike other nuts such as peanuts, roasted sunflower seeds lack a standard color. However, consumers are able to discern the difference between the aromas of roasted and unroasted sunflower seeds by the end of sensory analysis. Another researcher emphasized that roasting parameters, particularly time and temperature, are crucial for the formation of contaminants, as they significantly influence the concentration of compounds such as furan (Silva da Costa et al. 2023). In a separate study by Hojjati et al. (2015), the highest scores for volatile concentration and sensory odor intensity scores were determined in hot air roasted pistachios and microwaved pistachios at 640 watts for 4 minutes.

In a prior study, it was clearly demonstrated through Spider's web plots that microwave roasting for 8 minutes led to enhanced aroma in roasted kernels compared to samples roasted for 4 and 6 minutes. They also decided that the scores decrease when the microwave power and the time decreased. Furthermore, MW power of 600 W and roasting time of 6 min gave the best result in the sensory test. As a result, samples treated with high power for longer periods received scores significantly below the average. In our study, the panelists observed that after roasting process the seeds were generally liked but the scores significantly different compared to the control unroasted ones, while it can be thought that the type of roasting method did not significanty affect the sensorial characteristics ($P>0.05$). According to this study, the expert panel did not detect any significant changes in the texture of sunflower seeds after roasting, whereas raw seeds were evaluated as firmer. Additionally, in another study, seeds roasted in an electric oven received higher overall acceptability scores compared to seeds roasted in a microwave oven (Biosci et al., 2015; Mosayebi et al.,2018). Another work selected 900 W for 6 min. as the optimum for the MW process of sesame seeds because the most preferred sensory quality was found in this group. Indeed, excessive microwave pretreatment (at 900

W for 10 minutes) resulted in a further decrease in aroma-active heterocyclics and γ-tocopherol, while increasing the perception of undesirable sensory attributes such as a strong bitter taste and burnt flavor (Yin et al., 2023). It's worth noting that the acceptance of food is influenced by various factors including its sensory properties, consumer expectations, cultural background, physiological state (such as hunger, thirst, or illness), and many other factors. (Costell et al. 2010; Joyner, 2019).

CONCLUSION

Sunflower seeds are not only nutritionally beneficial but also highly favored by consumers. They are commonly incorporated into food mixes, multi-grain bread, and bars, which are particularly beloved choices among consumers. Microwave-assisted dry roasting of seeds offers several distinct advantages. The intense heat is generated directly within the food material, thanks to the uniform penetration and distribution of microwave radiation upon exposure. Results were evaluated and microwave+conventional roasted samples generally gave better results compared to individual treatments of microwave and conventional roasted samples. 300 W, 160ºC, 10 min and 600W, 160ºC, 5 min combined application groups had the highest color *(a** and *b**) values. Protein and fat contents also found higher in the 600 W, 160ºC, 10 min and 5 min groups. Sensorial test indicated that, consumers can prefer the roasted sunflower seeds with more tender texture. The combined effect of microwave (MW) and conventional roasting on seeds has a profound impact on their physicochemical characteristics. This study provided insights on the quality changes of roasted sunflower seeds using different techniques together. In further researches, optimizing parameters for different type of plant seeds and also the effects on the shelf life can be examined.

DECLARATION OF COMPETING INTEREST

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