

Influence of Thermal Processing on Oil Contents, Bioactive Properties of Melon Seed and Oils

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Abstract: The oil content and the fatty acid composition of roasted and unroasted melon seed and oils were determined. The oil contents of roasted melon seeds changed between 26.4% (Type 12) and 38.7% (Type 4). In general, oil contents of roasted melon seeds were found higher than that of unroasted seeds that could be due to the evaporation of water during roasting processes which consequently lead to increased concentrations of other seed components including oils. Saturated fatty acid contents of unroasted melon seed samples change between 13.5% (Type 6) and 17.1% (Type 20). In addition, polyunsaturated fatty acids of unroasted melon seed oils ranged from 51.9% (Type 13) to 70.2% (Type 6). Palmitic acid contents of roasted seed oils varied between 7.8% (Type 5) and 15.1% (Type 17). In addition, the oleic acid contents ranged from 15.4% (Type 10) to 37.7% (Type 17). Also, linoleic acid contents were found between 34.7% (Type 17) and 70.3% (Type 6). Saturated fatty acid contents of roasted melon seed oils ranged from 13.5% (Type 6) to 16.7% (Type 13). The major tocopherols in both roasted and unroasted melon seed oils were α -tocopherol, γ -tocopherol and δ -tocopherols. Melon seed oils are rich in linoleic, oleic acids and γ -tocopherol.

Key words: melon, seed, roasting, oil, fatty acids, tocopherols, GC, HPLC

1 Introduction

Cucurbit species (gourd, melon, cucumber, squash, and pumpkin) are grown in both temperate and tropical regions of the world^{1,2}. Melon seeds are well known as rich sources of essential oil³⁻⁵. Fatty acid compositions of edible oils are responsible for their stability and nutritional value^{6,7}. Most of these oils are used as cooking oil in some countries⁸. Roasting is the most important thermal process that cause substantial changes in physicochemical and sensory properties of coffee, nuts, and beans^{9,10}. Heating treatment is reported to increase the amounts of polyunsaturated fatty acids in some vegetable oils¹¹. α -Tocopherol is beneficial to human nutrition because it has a higher biological activity than other tocopherols¹². Since melon seed oils were used as cooking oil in some countries in Africa and Middle East, the melon seed oils could be developed into commercial products to serve as alternate vegetable oils^{4,8}. A few study on raw has been reported on the fatty acid composition of roasted melon seed oils. So, the aim of present study was to investigate oil content and the fatty acid composition of roasted and unroasted melon seed oils.

2 Material and Methods

2.1 Material

Melon seeds were collected from twenty-one types of melon fruits obtained from different locations (Adana, Afyonkarahisar, Ankara, Konya, Manisa, and Mersin (Mut)) provinces of Turkey during September 2018. After the melon samples were cut, seeds were collected manually and washed with tap water to remove fibers and foreign materials. After that, the seeds were dried in oven at 70°C and then kept at 4°C until processing and analysis.

2.2 Methods

2.2.1 Oven roasted

About 100 g of melon seeds were roasted at 120°C for 30 min on an electrically heated tray (Nüve FNO55, Ankara, Turkey). The heating time was controlled to avoid any excessive heating of the seed samples.

2.2.2 Oil content

Oil content of seed samples was determined according to ISO 659:1998 method¹³. Total oil content of melon seeds was extracted with petroleum ether (Merck, Darmstad,

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Germany) in Soxhlet Apparatus for 6 h and the solvent was removed with a rotary vacuum evaporator at 40°C and 25 Torr. The oil was dried by a stream of nitrogen and stored at -20°C until used.

2.2.3 Determination of fatty acids

Seed oils were esterified according to Hişil¹⁴. After the oil samples (50-100 mg) was converted to its fatty acid methyl esters (FAME), they were analyzed by gas chromatography (HP 6890) equipped with flame ionization detector (FID) and capillary column (60 m × 0.25 mm i.d.; film thickness 0.20 micrometres). The temperature of injection block and detector was 260°C. The running program was operated under the following conditions: oven temperature program 175°C for 7 min, raised to 250°C at a rate 5°C/min and then kept at 250°C for 15 min. Nitrogen was a carrier gas and was run at a flow rate of 1.51 mL/min, and split ratio of 1/50 µL/min.

2.2.4 Tocopherol content

In this assay, 20 µL oil samples were instantaneously injected into the Diol phase HPLC silica 60 column (25 cm × 4.6 mm ID) at a flow rate of 1.3 mL/min. The contents of tocopherol in both unroasted (raw) and roasted melon seed oils were determined following method of Spika *et al.*¹⁵. HPLC system for tocopherol analysis consisted of Shimadzu-HPLC equipped with PDA detector.

2.3 Statistical analyses

All analyses were carried out three times and the results are expressed as the mean ± standard deviation (MSTAT C) of independent melon seed samples¹⁶.

3 Results and Discussion

In this study, the effect of roasting on oil contents and fatty acids of melon seed and seed oils was investigated. Oil content and fatty acid composition of non-roasted and roasted melon seeds are shown in **Tables 1** and **2**. Regardless of roasting treatment, oil content was significantly varied among melon seeds, which could be due to the differences in the environmental conditions, agronomical practices, and genetic makeup of melon seeds. While oil contents of unroasted melon seeds changed between 26.1% (Type 12) and 37.3% (Type 4), oil contents of roasted seeds varied between 26.4% (Type 12) and 38.7% (Type 4). De Mello *et al.*¹⁷ reported that the melon (*Cucumis melo* var. *saccharinus* Naud, cv. Daimiel commercially classified as "Pele de Sapo") seeds contained 32.3% lipid. Teotia and Ramakrishna¹⁸ reported that oil contents of the seeds of melons grown in India varied between 40% and 47%. Due to the presence of the hulls, the oil content of melon seed ranged from 22.1 to 53.5%¹⁹. According to Raji and Orelaja²⁰, golden melon seed contained 31.86% crude oil. In addition, Egbibi²¹ reported that oil contents of three dif-

ferent melon seed were found between 44.00 % and 55.00 %. The results showed that the oil contents of roasted seeds were higher compared to oil contents of unroasted melon seeds. The high oil contents of roasted seeds may possibly be due to the concentration of oil in the seeds by evaporating the water during roasting processes.

The major fatty acids of unroasted melon seed oils were palmitic, stearic, oleic and linoleic acids (**Table 1**). While palmitic acid contents of melon seed oils change between 7.8% (Type 9) and 9.7% (Type 2), stearic acid contents of oil samples were found between 5.5% (Type 6) and 8.0% (Type 20). In addition, oleic acid contents of melon seed oils changed between 15.2% (Type 10) and 31.8% (Type 13). Besides these results, linoleic acid contents of samples ranged from 51.9% (Type 13) to 70.2% (Type 6). While saturated fatty acid contents of samples change between 13.5% (Type 6) and 17.1% (Type 20), monounsaturated fatty acid contents of oils were found between 15.2% (Type 10) and 30.5% (Type 12). In addition, polyunsaturated fatty acids ranged from 51.9% (Type 13) to 70.2% (Type 6). Fatty acids profiles were also different among melon seeds from different locations, and this could be due to the variation in environmental conditions and genetic background of the seeds. The differences in oleic and linoleic acids content in different unroasted seed types can be probably due to genetic properties and climatic and cultivation conditions. Melon seed oils are generally rich in n-6 fatty acid. The fatty acid profiles of the melon seed oil showed the contents of 77.4% unsaturated and 63.2% polyunsaturated fatty acid¹⁹.

Table 2 shows oil content and fatty acid compositions of roasted melon seed and seed oils. In general, oil contents of roasted melon seeds were found higher than that of unroasted seeds that could be due to the evaporation of water during roasting processes which consequently lead to increased concentrations of other seed components including oils. Palmitic acid contents of roasted seed oils ranged from 7.8% (Type 5) to 15.1% (Type 17). Stearic acid contents of samples were found between 5.4% (Type 6) and 12.3% (Type 17). While oleic acid contents of roasted seed oils change between 15.4% (Type 10) and 37.7% (Type 17), linoleic acid contents were determined between 34.7% (Type 17) and 70.3% (Type 6). It was observed statistically significant differences among the amounts of some fatty acids of melon seed oils depending on melon types ($p < 0.005$). Saturated fatty acid contents of roasted melon seed oils ranged from 13.5% (Type 6) to 16.7% (Type 13). Rayees *et al.*²¹ observed an amounts of 80.07% linoleic acid, 11.71% palmitic, 4.10% oleic, 3.74% stearic and 0.37% linolenic acids in winter melon (*Benincasa hispida* (Thunb.)) seed oil. The key fatty acid of melon seed oil was linoleic acid (62.2%) followed by palmitic (12.42%), stearic (10.2%), oleic (14.2%) and linoleic (1.02%)¹⁹. The seed oils of melon (*Cucumis melo* var. *agrestis*) contained 61.3

Table 1 Oil contents and fatty acid composition of non-roasted melon seeds (%).

| Melon Types | Oil % | Myristic | Palmitic | Stearic | Oleic | Linoleic | SAFA | MUFA | PUFA | n-3 | n-6 |
|-------------|---------------------------|--------------------------|--------------------------|--------------------------|---------------------------|--------------------------|------------|------------|------------|-------------|------------|
| 1 | 35.4 ± 0.91* ^b | - *** | 9.4 ± 0.11 ^b | 6.4 ± 0.17 ^g | 19.1 ± 0.98 ^l | 65.2 ± 0.48 ^e | 15.77 | 19.06 | 65.16 | - | 65.16 |
| 2 | 32.0 ± 1.13e** | - | 9.7 ± 0.47 ^a | 6.1 ± 0.09 ^l | 20.4 ± 0.37 ^k | 63.9 ± 0.51 ^g | 15.74 | 20.37 | 63.89 | - | 63.89 |
| 3 | 32.8 ± 1.68 ^e | - | 8.9 ± 0.61 ^d | 5.9 ± 0.07 ^k | 19.6 ± 0.41 ^l | 65.5 ± 0.73 ^e | 14.84 | 19.62 | 65.54 | - | 65.54 |
| 4 | 37.3 ± 1.37 ^a | - | 8.2 ± 0.18 ^g | 5.9 ± 0.05 ^k | 22.5 ± 0.54 ⁱⁱ | 63.3 ± 0.81 ^g | 14.21 | 22.46 | 63.32 | - | 63.32 |
| 5 | 33.9 ± 1.92 ^d | 0.05 ± 0.03 ^a | 8.1 ± 0.09 ^{gh} | 6.4 ± 0.13 ^g | 29.2 ± 0.48 ^d | 55.5 ± 0.36 ^k | 14.50 | 29.99 | 55.51 | - | 55.51 |
| 6 | 30.2 ± 1.45 ^f | - | 8.0 ± 0.11 ⁱ | 5.5 ± 0.08 ^m | 16.4 ± 0.32 ⁿ | 70.2 ± 0.48 ^a | 13.48 | 16.35 | 70.17 | - | 70.17 |
| 7 | 26.9 ± 1.36 ^h | - | 8.5 ± 0.27 ^f | 5.8 ± 0.21 ^{kl} | 16.8 ± 0.37 ⁿ | 68.9 ± 0.72 ^c | 14.35 | 16.79 | 68.86 | - | 68.86 |
| 8 | 33.2 ± 2.57 ^d | 0.04 ± 0.01 ^b | 7.9 ± 0.31 ⁱ | 6.4 ± 0.19 ^g | 22.2 ± 0.19 ⁱⁱ | 63.6 ± 0.98 ^g | 14.25 | 22.15 | 63.59 | - | 63.59 |
| 9 | 30.1 ± 1.69 ^f | 0.04 ± 0.01 ^b | 7.8 ± 0.23 ^{ij} | 6.7 ± 0.15 ^d | 30.0 ± 0.28 ^c | 55.5 ± 0.64 ^k | 14.46 | 30.04 | 55.49 | - | 55.49 |
| 10 | 29.9 ± 0.87 ^g | 0.04 ± 0.01 ^b | 8.9 ± 0.17 ^d | 6.6 ± 0.07 ^e | 15.2 ± 0.51 ^ö | 69.1 ± 0.59 ^b | 15.48 | 15.17 | 69.35 | 0.27 | 69.08 |
| 11 | 32.3 ± 1.68 ^e | 0.05 ± 0.03 ^a | 8.4 ± 0.13 ^{fg} | 6.8 ± 0.09 ^{cd} | 29.7 ± 0.17 ^{cd} | 55.1 ± 0.28 ^k | 15.21 | 29.69 | 55.10 | - | 55.10 |
| 12 | 26.1 ± 1.75 ^h | - | 8.3 ± 0.18 ^g | 6.4 ± 0.03 ^{fg} | 30.5 ± 0.17 ^{bb} | 54.8 ± 0.45 ^l | 14.65 | 30.53 | 54.82 | - | 54.82 |
| 13 | 34.3 ± 0.83 ^c | - | 8.1 ± 0.41 ^{gh} | 8.2 ± 0.05 ^a | 31.8 ± 0.34 ^a | 51.9 ± 0.42 ^m | 16.29 | 31.78 | 51.92 | - | 51.92 |
| 14 | 34.4 ± 0.67 ^c | - | 8.3 ± 0.22 ^g | 5.9 ± 0.07 ^j | 21.7 ± 0.28 ^{ij} | 64.1 ± 0.38 ^f | 14.17 | 21.70 | 64.13 | - | 64.13 |
| 15 | 35.8 ± 1.84 ^b | - | 8.8 ± 0.38 ^{de} | 6.5 ± 0.03 ^{ef} | 23.9 ± 0.31 ^h | 60.8 ± 0.53 ^h | 15.29 | 23.86 | 60.84 | - | 60.84 |
| 16 | 32.7 ± 1.45 ^e | - | 8.1 ± 0.23 ^{gh} | 6.0 ± 0.09 ⁱ | 22.5 ± 0.18 ⁱⁱ | 63.4 ± 0.29 ^g | 14.09 | 22.48 | 63.43 | - | 63.43 |
| 17 | 35.8 ± 2.89 ^b | - | 9.1 ± 0.35 ^c | 6.3 ± 0.05 ^{gh} | 18.3 ± 0.11 ^m | 66.3 ± 0.78 ^d | 15.39 | 18.28 | 66.33 | - | 66.33 |
| 18 | 34.7 ± 1.47 ^c | - | 8.5 ± 0.38 ^f | 6.9 ± 0.03 ^c | 25.8 ± 0.36 ^g | 58.9 ± 0.44 ⁱ | 15.35 | 25.79 | 58.86 | - | 58.86 |
| 19 | 32.1 ± 2.87 ^e | 0.04 ± 0.01 ^b | 7.9 ± 0.24 ⁱ | 6.7 ± 0.14 ^d | 28.7 ± 0.23 ^e | 56.6 ± 0.53 ^j | 14.71 | 28.69 | 56.60 | - | 56.60 |
| 20 | 30.7 ± 0.84 ^f | 0.05 ± 0.03 ^a | 9.0 ± 0.19 ^c | 8.0 ± 0.17 ^b | 27.3 ± 0.28 ^f | 55.5 ± 0.19 ^k | 17.12 | 27.36 | 55.52 | - | 55.52 |
| 21 | 29.9 ± 0.39 ^g | 0.05 ± 0.01 ^a | 8.4 ± 0.26 ^{fg} | 5.8 ± 0.09 ^{kl} | 19.0 ± 0.33 ⁱ | 66.8 ± 0.75 ^d | 14.20 | 19.01 | 66.79 | - | 66.79 |
| Mean ± SD | 32.4 ± 2.9 | 0.02 ± 0.02 | 8.5 ± 0.5 | 6.4 ± 0.07 | 23.4 ± 5.2 | 57.2 ± 15.9 | 14.9 ± 0.9 | 23.4 ± 5.3 | 61.7 ± 5.5 | 0.01 ± 0.05 | 61.7 ± 5.5 |

*mean ± standard deviation; **values within each column followed by different letters are significantly different at $p < 0.05$; ***nonidentified; SAFA: Saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: Polyunsaturated fatty acid.

Table 2 Oil content and fatty acid composition of roasted melon seeds (%).

| Melon Types | Oil % | Myristic | Palmitic | Stearic | Oleic | Linoleic | SAFA | MUFA | PUFA | n-3 | n-6 |
|-------------|----------------------------|--------------|--------------|--------------|---------------|--------------|------------|------------|------------|-------------|------------|
| 1 | 36.7 ± 2.23 ^{*b} | - *** | 9.4 ± 0.32c | 6.2 ± 0.51g | 18.7 ± 0.77j | 65.6 ± 0.46d | 15.57 | 18.86 | 65.57 | - | 65.57 |
| 2 | 32.6 ± 1.87 ^{g**} | 0.04 ± 0.01d | 9.7 ± 0.83b | 5.7 ± 0.34i | 20.2 ± 0.65ii | 64.3 ± 0.53e | 15.45 | 20.27 | 64.28 | - | 64.28 |
| 3 | 34.3 ± 3.28e | 0.05 ± 0.03c | 9.3 ± 0.17cd | 6.3 ± 0.09ef | 20.6 ± 0.38ii | 63.8 ± 0.78f | 15.64 | 20.58 | 63.77 | - | 63.77 |
| 4 | 38.7 ± 1.61a | 0.05 ± 0.02c | 8.4 ± 0.21g | 6.1 ± 0.07gh | 22.7 ± 0.23h | 62.8 ± 0.69g | 14.50 | 22.71 | 62.79 | - | 62.79 |
| 5 | 35.1 ± 1.13d | 0.05 ± 0.01c | 7.8 ± 0.37f | 6.6 ± 0.26de | 29.8 ± 0.43c | 55.7 ± 0.27i | 14.50 | 29.82 | 55.68 | - | 55.68 |
| 6 | 31.9 ± 1.56h | 0.04 ± 0.01d | 8.1 ± 0.09h | 5.4 ± 0.19j | 16.2 ± 0.28kl | 70.3 ± 0.51a | 13.52 | 16.19 | 70.29 | - | 70.29 |
| 7 | 27.3 ± 1.78j | - | 8.6 ± 0.07ef | 5.9 ± 0.42h | 16.6 ± 0.17k | 68.9 ± 0.44b | 14.55 | 16.59 | 68.86 | - | 68.86 |
| 8 | 34.5 ± 2.64c | 0.04 ± 0.01d | 8.1 ± 0.11h | 6.3 ± 0.21ef | 21.9 ± 0.38i | 63.7 ± 0.48f | 14.40 | 21.93 | 63.66 | - | 63.66 |
| 9 | 31.2 ± 2.87h | 0.05 ± 0.03c | 8.2 ± 0.14gh | 6.4 ± 0.13e | 29.6 ± 0.58c | 55.8 ± 0.63i | 14.63 | 29.57 | 55.80 | - | 55.80 |
| 10 | 31.9 ± 1.32h | 0.04 ± 0.01d | 8.9 ± 0.05e | 6.6 ± 0.11de | 15.4 ± 0.61m | 68.9 ± 0.29b | 15.58 | 15.44 | 68.98 | - | 68.98 |
| 11 | 33.7 ± 1.56f | 0.04 ± 0.01d | 8.4 ± 0.18g | 6.7 ± 0.08d | 29.2 ± 0.42c | 55.7 ± 0.17i | 15.12 | 29.16 | 55.71 | - | 55.71 |
| 12 | 26.4 ± 1.44k | 0.04 ± 0.02d | 8.3 ± 0.23eg | 6.3 ± 0.07ef | 29.2 ± 0.36c | 56.1 ± 0.53k | 14.65 | 29.23 | 56.11 | - | 56.11 |
| 13 | 34.4 ± 1.28e | 0.05 ± 0.01c | 8.3 ± 0.27eg | 8.3 ± 0.03b | 31.55 ± 0.13b | 51.7 ± 0.39m | 16.71 | 31.55 | 51.74 | - | 51.74 |
| 14 | 35.5 ± 0.67d | 0.04 ± 0.01d | 9.2 ± 0.18d | 6.4 ± 0.41e | 23.2 ± 0.11gf | 61.2 ± 0.54h | 15.62 | 23.15 | 61.22 | - | 61.22 |
| 15 | 36.1 ± 0.98c | 0.06 ± 0.03b | 9.0 ± 0.15de | 6.5 ± 0.09e | 24.4 ± 0.25e | 59.9 ± 0.79i | 15.61 | 24.49 | 59.90 | - | 59.90 |
| 16 | 34.1 ± 0.46c | 0.06 ± 0.03b | 9.0 ± 0.32de | 7.3 ± 0.45c | 25.2 ± 0.31d | 58.0 ± 0.81j | 16.53 | 25.23 | 58.24 | 0.22 | 58.02 |
| 17 | 38.7 ± 2.15a | 0.09 ± 0.02a | 15.1 ± 0.28a | 12.3 ± 0.87a | 37.7 ± 0.56a | 34.7 ± 0.48 | 27.46 | 37.82 | 34.72 | - | 34.72 |
| 18 | 36.0 ± 1.77c | 0.05 ± 0.01c | 9.3 ± 0.11c | 6.3 ± 0.49ef | 18.8 ± 0.62j | 65.4 ± 0.61d | 15.69 | 18.81 | 65.49 | - | 65.49 |
| 19 | 33.0 ± 1.89f | - | 8.3 ± 0.82eg | 6.7 ± 0.32d | 29.1 ± 0.49c | 55.9 ± 0.36i | 14.99 | 29.06 | 55.95 | - | 55.95 |
| 20 | 31.1 ± 1.21hi | - | 9.3 ± 0.64cd | 6.2 ± 0.29g | 18.6 ± 0.59j | 65.9 ± 0.43d | 15.40 | 18.64 | 65.96 | - | 65.96 |
| 21 | 30.3 ± 1.37i | 0.05 ± 0.03c | 8.6 ± 0.57ef | 5.8 ± 0.17hi | 18.9 ± 0.73j | 66.5 ± 0.53c | 14.51 | 18.99 | 66.50 | - | 66.50 |
| Mean ± SD | 33.5 ± 3.2f | 0.04 ± 0.02 | 9.0 ± 1.5 | 6.7 ± 1.4 | 23.7 ± 6.0 | 60.5 ± 7.9 | 15.7 ± 2.8 | 23.7 ± 6.0 | 60.5 ± 7.9 | 0.01 ± 0.05 | 60.5 ± 7.9 |

*mean ± standard deviation; **values within each column followed by different letters are significantly different at $p < 0.05$; ***nonidentified; SAFA: Saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: Polyunsaturated fatty acid.

and 61.4% linoleic acids for Ghibaish and Gezira samples, respectively⁵). De Mello *et al.*¹⁷) reported that melon seed oil contained 51% linoleic, 31% oleic, 8.5% palmitic and 6.1% stearic acids. Akoh and Nwosu²²) reported that melon (*Citrullus vulgaris*) seed oil contained 71.3% linoleic acid. *Citrullus vulgaris* seed oil contained 0.33% oleic, 76.24% linoleic, 9.01% stearic and 14.42% palmitic acids²³). These findings are indicated the amount of unsaturated fatty acid is higher than saturated in melon seed oil. The results are similar to those values given by De Mello *et al.*¹⁷), Milovanovic and Picuric-Jovanovic¹⁹), Mariod and Matthäus⁵), and Anwar *et al.*²⁴). The fatty acid composition of melon seed oils showed differences between unroasted and roasted samples. As mean, palmitic, oleic and linoleic acid contents of roasted seed oil samples were found partially high compared to results of the same fatty acids of unroasted melon seed oils. Mallek-Ayadi *et al.*²⁵) reported that the physicochemical properties of the seed oil revealed a high degree of unsaturation, and linoleic acid (68.98%) and oleic acid (15.84%) were the key fatty acids of melon seed oil, which makes this oil nutritionally valuable. Ali *et al.*²⁶) observed slight increases in palmitic and stearic acids with concomitant reduction in linoleic acid during roasting process of pumpkin seed oil and they attributed these changes to the thermal degradation of PUSF. In this study, roasting process slightly increased the mean values of SFA, while it concomitantly reduced the mean values of PUSF of melon seed oils. The change could be attributed to the degradation of PUFA during thermal treatment as reported previously in microwave-roasted pumpkin seeds²⁶), perah seed oil²⁷), and groundnut kernel oil²⁸).

Tocopherol contents of raw and roasted melon seed oils were given in **Table 3**. The major tocopherols in both unroasted and roasted melon seed oils were α -tocopherol, γ -tocopherol and δ -tocopherols. While α -tocopherol contents of unroasted melon seed oils change between 4.41% (Type 18) and 17.73% (Type 6), γ -tocopherol contents of unroasted seed oils were determined between 56.86% (Type 9) and 91.69% (Type 18). In addition, δ -tocopherol contents of unroasted melon seed oils varied between 5.43% (Type 8) and 15.67% (Type 11). There are significant differences in tocopherol contents in unroasted seeds oils of different melon types. The differences in tocopherol contents in different seed types can be probably due to genetic properties and climatic, cultivation factors. While α -tocopherol contents of roasted melon seed oils vary between 2.78% (Type 18) and 16.51% (Type 6), γ -tocopherol contents of roasted melon seed oils ranged from 54.61% (Type 9) to 88.74% (Type 18). The highest δ -tocopherol contents were found in Type 11 melon seed oil (14.11%). Also γ -tocotrienol contents of unroasted melon seed oils changed between 3.17% (Type 1) and 14.21% (Type 21), γ -tocotrienol contents of roasted melon seed oils varied between 2.21% (Type 1) and 11.53% (Type

21). Tocopherol composition of raw and roasted melon seed oil showed significant differences ($p < 0.05$), and the tocopherol values were found higher in unroasted seed oils than the roasted ones. Generally, tocopherol contents of roasted melon seed oils partly decreased compared to results of unroasted melon seed oils. The reduction of tocopherol content in roasted seed oil could be attributed to the thermal decomposition of tocopherols by roasting temperature. Tocopherols are usually completely destroyed before the point at which the frying oil should be replaced based on the content of polymerized triacylglycerol or polar compounds²⁹).

The present results indicated that melon seed oils contains substantial quantities of main classes of tocopherols namely α -, β - and γ -tocopherols. In a previous study, Petkova and Antova³⁰) reported that the key component in the melon seed oils was γ -tocopherol, where its quantity ranged from 71.4% (Dessert 5) to 91.5% (Honeydew). They also observed a higher content of α -tocopherol (19.7%) in the seed oil of Dessert melon variety, compared to 2.9% and 6.2% observed in Honeydew and Hybrid 1 melon varieties, respectively³⁰). β -Tocopherol was found in minimum quantities (1.7%) in the oil extracted from the seeds of melon variety Honeydew³⁰). The unsaturated tocopherol representatives in the oils were presented by γ -tocotrienol with quantities ranged from 3.9 to 15.3%. The results obtained in the current study correlated to the data reported previously on the tocopherol content of the melon seed oils of variety *C. melo* var. *agrestis*, cultivated in Sudan, in which the γ -tocopherol was dominant (80.7 and 77.6% of the total tocopherol quantity), followed by α -tocopherol (18.0–21.0%)⁵). However, our findings contradict those reported in melon seed oil from variety *C. melo* var. *tibish*, in which in the predominant tocopherols were δ -tocopherol (63.4%), followed by γ -tocopherol (30.3%) and α -tocopherol (6.3%)³¹). The total tocopherol content in the current study was higher than that of *Cucumis melo* var. *flexuosus* seed oil³²). Overall, our findings demonstrated that the key tocopherol in oil samples of melon seeds collected from different locations in Turkey was γ -tocopherol, followed by δ -tocopherol, α -tocopherol, and γ -tocotrienols.

4 Conclusion

This study investigated the oil, fatty acids and tocopherol contents of roasted and unroasted melon seeds obtained from different locations in Turkey. The findings revealed that oil content, fatty acid composition, and tocopherols were different among melon seed types. In addition, roasting temperature also affected the oil, fatty acids profile, and tocopherols of melon seed oils. Although, roasting treatment increased oil content of the seeds, it reduced the contents of unsaturated fatty acids and tocopherols in the

Table 3 Tocopherol contents of raw (non-roasted) and roasted melon seed oils (%).

| Melon Types | Raw seed (non-roasted) | | | | | Roasted seed | | | | | |
|-------------|-----------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------|---------------------------|--------------------------|----------------------------|---------------------------|---------------------------|
| | α -Tocopherol | β -Tocopherol | γ -Tocopherol | δ -Tocopherol | γ -Tocotrienol | Melon Types | α -Tocopherol | β -Tocopherol | γ -Tocopherol | δ -Tocopherol | γ -Tocotrienol |
| 1 | 13.5 ± 0.36 ^c | 0.78 ± 0.03 ^{mn} | 67.8 ± 0.54 ^m | 11.56 ± 0.31 ^e | 3.17 ± 0.04 ⁱ | 1 | 12.5 ± 0.43 ^c | 0.56 ± 0.07 ^g | 63.1 ± 0.78 ^l | 9.43 ± 0.11 ^e | 2.21 ± 0.09 ^l |
| 2 | 11.27 ± 0.16 ^{e**} | 0.91 ± 0.07 ^{kl} | 78.42 ± 1.23 ⁱ | 12.37 ± 0.09 ^d | 5.78 ± 0.03 ^g | 2 | 10.31 ± 0.24 ^e | 0.83 ± 0.09 ^d | 76.38 ± 1.09 ^h | 11.43 ± 0.03 ^c | 4.56 ± 0.03 ^h |
| 3 | 9.61 ± 0.09 ^g | 1.67 ± 0.05 ^b | 81.45 ± 1.14 ^h | 13.89 ± 0.17 ^c | 8.24 ± 0.11 ^d | 3 | 8.89 ± 0.29 ^g | 1.04 ± 0.11 ^b | 80.37 ± 1.17 ^f | 11.44 ± 0.09 ^c | 6.89 ± 0.11 ^e |
| 4 | 8.76 ± 0.23 ^h | 0.64 ± 0.09 ⁶ | 65.93 ± 1.27 ⁿ | 13.71 ± 0.19 ^c | 3.47 ± 0.07 ⁱ | 4 | 7.43 ± 0.17 ^h | 0.56 ± 0.03 ^g | 61.75 ± 0.81 ^m | 12.36 ± 0.17 ^b | 2.27 ± 0.07 ^k |
| 5 | 4.43 ± 0.05 ^l | 0.98 ± 0.13 ^k | 90.17 ± 1.19 ^c | 14.67 ± 0.09 ^b | 5.58 ± 0.06 ^g | 5 | 3.37 ± 0.42 ⁿ | 0.73 ± 0.09 ^e | 88.35 ± 0.71 ^b | 12.58 ± 0.13 ^b | 3.87 ± 0.11 ^l |
| 6 | 17.73 ± 0.09 ^a | 1.56 ± 0.17 ^d | 92.86 ± 0.92 ^a | 9.56 ± 0.07 ^f | 7.61 ± 0.13 ^e | 6 | 16.51 ± 0.57 ^a | 1.03 ± 0.10 ^b | 90.24 ± 0.38 ^a | 8.32 ± 0.09 ^f | 6.49 ± 0.09 ^{ef} |
| 7 | 10.87 ± 0.18 ^f | 1.47 ± 0.09 ^{ef} | 75.43 ± 0.87 ^j | 8.71 ± 0.14 ^g | 11.46 ± 0.24 ^c | 7 | 8.61 ± 0.34 ^{gh} | 0.98 ± 0.03 ^c | 73.11 ± 1.18 ⁱ | 7.65 ± 0.27 ^g | 10.22 ± 0.27 ^c |
| 8 | 5.68 ± 0.41 ^k | 0.98 ± 0.05 ^k | 84.54 ± 0.65 ^c | 5.43 ± 0.09 ⁱ | 12.58 ± 0.28 ^b | 8 | 4.21 ± 0.09 ^l | 0.56 ± 0.04 ^g | 82.34 ± 0.38 ^d | 4.33 ± 0.18 ⁱ | 10.98 ± 0.69 ^b |
| 9 | 8.91 ± 0.09 ^h | 0.81 ± 0.09 ^m | 56.86 ± 0.38 ⁶ | 7.64 ± 0.19 ^h | 8.67 ± 0.53 ^d | 9 | 7.43 ± 0.13 ^h | 0.51 ± 0.03 ^g | 54.61 ± 0.27 ⁿ | 6.43 ± 0.13 ^h | 7.38 ± 0.48 ^d |
| 10 | 12.78 ± 0.03 ^d | 1.16 ± 0.01 ⁱ | 67.45 ± 0.57 ^m | 11.23 ± 0.21 ^e | 4.36 ± 0.09 ^h | 10 | 11.27 ± 0.23 ^d | 0.86 ± 0.07 ^d | 65.13 ± 0.67 ^k | 9.98 ± 0.93 ^e | 3.57 ± 0.43 ⁱⁱ |
| 11 | 11.85 ± 0.21 ^e | 1.57 ± 0.03 ^c | 77.56 ± 0.27 ⁱ | 15.67 ± 0.47 ^a | 3.48 ± 0.07 ⁱ | 11 | 9.48 ± 0.45 ^f | 0.95 ± 0.09 ^c | 75.37 ± 0.84 ^h | 14.11 ± 0.78 ^a | 2.75 ± 0.29 ^j |
| 12 | 7.45 ± 0.17 ⁱ | 1.43 ± 0.08 ^g | 71.49 ± 0.65 ⁱ | 8.75 ± 0.36 ^g | 7.69 ± 0.47 ^e | 12 | 5.97 ± 0.16 ^j | 1.05 ± 0.01 ^b | 69.34 ± 0.13 ^j | 7.71 ± 0.51 ^g | 5.28 ± 0.87 ^g |
| 13 | 6.32 ± 0.23 ^j | 0.85 ± 0.05 ^l | 88.67 ± 1.09 ^d | 7.48 ± 0.29 ^h | 5.64 ± 0.38 ^g | 13 | 5.24 ± 0.45 ^{kl} | 0.57 ± 0.03 ^g | 83.18 ± 0.46 ^c | 5.76 ± 0.38 ⁱ | 4.47 ± 0.33 ^h |
| 14 | 15.57 ± 0.09 ^b | 1.49 ± 0.11 ^c | 65.89 ± 1.13 ^m | 12.43 ± 0.37 ^d | 4.38 ± 0.27 ^h | 14 | 13.18 ± 0.52 ^b | 0.87 ± 0.07 ^d | 63.41 ± 0.54 ⁱ | 10.27 ± 0.41 ^d | 2.48 ± 0.36 ^{jk} |
| 15 | 4.94 ± 0.03 ^l | 1.73 ± 0.13 ^a | 91.17 ± 1.56 ^b | 11.89 ± 0.44 ^e | 5.29 ± 0.14 ^g | 15 | 3.53 ± 0.09 ^{mh} | 1.12 ± 0.09 ^a | 88.23 ± 0.76 ^b | 9.71 ± 0.54 ^e | 4.18 ± 0.28 ^h |
| 16 | 5.57 ± 0.07 ^k | 1.26 ± 0.09 ⁱ | 74.69 ± 1.38 ^k | 13.29 ± 0.53 ^c | 4.37 ± 0.19 ^h | 16 | 3.91 ± 0.11 ^m | 0.87 ± 0.09 ^d | 70.32 ± 0.45 ⁱ | 10.41 ± 0.44 ^d | 3.54 ± 0.07 ⁱⁱ |
| 17 | 6.72 ± 0.11 ^j | 0.65 ± 0.03 ⁿ | 84.21 ± 1.44 ^e | 11.57 ± 0.62 ^e | 6.23 ± 0.42 ^f | 17 | 5.58 ± 0.23 ^{jk} | 0.37 ± 0.05 ^h | 81.44 ± 0.98 ^c | 8.93 ± 0.58 ^f | 4.75 ± 0.05 ^h |
| 18 | 4.41 ± 0.09 ^l | 1.38 ± 0.11 ^h | 91.69 ± 1.78 ^b | 9.43 ± 0.07 ^f | 7.65 ± 0.46 ^e | 18 | 2.76 ± 0.18 ⁶ | 0.65 ± 0.07 ^f | 88.74 ± 0.77 ^b | 7.17 ± 0.65 ^g | 6.42 ± 0.21 ^{ef} |
| 19 | 8.34 ± 0.13 ^h | 0.78 ± 0.07 ^{mn} | 83.57 ± 0.67 ^f | 7.56 ± 0.05 ^h | 8.64 ± 0.53 ^d | 19 | 6.56 ± 0.71 ⁱ | 0.27 ± 0.03 ⁱ | 79.32 ± 0.83 ^{fg} | 5.29 ± 0.36 ⁱⁱ | 6.27 ± 0.13 ^f |
| 20 | 9.47 ± 0.07 ^g | 1.13 ± 0.02 ^j | 82.65 ± 0.98 ^g | 8.61 ± 0.11 ^g | 7.59 ± 0.44 ^e | 20 | 7.58 ± 0.54 ^h | 0.87 ± 0.09 ^d | 80.43 ± 1.14 ^f | 6.58 ± 0.23 ^h | 5.34 ± 0.45 ^g |
| 21 | 12.68 ± 0.14 ^d | 0.56 ± 0.03 ^p | 64.41 ± 0.56 ⁿ | 5.47 ± 0.03 ⁱ | 14.21 ± 0.39 ^a | 21 | 10.37 ± 0.35 ^e | 0.29 ± 0.03 ⁱ | 60.53 ± 0.91 ^{mn} | 3.86 ± 0.17 ^j | 11.53 ± 0.67 ^a |
| Mean ± SD | 9.37 ± 3.73 | 1.13 ± 0.37 | 77.95 ± 10.46 | 10.52 ± 2.95 | 6.96 ± 3.01 | Mean ± SD | 7.84 ± 3.63 | 0.74 ± 0.26 | 75.03 ± 10.60 | 8.75 ± 2.81 | 5.52 ± 2.63 |

*mean ± standard deviation; **values within each column followed by different letters are significantly different at $p < 0.05$.

oils. Thus, roasting conditions should be controlled to avoid reduction and losses of essential nutrients (PUFA and tocopherols) in melon seeds and oils. Future work should specifically address the impacts of different roasting temperature and times on the quality of melon seed oils.

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