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## FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

# Proximate composition of seeds and seed oils from melon (*Cucumis melo* L.) cultivated in Bulgaria

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**Abstract:** The seeds of three varieties of melon (*Cucumis melo* L.) from Bulgaria were analyzed for their chemical composition and a detailed study of their lipids was carried out. Chemical composition values were as follows: fat content ranged from 41.6 to 44.5%, protein 34.4 to 39.8%, crude fiber 4.5 to 8.5%, carbohydrates 8.2 to 12.7%, soluble sugars 3.7 to 4.2%, and minerals 4.6 to 5.1%. The content of sterols, phospholipids, and tocopherols in the oils was 0.6, 0.7–1.7%, and 435–828 mg/kg, respectively. The major fatty acid in lipids was linoleic (51.1–58.5%), followed by oleic acid (24.8–25.6%). The trilinolein (31.3–32.2%), oleo dilinolein (31.0–34.0%), and palmitoyl dilinolein (14.9–22.3%) have represented 80.0% from the total triglyceride composition of the melon seeds oil.  $\beta$ -Sitosterol predominated in both free and esterified sterols, being, respectively, 52.9–70.8 and 50.4–58.4%. Phosphatidylinositol (24.4–33.9%), phosphatidylcholine (23.0–33.1%), and phosphatidylethanolamine (8.4–17.1%) were the main phospholipids. Palmitic acid (34.4–61.7%) was the major fatty acid of the phospholipids, followed by oleic acid (8.9–27.2%). Linoleic acid (32.7–39.1%) was the main component among the fatty acids of the sterol esters, followed by oleic acid (25.1–30.7%). In the tocopherol fraction of melon seed oils, the main component  $\gamma$ -tocopherol varied from 71.4 to 91.5%.

**Subjects:** Food Chemistry; Food Science & Technology; Lipids

### ABOUT THE AUTHORS

The group's main research activities are to lead investigations over the chemical and lipid composition of different animal fats and vegetable oils; determination of their biologically active components and the possibilities of their application in food, medicine, and cosmetic industry.

The research reported in this paper could relates to wider projects as stabilization of melon seed oils with different natural antioxidants; determination of the best antioxidant for these oils following of subjecting the oils of long-term storage and investigating how their chemical and lipid composition change during the storage under different conditions.

### PUBLIC INTEREST STATEMENT

The seeds of three melon varieties (*Cucumis melo*) from Bulgaria were analyzed for their chemical and lipid composition. Chemical composition consisted as follows: fats, proteins, crude fiber, carbohydrates, soluble sugar, and minerals. The lipid composition of melon seeds included fatty acids, sterols, phospholipids, and tocopherols. They take part in the biologically active components, which contribute to the natural preservation of the oils from auto-oxidation. The major fatty acid in lipids was linoleic, followed by oleic acid. The trilinolein, oleo dilinolein, and palmitoyl dilinolein have represented 80.0% from the total triglyceride composition of the oils.  $\beta$ -Sitosterol predominated in sterols. Phosphatidylinositol, phosphatidylcholine, and phosphatidylethanolamine were the main phospholipids. Palmitic and oleic acids were the major fatty acids of the phospholipids. Linoleic and oleic acids were the main components among the fatty acids of the sterol esters. The main component in tocopherol fraction was  $\gamma$ -tocopherol.

**Keywords:** *Cucumis melo* seeds; chemical composition; fatty acids; triacylglycerol structure; phospholipids; sterols; tocopherols

## 1. Introduction

Melon (*Cucumis melo* L., family *Cucurbitaceae*) is an annual plant (Ivanov, 1999), widespread in countries with temperate climate in Europe, Asia, and Africa. According to Food and Agriculture Organization (FAO), the world melon seeds' production is 782,205 tons and the cultivated area is 893,855 ha (FAO, 2013). The biggest producers are Uzbekistan, the USA, Spain, France, etc. During the recent years, the lands used for growing melons in Bulgaria are 11,196 da, and the total quantity of production in 2013 was 14,711 tons. Melons are grown mainly in southwest and southern Bulgaria, less space is used for their production in northern and northeast Bulgaria, and the most widespread varieties here in our country are—*Honeydew*, *Persian 5*, *Vidinski koravtzi*, and *Hybrid 1*. The widespread growing of melons is due to the excellent taste qualities of the fruit, as well as its application in folk medicine as a medicinal plant (Jeffrey, 1990). It is recommended in the cases of cardiovascular diseases, liver and kidney diseases, in case of anemia, for patients with atherosclerosis, rheumatism, and gout (Ivanova, 2012). Melon seeds have therapeutic effects, such as anti-oxidant, anti-inflammatory, and analgesic effects (Chen, Kang, & Suh, 2014; Gill et al., 2009). Along with their good taste qualities, melons have rich chemical composition, which makes them an excellent source of biologically active substances for the human organism. They contain carbohydrates, including glucose, fructose, and from 4.6 to 16.0–18.0% sucrose, starch, up to 4.5% pectin, vitamins A, C, D, K, from the groups B and E, folic acid, carotene, minerals (potassium, magnesium, phosphorus, sodium, selenium, and calcium), and various aromatic compounds (Ivanova, 2012).

The seeds that are a waste product are rich in glyceride oil (30.0–50.0%) and proteins (12.0–35.0%) (Azhari, Xu, Jiang, & Xia, 2014; de Mello, Narain, & Bora, 2000, 2001; Jacks, Hensarling, & Yatsu, 1972; Mian-Hao & Yansong, 2007; Obasi, Ukadilonu, Eze, Akubugwo, & Okorie, 2012). Globally, they are used for the production of glyceride oil by cold pressing. It possesses high nutritional value due to its high content of polyunsaturated fatty acids (PUFA). The data from the previous studies show that the main component of the melon seed oil is the linoleic acid (31.0–69.0%), followed by the oleic (12.1–31.0%), palmitic (7.8–39.36%), and stearic acid (4.9–10.45%) (Albishri, Almaghrabi, & Moussa, 2013; Azhari et al., 2014; de Mello et al., 2000, 2001; Imbs & Pham, 1995; Jacks et al., 1972; Lazos, 1986; Mariod & Matthäus, 2008; Mian-Hao & Yansong, 2007; Milovanović & Pićurić-Jovanović, 2005; Yanty, Lai, Osman, Long & Ghazali, 2008).

Melon seed oil is rich in biologically active substances such as tocopherols, sterols, phospholipids, which determine its beneficial effect on the human organism (Azhari et al., 2014; Imbs & Pham, 1995; Mariod & Matthäus, 2008). The information about the lipid composition of the melon seeds concerns mainly the physicochemical characteristics and the fatty acid composition of the oils, while the data obtained vary depending on the type of the tested seeds and on the region they originate from (Albishri et al., 2013; Azhari et al., 2014; de Mello et al., 2001; Ibeto, Okoye, & Ofoefule, 2012; Jacks et al., 1972; Lazos, 1986; Mian-Hao & Yansong, 2007; Milovanović & Pićurić-Jovanović, 2005; Obasi et al., 2012; Yanty et al., 2008). Regarding the content of the biologically active substances (sterols, tocopherols, and phospholipids) in the glyceride oils from melon seeds, the data are scarce. In Bulgaria, no research has been done with regards to the application of melon seeds (*C. melo*) as oilseed feedstock for food and industrial purposes. The information on the lipid composition (fatty acid composition of triacylglycerols, content and composition of sterols, tocopherols, and phospholipids) of melon seeds grown in Bulgaria is rather limited. The objective of this work is to study the general chemical composition of the seeds from three varieties of melon (*C. melo*), as well as to characterize the isolated lipids with regards to the fatty acid composition, structure of the triacylglycerols, content of the biologically active substances (tocopherols, sterols, and phospholipids).

## 2. Materials and methods

### 2.1. Plant material

The seeds were obtained from melon fruits (*C. melo* L.), varieties *Honeydew*, *Dessert 5*, and *Hybrid 1*, grown in region of Plovdiv, southern Bulgaria, crop 2012. Prior to use for analysis, the melon seeds were air dried for 72 h at 25°C.

### 2.2. Chemical composition of seeds

Crude protein was calculated from the nitrogen content by Kjeldahl method using factor 6.25 (Association of Official Analytical Chemist [AOAC], 1996). The carbohydrate content was calculated by the following formula:  $100 - (\text{weight in grams [crude protein + crude lipids + water + ash] in 100 g of seeds})$  (FAO, 2003). The soluble carbohydrates were identified by their extraction with water and was determined by high-performance liquid chromatography (HPLC) on a Agilent® LC 1220 (USA) instrument equipped with Zorbax Carbohydrate column (150-mm × 4.6-mm, 5-μm, Agilent) and Zorbax Reliance Cartridge guard-column (Agilent), and refractive index detector (RID 1260) (Georgiev, Ognyanov, Yanakieva, Kussovski, & Kratchanova, 2012). The mobile phase was acetonitrile/water (AcN/H<sub>2</sub>O) (80/20) at 1.0 mL/min. All standards (individual pure monosaccharides with purity ≥98%) were purchased from Sigma Chemical Company (USA). Crude fiber was determined by the gravimetric procedure of AOAC (1995). Ash content was evaluated by incinerating at 550°C in a muffle furnace for 6 h (AOAC, 1995). Moisture was determined according to AOAC (1995).

### 2.3. Isolation of glyceride oil and determination of oil content

The seeds (100 g sample) were air dried and the oil was extracted with n-hexane in Soxhlet for 8 h. The solvent was partly removed in rotary vacuum evaporator, the residue was transferred in pre-weight glass vessels and the rest of the solvent was removed under stream of nitrogen to a constant weight to determine the oil content (ISO 659, 2009).

### 2.4. Physicochemical parameters of glyceride oils

Peroxide and acid values were determined titrimetrically by procedures of ISO (ISO 660, 2009; ISO 3960, 2007). Oxidative stability was determined using accelerated “Rancimat” method where the temperature in the heating block was 100°C and the air flow rate was 20 l/h (ISO 6886, 2006).

### 2.5. Analysis of fatty acids

The fatty acid composition of the triacylglycerols as well as the fatty acid composition of sterol esters and the main classes of phospholipids were determined by gas chromatography (GC) after transmethylation of the respective sample with 2% H<sub>2</sub>SO<sub>4</sub> in absolute CH<sub>3</sub>OH at 50°C (ISO 5509, 2000). Fatty acid methyl esters were purified by thin-layer chromatography (TLC) on 20 × 20-cm plates covered with 0.2-mm Silica gel 60 G layer with mobile phase n-hexane diethyl ether 97:3 (v/v). GC was performed on a HP 5890 (Hewlett Packard GmbH, Austria) gas chromatograph equipped with a 60-m × 0.25-mm × 25-μm (I.D.) capillary DB-23 column and a flame ionization detector. The column temperature was programmed from 130°C (hold 1 min), at 6.5°C/min to 170°C, at 3°C/min to 215°C (hold 9 min), at 40°C/min to 230°C (hold 1 min); the injector and detector temperatures were 270 and 280°C, respectively. Hydrogen was the carrier gas at a flow rate 0.8 mL/min; split was 1:50 and software was *Data Apex Clarity TM 2.4.1.93/2005*. Identification was performed by comparison of retention times with those of a standard mixture of fatty acids subjected to GC under identical experimental conditions (ISO 5508, 2004). Iodine value (g I<sub>2</sub>/100 g fat) was calculated on the basis of fatty acid composition of the oil (American Oil Chemists Society, 1999).

### 2.6. Analysis of sterols

Unsaponifiables were determined after saponification of the glycerides oil and extraction with n-hexane (ISO 18609, 2000). Quantification of sterols was carried out spectrophotometrically (at 597 nm), after isolation of sterols from other unsaponifiable matter by TLC on Silica gel 60 G in the mobile phase diethyl ether : n-hexane (1:1 v/v) (Ivanov, Bitcheva, & Konova, 1972).

Sterol composition was determined on HP 5890 gas chromatograph (Hewlett Packard GmbH) equipped with 25 m × 0.25-mm DB-5 capillary column and flame ionization detector. Temperature gradient from 90°C (hold 2 min) up to 290°C at a rate of change 15°C/min and then up to 310°C at a rate of 4°C/min (hold 10 min); detector temperature—320°C; injector temperature—300°C and carrier gas—hydrogen, split—1:50 and software *Data Apex Clarity TM 2.4.1.93/2005*. Identification was confirmed by comparison of retention times with those of a standard mixture of sterols (ISO 12228, 1999).

### 2.7. Analysis of tocopherols

Tocopherols were determined directly in the oil by HPLC on a “Merck-Hitachi” (Merck, Darmstadt, Germany) instrument equipped with 250-mm × 4-mm Nucleosil Si 50-5 column (Merck, Darmstadt, Germany) and fluorescent detector “Merck-Hitachi” F 1000. The operating conditions were as follows: mobile phase of n-hexane:dioxan 96:4 (v/v), flow rate 1.0 mL/min, excitation 295 nm, emission 330 nm (ISO 9936, 2006). 20 µL of 1% solution (1 g in 100-mL n-hexane) of oil were injected. Tocopherols were identified by comparing the retention times with those of authentic individual tocopherols. The tocopherol content was calculated on the basis of tocopherol peak areas in the sample versus tocopherol peak area of standard α-tocopherol solution.

### 2.8. Analysis of phospholipids

Another part (100 g) of air-dried seeds was subjected to Folch extraction (Folch, Lees & Sloane-Stanley, 1956). The phospholipids classes were isolated by a variety of the two-dimensional TLC on 20 × 20-cm glass plates with 0.2-mm Silica gel 60 G layer impregnated with aqueous (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> (1 g in 100-mL water). In the first direction, the plate was developed with chloroform:methanol:ammonia, 65:25:5 (v/v/v) and in the second—with chloroform:acetone:methanol:acetic acid:water, 50:20:10:10:5 (v/v/v/v). The individual phospholipids were detected and identified by spraying with specific reagents: Dragendorff test (detection of choline-containing phospholipids), Ninhydrin spray (for phospholipids with free amino groups), and Schiff's reagent (for inositol containing phospholipids). Additional identification was performed by comparing the respective R<sub>f</sub> values with those of authentic commercial standards subjected to Silica gel 60 G TLC under identical experimental conditions. The quantification was carried out spectrophotometrically against a standard curve by measuring the phosphorous content at 700 nm after scrapping the respective phospholipid spot and mineralization of the substance with a mixture of perchloric acid and sulfuric acid, 1:1 by volume (ISO 10540-1, 2003).

### 2.9. Statistical analyses

The statistical analysis was performed using the statistical function from Microsoft Office Excel. For each sample, three determinations have done ( $n = 3$ , where  $n$  is the number of the replications). The data were presented as mean values ± standard deviation (SD). The level of significance was set at  $p < 0.05$ . The limit detection in GC and HPLC was 0.05%.

## 3. Results and discussion

### 3.1. Chemical composition of melon seeds

The data about the content of the main components in the seeds—oil, proteins, carbohydrates (soluble sugars and fibers), the minerals, and the moisture are presented in Table 1.

The content of raw oil in the seeds varied from 41.6% (*Honeydew* and *Hybrid 1*) to 44.5% (*Dessert 5*). The obtained results correspond to the literature sources by other authors regarding the seed oil content from different melon varieties, which were within the limits from 20.5 to 53.5% (Azhari et al., 2014; de Mello et al., 2000; Ibeto et al., 2012; Imbs & Pham, 1995; Jacks et al., 1972; Lazos, 1986; Mian-Hao & Yansong, 2007; Milovanović & Pićurić-Jovanović, 2005; Obasi et al., 2012; Yanty et al., 2008), and they were closer to the results obtained by Lazos (1986) (37.8%), Ibeto et al. (2012) (44.85%) and Jacks et al. (1972) (50.0%).

**Table 1. Proximate composition of melon seeds<sup>a</sup>**

Compounds (%)	Varieties of melon		
	<i>Honeydew</i>	<i>Dessert 5</i>	<i>Hybrid 1</i>
Glyceride oil	41.6 ± 0.2	44.5 ± 0.1	41.6 ± 0.1
Protein	34.6 ± 0.2	34.4 ± 0.1	39.8 ± 0.3
Carbohydrate (by difference)	12.7	10.6	8.2
Soluble sugars	4.2 ± 0.1	3.7 ± 0.1	3.7 ± 0.1
Crude fiber	8.5 ± 0.2	6.9 ± 0.3	4.5 ± 0.1
Ash	5.1 ± 0.1	4.9 ± 0.2	4.6 ± 0.2
Moisture	6.0 ± 0.3	5.6 ± 0.1	5.8 ± 0.2

<sup>a</sup>Values are means ± SD (n = 3 and p < 0.05).

The protein content in the melon seeds varied from 34.4% (*Dessert 5*) to 39.8% (*Hybrid 1*). These values were higher than the data announced by other authors which were within the limits from 11.67 to 35.0% (Azhari et al., 2014; de Mello et al., 2001; Jacks et al., 1972; Lazos, 1986; Mian-Hao & Yansong, 2007; Milovanović & Pićurić-Jovanović, 2005; Obasi et al., 2012; Yanty et al., 2008).

The tested seeds had lower carbohydrate content (around 8.0–13.0%) compared to the results announced by Yanty et al. (2008) (19.8%), Lazos (1986) (17.75%) and by Obasi et al. (2012) (29.47%). The quantity of water-soluble sugars in the seeds was about 4.0% and it was lower than the quantity found in the melon seeds with Sudan origin (6.94%) (Azhari et al., 2014). The fiber content varied from 4.5% (*Hybrid 1*) to 8.5% (*Honeydew*), which was within the limits announced in the literature resources (5.51–24.75%) (Azhari et al., 2014; Lazos, 1986; Obasi et al., 2012; Yanty et al., 2008). The mineral content in the studied seeds from melon was from 4.5% (*Hybrid 1*) to 5.1% (*Honeydew*). These values were higher than the data announced by Milovanovic and Picuric-Jovanovic (2005), Yanty et al. (2008), Lazos (1986), Azhari et al. (2014) and Obasi et al. (2012) (2.4–4.33%). The moisture content (about 6%) was similar to the data of other authors about the moisture, which was within the limits from 4.27 to 5.63% (Azhari et al., 2014; Ibeto et al., 2012; Obasi et al., 2012; Yanty et al., 2008).

Differences between the results about proteins, carbohydrates, and mineral content, which were obtained by our study and the data from other investigations, were probably due to the geographical regions and agricultural conditions such as temperature, moisture, and fertilizing.

### 3.2. Studies on lipid composition of the glyceride oil from melon seeds

The data about the biologically active substances (sterols, phospholipids, tocopherols) in the glyceride oils and in the seeds are presented in Table 2.

The quantity of unsaponifiables was within the limits from 0.7% to 1.0%, which coincided with the data from previous studies (0.65–1.2%) (Azhari et al., 2014; Lazos, 1986; Yanty et al., 2008). The sterol quantity in the three studied varieties was similar (0.6%) and it was close to the values obtained by other authors (0.3–0.8%) (Azhari et al., 2014; Imbs & Pham, 1995; Mariod & Matthäus, 2008). The highest quantity of phospholipids was found in the oil from variety *Hybrid 1* (1.7%), and it was close to the content of phospholipids in the seed oil from melon grown in northern Vietnam (1.6%) (Imbs & Pham, 1995).

Larger quantity of tocopherols was found in melon seed oils from varieties *Honeydew* and *Hybrid 1*—respectively, 828 and 731 mg/kg. The tocopherol content in the oil from variety *Dessert 5* (435 mg/kg) was close to that of the melon seed oil from *C. melo*, var. *tibish* with Sudan origin (432 mg/kg) (Azhari et al., 2014).

**Table 2. Content of biologically active substances in the oil and seeds of the studied varieties of melon and physicochemical parameters of glyceride oils<sup>a</sup>**

Compounds and parameters	Varieties of melon		
	Honeydew	Dessert 5	Hybrid 1
<i>Unsaponifiable matter</i>			
In oil (%)	1.0 ± 0.2	0.7 ± 0.1	0.9 ± 0.2
In seeds (%)	0.4 ± 0.1	0.3 ± 0.06	0.4 ± 0.1
<i>Sterols</i>			
In oil (%)	0.6 ± 0.05	0.6 ± 0.03	0.6 ± 0.05
In seeds, % (%)	0.3 ± 0.02	0.3 ± 0.02	0.3 ± 0.02
<i>Phospholipids</i>			
In oil (%)	0.8 ± 0.2	0.7 ± 0.1	1.7 ± 0.4
In seeds (%)	0.3 ± 0.1	0.3 ± 0.06	0.7 ± 0.2
<i>Tocopherols</i>			
In oil (mg/kg)	828 ± 20	435 ± 15	731 ± 25
In seeds (mg/kg)	345 ± 11	194 ± 10	304 ± 15
Peroxide value (meqO <sub>2</sub> /kg)	1.1 ± 0.1	3.4 ± 0.2	3.1 ± 0.1
Acid value (mgKOH/g)	1.5 ± 0.1	1.5 ± 0.1	2.1 ± 0.2
Iodine value (g I <sub>2</sub> /100 g)	128 ± 4	123 ± 3	115 ± 2
Oxidative stability (h)	7.2 ± 0.5	7.2 ± 0.2	14.3 ± 0.3

<sup>a</sup>Values are means ± SD (n = 3 and p < 0.05).

Melon seed oils were characterized with relatively high acid value (1.5–2.1 mgKOH/g), but with low peroxide value 1.1–3.4 meqO<sub>2</sub>/kg. The obtained results were close in value to these by other authors who had studied the physicochemical parameters of the oil obtained from seeds of various types of melon, where the acid value varied from 0.4 to 6.17 mgKOH/g (Azhari et al., 2014; de Mello et al., 2000; Imbs & Pham, 1995; Lazos, 1986; Mian-Hao & Yansong, 2007; Obasi et al., 2012; Yanty et al., 2008), while, respectively, the peroxide value was from 1.53 to 4.96 meqO<sub>2</sub>/kg (de Mello et al., 2000; Mian-Hao & Yansong, 2007; Obasi et al., 2012; Azhari et al., 2014; Yanty et al., 2008; Lazos, 1986; Imbs & Pham, 1995).

The iodine value (IV), which was a measure of the level of unsaturation of the plant oils was with high values (IV > 100 g I<sub>2</sub>/100 g), as a result of the higher content of the essential linoleic acid. In the literature sources, the iodine value of the melon oil varied from 89.5 to 153.4 g I<sub>2</sub>/100 g, (Azhari et al., 2014; de Mello et al., 2000; Lazos, 1986; Mian-Hao & Yansong, 2007; Obasi et al., 2012; Yanty et al., 2008), while the results obtained by us were close to those of melon oils studied by de Mello et al. (2000) (111.8 and 109.6 g I<sub>2</sub>/100 g), Lazos (1986) (124.5 g I<sub>2</sub>/100 g), Azhari et al. (2014) (110.99 g I<sub>2</sub>/100 g) and Obasi et al. (2012) (110.93–111.46 g I<sub>2</sub>/100 g).

The iodine value is an indirect indicator also for the oxidative stability of the oils. The similar values of the iodine values of the studied oils correspond to the similar oxidative stability (7.2–14.3 h). The studied melon oils had from two to three times higher oxidative stability compared to seed oils obtained from different varieties originating from Sudan (*C. melo*), studied by Mariod and Matthäus (2008) (5.7–5.9 h) and Azhari et al. (2014) (4.28 h).

### 3.3. Fatty acid composition

The data about the fatty acid composition of the triacylglycerols in the seed oils from the studied melon varieties are presented in Table 3.

**Table 3. Fatty acid composition of oils from the seeds of a melon<sup>a</sup>**

Total FA (%)	Varieties of melon		
	Honeydew	Dessert 5	Hybrid 1
C <sub>12:0</sub> <sup>b</sup>	– <sup>c</sup>	–	0.1 ± 0.01
C <sub>14:0</sub>	0.1 ± 0.03	0.1 ± 0.03	0.2 ± 0.02
C <sub>14:1</sub>	–	–	0.1 ± 0.01
C <sub>15:0</sub>	–	0.1 ± 0.02	0.1 ± 0.03
C <sub>16:0</sub>	9.4 ± 0.2	12.3 ± 0.3	16.4 ± 0.1
C <sub>16:1</sub>	0.1 ± 0.03	0.1 ± 0.02	0.2 ± 0.03
C <sub>17:0</sub>	0.1 ± 0.03	0.1 ± 0.01	0.1 ± 0.02
C <sub>18:0</sub>	6.6 ± 0.2	6.1 ± 0.1	6.5 ± 0.3
C <sub>18:1</sub>	25.0 ± 0.4	25.6 ± 0.3	24.8 ± 0.2
C <sub>18:2</sub>	58.5 ± 0.3	55.2 ± 0.2	51.1 ± 0.2
C <sub>18:3</sub>	–	0.1 ± 0.01	0.2 ± 0.02
C <sub>20:0</sub>	0.1 ± 0.01	0.1 ± 0.01	0.1 ± 0.02
C <sub>20:1</sub>	0.1 ± 0.01	0.2 ± 0.03	0.1 ± 0.01

<sup>a</sup>Values are means ± SD (n = 3 and p < 0.05).

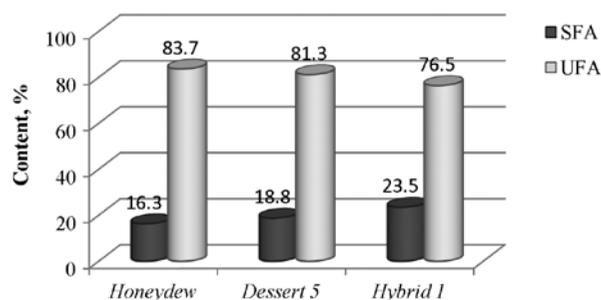
<sup>b</sup>C<sub>12:0</sub> is the lauric acid, C<sub>14:0</sub> is the myristic acid, C<sub>14:1</sub> is the myristoleic acid, C<sub>15:0</sub> is the pentadecanoic acid, C<sub>16:0</sub> is the palmitic acid, C<sub>16:1</sub> is the palmitoleic acid, C<sub>17:0</sub> is the margaric acid, C<sub>18:0</sub> is the stearic acid, C<sub>18:1</sub> is the oleic acid, C<sub>18:2</sub> is the linoleic acid, C<sub>18:3</sub> is the linolenic acid, C<sub>20:0</sub> is the arachidic acid, C<sub>20:1</sub> is the eicosenoic acid (gadoleic).

<sup>c</sup>Not detected.

The linoleic acid (C<sub>18:2</sub>) predominated in all oils (51.1–58.5%), followed by the oleic acid (C<sub>18:1</sub>) (24.8–25.6%), which classified them as linoleic type of oils. The ratio linoleic: oleic acid was about 2:1, similar to the soy bean oil (53.6%:22.9%) and corn germ oil (62.5%:24.1%) (O'Brien, Farr, & Wan, 2000). Linolenic acid (C<sub>18:3</sub>) was identified in insignificant quantity (0.1–0.2%). From the saturated fatty acids, the palmitic acid (C<sub>16:0</sub>) was predominant with quantity 9.4–16.4% (58.0–70.0% of the total quantity of the saturated fatty acids), followed by the stearic acid 6.1–6.6% (28.0–40.0% of their total content). The results about the fatty acid composition of the oils of the studied seeds from different melon varieties were similar to the data announced by other authors as a result of their studies of the composition of the melon seed oils, in which the main acids were: linoleic (31.0–69.0%), oleic (12.1–31.0%), palmitic (7.8–39.36%), and stearic acid (4.9–10.45%) (Albishri et al., 2013; Azhari et al., 2014; de Mello et al., 2000, 2001; Imbs & Pham, 1995; Jacks et al., 1972; Lazos, 1986; Mariod & Matthäus, 2008; Mian-Hao & Yansong, 2007; Milovanovic & Picuric-Jovanovic, 2005; Yanty et al., 2008).

In the glyceride oils from seeds of various varieties of melon, the unsaturated fatty acid (UFA) predominated, where their quantity was, respectively, from 76.5 to 83.7% (Figure 1).

**Figure 1. Content of saturated fatty acids and unsaturated fatty acids in the seed oils of studied varieties of melon (*C. melo*).**



**Table 4. Triacylglycerol structure of the melon seed oils<sup>a</sup>**

Triacylglycerol structure (%)	Varieties of melon		
	Honeydew	Dessert 5	Hybrid 1
LLL	31.3 ± 0.3	32.2 ± 0.2	31.5 ± 0.4
LLO	33.8 ± 0.4	31.0 ± 0.2	34.0 ± 0.2
LLP	14.9 ± 0.4	22.3 ± 0.3	18.1 ± 0.1
LOO	7.6 ± 0.1	5.0 ± 0.2	6.1 ± 0.1
LOP	7.0 ± 0.3	5.0 ± 0.1	5.9 ± 0.3
LLS	3.0 ± 0.1	3.2 ± 0.2	2.8 ± 0.1
LPP	<0.05	<0.05	<0.05
OOO	0.4 ± 0.05	0.3 ± 0.03	0.5 ± 0.02
OOP	1.5 ± 0.2	0.8 ± 0.1	0.9 ± 0.1
LOS	0.3 ± 0.04	0.2 ± 0.02	0.2 ± 0.01
LPS	0.2 ± 0.01	<0.05	<0.05

Notes: L is the linoleic acid (C<sub>18:2</sub>), O is the oleic acid (C<sub>18:1</sub>), S is the stearic acid (C<sub>18:0</sub>), P is the palmitic acid (C<sub>16:0</sub>).  
<sup>a</sup>Values are means ± SD (n = 3 and p < 0.05).

Their content in the oils of the studied seeds was similar to the data announced by other authors according to whom the quantity of the UFA in the melon seed oils had been from 67.5 to 82.76%, where the share of the PUFA had been over 60.0% (Azhari et al., 2014; de Mello et al., 2001; Mian-Hao & Yansong, 2007; Milovanovic & Picuric-Jovanovic, 2005; Yanty et al., 2008). The ratio of saturated fatty acids: UFA was 1.0:3.3 in the seed oil from *Hybrid 1*, 1.0:4.3 for the variety *Dessert 5*, and 1.0:5.1 in the oil from *Honeydew*. Similar ratio of the fatty acid content was noticed in the melon seed oil from variety *C. melo* var. *tibish* with origin from Sudan (SFA/UFA = 4.01) (Azhari et al., 2014).

### 3.4. Triacylglycerol structure

The triacylglycerol structure of the melon oils was determined as well (Table 4).

There were identified in the studied oils, 11 types of combinations between fatty acid radicals, and the three tested samples shown similar structure.

The linoleic acid was a major component in the three main types of triacylglycerols (LLL, LLO, and LLP). The quantity of trilinolein (LLL) in the studied melon oils was 31.3–32.2%, the quantity of oleo dilinolein (LLO) was 31.0–34.0%, and the quantity of palmitoyl dilinolein (LLP) was 14.9–22.3%. The contents of the three main types of triacylglycerol (LLL, LLO, and LLP) in the melon seed oils of variety *Honeydew*, which, respectively, were 31.3, 33.8, and 14.9% were close to the data obtained by Yanty et al. (2008) for the melon variety *Honeydew*, with origin from Malaysia (LLL—24.9%, LLO—21.5%, and LLP—15.9%). The other three classes of triacylglycerols (LOO, LOP, and LLS) were identified in quantities within 2.8–7.6%, while the remaining triacylglycerols (LPP, OOO, OOP, LOS, and LPS) existed in insignificant quantities (<0.05–1.5%).

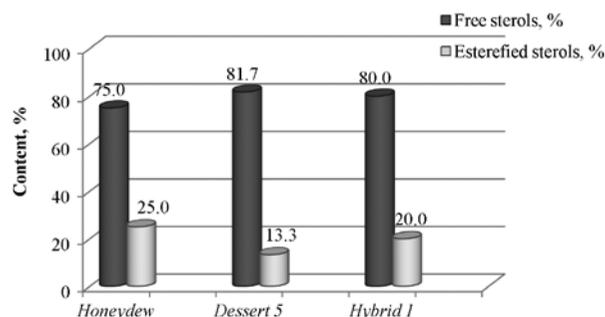
### 3.5. Sterol composition

The data of the content of free sterols and esterefied sterols in the seed oils are presented in Figure 2.

The main part of the sterols was the fraction of the free sterols (75.0–81.7%). These values were a bit higher in comparison to other vegetable oils (sunflower, safflower, and lallemantia seed oil) where the content of free sterols was 70.0–75.0% (Angelova & Zlatanov, 2004; Zlatanov et al., 2010, 2012).

The qualitative profile of free and esterified sterols was identical in the all investigated varieties, but the quantitative composition is found to be different (Table 5). The main components in both sterol fractions were β-sitosterol (over 50.0%), Δ<sup>5</sup>-avenasterol (19.7–42.7%), and stigmasterol (2.7–4.8%).

**Figure 2. Content of free and esterified sterols in melon seed oils.**



$\beta$ -Sitosterol (52.9–70.8%) and  $\Delta^5$ -avenasterol (19.7–38.1%) predominated in the fraction of free sterols. Stigmasterol and  $\Delta^7$ -avenasterol were identified, respectively, 3.1–4.6% and 0.5–11.1%. Campesterol and cholesterol were established in negligible amounts—about 0.3–0.7% and 0.2–0.3%, respectively. In variety *Honeydew*, the content of  $\beta$ -sitosterol was lower (52.9%) than in the other two varieties (70.8 and 64.7%, respectively) where the content of  $\Delta^5$ -avenasterol was lower.  $\Delta^7$ -Avenasterol was in higher quantity in *Hybrid 1* (11.1%) than in *Honeydew* and *Dessert 5* (4.7 and 0.5%, respectively).

$\beta$ -Sitosterol predominated also in the fraction of esterified sterols in three varieties of melon (50.4–58.4%), followed by  $\Delta^5$ -avenasterol (35.8–42.7%). The quantity of stigmasterol and campesterol was 2.7–4.8% and 0.6–1.3%, respectively. The cholesterol content in esterified sterols varied from 0.5 to 1.1%.  $\Delta^7$ -Avenasterol was observed in trace only.

The quantity of  $\beta$ -sitosterol in the fraction of free sterols in melon seed oils from varieties *Dessert 5* and *Hybrid 1* (70.8 and 64.7%, respectively) was significant higher than in esterified sterols (55.7 and 58.4%, respectively) while the amount of  $\Delta^5$ -avenasterol in the fraction of the esterified sterols was higher than in free sterols. In melon seed oil from variety *Honeydew*, the content of  $\beta$ -sitosterol in the fraction of free sterols (52.9%) was close to that in esterified sterols (50.4%). The amount of  $\beta$ -sitosterol in both fractions sterols of three melon seed oils (50.4–70.8%) was lower than the values reported by Azhari et al. (2014), wherein the amount of  $\beta$ -sitosterol was about 95.0%. The quantity of stigmasterol was the same in free and esterified sterols. A marked difference was established in the cholesterol content between free and esterified sterols. The content of cholesterol in sterol esters (0.5–1.1%) was several times higher than in the fraction of free sterols (0.2–0.3%). These differences could be put down to the different phases of the biosynthesis and accumulation of those compounds. In the first stage, cholesterol was synthesized and then it was used as precursor for

**Table 5. Individual composition of free and esterified sterols in melon seed oils<sup>a</sup>**

Sterols (%)	Varieties of melon					
	<i>Honeydew</i>		<i>Dessert 5</i>		<i>Hybrid 1</i>	
	Free	Esterified	Free	Esterified	Free	Esterified
Cholesterol	0.3 ± 0.1	0.5 ± 0.1	0.2 ± 0.1	1.1 ± 0.2	0.2 ± 0.1	0.9 ± 0.2
Campesterol	0.3 ± 0.05	0.6 ± 0.1	0.7 ± 0.1	1.3 ± 0.2	0.3 ± 0.1	1.0 ± 0.2
Stigmasterol	3.1 ± 0.1	4.8 ± 0.2	4.6 ± 0.3	2.7 ± 0.2	3.5 ± 0.3	3.1 ± 0.1
$\beta$ -Sitosterol	52.9 ± 0.4	50.4 ± 0.3	70.8 ± 0.4	55.7 ± 0.3	64.7 ± 0.2	58.4 ± 0.3
$\Delta^5$ -Avenasterol	38.1 ± 0.1	42.7 ± 0.2	22.9 ± 0.2	38.8 ± 0.4	19.7 ± 0.1	35.8 ± 0.4
$\Delta^{7,25}$ -Stigmastadienol	0.5 ± 0.05	0.5 ± 0.1	0.2 ± 0.01	0.4 ± 0.03	0.4 ± 0.05	0.5 ± 0.1
$\Delta^7$ -Stigmasterol	0.1 ± 0.01	0.5 ± 0.1	0.1 ± 0.01	– <sup>b</sup>	0.1 ± 0.01	0.3 ± 0.05
$\Delta^7$ -Avenasterol	4.7 ± 0.3	–	0.5 ± 0.1	–	11.1 ± 0.5	–

<sup>a</sup>Values are means ± SD ( $n = 3$  and  $p < 0.05$ ).

<sup>b</sup>Not detected.

synthesis of sterol esters (Vlahakis & Hazebroek, 2000). These results were similar with the finding of Mariod and Matthäus (2008) and Albishri et al. (2013), according to which  $\beta$ -sitosterol was the major sterol component, followed by campesterol, while cholesterol and stigmasterol were presented in traces in melon seed oil. In comparison with other vegetable oils, higher quantities of unsaturated sterol derivatives as stigmasterol,  $\Delta^5$ -avenasterol,  $\Delta^7$ -stigmasterol, and  $\Delta^7$ -avenasterol were established in all varieties of melon.

### 3.6. Fatty acid composition of sterol esters

The data of fatty acid composition of sterol esters are shown in Table 6.

In comparison with fatty acid composition of triacylglycerol fraction,  $C_{8:0}$ ,  $C_{10:0}$ , and  $C_{12:0}$  were detected in all fatty acid fractions of sterol esters. Palmitic (17.9–24.5%) and stearic acids (6.8–8.9%) predominated as SFA, and linoleic (32.7–39.1%) and oleic (25.1–30.7%) acids as UFA. Higher content of linoleic (39.1%) and oleic (30.7%) acids was established in *Hybrid 1*, at the expense of lower quantity of palmitic acid (17.9%). The UFA (62.0–71.2%) predominated in the sterol esters. The total amount of SFA in *Hybrid 1* was significantly lower than in other both varieties (28.8% versus 37.6% and 38.0%, respectively). On the other hand, the percentage of UFA was found to be higher (71.2% versus 62.0% and 62.4%, respectively).

In comparison with the fatty acid composition of triacylglycerols, the differences in the contents of the main components (linoleic, oleic, palmitic, and stearic acids) were established. A lower content of linoleic acid (32.7–39.1%) was determined in sterol esters than in triacylglycerols (51.1–58.5%). The

**Table 6. Fatty acid composition of sterol esters in melon seed oils<sup>c</sup>**

Total FA (%)	Varieties of melon		
	Honeydew	Dessert 5	Hybrid 1
$C_{8:0}$ <sup>a</sup>	0.4 ± 0.1	0.3 ± 0.1	0.3 ± 0.1
$C_{10:0}$	– <sup>b</sup>	–	0.1 ± 0.05
$C_{12:0}$	0.8 ± 0.2	0.5 ± 0.1	0.4 ± 0.1
$C_{14:0}$	3.7 ± 0.2	3.1 ± 0.1	1.4 ± 0.2
$C_{14:1}$	–	0.2 ± 0.05	–
$C_{15:0}$	0.8 ± 0.1	1.0 ± 0.2	0.5 ± 0.1
$C_{16:0}$	22.0 ± 0.3	24.5 ± 0.5	17.9 ± 0.2
$C_{16:1}$	0.5 ± 0.1	1.2 ± 0.2	0.4 ± 0.1
$C_{17:0}$	0.7 ± 0.1	0.7 ± 0.1	0.5 ± 0.1
$C_{18:0}$	8.9 ± 0.2	7.1 ± 0.3	6.8 ± 0.4
$C_{18:1}$	28.5 ± 0.5	25.1 ± 0.1	30.7 ± 0.3
$C_{18:2}$	32.7 ± 0.3	34.8 ± 0.4	39.1 ± 0.1
$C_{18:3}$	0.3 ± 0.1	0.9 ± 0.1	0.8 ± 0.1
$C_{20:0}$	0.4 ± 0.1	0.4 ± 0.1	0.4 ± 0.1
$C_{20:1}$	–	0.2 ± 0.05	0.2 ± 0.05
$C_{22:0}$	0.3 ± 0.1	–	0.5 ± 0.1
SFA	38.0	37.6	28.8
UFA	62.0	62.4	71.2

<sup>a</sup> $C_{8:0}$  is the caprylic acid,  $C_{10:0}$  is the capric acid,  $C_{12:0}$  is the lauric acid,  $C_{14:0}$  is the myristic acid,  $C_{14:1}$  is the myristoleic acid,  $C_{15:0}$  is the pentadecanoic acid,  $C_{16:0}$  is the palmitic acid,  $C_{16:1}$  is the palmitoleic acid,  $C_{17:0}$  is the margaric acid,  $C_{18:0}$  is the stearic acid,  $C_{18:1}$  is the oleic acid,  $C_{18:2}$  is the linoleic acid,  $C_{18:3}$  is the linolenic acid,  $C_{20:0}$  is the arachidic acid,  $C_{20:1}$  is the eicosenoic acid (gadoleic),  $C_{22:0}$  is the Behenic acid, SFA is the saturated fatty acids, UFA is the unsaturated fatty acids.

<sup>b</sup>Not detected.

<sup>c</sup>Values are means ± SD ( $n = 3$  and  $p < 0.05$ ).

content of palmitic acid was higher in sterol esters (from 17.9 to 24.5%), while their content in triacylglycerols was between 9.4 and 16.4%. Significantly higher quantities of SFA (38.0, 37.6, and 28.8%, respectively) were established in sterol esters of the expense of lower levels of PUFA (33.0–39.9%), while in triacylglycerols, the amount of SFA was lower (16.3–23.5%) and the levels of PUFAs were higher (51.3–58.5%). The content of monounsaturated fatty acids (MUFA), mainly oleic acid, in sterol esters (25.1–30.7%), and triacylglycerols (24.8–25.6%) was found to be close.

### 3.7. Phospholipid composition

The composition of the phospholipid fraction of the melon seed oils is presented in Table 7.

In the phospholipid fraction of the melon seed oils from different varieties, there were identified all major classes of phospholipids. On the grounds of the obtained data, it can be seen that in the phospholipid fraction from varieties *Honeydew* and *Hybrid 1*, there predominated phosphatidylinositol (33.9 and 30.9%) as a major component, followed by phosphatidylcholine (23.0 and 27.7%), while in the variety *Dessert 5*, phosphatidylcholine was with higher content (33.1%), followed by phosphatidylinositol (24.4%). The highest content of phosphatidylethanolamine was found to be in the variety *Hybrid 1* (17.1%), while in varieties *Dessert 5* and *Honeydew*, its content was, respectively, 11.6 and 8.4%. A relatively high content was found out of phosphatidic acids (13.5–16.3%), which were decomposition products of hydrolysis processes, or were the result of uncompleted stage of biosynthesis of the other phospholipids. The quantity of sphingomyelin in variety *Dessert 5* was higher (4.3%), while in the phospholipids from variety *Honeydew* and *Hybrid 1*, it was lower (0.8 and 0.4%) compared to other vegetable oils where its quantity was within 1.0–2.0% (Gunstone, Harwood, & Dijkstra, 2007). Higher quantity was observed of lysophosphatidylcholine and lysophosphatidylethanolamine (1.7–6.6%). The quantities of monophosphatidylglycerol and diphosphatidylglycerol in the phospholipid fraction were from 0.4% to 0.8%. The data show that the phospholipids of the seeds from different melon varieties had similar qualitative and quantitative composition, with the exception of *Dessert 5* variety where the content of phosphatidylinositol and phosphatidylcholine was different.

### 3.8. Fatty acid composition of main classes of phospholipids

The data about the fatty acid composition of the main phospholipid classes of the studied Bulgarian varieties of melon are presented in Table 8.

Within one given variety, we could see differences between the main phospholipid classes. In variety *Honeydew*, the content of palmitic acid increased in direction phosphatidylethanolamine > phosphatidylcholine > phosphatidylinositol, which was at the expense of lessening of the quantity of the other major component—the oleic acid (from 23.2 to 15.2%). In the other two varieties *Dessert 5* and *Hybrid 1*,

**Table 7. Individual composition of phospholipid fraction of melon seed oils<sup>a</sup>**

Phospholipids (%)	Varieties of melon		
	<i>Honeydew</i>	<i>Dessert 5</i>	<i>Hybrid 1</i>
Phosphatidylinositol	33.9 ± 0.5	24.4 ± 0.4	30.9 ± 0.2
Phosphatidylcholine	23.0 ± 0.3	33.1 ± 0.5	27.7 ± 0.2
Phosphatidylethanolamine	8.4 ± 0.1	11.6 ± 0.3	17.1 ± 0.2
Phosphatidylserine	3.3 ± 0.1	4.2 ± 0.2	2.9 ± 0.1
Phosphatidic acids	16.3 ± 0.5	13.5 ± 0.3	15.6 ± 0.2
Sphingomyelin	0.8 ± 0.1	4.3 ± 0.2	0.4 ± 0.1
Monophosphatidylglycerol	0.5 ± 0.1	0.4 ± 0.1	0.4 ± 0.1
Diphosphatidylglycerol	0.6 ± 0.1	0.5 ± 0.1	0.8 ± 0.2
Lysophosphatidylcholine	6.6 ± 0.2	3.3 ± 0.3	1.7 ± 0.2
Lysophosphatidylethanolamine	6.6 ± 0.4	4.7 ± 0.2	2.5 ± 0.1

<sup>a</sup>Values are means ± SD (n = 3 and p < 0.05).

the quantity of the palmitic acid was higher in phosphatidylinositol (57.9% *Dessert 5* and 61.6% *Hybrid 1*) and in phosphatidylethanolamine (56.4% *Dessert 5* and 61.7% *Hybrid 1*) compared to phosphatidylcholine (48.8 and 46.8%).

The quantity of stearic acid varied within the limits from 9.4% to 16.3%, and in variety *Honeydew*, its quantity was the same in the separate phospholipid classes (11.2–11.5%), while in the other two varieties, its quantity increased in the following order phosphatidylinositol > phosphatidylcholine > phosphatidylethanolamine.

A tendency was noticed for lessening the content of the oleic acid in direction phosphatidylinositol > phosphatidylcholine > phosphatidylethanolamine in the phospholipids of variety *Honeydew*, while in variety *Dessert 5*, its content increased from 8.9% (phosphatidylinositol) to 22.7% (phosphatidylcholine and phosphatidylethanolamine), while in variety *Hybrid 1*, it increased in the direction phosphatidylcholine > phosphatidylethanolamine > phosphatidylinositol.

The quantity of linoleic acid in the separate phospholipid classes in the three studied melon varieties was within the limits from 6.7 to 19.8%, and it was highest in the three phospholipid classes of *Honeydew*.

The content of the other saturated fatty acids ( $C_{8:0}$ ,  $C_{10:0}$ ,  $C_{12:0}$ ,  $C_{14:0}$ ,  $C_{15:0}$ ,  $C_{17:0}$ ,  $C_{20:0}$ , and  $C_{22:0}$ ), as well as of the UFA ( $C_{12:1}$ ,  $C_{14:1}$ ,  $C_{16:1}$ ,  $C_{18:3}$ , and  $C_{20:1}$ ) in the phospholipid fraction existed in insignificant quantities.

**Table 8. Fatty acid composition of main classes of phospholipids (PI, PC, PE)<sup>a</sup>**

Total FA (%)	Varieties of melon								
	Honeydew			Dessert 5			Hybrid 1		
	PI	PC	PE	PI	PC	PE	PI	PC	PE
$C_{8:0}^b$	0.5 ± 0.1	0.5 ± 0.1	0.3 ± 0.05	0.1 ± 0.02	0.1 ± 0.02	– <sup>c</sup>	0.2 ± 0.05	0.1 ± 0.02	–
$C_{10:0}$	0.1 ± 0.02	–	0.3 ± 0.05	–	–	–	0.1 ± 0.02	–	–
$C_{12:0}$	0.7 ± 0.1	0.5 ± 0.05	1.0 ± 0.1	0.2 ± 0.05	0.5 ± 0.1	0.2 ± 0.05	1.6 ± 0.1	0.6 ± 0.1	1.7 ± 0.1
$C_{12:1}$	0.1 ± 0.02	0.1 ± 0.02	0.2 ± 0.02	–	–	–	–	–	–
$C_{14:0}$	3.1 ± 0.2	3.1 ± 0.1	3.0 ± 0.1	0.6 ± 0.1	2.0 ± 0.2	1.5 ± 0.1	1.1 ± 0.2	1.2 ± 0.2	2.5 ± 0.3
$C_{14:1}$	0.5 ± 0.05	0.3 ± 0.05	0.1 ± 0.02	–	0.1 ± 0.02	–	–	–	–
$C_{15:0}$	1.3 ± 0.1	1.4 ± 0.2	1.2 ± 0.2	0.3 ± 0.05	0.7 ± 0.2	0.6 ± 0.1	0.3 ± 0.05	0.3 ± 0.05	0.8 ± 0.1
$C_{16:0}$	34.4 ± 0.4	38.3 ± 0.4	42.0 ± 0.5	57.9 ± 0.5	48.8 ± 0.4	56.4 ± 0.4	61.6 ± 0.5	46.8 ± 0.5	61.7 ± 0.3
$C_{16:1}$	4.1 ± 0.2	4.9 ± 0.3	3.2 ± 0.2	0.4 ± 0.1	1.2 ± 0.2	1.2 ± 0.2	0.2 ± 0.02	0.2 ± 0.05	1.0 ± 0.03
$C_{17:0}$	0.7 ± 0.1	0.7 ± 0.1	0.9 ± 0.1	0.5 ± 0.05	0.6 ± 0.1	0.5 ± 0.1	0.6 ± 0.1	0.4 ± 0.1	0.9 ± 0.2
$C_{18:0}$	11.3 ± 0.3	11.2 ± 0.3	11.5 ± 0.4	16.3 ± 0.3	14.8 ± 0.4	9.4 ± 0.3	14.4 ± 0.4	12.8 ± 0.3	11.5 ± 0.5
$C_{18:1}$	23.2 ± 0.2	15.9 ± 0.4	15.2 ± 0.2	8.9 ± 0.3	22.7 ± 0.2	22.7 ± 0.2	9.1 ± 0.3	27.2 ± 0.2	13.0 ± 0.4
$C_{18:2}$	16.4 ± 0.3	19.8 ± 0.2	19.2 ± 0.5	14.1 ± 0.1	6.9 ± 0.3	7.3 ± 0.2	10.6 ± 0.4	10.3 ± 0.3	6.7 ± 0.3
$C_{18:3}$	0.4 ± 0.1	0.2 ± 0.05	0.2 ± 0.05	–	–	–	–	–	–
$C_{20:0}$	0.8 ± 0.2	0.8 ± 0.1	0.5 ± 0.1	0.3 ± 0.05	1.5 ± 0.1	0.1 ± 0.02	0.1 ± 0.02	–	0.1 ± 0.02
$C_{20:1}$	0.4 ± 0.05	0.6 ± 0.1	0.5 ± 0.05	0.4 ± 0.1	0.1 ± 0.02	0.1 ± 0.02	0.1 ± 0.02	0.1 ± 0.02	0.1 ± 0.02
$C_{22:0}$	2.0 ± 0.2	1.7 ± 0.2	0.7 ± 0.1	–	–	–	–	–	–
<b>SFA</b>	<b>54.9</b>	<b>58.2</b>	<b>61.4</b>	<b>76.2</b>	<b>69.0</b>	<b>68.7</b>	<b>80.0</b>	<b>62.2</b>	<b>79.2</b>
<b>UFA</b>	<b>45.1</b>	<b>41.8</b>	<b>38.6</b>	<b>23.8</b>	<b>31.0</b>	<b>31.3</b>	<b>20.0</b>	<b>37.8</b>	<b>20.8</b>

<sup>a</sup>Values are means ± SD ( $n = 3$  and  $p < 0.05$ ), PI is the Phosphatidylinositol, PC is the Phosphatidylcholine, PE is the Phosphatidylethanolamine.

<sup>b</sup> $C_{8:0}$  is the caprylic acid,  $C_{10:0}$  is the capric acid,  $C_{12:0}$  is the lauric acid,  $C_{12:1}$  is the lauroleic acid,  $C_{14:0}$  is the myristic acid,  $C_{14:1}$  is the myristoleic acid,  $C_{15:0}$  is the pentadecanoic acid,  $C_{16:0}$  is the palmitic acid,  $C_{16:1}$  is the palmitoleic acid,  $C_{17:0}$  is the margaric acid,  $C_{18:0}$  is the stearic acid,  $C_{18:1}$  is the oleic acid,  $C_{18:2}$  is the linoleic acid,  $C_{18:3}$  is the linolenic acid,  $C_{20:0}$  is the arachidic acid,  $C_{20:1}$  is the eicosenoic acid (gadoleic),  $C_{22:0}$  is the Behenic acid, SFA is the saturated fatty acids, UFA is the unsaturated fatty acids.

<sup>c</sup>Not detected.

A common tendency was not found out in the change of the content of saturated fatty acids in the separate classes of phospholipids in the three melon varieties; in the variety *Honeydew*, the quantity of the saturated acids increased in direction phosphatidylethanolamine (61.4%) > phosphatidylcholine (58.2%) > phosphatidylinositol (54.9%), in variety *Dessert 5*—in direction phosphatidylinositol (76.2%) > phosphatidylcholine (69.0%) > phosphatidylethanolamine (68.7%), and in variety *Hybrid 1*—phosphatidylinositol (80.0%) > phosphatidylethanolamine (79.2%) > phosphatidylcholine (62.2%). In the given rows about the three studied melon varieties, it was noticed a decrease in the content of the UFA, where this of the PUFA was too low.

Compared to the fatty acid composition of the triacylglycerol fraction considerable differences were noticed. While in the triacylglycerols of all studied oils, the polyunsaturated linoleic acid predominated (51.1–58.5%), however, its quantity in the phospholipid fraction was 6.7–19.8% at the expense mainly of the saturated fatty acids (54.9–80.0%), which quantity is 3–4 times higher than that in the triacylglycerols (16.3–23.5%). The content of SFA in phospholipids was significantly higher and in comparison with sterol esters (28.8–38.0%). From the other side, the smallest were the changes in the content of the MUFA in the fractions of the triacylglycerols and phospholipids.

These differences can be explained with the various stages of biosynthesis of fatty acids—at one side of the phospholipids and at the other—of the triacylglycerols. At the first stage of biosynthesis, mainly the saturated fatty acids were synthesized, as well as in the phospholipids, and after them—in the sterol esters. The phospholipids were synthesized in the following order: phosphatidylinositol, phosphatidylethanolamine, and phosphatidic acids, while finally, the triacylglycerols were synthesized. In this situation, in the molecules of the phospholipids more saturated fatty acids were included, firstly in phosphatidylinositol, afterwards in phosphatidylethanolamine, phosphatidylcholine, and finally, in the triacylglycerols, when the intensity of synthesis of UFA increased. At last stage, PUFA was synthesized which was included in triacylglycerols (Munshi, Sukhija, & Bhatia, 1983).

### 3.9. Tocopherol composition

The data from the tocopherol composition of melon seed oils are presented in Table 9.

The presence of main classes of tocopherols was found out ( $\alpha$ -,  $\beta$ - and  $\gamma$ -tocopherols). The main component in the oils was  $\gamma$ -tocopherol, where its quantity varied from 71.4% (*Dessert 5*) to 91.5% (*Honeydew*). A higher content of  $\alpha$ -tocopherol was found in the oil from variety *Dessert 5* (19.7%), compared to the other two varieties, where its content was from 2.9% (*Honeydew*) to 6.2% (*Hybrid 1*).  $\beta$ -Tocopherol was found in minimum quantities in the oil extracted from the seeds of melon variety *Honeydew* (1.7%). The unsaturated tocopherol representatives in the oils were presented by  $\gamma$ -tocotrienol with quantities from 3.9 to 15.3%. The results we have obtained correlated to the data found in the literature sources about the tocopherol content of the seed oils of variety *C. melo* var. *agrestis*, cultivated in Sudan, where  $\gamma$ -tocopherol dominated and it was 80.7 and 77.6% of the total tocopherol quantity, followed by  $\alpha$ -tocopherol (18.0–21.0%) (Mariod & Matthäus, 2008), but they differed from the data by Azhari et al. (2014), in which in the melon seed oil from variety *C. melo* var. *tibish* there predominated  $\delta$ -tocopherol (63.4%), followed by  $\gamma$ -tocopherol (30.3%) and  $\alpha$ -tocopherol (6.3%).

**Table 9. Individual tocopherol composition of melon seed oils<sup>a</sup>**

Total tocopherols (%)	Varieties of melon		
	<i>Honeydew</i>	<i>Dessert 5</i>	<i>Hybrid 1</i>
$\alpha$ -Tocopherol	2.9 ± 0.1	19.7 ± 0.3	6.2 ± 0.2
$\beta$ -Tocopherol	1.7 ± 0.1	– <sup>b</sup>	–
$\gamma$ -Tocopherol	91.5 ± 0.5	71.4 ± 0.3	78.5 ± 0.5
$\gamma$ -Tocotrienol	3.9 ± 0.1	8.9 ± 0.5	15.3 ± 0.3

<sup>a</sup>Values are means ± SD (n = 3 and p < 0.05).

<sup>b</sup>Not detected.

#### 4. Conclusion

The seeds of the three melon varieties (*Honeydew*, *Dessert 5*, and *Hybrid 1*) exhibited similar chemical composition. They are consisted of comparatively high amount of oil (41.6–44.5%), protein (34.4–39.8%), fiber (4.5–8.5%), and minerals which determine their high nutritional value. Melon seed oils are rich in essential fatty acids, such as linoleic as well as biologically active substances (phospholipids, sterols, and tocopherols). It is established that the fatty acid composition of sterol esters and phospholipids differ a lot from that of the triacylglycerols. In comparison, the seeds from *Honeydew* possess higher amounts of the following compounds than the other two varieties; therefore, it is considered healthier for human consumption. This study offers a complete observation upon chemical and lipid composition of melon seeds which can characterize them entirely. Because of their composition, melon seed kernels can be used successfully as an alternative source in the food industry as functional food, which is related to health promotion or disease prevention, as snacks after roasting, as a thickener and flavor component of soups, etc. The oil can be used in medicine as food additives and in cosmetics as ingredient in facial and body creams, sunscreens, soaps, etc. Melon seed oils are not widespread in food industry, but it is proved that they are not inferior in quality from the common oils in the market. A lot of examinations about the melon seed oils were made internationally recently but this is the first detailed study on the melons grown in Bulgaria and further investigations will take place in the future as well.

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