Fatty Acid and Proximate Composition of Bee Bread

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Summary
Palynological spectrum, proximate and fatty acid (FA) composition of eight bee bread samples of different botanical origins were examined and significant variations were observed. The samples were all identified as monofloral, namely Castanea sativa (94.4 %), Trifolium spp. (85.6 %), Gossypium hirsutum (66.2 %), Citrus spp. (61.4 %) and Helianthus annuus (45.4 %). Each had moisture content between 11.4 and 15.9 %, ash between 1.9 and 2.54 %, fat between 5.9 and 11.5 %, and protein between 14.8 and 24.3 %. A total of 37 FAs were determined with most abundant being (9Z,12Z,15Z)-octadeca-9,12,15-trienoic, (9Z,12Z)-octadeca-9,12-dienoic, hexadecanoic, (Z)-octadec-9-enoic, (Z)-icos-11-enoic and octadecanoic acids. Among all, cotton bee bread contained the highest level of ω-3 FAs, i.e. 41.3 %. Unsaturated to saturated FA ratio ranged between 1.38 and 2.39, indicating that the bee bread can be a good source of unsaturated FAs.

Key words: bee bread, fatty acid composition, proximate composition, monofloral pollen, pollen analysis

Introduction
Pollens and nectar are essential components of honeybee, Apis mellifera L., diet. Nectar provides carbohydrates, while pollen supplies protein, lipid and vitamins. Pollen collected by foraging worker bees is combined with honeybee secretions (1). Bee bread is processed pollen stored and packed in the honeycomb cells following the addition of various enzymes and nectar or honey as it undergoes lactic acid fermentation. Generally, the methods employed for quantification of nutritional dissimilarities amongst the levels of hive-stored and collected pollen have been proven difficult. There is a limited number of studies in the literature regarding the nutritional properties attributed to the stored pollen. The reported results are contradictory, indicating either no significant change or marginally increased nutrition (2). Bee pollen collection is a fairly new development. The pollen trap is used to scrape off the pollen from the legs of bees as they enter the hive. The scientific studies revealed various beneficial therapeutic and nutritional properties of the bee pollen and enabled the scientists to identify its antimicrobial, antioxidant, antiradical, anticancer, and anti-inflammatory activities (3). The main constituents of the bee pollen are carbohydrates (13–55 %), crude proteins (10–40 %), crude fibre (0.3–20 %) and lipids (1–10 %) (4–6).

As bee pollen contains all the essential amino acids required for the human organism, it is referred to as 'the only perfectly complete food’ (7). Notwithstanding, there are only few papers published on the FA composition of the bee bread. Human and Nicolson (8) reported only 18 fatty acids in bee bread originating from an indigenous South African bee plant. Ceksteretyé et al. (9) identified 22 fatty acids in the bee bread (containing >45 % rape or willow pollen) collected in the spring and summer seasons. (Z)-octadec-9-enoic and (5Z,8Z,11Z,14Z)-icos-5,8,11,14-tetraenoic acids were the most abundant unsaturated FAs, constituting around 15 % of total fatty acids. In another

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study, Českertény and Jansen (10) reported the highest content (27–43.8 %) of (9Z,12Z,15Z)-octadeca-9,12,15-trienoic acid (ω-3) among 22 FAs identified in spring rape and willow bee bread.

Fatty acids are of high importance in fertility and health of the honeybees. Unsaturated FAs have also many beneficial health effects such as reducing triglyceride (11) and cholesterol levels in blood and show anti-inflammatory and antithrombotic activities (12). Current literature suggests that pollen and bee bread are good sources of polyunsaturated FAs (PUFAs) that are crucial for human nutrition. PUFAs cannot be synthesized in human body endogenously and must be obtained from food. In this respect, bee bread can be considered as a potential source of PUFAs in human diet. However, in particular, scientific research exploring various properties of bee bread is scarce and additional research into this topic is highly required. Therefore, the aim of the current study is to obtain and compare data on the FA content, pollen and proximate composition of bee bread samples harvested in Turkey.

Materials and Methods

Bee bread samples

Eight bee bread samples were obtained from apiaries located in different monofloral honey production regions in Turkey between June and October of 2014. The pooled samples were collected from minimum three beehives in apiaries with 50–100 colonies. Bee bread samples were hand collected from honeycombs and kept at –20 °C before the analyses. The type of flora and sampling locations were as follows: cotton from Adana and Urfa, citrus from Adana and Mersin, chestnut from Zonguldak, sunflower from Edirne and clover from Urfa and Adiyaman.

Reagents and chemicals

The used reagents were purchased from Sigma-Aldrich-Fluka Co. Ltd. (Steinheim, Germany), unless otherwise stated. Anhydrous sodium sulphate and potassium hydroxide were obtained from Merck (Darmstadt, Germany). The standard reference mixture, Supelco-18919, of fatty acid methyl esters (FAMEs) was purchased from Supelco (Belfonte, PA, USA). The standard mixture contained the following 37 FAMEs: butanoic, hexanoic, octanoic, decanoic, undecanoic, dodecanoic, tridecanoic, tetradecanoic, pentadecanoic, hexadecanoic, heptadecanoic, octadecanoic, icosenoic, heneicosanoic, docosanoic, tricosanoic, tetracosanoic, (Z)-tetradec-9-enoic, (Z)-pentadec-10-enoic, (9Z)-hexadec-9-enoic, cis-10-heptadecenoic, (E)-octadec-9-enoic, (Z)-octadec-9-enoic, (Z)-icos-11-enoic, (Z)-docos-13-enoic, (Z)-tetracos-15-enoic, octadeca-9,12-dienoic, (9Z,12Z)-octadeca-9,12-dienoic, octadeca-6,9,12-trienoic, icosa-11,14-dienoic, (11Z,14Z,17Z)-icos-11,14,17-trienoic, (5Z,8Z,11Z,14Z)-icos-5,8,11,14-tetraenoic, docosa-13,16-dienoic, (9Z,12Z,15Z)-octadeca-9,12,15-trienoic, (11Z,14Z,17Z)-icos-11,14,17-trienoic, (5Z,8Z,11Z,14Z)-icoso-5,8,11,14,17-pentatetraenoic acid and docosa-4,7,10,13,16,19-hexaenoic acids.

Chemical analysis

Determination of FAMEs was performed using the ISO 12966-2:2011 standard method (17). Briefly, 0.1 g of bee bread oil was weighed into a test tube. After the addition of 5 mL of heptane and 0.5 mL of methanolic 2 M KOH, the tube content was mixed by vortexing for 1 min at room temperature. Then, the upper layer was dried with anhydrous sodium sulphate for gas chromatography analysis.

Chromatographic analysis was carried out by a gas chromatography (GC) system Clarus 500 (PerkinElmer, Shelton, CT, USA) equipped with an autosampler, split-splitless injector and a flame ionization detector. A 100-metre Supelco 2380 capillary column (Sigma-Aldrich, Belle-
fonte, PA, USA) with an internal diameter of 0.25 mm and 0.2 μm film thickness was used for chromatographic separation. Helium carrier gas flow rate was set at 1.2 mL/min. The injector and detector temperatures were set at 250 and 260 °C, respectively. The initial GC oven temperature was 165 °C, held for 5 min, increased to 240 °C at 5 °C/min and held at 240 °C for 10 min. A volume of 1.0 μL of sample was injected using the split injection mode (1:50). The peaks were identified by comparison of their relative retention times with a standard FAME mixture. The results were expressed as percentage of total FAMEs.

The resulting FAMEs were also confirmed by GC-MS through comparison of retention time and mass spectrometry data using the authentic reference standards. Confirmation analyses of individual FAMEs were performed under identical conditions. Chromatographic separation of compounds was carried out using an Agilent GC-MS system (Agilent Technologies, Palo Alto, CA, USA) equipped with Agilent 6890 gas chromatograph and Agilent 5973 mass spectrometer.

Chromatographic separation of fatty acids was achieved on a 30-metre DB-WAX capillary column (0.25 mm i.d., film thickness 0.25 μm; Agilent Technologies, Folsom, CA, USA). The carrier gas (helium) flow rate was 1.5 mL/min. The injection port temperature was set at 250 °C. The volume of the injected sample was 1 μL (split ratio 1:10). Initially, the GC oven temperature was maintained at 180 °C for 3 min. Then it was increased to 210 °C at a rate of 2 °C/min and after 20-minute isothermal run at 210 °C, finally increased to 240 °C at 10 °C/min and held for 5 min. The mass spectra were acquired in an electron-impact (EI) ionization mode at 70 eV in the mass scan range of m/z=35–550. The temperatures of electron ionization source and mass quadrupole analyser were 150 and 280 °C, respectively.

The mass spectra of compounds were identified by comparing the mass spectra obtained from their related chromatographic peaks with the Wiley and NIST mass spectral libraries (18,19).

Statistical analysis
All chemical assays were performed in triplicate. The obtained data were expressed as mean value±standard deviation. The data were compared using one-way analysis of variance (ANOVA) followed by least significant difference (LSD) test. Differences between the mean values at the 95 % confidence interval (p<0.05) were considered statistically significant.

Results and Discussion

Pollen content of the samples

Botanical origin of the bee bread samples was identified by pollen analysis. The results are presented in Table 1. All of the eight samples studied were unifloral: cotton (two), clover (two), citrus (two), chestnut (one) and sunflower (one). Chestnut bee bread contained 94.4 % Castanea sativa pollen, while the clover bee bread samples contained Trifolium spp. (T. repens and T. pratense) pollen >85 %. Cotton bee bread samples contained Gossypium hirsutum L. pollen at 65.6 and 66.2 %, citrus samples comprised Citrus spp. at 61.4 and 54.4 %, and sunflower sample contained Helianthus annuus L. at 45.4 %. Other pollen taxa found in the samples were Fabaceae, Lamiaceae, Brassicaceae, Rhamnaceae, Apiaceae, Myrtaceae and Rosaceae.

Characterization of honeybee products such as honey, bee pollen and bee bread is important for consumers. Honey with a pollen frequency >45 % is considered to be monofloral or unifloral. In monofloral honey, underrepresented pollen (e.g. citrus) frequency is minimum 10–20 % or 20–30 %, and overrepresented pollen (such as chestnut, eucalyptus) frequency is minimum 70–90 % (20). Similarly, the results of pollen analysis revealed that more than 45 % of total pollen detected in the bee bread samples was from monofloral source. In particular, chestnut and clover samples had the monofloral pollen contents of over 85 %. Castanea sativa is an important nectar and pollen source for a pollen forager bee (21) as it is abundantly available and easy to manage. The anemophilous plants like chestnut produce large quantities of small pollen grains and nectar foraging honeybees actively collect them mainly earlier in the day during the flowering season to strengthen and improve the colony life (22,23). All the above information explains the preference of chestnut pollen by honeybees and high rate of Castanea sativa representation in bee bread.

Frequency of Trifolium spp. in clover bee bread samples from Adiyaman and Urfa was 85.6 and 86.2 % respectively. Trifolium species classified under the Fabaceae family is among the most important pollen sources for honey-

| Sample | Geographical origin | Botanical origin | w(pollen) % | w(other important pollen) % |
|--------|---------------------|-----------------|-------------|-----------------------------|
| 1 Clover | Urla              | Trifolium pratense, T. repens | 86.2        |                             |
| 2 Clover | Adiyaman           | Trifolium pratense, T. repens | 85.6        |                             |
| 3 Cotton | Adana             | Gossypium hirsutum | 65.6        | Fabaceae, Lamiaceae         |
| 4 Cotton | Urla              | Gossypium hirsutum | 66.2        | Fabaceae, Astereaceae, Lamiaceae |
| 5 Chestnut | Zonguldak          | Castanea sativa | 94.4        | Fabaceae                    |
| 6 Citrus | Adana             | Citrus spp. | 54.4        | Fabaceae, Brassicaceae, Lamiaceae, Rhamnaceae, Rosaceae |
| 7 Citrus | Mersin             | Citrus spp. | 61.4        | Fabaceae, Brassicaceae, Lamiaceae, Rhamnaceae, Myrtaceae |
| 8 Sunflower | Edirne            | Helianthus annuus | 45.4        | Fabaceae, Rosaceae, Apiaceae |
The samples could be ascribed to the altitude and diurnal differences. Therefore, changes determined in the moisture levels of samples collected at different altitudes from the sea level. Furthermore, the sample collection points were at different altitudes from the sea level. Therefore, changes determined in the moisture levels of the samples could be ascribed to the altitude and different climatic conditions. Clover bee bread samples had the highest protein content (22.6 and 24.2 g/100 g) and cotton appeared to have the lowest content of protein (14.8 and 15 %). Clover bee bread also had the highest fat content along with citrus. Our results showed that the protein and lipid content varies according to the botanical origin of the bee bread. Herbert Jr and Shimanuki (33) reported similar findings for the seven bee bread samples they studied but their data spread out over a wider range than ours. They found moisture content ranging between 18.8 and 28.0 %, protein content between 19.3 and 26.5 %, ash content between 2.1 and 3.2 %, and lipid content between 3.9 and 6.7 %.

### Fatty acid composition

A total of 37 FAs including 20 saturated and 17 unsaturated fatty acids were identified in the bee bread samples obtained from different botanical origins (Table 3). The results of fatty acid determination included both free acids and esters. The nectar and pollen collected by honeybees for honey production. However, honeybees seldom visit and obtain pollen from cotton plants (25,26). Cotton pollen is covered with sticky material (27) which makes its grooming from the body of bees painstakingly hard and it explains the avoidance of cotton pollen by honeybees (28). Another study, the repellency of cotton is attributed to the gossypol, which is a dimeric sesquiterpenoid (25).

Sunflower bee bread contained the lowest pollen content from *Helianthus annuus* (45.4 %). This could be explained by the fact that although honeybees are the most frequent visitors of the sunflowers, they rather collect nectar from sunflowers and are less attracted to their pollen compared to other pollen types (29). Furthermore, it is reported that the protein content of sunflower pollen is low in both quality and quantity, so it is considered to be poor pollen source for honeybees (30).

Although citrus trees are considered as the most significant floral source for the production of honey, they are rarely a good pollen source due to their low protein level. This could be one of the reasons for low representation of *Citrus* spp. pollen in the citrus bee bread samples (31).

Moreover, it is known that the nectar and pollen collecting behaviours of honeybees are different. There are several factors which have to be taken into consideration regarding pollen collection by honeybees; the need of the colonies for pollen, brood production, the rhythm of the colony life throughout the season, biological value of bee pollen for honeybees, age of the foragers, handling time and factors related to pollen (size, colour, floral shape and symmetry, pigmentation patterns, attractiveness, etc.) (32).

### Protein, fat, moisture and ash contents

The proximate compositions of the studied samples are given in Table 2. The moisture fractions of the samples were between 11.4 and 15.9 %. The mass fractions of ash were 1.9 to 2.5 %, the fat from 5.9 to 11.5 % and protein from 14.8 to 24.3 %.

The bee bread samples studied were obtained from regions with different climatic conditions. For example, while the Mersin and Adana regions are under the influence of Mediterranean climate, continental climate is found in the other regions. Moreover, the sample collection points were at different altitudes from the sea level. Therefore, changes determined in the moisture levels of the samples could be ascribed to the altitude and different climatic conditions. Clover bee bread samples had the highest protein content (22.6 and 24.2 g/100 g) and cotton appeared to have the lowest content of protein (14.8 and 15 %). Clover bee bread also had the highest fat content along with citrus. Our results showed that the protein and lipid content varies according to the botanical origin of the bee bread. Herbert Jr and Shimanuki (33) reported similar findings for the seven bee bread samples they studied but their data spread out over a wider range than ours. They found moisture content ranging between 18.8 and 28.0 %, protein content between 19.3 and 26.5 %, ash content between 2.1 and 3.2 %, and lipid content between 3.9 and 6.7 %.

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### Table 3. Fatty acid composition of bee bread samples

| Saturated fatty acid | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 | Sample 6 | Sample 7 | Sample 8 | \( w(\text{fatty acid})/\% \) |
|----------------------|----------|----------|----------|----------|----------|----------|----------|----------|-----------------|
| C4:0 Butanoic        | (0.75±0.01) | (0.65±0.01) | (1.29±0.46) | (0.37±0.01) | (1.16±0.01) | (1.03±0.04) | (1.06±0.02) | (1.30±0.41) |
| C6:0 Hexanoic        | (0.08±0.00) | – | (0.35±0.01) | – | – | (0.22±0.07) | – | – |
| C8:0 Octanoic        | (0.10±0.01) | – | (0.12±0.00) | (0.02±0.00) | (0.04±0.00) | (0.34±0.03) | – | (0.08±0.01) |
| C10:0 Decanoic       | (0.07±0.01) | (0.02±0.00) | (0.05±0.01) | (0.16±0.00) | (0.04±0.00) | (0.04±0.00) | (0.04±0.00) | (0.04±0.00) |
| C11:0 Undecanoic     | – | – | – | (0.07±0.00) | – | – | (0.07±0.00) | – |
| C12:0 Dodecanoic     | (0.14±0.00) | (0.05±0.01) | (0.29±0.01) | (0.11±0.00) | (0.07±0.04) | (6.15±10) | (0.06±0.00) | (0.14±0.02) |
| C13:0 Tridecanoic    | – | – | – | – | (0.07±0.01) | – | (0.07±0.01) | – |
| C14:0 Tetradecanoic  | (1.29±0.04) | (0.36±0.01) | (0.51±0.01) | (0.21±0.01) | (0.41±0.01) | (0.38±0.01) | (0.30±0.00) | (1.26±0.04) |
| C15:0 Pentadecanoic  | (0.14±0.00) | – | (0.21±0.02) | (0.14±0.01) | (0.53±0.01) | (0.15±0.00) | (0.13±0.01) | (0.21±0.02) |
| C16:0 Hexadecanoic   | (29.63±0.42) | (26.34±0.51) | (38.69±0.31) | (22.32±0.33) | (24.56±0.29) | (27.18±0.14) | (24.71±0.25) | (28.87±0.38) |
| C17:0 Heptadecanoic  | (0.23±0.02) | (0.20±0.01) | (0.46±0.03) | (0.32±0.02) | (0.91±0.01) | (0.35±0.04) | (0.35±0.03) | (0.51±0.03) |
| C18:0 Octadecanoic   | (3.21±0.05) | (1.31±0.02) | (6.27±0.12) | (2.33±0.03) | (2.37±0.10) | (1.59±0.09) | (1.91±0.05) | (3.39±1.11) |
| C20:0 Icosanoic      | (0.73±0.03) | (0.80±0.04) | (3.23±0.07) | (1.04±0.03) | (1.41±0.06) | (1.12±0.02) | (0.61±0.02) | (1.64±0.03) |
| C21:0 Heneicosanoic  | (0.04±0.00) | (1.17±0.04) | (0.05±0.00) | (1.70±0.04) | (0.37±0.00) | (0.08±0.01) | – | – |
| C22:0 Docosanoic     | (0.55±0.02) | (0.44±0.01) | (0.08±0.01) | (0.89±0.05) | (1.20±0.04) | (2.60±0.18) | (0.13±0.01) | (0.60±0.03) |
| C23:0 Tricosanoic    | (0.28±0.01) | (1.07±0.02) | – | (5.07±0.07) | (1.02±0.03) | (0.58±0.04) | – | (0.62±0.06) |
| C24:0 Tetracosanoic  | (0.03±0.00) | (0.05±0.00) | – | (0.04±0.00) | (0.23±0.01) | (0.06±0.01) | – | – |

Unsaturated fatty acid

| Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 | Sample 6 | Sample 7 | Sample 8 |
|----------|----------|----------|----------|----------|----------|----------|----------|
| 37.28    | 32.48    | 51.59    | 35.25    | 34.51    | 41.97    | 29.37    | 38.67    |

**Unsaturation (%):**

- C14:1n5 (Z)-tetradec-9-enoic
- C15:1 (Z)-pentadec-10-enoic
- C16:1n7 (Z)-hexadec-9-enoic
- C17:1 cis-10-heptadecenoic
- C18:1n9 (Z)-octadec-11-enoic
- C19:1n9 (Z)-docos-13-enoic
- C20:1n9 (Z)-tetracos-15-enoic
- C18:2n6t Octadeca-9,12-dienoic
- C18:2n6c (9Z,12Z)-octadeca-9,12-dienoic
- C18:3n6 Octadeca-6,9,12-trienoic
### Table 3 – continued

| Geographical and botanical origin of the samples | Unsaturated fatty acid | Total number of FAs identified | Values in the same row with different letters in superscript are statistically significant (p<0.05) |
|-------------------------------------------------|------------------------|-------------------------------|------------------------------------------------------------------------------------------------|
| Citrus sample from Adana | (9Z,12Z)-octadeca-9,12-dienoic, (8Z,12Z)-octadeca-8,12-dienoic | 31 | Values in the same row with different letters in superscript are statistically significant (p<0.05) |
| Sunflower sample from Adana | (9Z,12Z)-octadeca-9,12-dienoic | 31 | Values in the same row with different letters in superscript are statistically significant (p<0.05) |
| Sunflower sample from Urfa | (9Z,12Z)-octadeca-9,12-dienoic | 31 | Values in the same row with different letters in superscript are statistically significant (p<0.05) |
| Chestnut sample from Adana | (9Z,12Z)-octadeca-9,12-dienoic | 31 | Values in the same row with different letters in superscript are statistically significant (p<0.05) |

Significantly different from each other. (9Z,12Z)-octadeca-9,12-dienoic acids were detected in the cotton sample from Adana at a higher level than in that from Urfa. On the contrary, (9Z,12Z)-octadeca-9,12,15-trienoic acid content of the cotton sample from Urfa was extremely high (40.7 %) and in that from Adana it was found only in traces (0.17 %). The dominant fatty acid in the cotton sample from Adana was (9Z,12Z)-octadeca-9,12-dienoic acid (36.9 %), while (9Z,12Z)-octadeca-9,12,15-trienoic acid was the most abundant in the cotton sample from Urfa (40.7 %), which also had the second highest unsaturated fatty acid content (67.5 %), after the clover sample from Urfa (70.3 %). Total number of FAs identified in the citrus bee bread samples from Adana and Mersin was 33 and 34, respectively. Citrus bee bread from Adana was the only sample containing higher mass fraction of saturated FAs (51.6 %) than unsaturated FAs (48.3 %). Hexadecanoic acid fraction was the highest (38.7 %) in these samples, while tricosanoic acid was present only in the citrus bee bread sample from Mersin at 5.6 %.

Each of the clover bee bread samples obtained from the Urfa and Adana provinces contained 31 FAs that are mostly unsaturated. Fatty acid profiles of the samples were slightly different from one another. Undecanoic and heptadecanoic acids were barely detected in the clover bee bread sample from Urfa, while two of the saturated fatty acids, octanoic and tricosanoic acids, were found only in the clover bee bread sample from Adana.

Thirty-four fatty acids were identified in the chestnut bee bread sample. (11Z,14Z,17Z)-icosanoic acid (ω-3), detected in all other samples, was not present in chestnut bee bread. However, the chestnut sample contained the highest mass fraction (1.8 %) of (11Z,14Z,17Z)-icosanoic acid (ω-3) among the samples.

The most abundant fatty acid in sunflower bee bread was (9Z,12Z)-octadeca-9,12,15-trienoic acid (29.8 %), followed by hexadecanoic acid (27.2 %). Sunflower bee bread contained the largest number of fatty acids. Only undecanoic acid was missing from this sample. It was the only sample with the highest dodecanoic acid content (6.15 %); other samples contained this acid at very low levels (between 0.05 and 0.29 %). Additionally, tricosanoic acid was detected solely in the sunflower bee bread.

The major FAs found in all bee bread samples were hexadecanoic (22.3–38.7 %), (9Z,12Z)-octadeca-9,12-dienoic (6.3–37 %), (Z)-octadec-9-enoic (3.9–21.2 %), octadecanoic (1.3 to 6.3 %) and (9Z,12Z,15Z)-octadeca-9,12,15-trienoic (0.2–40.7 %) acids. However, there were statistically significant (p<0.01) differences in the types and mass fractions of FAs detected in the bee bread samples obtained from the different botanic origins.

A total of four ω-3 fatty acids, including (9Z,12Z)-octadeca-9,12,15-trienoic, (11Z,14Z,17Z)-icosanoic, (11Z,14Z,17Z)-icosanoic, (5Z,8Z,11Z,14Z,17Z)-icosanoic acid, and docosa-13,16-dienoic acids, were detected in bee bread samples and their mass fractions ranged from 0.04 to 40.70 %. The total ω-3 fatty acid content was the highest (41.3 %) in the cotton bee bread sample from Adana and the lowest (0.8 %) in the citrus bee bread sample from Adana. Seven ω-6 fatty acids, including octadeca-9,12-dienoic, (9Z,12Z)-octadeca-9,12-dienoic, octadeca-6,12,15-trienoic, (5Z-
Omega-3 fatty acids provide many beneficial effects such as anti-inflammatory function and prevention of cardiovascular diseases. Omega-6 fatty acids are also beneficial to human health. However, they have opposite effects on inflammatory response and cardiovascular health. Because they compete for the same enzymes to produce signalling molecules, they have opposing physiological functions. For example, while ω-6-derived molecules are proinflammatory, ω-3-derived signalling molecules are anti-inflammatory. Furthermore, they compete to incorporate into cell membranes. Therefore, the balance of ω-6/ω-3 fatty acids is important for human health. Modern Western diets have ω-6/ω-3 ratio of 15:1 or 20:1. It was concluded that while very high ω-6/ω-3 ratio promotes the pathogenesis of many diseases, a reduced ω-6/ω-3 ratio can prevent these diseases. In addition to the ratio 2:1, the ratio 3:1 suppressed inflammation in patients with rheumatoid arthritis, and the ratio 5:1 had a beneficial effect on asthma (37). Therefore, the optimal ratio may vary because chronic diseases are multigenic and multifunctional.

Simopoulos (38) concluded in his review that a lower ratio of ω-6/ω-3 fatty acids is more desirable for reducing the risk of many diseases.

**Conclusion**

The pollen content, fatty acid composition, and chemical composition of bee bread samples from different botanical origins vary. Preferred or readily available plants for the bees as pollen source are also present in the bee bread samples, whereas others can be found in smaller amounts as a result of selective low preference.

The total amount of unsaturated fatty acids (FAs) is higher than the sum of saturated FAs found in all the samples except citrus sample from the Adana region. The results obtained in the current study confirmed that the bee bread can be considered as a good source of unsaturated FAs. The fatty acid content of bee bread is very important for the honeybees and PUFAs are essential for a healthy body development and productivity. However, unsaturated FAs are not essential just for the bees but also for the human nutrition. The unique results of this study can thus be used as a reference for research into the bee and also human health. The findings can also provide a scientific basis for the nutritional value assessment of the bee bread, thereby making contribution to the food composition database.

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