Biochemical and technological properties of seeds and oils of Capparis spinosa and Capparis ovata plants growing wild in Turkey

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Abstract

The physical and chemical properties of seeds of Capparis spinosa var. spinosa and Capparis ovata Desf var. canescens (Heywood) were determined. Seeds were evaluated for dry matter, crude protein, crude oil, crude fibre, ash, carbohydrates, crude energy and ash. Contents of Al, Ca, Cu, Fe, K, Mg, Na, P and Zn in both the seeds were also determined by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES). The main fatty acids identified by gas chromatography were oleic (38.45% and 44.62%), linoleic (23.71% and 18.26%) and palmitic (10.23% and 8.41%) acids. The seeds were found to be rich in oil and minerals and fatty acids, suggesting that they may be valuable for edible oil sources and industrial by-product. The data may also be useful for the evaluation of nutritional information. Also, physical properties such as length (3.76 mm and 3.68 mm), unit mass (0.012 g and 0.012 g), geometric mean diameter (2.92 mm and 2.87 mm), projected area (0.092 cm² and 0.095 cm²), sphericity (0.778 and 0.781), kernel density (728.44 kg/m³ and 794.50 kg/m³), porosity (30.21 % and 37.06 %), bulk density (502.88 kg/m³ and 488.48 kg/m³), static (0.345 - 0.665 and 0.369-0.658) and dynamic coefficient of friction (0.297 - 0.563 and 0.314 – 0.558) of friction of C.spinosa and C.ovata species were measured at 5.18% and 4.93% moisture content levels, respectively.

Keywords: Caperberry seeds; Physical properties; Composition; Fatty acids; Minerals.

Nomenclature: Dg: geometric mean diameter (mm); T1: beginning value of the torque (N cm); L: length of caper seed (mm); Tm: average value of the torque (N cm); M: mass of caper seed (g); V: volume of seed (mm³); m1000: thousand of caper seed (g); Vt: terminal velocity (m/s); A: projected area (cm²); W: width of seed (mm); ρb: bulk density (kg/m³); Ws: sample weight (10N); ρk: seed density (kg/m³); Ø: sphericity of seed; ε: porosity of seed (%); ρi: initial pressure (kg/cm²); ρf: final pressure (kg/cm²); μs: static coefficient of friction; μd: dynamic coefficient of friction; T: thickness of caper seed (mm); q: torque arm (cm) (10.5 cm)

Introduction

Caper is a plant with medicinal and aromatic properties. It is a long-lasting shrub plant that belongs to the Capparaceae family; capers occurs in various types (more than 350) and grows naturally in all the continents in many different regions of the world [1-3]. It is a tropical/subtropical plant [1,4]. The caper plant, which is called bubu, gebre, gabar, gevil, kapari, keper, kebere, turşuotu and Şebellah in different parts of Turkey, is an economically valuable plant. In various regions of the world different organs of caper species have been profitable for several purposes since ancient times. Young shoots, flower buds, and fruit are used for human nutrition. Capers have very important roles in the food industry; the flower buds were stored in brine and have become a costly product during recent years [2,5-9].

Material and Methods

Material

Ripened caperberries (fruit) of wild growing plants of C.ovata and C.spinosa were collected from Konya (Selçuklu) and Mersin (Silifke), respectively. The seeds were obtained from ripened fruit. The seed samples were put into paper bags for transport to the laboratory. The seeds were dried under the air condition, and cleaned in an air screen cleaner to remove all foreign matter such as dust, dirt and chaff as well as immature and damaged seeds. The initial moisture content of seeds was determined by using a Standard method [13]. The remaining material was packed in a 2000 ml hermetic glass vessel and kept in cold storage until use.

Chemical properties

Chemical properties of both caper plant seeds picked in August were analysed according to AOAC [14]. The dried seeds were finely powdered. The oil was extracted with petroleum ether (50°C) in a soxhlet apparatus. The extract was evaporated in vacuum. The lipid extract was collected in a flask. The extracted lipid was weighed to determine the oil content and stored under nitrogen at 4°C for further analyses.

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Determination of mineral contents

About 0.5g of dried and ground caperberry seeds were put into a burning cup with 15 ml of pure \( \text{NH}_3 \). The sample was incinerated in a MARS 5 microwave oven at 200°C. Distilled deionized water and ultrahigh-purity commercial acids were used to prepare all reagents, standards, and walnut samples. After digestion treatment, samples were filtrated through whatman No 42. The filtrates were collected in 50 ml Erlenmayer flasks [15] and analysed by ICP-AES. The mineral contents of the samples were quantified against standard solutions of known concentrations which were analyzed concurrently [16].

Working conditions of ICP-AES

| Instrument          | ICP-AES (Varian-Vista) |
|---------------------|------------------------|
| RF Power            | 0, 7-1, 5 kw (1, 2-1, 3 kw for Axial) |
| Plasma gas flow rate \( (\text{Ar}) \) | 10, 5-15 L/min. (radial) 15 °(axial) |
| Auxilary gas flow rate \( (\text{Ar}) \) | 1, 5 ° |
| Viewing height      | 5-12 mm |
| Copy and reading time | 1-5 s (max.60 s) |
| Copy time           | 3 s (max. 100 s) |

Determination of fatty acids

Fatty acid composition for caperberry seeds samples was determined using a modified fatty acid methyl ester method as described by Akgül and Özcan [7]. The oil was extracted three times from 2 g air-dried seed sample by homogenization with petroleum ether. The oil sample (about 0.15-0.20 g) was converted to its fatty acid methyl esters (FAME). The methyl esters of the fatty acids (0.5 μl) were analysed in a gas chromatograph (Shimadzu GC-2010, Japan) equipped with a flame ionising detector (FID), a fused silica capillary column (MN FFAP (60 m x 0.25 mm i.d.; film thickness 0.20 μm). It was operated under the following conditions: oven temperature program, 90°C for 7 min. Raised to 240°C at a rate of 6°C/min and then kept at 240°C for 15 min); injector and detector temperatures, 260 and 260 oC; respectively, carrier gas, nitrogen, at flow rate of 14 psi; split ratio 1/50 μl/min. A Standard fatty acid methyl ester mixture (Sigma Chemical Co.) was used to identify sample peaks. Commercial mixtures of fatty acid methyl esters were used as reference data for the relative retention times [14]. Quantitative analyses of the fatty acids were performed using the heptadecanoic acid methyl ester as internal standard. The results are mean values of three replicates.

Determination of physical properties

All physical properties of \( C.\text{spinosa} \) 5.18 % m.c.d.b and \( C.\text{ovata} \) 4.93 % were determined at natural moisture content at 20 repetitions, respectively. To determine the size of the seeds, ten groups of samples consisting of 1000 seeds have been selected randomly. 100 grains have been taken from each group and their linear dimensions - length (L), width (W) and thickness (T) - and projected areas have been measured. Linear dimensions were measured by a micrometer to an accuracy of 0.01mm.

Projected area (A) of seeds was determined by using a digital camera (Kodak DC 240) and Sigma Scan Pro 5 program [17,18].

The mass (M) of seeds and a thousand seeds mass (\( \text{m}_{1000} \)) were measured by an electronic balance to an accuracy of 0.0001g. To evaluate 1000 seed mass, 100 randomly selected seeds from the bulk were averaged.
The porosity of the bulk ($\varepsilon$) were measured using a porosity device [27,28]. Which consists of two identical tanks, one containing air under pressure ($p_1$) and the other one containing the samples of seed. When the valve between the two tanks opened, the air pressure in the two tanks equalized to a value $p_2$. Porosity was calculated from the following equation; 

$$\varepsilon = (p_1-p_2)/p_2 \times 100$$

The rupture strength values of caper seeds were measured by forces applied through three axis (length, width and thickness). The device, has three main components which are stable up and motion bottom of platform, a driving unit (AC electric motor and electronic variator) and the data acquisition (Dynamometer, amplifier and XY recorder) system. The rupture force of seeds was measured by the data acquisition system. The seed was placed on the moving bottom platform and was pressed with stationary platform. Experiment was conducted at a loading velocity at 50 mm min$^{-1}$.

Geometric mean diameter ($D_g$) and sphericity ($\Theta$) values were found using the following formula; [20,22] 

$$D_g = (LWT)^{0.333}$$
$$\Theta = (LWT)^{0.333}/L$$

The coefficient of friction caperberry seed was measured using a friction device modified by Tsang-Mui Chung, Verma & Wright [29] and improved by Chung and Verma [30]. Also, both the static and dynamic coefficient of friction was measured and calculated using the equation [30].

$$\mu_s = T_a / W_s \times q$$
$$\mu_d = T_m / W_s \times q$$

Where $\mu_s$ equals static coefficient of friction, $T_a$ equals beginning value of torque, $\mu_d$ equals dynamic coefficient of friction, $T_m$ equals average value of the torque, $q$ the length of torque arm, and $W$ is the weight of seeds to calculate the dynamic and static coefficients of friction. The average value of the torque during the rotation of the disk and the maximum value of torque obtained as the disk started to rotate were used.

Statistical analyses

Results of the research were analysed for statistical significance by analysis of variance [31].

Results and Discussion

Chemical properties

The chemical properties of caperberry seeds are given in Table 1. The crude oil, crude fibre, ash, crude energy and ether soluble extract contents of $C. ovata$ seeds were higher than that of $C. spinosa$. But, protein content (8.71%) of $C. spinosa$ was high compared with $C. ovata$. Also, crude protein contents of both seeds was higher than those caperberries fruits (17.4% and 18.6% for $C. spinosa$ and $C. ovata$, respectively) reported by Özcan and Aydin [32]. The moisture, crude oil and crude energy contents were similar to those for caperberry seeds reported by Akgül and Özcan [7].

The mineral contents of caperberry seeds were determined by ICP-AES (Table 2) and found to be excellent. The seeds were composed Mg, K, P and Ca. The Fe, K, Mg, Na, P and Zn contents of $C. spinosa$ seeds were found high compared with $C. ovata$ seeds. Contents in seeds of some minerals were determined to be higher compared with those of caper ($C. ovata$) seeds reported by Özcan [3]. Mineral contents were determined to vary widely depending on the different species and locations of caper plant. The soil, fertilizers and other cultural factors effect the presence of minerals in oil-bearing seeds [33]. The fatty acid composition of caperberries seed oils was determined by gas chromatography (Table 3).

Oleic acid (38.45% and 44.62% for $C. spinosa$ and $C. ovata$, respectively) was present in the highest concentration, followed by linoleic (23.71% and 18.26%), palmitic (10.23% and 8.41%), stearic (2.61% and 2.07%) and linolenic (1.17% and 0.56%) acids. Akgül and Özcan [7] found that the contents of the main fatty acids of caperberries seed oils of $C. spinosa$ and $C. ovata$ were 13.2% and 11.3% palmitic, 3.2% and 2.7% stearic, 49.87% and 34.66% oleic, 25.2% and 24.5% linoleic and 1.0% and 0.3% linolenic, respectively. Mannina et al. established that the contents of the main fatty acids of hazelnut oils were 5.1-

Table 1: Chemical properties of caper seeds.

| Properties         | $C. spinosa$ | $C. ovata$ |
|--------------------|--------------|------------|
| Crude dry matter (%)| 93.6±1.6     | 94.1±1.3   |
| Crude protein (%)   | 19.7±1.1     | 20.4±0.7   |
| Crude oil (%)       | 30.7±2.4     | 32.6±1.6   |
| Crude fibre (%)     | 24.3±1.1     | 23.8±0.9   |
| Ash (%)             | 2.1±0.7      | 1.9±0.1    |
| Crude energy (cal/g)| 596.4±11.4   | 574.1±7.6  |
| Ether-soluble extract (%)| 17.8±1.1     | 23.4±1.7   |

Table 2: Some mineral contents of $C. spinosa$ and $C. ovata$ seeds (mg/kg).

| Properties         | $C. spinosa$ | $C. ovata$ |
|--------------------|--------------|------------|
| Palmitic           | 10.23        | 8.41       |
| Stearic            | 2.61         | 2.07       |
| Oleic              | 38.45        | 44.62      |
| Linoleic           | 23.75        | 18.26      |
| Linolenic          | 1.17         | 0.56       |

Table 3: Fatty acid composition of caper seeds (%).

| Properties         | $C. spinosa$ | $C. ovata$ |
|--------------------|--------------|------------|
| Mass (g)           | 0.01±0.00    | 0.01±0.00  |
| Length (mm)        | 3.76±0.02    | 3.68±0.02  |
| Width (mm)         | 3.04±0.02    | 2.98±0.023 |
| Thickness (mm)     | 2.19±0.01    | 2.16±0.02  |
| Geometric mean diameter (mm) | 2.92±0.01     | 2.87±0.02  |
| Sphericity         | 0.78±0.00    | 0.78±0.00  |

Table 4: Dimensional properties of $C. spinosa$ and $C. ovata$ seeds.
6.4% palmitic, 2.2-2.5% stearic, 77.8-84.2% oleic, 6.4-12.0% linoleic and 0.10-0.18% linolenic acids. The main fatty acids identified by gas chromatography were oleic (52.3%), palmitic (21.3%) and linoleic (19.7%) acids for P.terebinthus fruits [34].

As a result, the differences in chemical properties, mineral contents and fatty acid composition of caper seed and seed oil belong to both plants were probably due to environmental conditions in conjunction with the analytical methods used. The analytical values revealed nutritional properties such as protein, oil, ash, fibre, mineral contents and fatty acid composition. These findings may be useful for dietary information, which requires prior knowledge of the nutritional composition of caperberry seeds.

Physical properties

Dimensional properties, sphericity and the values of geometric mean diameter of C.spinosa and C.ovata seeds are given in Table 4. The frequency distributions of these seeds and dimensional properties are given in Figure 3. The 89% of the measured C.spinosa is between 0.011 to 0.013g in terms of moisture content of 5.18% in weight, 85% of them is between 3.5 to 4 mm in length, 96% of them is between 2.6 to 3.5 mm in width, and 93% is between 2.0 to 2.50 mm in thickness. The 96% of C.ovata is between 0.012 to 0.013 g in terms of moisture content of 4.93 % in weight, 91% of them is between 3.2 to 4.0 mm in length, 96% of them is between 2.6 to 3.5 mm in width, and 96 % is between 1.90 to 2.50 mm in thickness.

The relationship between length, width, thickness, weight, geometric mean diameter and sphericity of C.spinosa has been determined. This relationship was found to be as the follows.

\[
L = 298.41xM = 1.24xW = 1.72xT = 1.29xDg = 4.83xØ
\]

The same comparison between length, width, thickness and weight, the relationships for C.ovata has been established. This relationship for this seed was found to be as follows.

\[
L = 287.5xM = 1.23xW = 1.70xT = 1.28xDg = 4.71xØ
\]

Correlation coefficients for these relations are given Table 5.
C. spinosa and C. ovata static and dynamic on galvanized steel, iron sheet, plywood and rubber and 0.78-0.78, respectively. At the same moisture content, fruit density, C. ovata length, width, geometric mean diameter and sphericity of C. spinosa and C. ovata seeds for various material surfaces.

I/M For both seeds these relations are found statistically insignificant, the relationships between L/W, L/T , L/Dg and L/O have been found to be statistically significant. Similar results were reported by Demir et al. [35], Gezer et al. [36], Carman [26], Joshi et al. [37].

This indicates that the length, mass, the geometric mean diameter and sphericity are closely related to the diameter of seed. Some technological properties of seeds used in experiment are shown in Table 6.

Similar investigations have been made to evaluate the projected area, volume, bulk density, fruit density and terminal velocity by Özcan et al. [8] for caper buds. The static and dynamic coefficients of friction for caperberry seeds determined with respect to iron sheet and galvanized steel surfaces are represented in Table 7. At the same moisture contents, both the static and dynamic coefficients of friction were greatest for seeds on iron sheet.

Conclusions

It is important, however, to know, the physical properties of equipment used in plantation, harvesting, transportation, storage and processing of caperberry seeds.

Also length, mass, geometric mean diameter, sphericity, volume, seed density, bulk density, porosity, projected area, terminal velocity and seed hardness values were at 5.18% and 4.93% moisture content levels for C. spinosa and C. ovata seeds, respectively. The values of mass, length, width, geometric mean diameter and sphericity of C. spinosa and C. ovata seeds established were 0.01-0.01 mm, 3.76-3.68 mm, 2.92-2.87 and 0.78-0.78, respectively. At the same moisture content, fruit density, bulk density, projected area and terminal velocity of both species were determined as 728.44 and 794.50 kg/m², 502.88 and 488.48 kg/m², 0.09 and 0.09 cm² and 4.01 and 3.91 m/s, respectively. The coefficient of static and dynamic on galvanized steel, iron sheet, plywood and rubber ranged between 0.35-0.67 and 0.29-0.56; 0.37-0.66 and 0.31-0.56 for C. spinosa and C. ovata seeds, respectively.

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Table 7: Relationships between friction coefficients and moisture content of C. spinosa and C. ovata seeds for various material surfaces.

| Materials    | Static friction coefficient | Dynamic friction coefficient |
|--------------|-----------------------------|------------------------------|
| Galvanized steel | 0.35±0.02                  | 0.29±0.02                   |
| Iron sheet    | 0.48±0.01                  | 0.41±0.02                   |
| Plywood      | 0.51±0.04                  | 0.43±0.02                   |
| Rubber       | 0.67±0.03                  | 0.56±0.03                   |

Materials

C. spinosa

| Materials    | Static friction coefficient | Dynamic friction coefficient |
|--------------|-----------------------------|------------------------------|
| Galvanized steel | 0.36±0.03                  | 0.31±0.02                   |
| Iron sheet    | 0.42±0.02                  | 0.36±0.03                   |
| Plywood      | 0.56±0.03                  | 0.49±0.02                   |
| Rubber       | 0.65±0.03                  | 0.55±0.03                   |

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