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Physico-Chemical Properties of Wild Chestnut (*Castanea sativa* Mill.) Fruit Grown in Turkey

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Abstract: Physico-chemical properties of chestnut (*Castanea sativa* Mill.) fruit including ash, crude oil, crude protein, crude fibre, crude energy, total carbohydrate and minerals (S, Zn, Mn, Na) contents of completely ripe fruits were determined. The major minerals (mg/kg) of chestnut fruit were established as Zn (5099.4 mg/kg), Mn (3031.9 mg/kg), Na (1058.6 mg/kg) and Ca (308.5 mg/kg). Also, physical properties such as length, diameter of fruit, mass, volume of fruit, geometric mean diameter, sphericity, surface area, bulk density, fruit density, porosity, projected area, terminal velocity, 1000 fruit mass, static and dynamic coefficient of friction were measured at 54.8% moisture content level. The average length, width, thickness, mass, the geometric mean diameter and sphericity were established as 21.79 mm, 23.94 mm, 14.55 mm, 4.68 g, 19.62 mm and 0.89. In the same moisture content, projected area, volume, bulk density, fruit density, porosity, terminal velocity, fruit hardness, static friction and dynamic friction coefficients were determined as 5.70 cm^2, 4.26 cm^3, 585.8 kg/m^3, 1135.68 kg/m^3, 49.19 %, 14.51 m/s, 54.35-77.05 N, 0.295-0.424 and 0.253-0.356, respectively.

Key words: Chestnut · *Castanea sativa* · Minerals · Physical and chemical properties

INTRODUCTION

Chestnuts (*Castanea sativa*), a member of the family Fagaceae, is annual plant which grows in Turkey. Turkey is the motherlannd and one of the oldest cultivation area of chestnut (*Castanea sativa* Mill.) [1].

The Genus Castanea, the chestnuts, comprises eleven species of small to medium-sized deciduous trees found in south western Asia, Southern Europe, North Africa and the Eastern United States [2,3]. It is a large and wide-spreading tree (up to 15 m tall and 20 m wide). The nuts are variable, but superior varieties are good sized, sweet and easy to peel. There are four main economic species of chestnut: *Castanea crenata* (Japanese), *C. dentata* (American), *C. mollissima* (Chinese) and *C. sativa* (European). All chestnut species are native to the northern hemisphere. Chestnut is a deciduous tree or shrub, which is cultivated in a similar manner to other deciduous nut trees. It bears brown nuts, about an inch in diameter, which are usually consumed after they are roasted. From one to nine nuts are produced in a spiny involucres or burr [4,5].

Chestnuts have been cultivated for centuries. In Europe , chestnuts are thought to have introduced by Greeks in north-west and central Europe. The oldest planted sweet chestnut in England is the chestnut. It was commonly found on mountains, hills and slopes in gravelly or rocky, well-drained glacial soils [6,7]. Chestnuts are often used as a substitute for potatoes or pasta in Europe due to their high starch content. Mashed or whole braised chestnuts are good partners with sweet potatoes, Brussels sprouts and cabbage, but most Turkish people use them in deserts. Chestnuts have a remarkable nutritional composition. Fresh chestnuts contain about 50% moisture. They contain complex carbohydrates are low in protein (about 5%), are very low in fat, have reasonable quantities of vitamin C and potassium and are very low in sodium. The protein is high quality (comparable to eggs) and is easily assimilated by the human body [2].

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Little research has been done on the Chestnut in Turkey. Thus, we know little about its physical and chemical properties. It was carried out more studies on nut breeding and nut tree culture [4,7,8,9]. The objective of this work was to determine the chemical composition, mineral content and physical properties such as length, mass, diameter of fruit, volume, geometric mean diameter, bulk density, porosity, projected area and fruit density of chestnut.

MATERIAL AND METHODS

Material: Maturate wild chestnut fruits (about 20 kg peeled chestnuts) were collected from chestnut trees growing from Kastamonu in the west black Sea region of Turkey in October 2003. The fruits were transported in polypropylene bags and held at room temperature. Fruits were cleaned by a combination of manual and mechanical means to get rid of all foreign matter and crushed and immature fruits. Moisture contents were measured immediatelyon arrival soon.

Method

Chemical Analyses: Moisture, crude oil, crude protein, crude energy, ash, crude fibre and ether-soluble extract, according to Cemeroğlu [10].The total carbohydrate content of chestnut was established by subtracting the amount of total ash and protein and fat from total weight [11].

Determination of Mineral Contents: About 0.5g dried and ground fruit was put into a burning cup and added pure 15 ml pure HNO_3. The sample was incinerated in a MARS 5 Microwave Oven at 200°C and solution was diluted to the specify volume with water. Then, mineral content of samples were determined with an ICP-AES [12].

Working conditions of ICP-AES

Instrument	:	CP-AES (Varian-Vista
RF Power	:	0.7-1.5 kw (1.2-1.3 kw for Axial)
Plasma gas flow rate (Ar)	:	10.5-15 L/min. (radial) 15 " (axial)
Auxiliary gas flow rate (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)

Physical Properties: All physical properties of chestnuts were determined using 10 repetitions at the natural moisture content of 54.84% d.b.

To determine the size of the fruits, ten groups of samples consisting of 100 fruits were selected randomly. 10 fruits were taken from each group and their linear dimensions – length (L), width (W) and thickness (T) and projected areas (P_a) measured. A micrometer measured linear dimensions to an accuracy of 0.01mm.

Projected area of chestnuts was determined by using a digital camera (Kodak DC 240) and Sigma Scan Pro 5 program [13,14]. The fruit mass (M) was measured by an electronic balance to an accuracy of 0.001g.

The bulk density ($\tilde{n}_b$) was determined with a hectolitre tester, which was calibrated in kg per hectolitre [15-17]. The chestnuts were dropped into a bucket from a height of approximately 15 cm. The excess chestnuts were removed by sweeping the surface of the bucket. The fruits were not compressed in any way.

The chestnuts volume (V) and density ($\tilde{n}_f$), as a function of moisture content, were determined by using the liquid displacement method. Toluene (C_7H_8) was used instead of water because it is absorbed by the fruit to a lesser extent. Also, its surface tension is low, so that it fills even shallow dips in a fruit and its dissolution power is low [18,19].

The porosity (ε) was determined by the following equation:

$$\varepsilon = 1 - \rho_b / \rho_k$$

In which ρ_b and ρ_k are the bulk density and the fruit density, respectively [19,21].

Hardness values of chestnuts were measured by forces applied through three axes (length, width and thickness). Hardness was determined with a Test Instrument of Biological Materials using the procedure described by Aydın and Öğüt [22] (Fig.1). The device has three main components which are a fixed support platform, a driving unit (AC electric motor and electronic variator) and a data acquisition (Dynamometer, amplifier and XY recorder) system. The fruit was placed on the moving lower platform and pressed with the stationary platform. The Probe used in the experiment had a 1.20 mm diameter and was connected to the dynamometer. The Experiment was conducted at a loading velocity at 50 mm min^{-1}.

The terminal velocities (V_t) of chestnuts were measured using an air column. For each test, a sample was dropped into the air stream from the top of the air column, up which air was blown to suspend the material. The air velocity near the location of the fruit suspension was measured by an electronic anemometer having a least count of 0.1 m/s [23,24] (Fig.2).

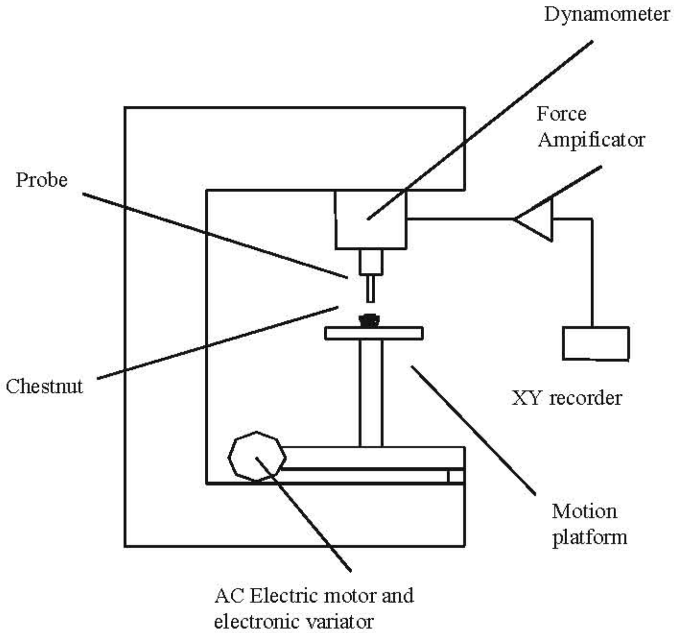

Fig. 1: Biological material test unit (BMTU)

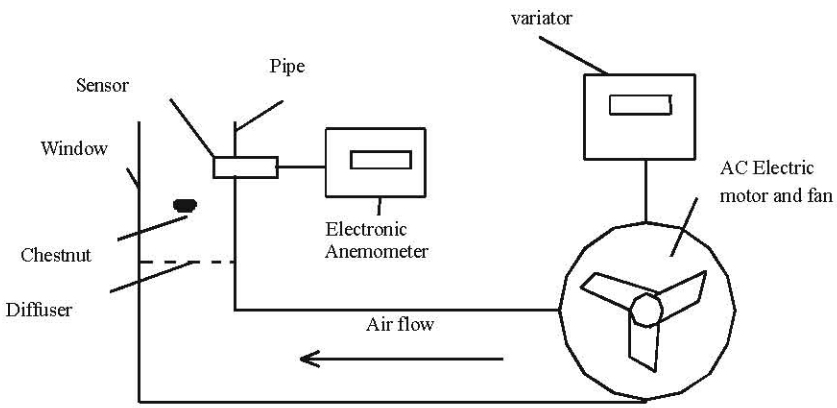

Fig. 2: Unit for measuring terminal

Geometric mean diameter (D_g) and sphericity ($\varnothing$) values were found using the following formula; (Mohsenin 1970; Jain and Bal 1997)

$$D_g = (LWT)^{0.333}$$

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

The coefficient of friction of chestnuts was measured using a friction device as modified by Tsang-Mui Chung, Verma and Wright [25] and improved by Chung and Verma [26]. Also, both the static and dynamic coefficient of friction with an applied torque were measured and calculated using the equation [26].

$$\mu_s = Ta / Wt.q$$

$$\mu_d = Tm / Wt.q$$

Where μ_s equals static coefficient of friction, T_a equals the initial torque value, μ_d equals the dynamic coefficient of friction, T_m equals the average value of the torque, q the length of the torque arm and Wt *is* the weight of fruits to calculate the dynamic and static coefficients of friction.

The statistical evaluation were done by using MINITAB package program [27].

RESULTS AND DISCUSSION

Chemical Properties: The chemical properties of chestnut fruits are shown in Table 1. Moisture, crude oil, crude protein, crude fibre, crude energy, ash, dry matter, total carbohydrate and ether soluble extract values were determined as 54.84%, 2.24%, 8.93%, 3.92%, 4046 kcal/100 g, 2.078%, 45.16%, 11.21% and 4.44%, respectively. Total carbohydrate quantities changed between 75.32 g/100g depending on cultivars, with a mean value of 80.73 g/100 g [1]. The chestnut fruits generally contained high rates of carbohydrates; this was 86.26 g/100 g in American chestnuts (*C. dentata* Borkh.) [29] and 71.68-88.10 g/100 g in European chestnuts [28-30]. The ash content of the chestnut cultivars changed between 1.02 and 3.22 g/100 g [1]. Many other researchers found this value between 0.83 and 4.92 g/100 g in various species and genotypes [31-35]. The crude cellulose quantities of the chestnut cultivars ranged from 3.58 to 5.96 g/100 g [1]. Demiate *et al.*[33] found the crude cellulose quantity in Brezilian cultivars (*C. sativa*) as 2.34 g/100 g. The total fat content of the chestnut samples ranged from 0.49 to 2.01 g/100 g [1]. This value was found between 0.66 and 5.59 g/100 g by some other researchers in the cultivars belonging to the species *C. sativa* Mill. [31-33,36,37].Total protein quantity of chestnut cultivars changed between 4.88 and 10.87 g /100 g, but it was between 5.23 and 8.73 g/100 g in most of the samples [1]. This range was narrower in the Chinese chestnuts being between 2.12 and 7.49 g/100 g [28].

The mineral content of chestnut fruit were determined by ICP-AES (Table 1) and found to be excellent. Zinc (5099.4 mg/kg), Manganese (3031.9 mg/kg), Sodium (1058.6 mg/kg) and Calcium (308.5 mg/kg) were established as major minerals of chestnut fruit. Al, B, Fe, Sr and Ti were found in minor amounts. The chestnut cultivars contained different amounts of Ca, Mg, Fe, Mn, Cu, Zn, P, Na and K. These values were found as 43-230 mg/100g, 70-160 mg/100g, 0.4-5.7 mg/100g, 0.7-5.5 mg/100 g, 0.6-3.8 mg/100 g,1.8-9.1 mg/100 g, 6.0-41.0 mg/100 gand 761-1271 mg/100 g, respectively [1].

The reference moisture content of the plant material here is important because many of the physical properties of grains are known to vary with moisture content [38,39]. The oil levels are too low in most of the fruits and depending on the type crude fiber contents (ranged from 0.5 to 2.81%). The crude protein content of many edible

Table 1: The chemical properties and mineral contents of chestnut fruit

Properties	Values
Proximate composition	
Moisture (%)	54.84
Drymatter (%)	45.16
Crude protein* (%)	8.93
Crude oil (%)	2.24
Crude fibre (%)	3.92
Crude energy (kcal/100 g)	4046.00
Ash (%)	1.078
Ether-soluble extract (%)	4.44
Total carbohydrate (%)	11.21
Minerals (mg/kg)	
Al	21.52
As	7.82
B	15.87
Bi	1.54
Ca	308.52
Co	0.12
Cr	5.72
Fe	38.15
Mn	3031.86
Na	1058.64
Sr	15.22
Ti	768.72
Zn	5099.45

Table 2: Dimensional properties of chesnut at 51.32% m.c.d.b.

Length (mm)	21.79±0.196
Width (mm)	23.94±0.197
Thickness (mm)	14.55±0.171
Mass (g)	4.678±0.094
Geometric mean diameter (mm)	19.62±0.141
Sphericity	0.899±0.005

wild fruits is usually lower than 5% and varies considerably [40]. But, the protein content of chestnut fruit was found high than that of literature value. Some chemical properties and mineral contents of chestnut fruits were found to be higher than that of reported for terebinth (*Pistacia terebinthus* L.) [41].

Chestnut fruits have advantage over fruits such as peanut, hazelnut and walnut in terms of certain mineral concentrations: Fe, Ca, Mn, Mg, Na, Zn and K. Calcium is the major component of bone and assists in teeth development [42,43].

Physical Properties: Dimensional properties, sphericity and the values of geometric mean diameter of chestnut are given in Table 2. The frequency distributions of the dimensional properties are given in Figure, 3.90% of chestnut is between 3 to 6 g in terms of moisture content of 54.84% in weight, 96% of them are between 17 to 25 mm

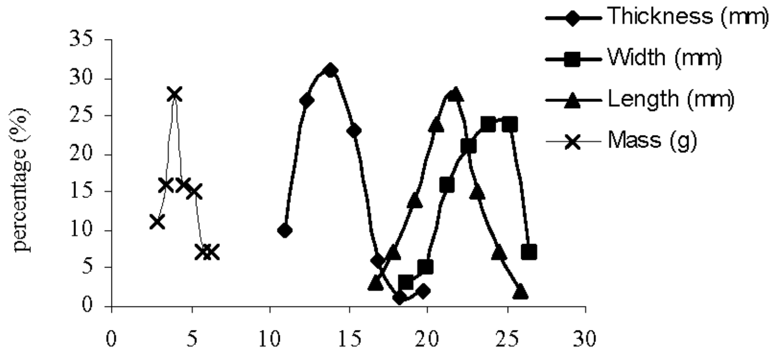

Fig. 3: Percentage distribution curves of mass, length, width and thickness measuring of chestnut at the moisture content of 51.32%

in length, 72% of them is between 18 to 25 mm in width and 70% are between 10 to 26 mm in thickness.

For a comparison between length, width, thickness and weight, the relationships between has been established. This relationship was found to be as the follows.

$$L=0.910xW=1.497xT=4.657xM$$

Correlation coefficients for these relations are given Table 3. The relationships between *L/W* , *L/T* and *L/M* have been found to be statistically significant. Similar results were reported by Demir, Doğan, Özcan and Hacıseferoğulları [44], Gezer, Hacıseferoğulları and Demir [45]; Joshi, Das and Mukherji [23].

Some physical properties of chestnut obtained in the research are shown in Table 4. Similar investigations have been made to evaluate the project area, volume, 1000 fruits mass, bulk density, fruit density and terminal velocity by Deshpande *et al.* [15] for soybean; Dutta, Nema and Bhardwaj [46] for gram ; Demir and Özcan [47] for rose fruits and Haciseferogullari *et.al* [48] for faba beans. The projected areas of the hazelnut and kernels varied from 206.84 to 265.57 mm^2 and from 125.64 to 174.83 mm^2, respectively [49]. In addition, fruit hardness of chestnut were measured applying the force by different positions. The highest strength value were found to be on by force applied length axis. The differences between the means of volume, surface and projected areas should be considered in the handling and processing the chestnuts and in the evaluation of their quality.In addition, the static - dynamic coefficient (Table 5) of friction for chestnut were found as 0.295-0.253, 0.424-0.356 and 0.338-0.281 on galvanized steel, plywood and steel surface, respectively. Demir *et al.* [44] reported that the static and dynamic of friction coefficient for hackberry fruits were found similar. The static coefficient of friction for hazelnuts and kernels was determined on the plywood surface. These coefficient values varied from 0.212 to 0.296 and 0.298 to 0.376, respectively [49].

As a result, the differences in chemical properties of chestnut fruits having about the same size were probably due to environmental conditions and analytical methods used. These results may be useful for dietary information,

Table 3: The correlation coefficient of chestnut

	Particulars	Ratio	Degrees of freedom	Correlation coefficient
Chesnut	*L/W*	0.910	98	0.621**
	L/T	1.497	98	0.295**
	L/M	4.657	98	0.649**

**P>0.01

Table 4: Some physical properties of chesnut at 51.32% m.c.d.b

Projected area (cm^2)	5.70±0.271
Volume (cm^3)	4.26±0.826
Thousand of chestnut (g)	4633.00±85.65
Bulk density (kg/m^3)	585.85±10.48
Fruit density (kg/m^3)	1135.68±38.64
Porosity(%)	49.19±1.29
Terminal velocity (m/s)	14.51±0.14
Fruit hardness, applied force (N)	
Through length	77.05±6.92
Width thickness	56.72±5.28
Through width	54.35±6.78

Table 5: Friction coefficients of chestnut fruits agent various surfaces

Materials	Static friction coefficient	Dynamic friction coefficient
Galvanized steel	0.295±0.018	0.253±0.015
Plywood	0.424±0.028	0.356±0.023
Steel	0.338±0.021	0.281±0.017

which requires prior knowledge of the nutritional composition of edible wild fruits. This work attempts to contribute to the knowledge of the nutritional and physical properties of these plants. In addition, knowledge of their mineral contents of condiments is of great interest. In addition, the physical properties of chestnut fruit are very important to design the equipment for processing, transportation, separation and storing. Therefore determinations of these properties have an important role in the design of this equipment. Also, this study attempts to contribute to knowledge of the nutritional properties of these fruits.

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NOMENCLATURE

D_g geometric mean diameter of chesnut (mm)
T thickness of chestnut (mm)
L length of chestnut (mm)
T_a beginning value of the torque (Ncm)
M mass of chestnut (g)
T_m average value of the torque (Ncm)
m_c moisture content, (%) d.b.
V volume of chestnut (mm^3)
m_{1000} thousand of chestnut (g)
V_t terminal velocity of chestnut (m/s)

ε porosity of chestnut (%)
W width (mm)
P_a projected area of chestnut (cm^2)
Wt sample weight (10N)
$\tilde{n}_b$ bulk density of chestnut (kg/m^3)
$\emptyset$ sphericity of chestnut
$\tilde{n}_f$ fruits density (kg/m^3)
μ_s static coefficient of friction
q torque arm (cm) (10.5 cm)
μ_d dynamic coefficient of friction