Some Physico-chemical Properties of *Mahonia acquifolium* Fruits

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Mahonia aquifolium fruits were investigated for some technological and chemical properties such as: dimensions, geometric mean diameter, sphericity, bulk density, fruit density, volume, terminal velocity, rupture strength, porosity, moisture, reducing sugar, total anthocyanin and phenolics, crude protein, crude oil, crude energy, crude fiber, ash, pH, acidity, alcohol soluble extract and color. Mineral content of *Mahonia aquifolium* fruits growing in Turkey were established by Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES). *Mahonia aquifolium* fruit contained high amounts of K, P, Ca, Na and Mg. The average pulp mass ratio, thickness, width, length, mass, volume, geometric mean diameter, sphericity and projected area were measured to be 88.21 %, 7.05 mm, 7.85 mm, 9.10 mm, 0.28 g, 233 mm^3, 7.92 mm, 0.88 and 68.40 mm^2, respectively. The energy, reducing sugar, protein, cellulose, oil, ash, acidity, total phenolics, total anthocyanin and soluble solid matter values of *Mahonia aquifolium* fruits were determined to be 47.85 kcal/100g, 47.6 g/kg, 30.8 g/kg, 17.8 g/kg, 21.7 g/kg, 11.0 g/kg, 33.7 g/kg, 4574.6 mg/kg, 655.64 mg/kg and 176.0 g/kg, respectively. It is very important to evaluate the technological properties of equipment used harvesting, transportation, storage and processing of fresh fruits. In additon, the information supplied on the chemical properties of the *Mahonia aquifolium* fruits serves as food in human nutrition.

Key Words: *Mahonia aquifolium*, Proximate composition, Technological properties.

INTRODUCTION

Mahonia aquifolium is widespread in the forests of North America and is known as the cultivated plant mahonia. It is commonly found in gardens and parks growing as high as 1-2 meters with evergreen, leathery pinnate leaves, with a very shiny upper surface and a thorny tooted edge. It is yellow buds develop into blue, frost-covered berries which contain a dark-red juice and contain 2-5 shiny seeds. It contains many pharmacologically important alkaloids which justify its use in traditional medicine for treatment of skin disorders, such as psoriasis, dermatitis and eczema[1]. At present, a mahonia ointment is available as a tropical antipsoriatic drug[2]. The

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berries are edible and are used to make wine and brandy. The bark of roots and stems contain alkaloids which have a number of therapeutic properties. In North American medicine, *Mahonia aquifolium* has been traditionally used to treat fever, diarrhea, dyspepsia, gout, rheumatic ailments, kidney and liver diseases, but most prominently for skin problems. However, only in the last five years the scientists discovered how and why this herbal extract is so beneficial for psoriasis sufferers[1,3,4]. Thus, attempts have been made in this study to determine the chemical composition and the technological properties of equipment used in plantation, harvesting, transportation, storage and processing of matured wild *Mahonia aquifolium* fruits.

EXPERIMENTAL

Fresh *Mahonia aquifolium* fruits were collected from mahonia trees growing from the Konya region of Turkey in July 2008. The fruits were transported in polypropylene bags and held at room temperature. Fruits were cleaned by a combination of manual and mechanical means to remove all foreign matter and crushed and unripe fruits. Their moisture contents were measured immediately on arrival.

Physical properties: All the physical properties of fruits were determined by using 10 repetitions at the natural moisture content of 72.90 % by weight basis. To determine the size of fruits, 10 groups of samples, each of which consists of 100 fruits, were selected randomly. Ten fruits from each group were taken and their linear dimensions, such as thickness, width and length, were measured. Linear dimensions were measured by a micrometer to an accuracy of 0.01 mm. Projected area of fruits was determined by using a digital camera (Canon A 200) and Sigma Scan Pro 5 program[5]. The mass (M) of fruits were measured with an electronic balance to an accuracy of 0.001 g. The bulk density (ρ_b) was determined with a hectoliter tester, which was calibrated in kilogram per hectoliter[6]. The fruits were placed into the calibrated bucket from a height of about 15 cm and the excess buds were removed by a strike with stick. The fruits were not compacted in any way. The volume and density (ρ_f), as a function of moisture content, were determined by the liquid displacement method using toluene. As its surface tension is low, it fills even shallow dips in a fruit and its dissolution power is low[7,8]. The porosity (ε) was determined by the following equation:

$$\varepsilon = 1 - \frac{\rho_b}{\rho_f}$$

In which ρ_b and ρ_f are the bulk density and the fruit density, respectively[8,9].

Rupture strength radial and axial values of the fruits were measured by applied forces. The rupture strength of the fruits, were determined with test instrument of biological materials using the procedure described by Aydin and Ogut[10] (Fig.1). The device has three main components, which are stable up and motion bottom of platform, a driving unit [alternating current (AC) electric motor and electronic variator] and the data acquisition (dynamometer, amplifier and XY recorder) system.

The rupture strength of the fruit was measured by a data acquisition system. The fruit was placed on the moving bottom platform and was pressed against the stationary upper platform. A probe with a diameter of 2 mm used in the experiment was connected to a dynamometer. The experiment was conducted at a loading velocity at 50 mm/min.
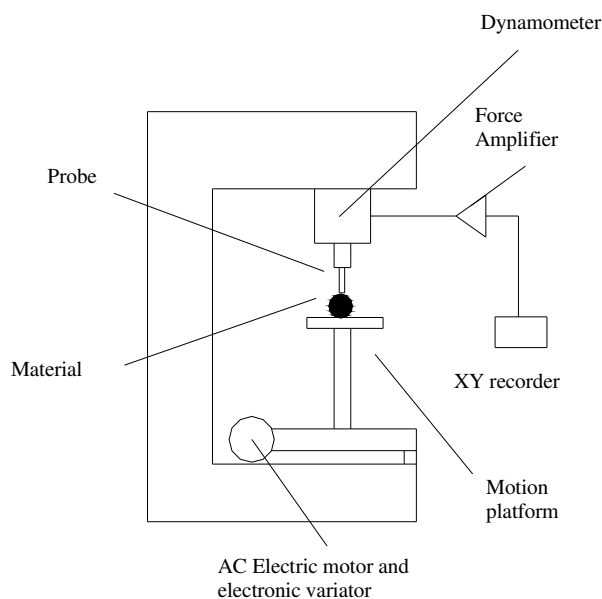
Fig. 1. Biological material test unit AC, alternating current

The terminal velocities of the fruits were evaluated using an air column. For each test, a sample was filled into the air stream from the top of the air column, up which air was blown to suspend the material in the air stream (Fig. 2). The air velocity near the location of the fruits suspension was measured with a sensitive of ± 0.1 m/s [11].
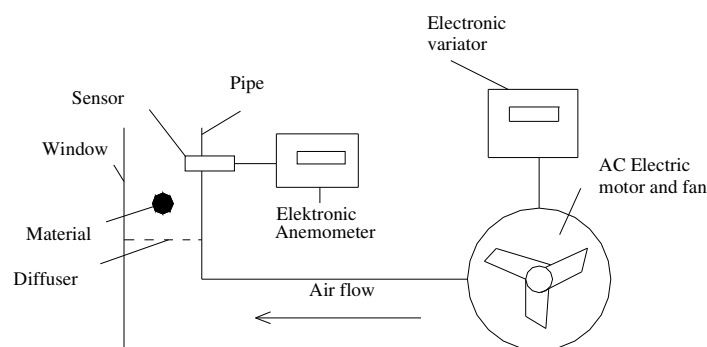
Fig. 2. Unit for measuring terminal velocity

Geometric mean diameter (D_g) and sphericity (Ø) values were calculated by using the following formula[9]:

$$D_g = (WTL)^{0.333}$$
$$Ø = Dg/L$$

The coefficient of friction of the fruit was measured using a friction device modified by Chung *et al.*[12] and improved by Chung and Verma[13]. Both the static and dynamic coefficient of friction with an applied torque was also measured and calculated using the equation[13]:

$$\mu_s = T_a/G.q$$
$$\mu_d = T_m/G.q$$

where μ_s is the static coefficient of friction, T_a is the beginning value of the torque, μ_d is the dynamic coefficient of friction, T_m is the average value of the torque, q is the length of torque arm and G is the weight of fruits in order 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 the torque obtained as the disk started to rotate were used.

Chemical analysis: Moisture, reducing sugar, crude oil, crude protein, crude energy, ash, crude fiber, water-soluble extract, alcohol-soluble extract, pH, acidity and non soluble extract were determined according to Cemeroglu[14] and AOAC[15]. Total anthocyanin and phenolic compounds analysis were determined according to Fuleki and Francis[16] and Spanos *et al.*[17] with small modifications. Colour of *Mahonia aquifolium* fruits was analyzed by measuring Hunter L (Brightness; 100: white, 0: black), a(+: red; –: green) and b(+: yellow; –: blue) parameters with a colorimeter (Model CR 400, Chromometer, Minolta, Japan)[18].

About 0.5 g dried and ground fruit was put into a burning cup and 15 mL of pure HNO_3 was added. The sample was incinerated in MARS 5 Plus microwave oven (Cem Corp., Matthews, NC) at 20 ºC and the solution was diluted to a certain volume with water. Concentrations were determined with inductively coupled plasma-atomic emission spectrometry (ICP-AES)[19]. Working conditions of ICP-AES include the following: instrument, ICP-AES Varian-Vista; RF power, 0.7-1.5 kW (1.2-1.3 kW for axial); plasma gas flow rate (Ar), 10.5-15.0 L/min (radial) and 15 L/min (axial); auxiliary gas flow rate (Ar), 1.5 L/m; viewing height, 5-12 mm; copy and reading time, 1-5 s (maximum of 60 s); copy time, 3 s (maximum of 100 s).

RESULTS AND DISCUSSION

The physical properties, such as size distribution of *Mahonia aquifolium* fruits are given in Table-1. The following general expression can be used to describe the relationship among the average dimensions of fruits at 72.90 % (w.b.) moisture content.

TABLE-1
THE TECHNOLOGICAL PROPERTIES OF *Mahonia aquifolium* FRUITS

Properties	Values
Thickness (mm)	7.05 ± 0.142
Width (mm)	7.85 ± 0.159
Length (mm)	9.10 ± 0.156
Pulp mass ratio (%)	88.21 ± 3.08
Mass (g)	0.28 ± 0.010
Geometric mean diameter (mm)	7.92 ± 0.098
Sphericity	0.88± 0.0170
Projected area (mm^2)	68.40 ± 3.013
Fruit density (kg/m^3)	1075 ± 54.168
Bulk density (kg/m^3)	488.06 ± 5.472
Volume (mm^3)	233.00 ± 41.00
Terminal velocity (m/s)	6.990 ± 0.1200
Rupture strength at radial direction (N)	0.569 ± 0.0383
Rupture strength at axial direction (N)	0.866 ± 0.0982
Porosity (%)	54.34 ± 1.2100

The technological properties including pulp mass ratio, thickness, width and length of fruit, mass, volume of fruit, geometric mean diameter, sphericity, bulk and fruit density, porosity, projected area, terminal velocity, rupture strength at radial and axial direction, static and dynamic coefficient of friction were observed at 72.90 % moisture content level. The average pulp mass ratio, thickness, width, length, mass, volume, geometric mean diameter, sphericity and projected area were measured to be 88.21 %, 7.05 mm, 7.85 mm, 9.10 mm, 0.28 g, 233 mm^3, 7.92 mm, 0.88 and 68.40 mm^2, respectively. The moisture content have a high important because it is effective on some technological properties such as bulk density, fruit density, porosity and pulp mass ratio, static and dynamic coefficient of friction of *Mahonia aquifolium* fruits[20]. Similar studies were conducted to determine the projected area, volume, bulk density, fruit density and terminal velocity for cherry tomatoe[21], almond[22], European cranberry bush[23] and barberry fruits[18].

The frequency distributions of the dimensional properties are displayed in Figs. 3-4. Eighty-two per cent of fruits are between 0.21 and 0.4 g in terms of moisture content of 72.90 % in mass, 86 % of them is between 5.9-8.2 mm in thickness, 84 % of them are between 6.4-9.8 mm in width and 86 % of them is between 7.8-11.2 mm length.

The following general expression can be used to describe the relationship among the average dimensions of the fruits at 72.90 % (w.b.) moisture content:

$$W = 1.113x, T = 0.862x, L = 0.992x, D_g = 8.920x, \emptyset = 28.035x \text{ M}$$

The significant coefficients of correlation (Table-2) show that the W/T, W/L, W/D_g, W/M and W/$\emptyset$ ratios were highly correlated. Similar results were found by Akbulut *et al.*[18] for barberry. This indicates that the length, mass, the geometric mean diameter and sphericity are closely related to the diameter of the fruit.
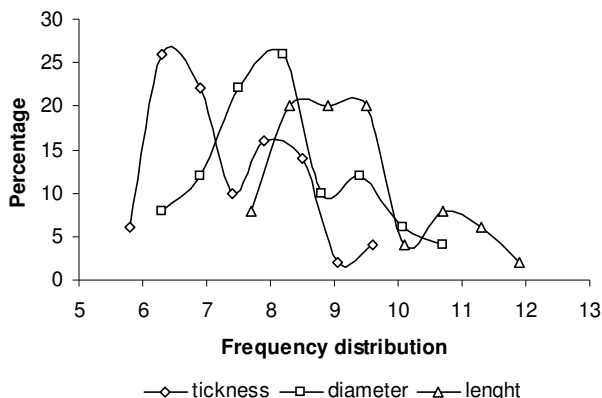
Fig. 3.   Frequency distribution curves of thickness, width and length measuring of *Mahonia aquifolium* fruits at the moisture content of 72.90 % wet basis
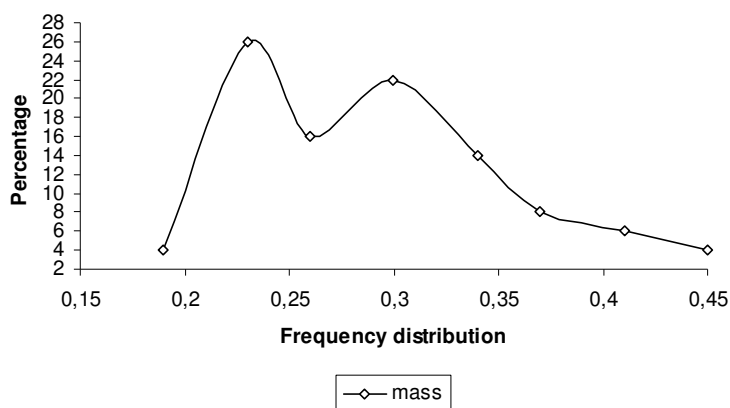

Fig. 4.   Frequency distribution curves of mass measuring of *Mahonia aquifolium* fruits at the moisture content of 72.90% w.b.

TABLE-2
CORRELATION COEFFICIENT OF *Mahonia aquifolium* FRUITS

Particulars	Ratio	Degrees of freedom	Correlation coefficient
W/T	1.113	98	0.736*
W/L	0.862	98	−0.298*
W/D$_g$	0.992	98	0.804*
W/Ø	8.920	98	0.813*
W/M	28.035	98	0.830*

*Significant at $p < 0.01$

The static and dynamic coefficients of friction for *Mahonia aquifolium* fruits examined with galvanized steel sheet and plywood sheet surfaces are given in Table-3. At the same moisture contents, both the static and dynamic coefficients of friction were greatest for *Mahonia aquifolium* fruits on plywood sheet.

TABLE-3
RELATIONSHIPS BETWEEN FRICTION COEFFICIENTS AND MOISTURE CONTENT
OF *Mahonia aquifolium* FRUITS FOR VARIOUS MATERIAL SURFACES

Properties	Galvanized steel sheet	Plywood sheet*
Dynamic	0.240 ± 0.028	0.352 ± 0.026
Static	0.277 ± 0.032	0.412 ± 0.030

* Mean ± standard error of the mean.

Chemical properties: The chemical properties of *Mahonia aquifolium* fruits are given in Table-4. The moisture, reducing sugar, total anthocyanin and phenolic compounds, crude protein, crude oil, crude cellulose, crude energy, ash, non-soluble HCl acid ash, pH, acidity, alcohol-soluble extract values, color and mineral contents were determined. The energy, reducing sugar, total phenolics, total anthocyanin, crude protein, crude cellulose, crude oil, ash, acidity, soluble solid matter and alchol-soluble extract values of *Mahonia aquifolium* fruits were found to be 47.85 kcal/ 100 g, 4.76 %, 4574.6 mg/kg, 655.64 mg/kg, 3.08 %, 1.78 %, 2.17 %, 1.10 %, 3.37 %, 17.6 % and 28.42 %, respectively. The crude protein content of barberry fruit is reported to be 10.32 %[18]. However, higher values were observed in this work than in the previous studies which may be due to several differences and also to method of sample preparation suggesting the significant impact of variety on the protein, oil, fiber, energy and moisture contents of wild fruits. But generally the protein contents are always higher than the fat contents. As shown in Table-5, *Mahonia aquifolium* fruits contained high amounts of K, P, Na, Ca, and Mg. These values were determined to be 6006.76, 1949.77, 1630.41, 1028.17 and 583.71 ppm, respectively. Akbulut *et al.*[23] established that Ca, K, Mg and P reported as major elements in European cranberrybush fruit samples.

TABLE-4
CHEMICAL PROPERTIES *Mahonia aquifolium* OF FRUITS

Properties	Values
Moisture (%)	72.90 ± 2.68
Soluble dry matter (%)	17.60 ± 1.03
Reducing sugar (%)	4.76 ± 0.230
Total phenolics (mg/kg)	4574.6 ± 225.7
Total Anthocyanin (mg/kg)	655.64 ± 68.53
Crude protein* (%)	3.08 ± 0.12
Crude oil (%)	2.17 ± 0.08
Crude cellulose (%)	1.78 ± 0.11
Crude energy (kcal/100g)	47.85 ± 2.74
Ash (%)	1.10 ± 0.04
Non-soluble HCl ash (%)	0.0014 ± 0.0001
pH	3.07 ± 0.00
Acidity (%)	3.37 ± 0.14
Alcohol-soluble extract (%)	28.42 ± 2.24
Color index	L: 26.46 ± 2.19
	a: –0.41 ± 0.03
	b: –4.70 ± 0.80

*Nx6.25

TABLE-5
THE MINERAL CONTENTS OF *Mahonia aquifolium* FRUITS (n = 3)

Minerals	ppm	Minerals	ppm
Ag	91.84 ± 13.26	K	6996.76 ± 786.32
Al	10.23 ± 2.76	Li	0.42 ± 0.18
As	6.05 ± 2.02	Mg	583.71 ± 67.29
B	17.65 ± 3.98	Mn	12.48 ± 2.04
Ba	0.97 ± 0.18	Na	1630.41 ± 120.92
Bi	1.24 ± 0.37	Ni	21.82 ± 5.35
Ca	1028.17 ± 256.98	P	1949.77 ± 128.86
Co	0.05 ± 0.02	Sr	3.67 ± 2.10
Cr	35.19 ± 2.53	V	0.32 ± 0.23
Cu	3.85 ± 1.09	Zn	9.26 ± 3.27
Fe	296.22 ± 24.72		

Some minerals like lithium and bromine contribute to biological process[24]. Lithium has some beneficial pharmacological properties. It has been used effectively in the treatment of manic depressive disorders. There is evidence to suggest that lithium is also an essential element[25]. However, knowledge of their mineral contents of fruit and vegetable materials is very important for human nutrition.

Total anthocyanin and total phenolics contents of *Mahonia aquifolium* fruits were established as 655.64-4574.6 mg/kg, respectively. These values of *Mahonia aquifolium* fruit were found higher than that of Kalyoncu *et al.*[26].

It is known that anthocyanin and phenolics are a good source of natural anti-oxidant, but they are quite unstable during the processing and storage. Temperature, pH, oxygen and water activity are considered to be important factors influencing its stability. During heating, degradation and polymerization usually lead to its discolouration[27,28].

Nomenclature

W	width of gilaboru (mm)	q	torque arm (cm) (10.5 cm)
D_g	geometric mean diameter (mm)	T_a	beginning value of the torque (Ncm)
L	length of gilaboru (mm)	T_m	average value of the torque (Ncm)
M	mass of gilaboru (g)	G	sample weight (10N)
m_c	moisture content, (%) d.b.	Ø	sphericity of gilaboru
ε	porosity of gilaboru (%)	μ_s	static coefficient of friction
T	thickness of gilaboru (mm)	μ_d	dynamic coefficient of friction
ρ_b	bulk density (kg/m^3)	L, a, b	color indicators
ρ_k	fruit density (kg/m^3)		

Conclusion

As a result, the chemical properties revealed nutritional values of *Mahonia aquifolium* fruits such as anthocyanin and phenolic compounds, reducing sugar, crude protein, crude fiber, crude oil, ash and mineral contents of *Mahonia aquifolium* fruits. At the same time, it has a high important to establish the physical properties

of equipment used harvesting, transportation, storage and processing of fresh fruits. However, further studies are required to understand the technological properties of equipment design and to provide necessary information for the use of wild edible fruits.

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