Asian Journal of Chemistry Vol. 20, No. 3 (2008), 2358-2366

Physical and Nutritional Properties of Oleaster (*Elaeagnus angustifolia* L.) Growing in Turkey

D. AKBOLAT*, C. ERTEKIN†, H.O. MENGES‡, E. GUZEL§ and K. EKINCI
Department of Agricultural Machinery, Faculty of Agriculture
Suleyman Demirel University, Cunur 32260, Isparta, Turkey
Fax: (90)(246)2111693; Tel: (90)(246)2114613; E-mail: dakbolat@ziraat.sdu.edu.tr

Several physical and nutritional properties of oleaster fruits (*Elaeagnus angustifolia* L.) grown in Turkey were investigated. These properties are necessary for the design of equipments for harvesting, processing and transportation, sorting, separating and packing. The average fruit length, width, thickness, the geometric mean diameter, sphericity index, fruit mass, thousand of fruit mass and volume of fruit of oleaster fruits were determined as 25.39 mm, 18.22 mm, 18.27 mm, 20.28 mm, 80.26 %, 2.09 g, 2101.4 g and 4.73 cm^3, respectively. The bulk density, fruit density and porosity were 277 kg m^{-3}, 462 kg m^{-3} and 35.03 %, respectively. While the static friction coefficient on galvanized iron sheet, iron sheet, thin plate, wood and rubber were 0.511, 0.438, 0.292, 0.511 and 0.729, the dynamic friction coefficient on the same surfaces were 0.438, 0.365, 0.219, 0.438 and 0.584, respectively. The moisture content, titrable acidity, ascorbic acid, skin firmness and terminal velocity were 16.91 %, 4.99 %, 4.65 mg 100 g fresh $weight^{-1}$, 6.65 N mm^{-2} and 8.26 m s^{-3}, respectively. Protein, K, Ca, P, Mg and N amount were 12.33, 1.10, 0.07, 0.06, 0.05 and 1.97 %, respectively.

Key Words: Oleaster (*Elaeagnus angustifolia* L.), Physical and Nutritional properties.

INTRODUCTION

Oleaster, Russian olive (*Elaeagnus angustifolia*) is a shrub or tree up to 7 m high. The fruit are elliptical or oblong, 10-30 × 6-20 mm i.d. and reddish-brown. One variety of *Elaeagnus* L., *angustifolia* L.var. *orientalis* (L.) cv. Kuntze, probably native to Turkey, is widely cultivated for its

†Department of Agricultural Machinery, Faculty of Agriculture, Akdeniz University, Antalya 07070, Turkey.
‡Department of Agricultural Machinery, Faculty of Agriculture, Selcuk University, Konya 42079, Turkey.
§Department of Agricultural Machinery, Faculty of Agriculture, Cukurova University, Balcali 01330, Adana, Turkey.

edible fruit in Middle and East Anatolia[1]. Oleaster is a native to Western and Central Asia, from Southern Russia and Kazakhistan to Turkey[2]. The leaves and flowers of this plant are well known for their use as diuretic and antipyretic drugs in folk medicine and the fruits are eaten during winter as appetizer in Turkey[3]. The fruit is edible and sweet, though with a dryish mealy texture[2]. Establishment and reproduction is primarily by seed, although some vegetative propagation also occurs. Oleaster is commonly found growing along flood plains, riverbanks, stream courses, marshes and irrigation ditches in the West at elevations from 1.4 to 1.8 kilometers. It is tolerant of considerable amounts of salinity or alkalinity and can survive considerable droughts[4]. *E. angustifolia* thrives under a wide range of soil textures from sand to heavy clay and can withstand prolonged flooding and silting. It grows best in deep sandy or loamy soils with only slight salt and alkali content. *E. angustifolia* requires a minimum of 20 cm of precipitation per year and has a high rate of evapotranspiration. *E. angustifolia* can withstand temperatures ranging from - 45 to 46 ºC. It has also been widely planted as an ornamental plant, for windbreaks and for erosion control[5].

The physical properties of any product are valuable for designing of equipments for handling, transportation, sorting, separating, packing and also processing it into different foods. Any system designed without taking these criteria into consideration results in inadequate applications, decreasing working efficiency and increasing product loss. Therefore, for the proper mechanization of oleaster, its physical properties are a pre-requisite for the design and development of any equipment[6].

In recent years, physical and nutritional properties have been studied for various crops such as okra seeds[7], lentil seeds[8], hackberry[9], sweet cherry[10], plum[11], fenugreek seeds[12], garlic[13], hawthorn[14], terebinth[15], locust bean seed[16], myrtle[17], aonla fruits[18], jujube fruit[19] and gumbo fruit[20].

However, no detailed studies have been published on physical and nutritional properties of oleaster. The aim of this work was to establish the proximate composition and some technological properties, namely, fruit dimensions, fruit density, bulk density, porosity, volume, projected area, spread area, terminal velocity, skin firmness, static and dynamic coefficient of friction.

EXPERIMENTAL

Oleaster fruits were supplied from a local market in May of 2006 from Isparta-Turkey. The fruits were transferred to the laboratory in polythene bags to prevent water loss during transport. All foreign matters and immature fruits were cleaned away. The initial moisture content of fruits was determined by using a standard method[21].

The physical and nutritional properties of oleaster were determined as follows: The linear dimensions of the fruits and stones were measured in three directions using a digital caliper gauge (± 0.01 mm). The major dimension was the length (L), the intermediate dimension was the width (W) and the minor dimension was the thickness (T). The caliper was held perpendicular to the direction of the dimension being measured. The linear dimensions were measured on 100 samples for fruits and 20 samples for stones.

The mass of fruits and stones was determined on 20 randomly selected samples by using an electronic balance with 0.01 g sensitivity, then also converted to a 1000 mass basis.

Geometric mean diameter (D_g), sphericity index (S_p) and aspect ratio (R_a) were calculated using the following equations[22-24]:

$$D_g = (LWT)^{1/3} \quad (1)$$

$$S_p = \frac{D_g}{L} 100 \quad (2)$$

$$R_a = W/L \quad (3)$$

To obtain the surface area (S) of the fruits and stones, the relationship given by Mohsenin[22], Oyelade *et al.*[25] and Sacilik *et al.*[26] was used:

$$S = \pi D_g^2 \quad (4)$$

The volume of fruit (V) and fruit density (P_k) defined as the ratio of the mass of a sample to the solid volume accordingly occupied was determined by the liquid displacement method. The amount of displaced toluene was recorded from the graduated scale of the measuring cylinder[22,27,28]. The bulk density (P_b) is the ratio of the mass of a sample of a fruit to its total volume and was determined with a weight per hectoliter tester, which was calibrated in kg m^{-3}. The hectoliter tester filled with fruits from a height of about 15 cm, striking the top level and then weighing the contents[22,29,30].

Porosity of bulk fruit (ε) is defined as the ratio of the intergranular space to the total space occupied by the fruit and can be calculated from fruit and bulk densities[22,31,32];

$$\varepsilon = 100\,[1-(P_b/P_k)] \quad (5)$$

Projected area of fruits was determined in x and y-axis using a digital camera (Kodak DC5000) and Sigma Scan Pro 5 program[33-35].

The angle of repose was measured by using a specially constructed box with a removable front panel. The box is filled with fruits and then the front panel is quickly removed. This allows the fruit to flow along its natural slope. This slope is taken as a measure of the angle of repose[12,31,36]. Spread area of fruits was determined by spreading 1 kg of fruits.

The skin colours of 20 oleaster fruits were determined with CR-300 chromometer (Minolta, Japan). The measurements were recorded using the L*a*b* colour scale[37].

The skin firmness of fruits was measured with a Test Instrument of Biological Materials using the procedure described by Aydin and Ogut[38] (Fig. 1). The device has three main components: a stationary and moving platform, a driving unit (AC electric motor and electronic variator) and a data acquisition (Dynamometer, amplifier and XY recorder) system. The skin firmless was measured by the data acquisition system. The fruit was placed on the moving bottom plateform and was pressed against 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[20] at a loading velocity of 50 mm/min.

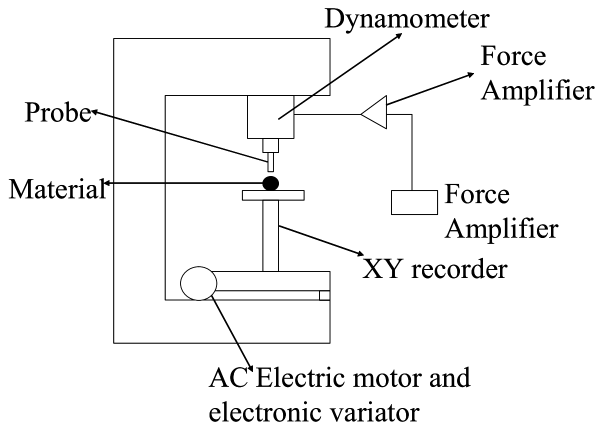

Fig. 1. Schematic diagram of biological material test unit

The terminal velocities (V_t) of fruits and their stones were measured using an air column. For each test, a sample was dropped into an air stream from the top of the air column, up which air was blown to suspend the material (Fig. 2). The air velocity near the location of the suspended fruits was measured[14,15,36,39,40] by electronic anemometer with at least count of 0.1 m s^{-1}.

The coefficients of frictions of fruits were measured using a friction device. It has three main components: a stationary sample container with its support shaft, a driving unit with rotating disc and the data acquisition system. The samples were placed on the rotating surface and the torque necessary to restrain the sample was measured by the data acquisition system. This torque was used to determine the static (μ_s) and dynamic (μ_d) coefficients of friction using the following equation;

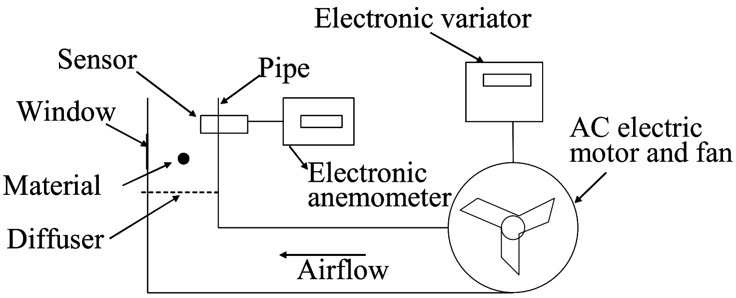

Fig. 2. Schematic diagram of terminal velocity measuring unit

$$\mu = T_m/(w\ q) \quad (6)$$

where μ is the coefficient of friction, T_m is the measured torque, q is the length of the torque arm and w is the sample weight on the rotating surface. The maximum value of torque obtained as the disc started to rotate was used to calculate the static coefficient of friction and average value of the torque during the rotation of disc was used to calculate the dynamic coefficient of friction[28,41-43].

The samples were dried at 65 ºC and then wet digested in HNO_3 and $HClO_4$ acid (4/1, v/v) mixture[44]. Fe, Ca, Mg, K, Mn, Zn and Cu concentration were determined by atomic absorption spectrophotometry. Phosphorus was determined according to vanadomolybdate yellow colour method with spectrophotometer[45].

To determine protein content in oleaster fruit, first N concentrations of fruit were determined according to a Kjeldahl method[46]. Then N concentration was multiplied by 6.25 factor to calculate protein content[47].

RESULTS AND DISCUSSION

Some of the physical properties of oleaster are presented in Table-1. The moisture content changed between 16.44 and 17.55 % (w.b.) for oleaster fruit. While mean fruit length was 25.39 mm, fruit width was 18.22 mm and thickness was 18.27 mm for oleaster fruit. The stone dimensions (length, width and thickness) were 19.77, 5.91 and 5.80 mm, respectively. While the mean masses of fruit and 1000 fruits mass were 2.09 g and 2101.4 g, these values were 0.38 g and 384.11 g for its stones, respectively. The average values of the geometric mean diameter were calculated as 20.28 mm for fruits and 8.73 mm for stones, respectively. Sphericity index is an expression of a shape of a solid relative to that of a sphere of the same volume, while the aspect ratio relates the width to the length of the fruit, an indicative of its tendency toward being oblong in shape[23]. These values were 80.26 % and 0.72 for fruits and 44.22 % and 0.30 for stones, respectively.

TABLE-1
SOME PHYSICAL PROPERTIES OF OLEASTER

Fruit	Min	Max	Mean	SD
Moisture content (%w.b.)	16.44	17.55	16.91	0.43
Length (mm)	17.80	33.65	25.39	2.94
Width (mm)	12.25	22.00	18.22	1.83
Thickness (mm)	13.75	21.70	18.27	1.76
Geometric mean diameter (mm)	15.39	24.31	20.28	1.82
Sphericity index (%)	64.16	94.09	80.26	5.27
Aspect ratio-Ra	0.43	0.91	0.72	0.08
Surface area (mm^2)	743.93	1855.45	1301.25	228.41
Mean mass of fruit (g)	0.96	3.80	2.09	0.75
1000 fruit mass (g)	1962.8	2289.6	2101.4	98.3
Fruit density (kg m^{-3})	366	619	462	73
Bulk density (kg m^{-3})	264	296	277	9.00
Volume of fruit (cm^3)	1.80	8.50	4.73	1.98
Porosity (%)	23.48	46.45	35.03	7.74
Angle of repose (º)	14.73	22.68	17.46	2.38
Spread area (m^2 kg^{-1})	0.217	0.228	0.223	0.004
Terminal velocity (m s^{-1})	7.25	9.66	8.26	0.60
Projected area (mm^2)				
x-axis	205.96	264.09	273.47	33.57
y-axis	285.86	525.01	373.74	47.59
Skin colour				
L*	31.46	63.32	40.50	5.24
a*	8.38	27.65	22.91	2.64
b*	14.61	38.02	25.70	5.66
Skin firmness (N mm^{-2})	3.66	9.72	6.65	1.59
Static/Dynamic coefficient of friction				
Galvanized iron sheet	0.496/0.433	0.525/0.442	0.511/0.438	0.015/0.004
Iron sheet	0.423/0.364	0.452/0.366	0.438/0.365	0.015/0.001
Thin plate	0.284/0.217	0.300/0.221	0.292/0.219	0.008/0.002
Rubber	0.722/0.575	0.737/0.592	0.729/0.584	0.007/0.009
Wood	0.496/0.433	0.525/0.442	0.511/0.438	0.015/0.004
Stone				
Length (mm)	12.25	24.6	19.77	2.42
Width (mm)	3.45	10.3	5.91	1.15
Thickness (mm)	3.70	10.95	5.80	1.24
Geometric mean diameter (mm)	5.86	13.97	8.73	1.29
Sphericity index (%)	32.88	57.36	44.22	4.87
Aspect ratio	0.19	0.51	0.30	0.05
Surface area (mm^2)	107.92	612.54	244.14	75.00
Mean mass of stone (g)	0.13	0.62	0.38	0.089
1000 stone mass (g)	353.60	404.40	384.11	17.07
Terminal velocity (m.s^{-1})	6.87	7.34	7.09	0.14
Static/Dynamic coefficient of friction				
Galvanized iron sheet	0.803/0.526	0.831/0.564	0.817/0.545	0.016/0.022
Iron sheet	0.825/0.549	0.843/0.563	0.834/0.556	0.011/0.008
Thin plate	0.539/0.258	0.546/0.285	0.543/0.271	0.004/0.016
Rubber	0.812/0.545	0.829/0.549	0.820/0.547	0.010/0.003
Wood	0.813/0.542	0.847/0.564	0.830/0.553	0.019/0.013

The volume of fruit was 4.73 cm^3. While fruit densities were between 366 and 619 kg m^{-3}, bulk densities were between 264 and 296 kg m^{-3}, respectively. The porosity ranged from 23.48 to 46.45 % for oleaster fruits.

The angle of repose changed between 14.73 and 22.68 degrees for oleaster fruits. The spread area was between 0.217 and 0.228 m^2 kg^{-1}.

The skin firmness changed between 3.66 and 9.72 N mm^{-2}. While terminal velocity values ranged from 7.25 and 9.66 m s^{-1} for oleaster fruits, it was changed between 6.87 and 7.34 m s^{-1} for its stones, respectively.

While the brightness was L* 40.50, the redness a* 22.91 and the blueness was b* 25.70 for oleaster fruits.

The static friction coefficients ranged from 0.292 for thin plate and 0.729 for rubber for oleaster fruit and ranged from 0.543 for thin plate and 0.834 for iron sheet for oleaster stone. The dynamic coefficient of friction changed between 0.219 for thin plate and 0.584 for rubber for fruit and between 0.271 for thin plate and 0.556 for iron sheet for stone. Static and dynamic friction coefficients of fruit reached their maximum values on rubber surface in different studies[26,48-51].

Titrable acidity varied from 4.94 to 5.09 % for oleaster fruits. Ascorbic acid content ranged between 4.07 and 5.23 mg 100 g^{-1} fresh weight. This value is lower than those reported for cornelian cherry[51] and different orange varieties[52].

Some nutritional properties of oleaster fruits are given in Table-2. Protein content was found as approximately 12.33 %, which is about the same with some walnut genotypes[53] and lower than barbunia bean[54], chickpea or beans[47] and white speckled red kidney bean[32].

TABLE-2
SOME NUTRITIONAL PROPERTIES OF OLEASTER

	Min	Max	Mean	SD
K (%)	0.90	1.30	1.10	0.187
Mg (%)	0.04	0.06	0.05	0.008
Ca (%)	0.05	0.08	0.07	0.014
N (%)	1.88	2.04	1.97	0.076
P (%)	0.05	0.07	0.06	0.008
Fe (ppm)	113.05	125.50	118.37	4.865
Mn (ppm)	47.10	53.50	49.76	2.701
Zn (ppm)	2.10	2.70	2.32	0.228
Cu (ppm)	24.60	29.50	26.58	1.997
Protein (%)	11.75	12.75	12.33	0.475
Ash	1.00	1.00	1.00	0.000
Titrable acidity (%)	4.94	5.09	4.99	0.080
Ascorbic acid content (mg 100 g^{-1} fresh weight)	4.07	5.23	4.65	0.580

Conclusion

Moisture content was between 16.44 and 17.55 % for oleaster fruit. The average fruit length, fruit width, fruit thickness and geometric diameter were 25.39, 18.22, 18.27 and 20.28 mm for fruit and 19.77, 5.91, 5.80 and 8.73 mm for its stones, respectively. The average mass, 1000 fruit mass and volume of fruits were 2.09 g, 2101.4 g and 4.73 cm^3.

The fruit density, bulk density, porosity, angle of repose and spread area were 462 kg m^{-3}, 277 kg m^{-3}, 35.03 %, 17.46º and 0.223 m^2 kg^{-1} for oleaster, respectively.

The sphericity index and aspect ratio were 80.26 % and 0.72 for oleaster fruits and 44.22 % and 0.30 for its stones, respectively.

The skin firmness 6.65 N mm^{-2} and terminal velocity 8.26 m s^{-1}.

The static and dynamic friction coefficient was highest for rubber and followed by wood and galvanized iron sheet then iron sheet and thin plate for oleaster fruits.

ACKNOWLEDGEMENTS

The authors are grateful to the Scientific Research Project Units of Akdeniz University and Suleyman Demirel University. The authors also thank to Dr Mehmet Ali Koyuncu for insightful contributions.

REFERENCES

1. D.R. McKean, in ed.: P.H. Davis, Flora of Turkey and the East Aegean Islands, Edinburg University Press, Edinburg, Vol. 7, pp. 533-534 (1982).
2. Anonymous, http://www.wikipedia.org (2007a).
3. F.A. Ayaz and E. Bertoft, *J. Food Compos. Anal.*, **14**, 505 (2001).
4. Anonymous, http://www.extension.usu.edu/rangeplants/Woody/russianolive.htm (2007b).
5. M. Tu, Element Stewardship Abstract for *Elaeagnus angustifolia* L. - Russian Olive, Oleaster. Available:http://tncweeds.ucdavis.edu/esadocs/documnts/elaeang.pdf, Prepared for The Nature Conservancy, Arlington, VA 10 pp. (October 2004) (2003).
6. E. Guzel, P. Ulger and B. Kayisoglu, Urun Isleme ve Degerlendirme Teknigi [Food Processing Technology of Agricultural Materials]. Cukurova Universitesi Ziraat Fakultesi Genel Yayin No:145, Adana, Turkey (1999).
7. S. Calisir, M. Ozcan, H. Haciseferogullari and M.U. Yildiz, *J. Food Eng.*, **68**, 73 (2005).
8. M.N. Amin, M.A. Hossain and K.C. Roy, *J. Food Eng.*, **65**, 83 (2004).
9. F. Demir, H. Dogan, M. Ozcan and H. Haciseferogullari, *J. Food Eng.*, **54**, 241 (2002).
10. K. Vursavus, H. Kelebek and S. Selli, *J. Food Eng.*, **74**, 568 (2006).
11. C. Ertekin, S. Gozlekci, O. Kabas, S. Sonmez and I. Akinci, *J. Food Eng.*, **75**, 508 (2006).
12. E. Altuntas, E. Ozgoz and O.F. Taser, *J. Food Eng.*, **71**, 37 (2005).
13. H. Haciseferogullari, M. Ozcan, F. Demir and S. Calisir, *J. Food Eng.*, **68**, 463 (2005).
14. M. Ozcan, H. Haciseferogullari, T. Marakoglu and D. Arslan, *J. Food Eng.*, **69**, 409 (2005).
15. C. Aydin and M. Ozcan, *J. Food Eng.*, **53**, 97 (2002).
16. L.A.O. Ogunjimi, N.A. Aviara and O.A. Aregbesola, *J. Food Eng.*, **55**, 95 (2002).

17. C. Aydin and M.M. Ozcan, *J. Food Eng.*, **79**, 453 (2007).
18. R.K. Goyal, A.R.P. Kingsly, P. Kumar and H. Walia, *J. Food Eng.*, **82**, 595 (2007).
19. D. Akbolat, C. Ertekin, H.O. Menges, K. Ekinci and I. Erdal, *Asian J. Chem.*, **20**, 757 (2008).
20. R. Akar and C. Aydin, *J. Food Eng.*, **66**, 387 (2005).
21. USDA, Official Grain Standards of the United States, US Department of Agricultural Consumer and Marketing Service Grain Division (1970).
22. N.N. Mohsenin, Physical Properties of Plant and Animal Materials, Gordon and Breach Science Publisher, New York (1970).
23. O.T. Omobuwajo, A.E. Akande and A.L. Sanni, *J. Food Eng.*, **40**, 241 (1999).
24. S.M.A. Razavi, B. Emadzadeh, A. Rafe and A.M. Amini, *J. Food Prop.*, **81**, 209 (2007).
25. O.J. Oyelade, P.O. Odugbenro, A.O. Abioye and N.L. Raji, *J. Food Eng.*, **67**, 435 (2005).
26. K. Sacilik, R. Ozturk and R. Keskin, *Biosys. Eng.*, **86**, 191 (2003).
27. K.K. Singh and T.K. Goswami, *J. Agric. Eng. Res.*, **64**, 93 (1996).
28. M. Paksoy and C. Aydin, *J. Food Eng.*, **65**, 225 (2004).
29. S.D. Deshpande, S. Bal and T.P. Ojha, *J. Agric. Eng. Res.*, **56**, 89 (1993).
30. M. Konak, K. Carman and C. Aydin, *Biosys. Eng.*, **82**, 73 (2002).
31. S.S. Sablani and H.S. Ramaswamy, in eds.: A. Chakraverty, A.S. Mujumdar, G.S.V. Raghavan and H.S. Ramaswamy, Physical and Thermal Properties of Cereal Grains, Handbook of Postharvest Technology: Cereals, Fruits, Vegetables, Tea and Spices (2003).
32. E. Isik and H. Unal, *J. Food Eng.*, **82**, 209 (2007).
33. T.P. Trooien and D.F. Heermann, *Trans. ASAE*, **35**, 1709 (1992).
34. M. Ayata, M. Yalcin and V. Kirisci, Evaluation of Soil-Tine Interaction by using Image Processing System, National Symposium on Mechanization in Agriculture, Tokat, Turkey, pp. 267-274 (1997).
35. O. Kabas, A. Ozmerzi and I. Akinci, *J. Food Eng.*, **73**, 198 (2006).
36. D.C. Joshi, S.K. Das and R.K. Mukherjee, *J. Agric. Eng.*, **22**, 127 (1993).
37. Y. Coskuner, R. Ercan, E. Karababa and A.N. Nazlican, *J. Sci. Food Agric.*, **82**, 625 (2002).
38. C. Aydin and H. Ogut, *J. Agric. Fac., Selcuk Univ.*, **1**, 45 (1991) (in Turkish).
39. H. Haciseferogullari, M. Ozcan, M.H. Sonmete and O. Ozbek, *J. Food Eng.*, **69**, 1 (2005).
40. P.M. Nimkar and P.K. Chattopadhyay, *J. Agric. Eng. Res.*, **80**, 183 (2001).
41. C. Aydin, *J. Food Eng.*, **60**, 315 (2003).
42. E.A. Baryeh, *J. Food Eng.*, **47**, 321 (2001).
43. J.H. Chung and L.R. Verma, *Transactions of the ASAE*, **32**, 745 (1989).
44. B. Kacar, Chemical Analysis of Plant and Soil. II Plant analysis, Ankara University Agriculture Faculty. 453. Application Quide 155 (1972).
45. M.L. Jackson, Soil chemical analysis. Prentice Hall, Englewood Clifs, New Jersey (1967).
46. J.M. Bremner, Methods of Soil Analysis, American Society of Agronomy Inc, Medison, USA (1965).
47. Y. Amir, A.L. Haenni and A. Youyou, *J. Food Compos. Anal.*, **20**, 466 (2007).
48. C. Aydin, *Biosys. Eng.*, **82**, 297 (2002).
49. H. Haciseferogullari, I. Gezer, M. Ozcan and B.M. Asma, *J. Food Eng.*, **79**, 364 (2007).
50. M. Ozcan, H. Haciseferogullari and F. Demir, *J. Food Eng.*, **65**, 151 (2004).
51. F. Demir and H.I. Kalyoncu, *J. Food Eng.*, **60**, 335 (2003).
52. A. Topuz, M. Topakci, M. Canakci, I. Akinci and F. Ozdemir, *J. Food Eng.*, **66**, 519 (2005).
53. N. Caglairmak, *Nahrung-Food*, **47**, 28 (2003).
54. M. Cetin, *J. Food Eng.*, **80**, 353 (2007).

(*Received*: 12 July 2007; *Accepted*: 10 December 2007) AJC-6114