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Full Length Research Paper

Some chemical and physical properties at physiological maturity and ripening period of kiwifruit ('Hayward')

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This study was carried out to determine some chemical and physical properties at physiological maturity and ripening period of kiwifruit. The average geometric mean diameter, sphericity, bulk density, porosity, projected area along three axes (X, Y, Z) and colour characteristics (*L*, a*, b) were measured at physiological maturity and ripening period. Total soluble solid content, titratable acidity, pH, total phenolic, total antioxidant activity and total sugar of kiwifruit were also determined. The total antioxidant value was higher at physiological maturity than ripening period.**

Key words: Kiwifruit (Hayward), chemical properties, physical properties, physiological maturity, ripening period.

INTRODUCTION

Kiwifruit (*Actinidia deliciosa*) is rich in many vitamins (especially, vitamin C), flavonoids and minerals. Kiwifruit is native to South Asia. There are more than 60 species in *Actinidias* and many have commercial potential. Kiwifruit is commercially cropped in many countries such as Italy, New Zealand, Chile, France, China, Iran and Greece (Ferguson, 1999). Turkey produced about 10315 Mt of kiwifruit from 14 000 ha in 2007 (Food and Agricul-ture Organization, 2007).

The cultivar 'Hayward' of *A. deliciosa* occupies the majority of the world kiwifruit cultivated surface. This cultivar eventually became the cultivar of choice because its fruit were larger, had a better appearance, high vitamin C content, long storage life and its excellent flavour was considered by many to be superior (Ferguson, 1999). Most fleshy fruits attain physiogical maturity at an unripe state unsuitable for immediate consumption. The ripen-ing process that follows, either on the tree or after picking, is the result of the number of physiological and biochemical process which are revealed in a squence of changes in color, texture, aroma and taste, leading eventually to a physiological state at whickh the fruit is commercially considered as edible (Teixeira and Ferreira, 1993). Kiwifruits are classified as climacteric fruit, since they ripen in response to exo-genous ethylene and their ripening is characterized by a period of autocatalytic ethylene production (Whittaker et al., 1997). The characteristic of commercial harvest maturity of kiwifruit is determined on the basis of total solids or TSSC (Hasey et al, 1994). Several pre-harvest factors, during harvest and post-harvest factors affect storage life of kiwifruits. The main pre-harvest factors are the stage of maturity, climatic, soil and cultivation condi-tions, water relations, position of fruiting shoots and pre-harvest spray with Ca^{2+} (Boukouvalas and Chouliaras, 2005).

To design and improve of relevant machines and facilities used in plantation, harvesting, separating, conveying, storing, handling, processing, packaging systems and estimating the cooling and heating loads of kiwifruit, there is a need to know the various chemical and physical properties. The physical properties of kiwifruits are to be known for design and improve of relevant machines and facilities for harvesting, storing,

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handling and processing. The size and shape of kiwifruits are important in designing of harvesting, separating, sizing, storage and packaged machines; bulk density and porosity affect designing of storage and transporting structures. The coefficient of friction of the kiwifruit against the various surfaces is also necessary in designing of conveying, transporting and storing structures. The maturity level, colors, sugar, solids, size and firmness are some of the importance factors considered for kiwi-fruit marketing.

Several researchers have investigated the chemical and physical, properties of kiwifruit (Sanz et al., 2004; Razavi and Parvar, 2007; Nishiyama et al., 2008; Celik et al., 2007). No detailed study concerning chemical and physical properties at physiological maturity and ripening period of kiwifruit were studied comparatively. Thus, the objective of this study was to examine the chemical properties (total soluble solid content, titratable acidity, pH, total phenolic, total antioxidant activity and total sugar) and physical properties (geometric mean diameter, sphericity, bulk density, porosity, projected area, colour characteristics, etc.) at physiological maturity and ripening period.

MATERIALS AND METHODS

The kiwifruit samples ('Hayward') were harvested manually from Ordu city in Black Sea region at the harvest season in 15 November 2008. Harvested fruits were transferred to the laboratory in polyhthene bags to reduce water loss during transport. This study was carried out at physiological maturity and ripening period of kiwifruit. Fruits were treated with 0.5% acetylene in sealed polyethylene bags for 24 h and allowed to ripen at the same temperature (Bal and Kok, 1994).

The chemical composition such as pH of kiwifruit was determined according to the methods presented by the Association of Official Analytical Chemists (1984). The total soluble solid content (TSSC) was determined by a digital refractometer (Kyoto Company, Kyoto, Japan). Titratable acidity (TA) was measured by titration with 0.1 N NaOH. Total phenolic (TP) content was measured by Singleton and Rossi (1965) procedure. Gallic acid was used as a standard. The results were expressed as mg gallic acid equivalent in kg fresh weight basis (GAE/kg fw). The total antioxidant activity (TAA) was estimated by two standard procedures FRAP (ferric reducing ability of plasma) and TEAC(Trolox-Equivalent Antioxidant Capacity) assays as suggested by Ozgen et al. (2006). FRAP was determined according to the method of Benzie and Strain (1996). The individual sugars of kiwifruit ('Hayward') fruits pulp (5 g) were diluted with purified water and homogenizated for extraction. The homogenate was centrifuged at 6000 rpm for 5 min. Supernatants were filtered through a 0.45 µm membrane filter before HPLC analysis and the mobile phase solvents were degassed before using. All the samples and standards were injected three times, and mean values were used. Analysis of sugars was performed according to the method described by Bartolome et al. (1995).

One hundred (100) fruits were randomly selected to determine the kiwifruit size. The length, width and thickness were measured using a dial-micrometer to an accuracy of 0.01 mm. The fruit mass of kiwifruit was measured using a digital electronic balance with a resolution of 0.01 g. The geometric mean diameter (D_g), sphericity (Φ), volume, true (fruit) and bulk densities of a fruit of kiwifruit were determined according to Mohsenin (1970) and Fathollahzadeh and Rajabipour(2008). The projected area was measured by a digital planimeter (Placom Roller-Type, KP90N). The measurements along X- and Y-axes were determined according to the method of Razavi and Parvar (2007). The coefficient of friction (μ) is defined as tangent value of the angle of α (slope) between sliding surface and vertical and horizontal planes (Celik et al., 2007). The experiment was conducted using friction surfaces of plywood, chipboard and galvanized metal.

The colour of kiwifruits in terms of *L*, a*, b** values were determined using a Minolta colourimeter (CR-3000 Model). *L** denotes the lightness or darkness; *a** is green or red; *b** is blue or yellow colour of the samples. The colour was measured at three points of each sample. Measurements were conducted on skin, flesh, core and two sides of cut surface along longitudinal axis (Jha et al., 2005). The colour measurements of kiwifruit samples were computed as the means of three replication values. To firmness measurement, a biological material test device (Zwick/Roell, Instruction Manual for Materials Testing Machines/BDO-FB 0.5 TS) was used. For skin and flesh firmness measurements, the apparatus was directly inserted into the external surface (Celik et al., 2007). The firmness of kiwifruits was measured using a 7.9 mm diameter stainless steel probe. The skin firmness was measured at 20 mm min^{-1} test speeds and 22.5 mm puncture depth. To determine the flesh firmness, operating conditions were, 10 mm min^{-1} and 8 mm puncture depth (Razavi and Parvar, 2007). Kiwifruit samples were penetrated along X- and Y- axes to determine the skin and flesh firmnesses.

RESULTS AND DISCUSSION

TSSC and pH of kiwifruit changed from 7.43 to 14.67% and 3.16 to 3.27 at physiological maturity and ripening period, respectively. TSSC and pH of kiwifruit increase of 97.44 and 3.48%, was observed from physiological maturity to ripening period, respectively (Table 1). Celik et al. (2007) reported that, TSSC, pH and TA was found as 7.32, 3.41, and 1.64%, respectively for kiwifruit ('Hayward') at physiological maturity

The glucose and fructose in the 'Hayward' kiwifruit consist of the main soluble sugar amounts, but sucrose is smaller than the other sugars (Sanz et al., 2004; Nishiyama et al., 2008). Total sugar content, fructose, glucose and sucrose contents of kiwifruit changed from 5.98 to 9.79 g/100 g; 2.23 to 3.04 g/100 g; 2.67 to 4.79 g/100 g; 1.08 to 1.96 g/100 g, at physiological maturity and ripening period, respectively (Table 1). The soluble sugar, glu-cose, fructose and sucrose of kiwifruit observed in our study closely match those reported in the literature (Sanz et al., 2004; Nishiyama et al., 2008).

The titratable acidity of kiwifruit ranged from 1.84 to 1.73 g/100 g at physiological maturity and ripening period, respectively. These results are essentially consis-tent with the results of previous studies (Marsh et al., 2004; Nishiyama et al., 2008). The total phenolic of kiwifruit ranged from 1398.6 to 1933.7 mg GAE/g fw at physiological maturity and ripening period, respectively (Table 1). In Dawes and Kene (1999) study, phenolic compounds in clarified 'Hayward' kiwifruit juice were found at levels of <1-7 mg/l. Park et al. (2006) found that total polyphenols content and antioxidant activity were significantly higher in kiwifruits treated with ethylene than in untreated samples.

The total antioxidant activity (TAA) of kiwifruit ranged

Table 1. Some chemical properties at physiological maturity and ripening period of kiwifruit cv. 'Hayward'.

Chemical property	Physiological maturity		Ripening period	
	Mean	**Standard deviation**	**Mean**	**Standard deviation**
pH	3.16	0.006	3.27	0.06
TSSC (%)	7.43	0.32	14.67	0.06
TA (%)	1.84	0.01	1.73	0.001
TP (mg GAE/g fw)	1398.6	264.4	1933.7	201.2
Total antioxidant activity				
TEAC (mmol TE/g fw)	4.627	0.046	4.444	0.066
FRAP (mmol TE/g fw	7.813	0.863	5.124	0.337
Sugars (g/100 g)				
Fructose	2.229	0.0309	3.037	0.019
Glucose	2.669	0.0577	4.786	0.020
Sucrose	1.078	0.070	1.963	0.029
Total	5.976	0.158	9.786	0.068

TSSC, Total soluble solid content; TA, titratable acidity; TP, total phenolic; TEAC, trolox-equivalent antioxidant capacity; FRAP, ferric reducing ability of plasma)

from 4.63 to 4.44 mmol TE/g fw as TEAC and 7.81 to 5.12 mmol TE/g fw as FRAP procedures at physiological maturity and ripening period, respectively. The lowest total antioxidant values were obtained at ripening period (Table 1). Park et al. (2006) reported that the antioxidant activity of 'Hayward' kiwifruit increased significantly in treated fruit, whereas it did not in the untreated fruits and the acidity and pH were not influenced by ethylene treatment.

The average length, width, thickness, geometric mean diameter and unit mass of kiwifruits ranged between 64.1 to 63.2 mm, 52.0 to 51.5 mm, 46.8 to 46.3 mm, 53.6 to 53.0 mm and 91.4 to 89.2 g at physiological maturity and ripening period, respectively. About 86.7% of the kiwifruits at physiological maturity have a length ranging from 60.9 to 66.6 mm; about 86.7% width ranging from 50.1 to 53.9 mm; about 78.3% thickness ranging from 44.75 to 48.75 mm and about 80% fruit mass ranging from 86.7 to 98.1 g, respectively (Figure 1). About 80% have length ranging from 61.1 to 64.9 mm; about 86.7% width ranging from 49.8 to 53.2 mm, about 80% thickness ranging from 43.7 to 48.3 mm and about 70% unit mass ranging from 84.7 to 93.3 g at ripening period of kiwifruit, respectively (Figure 2). A comparison between length and the rest of the physical properties, width, thickness, geometric mean diameter, sphericity, surface area and volume of kiwifruit at physiological maturity and ripening period has been established. The correlation coefficients between L/T have not been found to be statistically significant. The other relations have been found to be statistically signifi-cant (Table 2).

The average sphericity, surface area, bulk and fruit densities and porosity ranged from 83.6 to 83.9%; 90.2 to 88.2 mm^2; 374.5 to 397.7 kg/m^3; 1014.6 to 1047.8 kg/m^3 and 63.2 to 61.1% for kiwifruits at physiological maturity and ripening period, respectively (Table 3). The surface area and porosity of kiwifruits decreases of 2.22 and 3.32% occurred at ripening period, respectively. The bulk and fruit densities of kiwifruits increases of 6.19 and 3.27% occurred at ripening period, respectively (Table 3). Celik et al. (2007) reported that the average geom-etric mean diameter, sphericity, surface area, bulk and fruit densities and porosity of 'Hayward' kiwifruit were 49.03 mm, 83.0%, 7.55 mm^2, 575.0 kg/m^3, 1.093 kg/m^3 and 47.13%, respectively. Razavi and Parvar (2007) reported that the average geometric mean diameter, sphericity, surface area, bulk and fruit densities and porosity of 'Hayward' kiwifruit were 54.1 mm, 79.8%, 91.97 cm^2, 563.2 kg/m^3, 996 kg/m^3 and 43.4%, respectively. The experimental results for projected area along X-, Y- and Z- axes of kiwifruit at physiological maturity obtained were 9.66, 13.10 and 12.01 cm^2, respectively (Table 3). The projected area along X-, Y- and Z- axes of the kiwifruit has been reported as 4.11, 3.24 and 3.93 mm^2, respectively (Celik et al., 2007).

The static coefficients of friction of kiwifruits at physiological maturity and ripening period of kiwifruit were greater at rubber than at the other friction sur-faces. The static coefficients of friction linearly increased at ripening period of kiwifruit for all friction surfaces (Table 3). This is a result of the increasing adhesion between the product and the surface of softened fruit at higher maturity according to physiological maturity (Razavi and Parvar, 2007). Celik et al. (2007) reported that the static coefficient of friction were 0.158, 0.163,

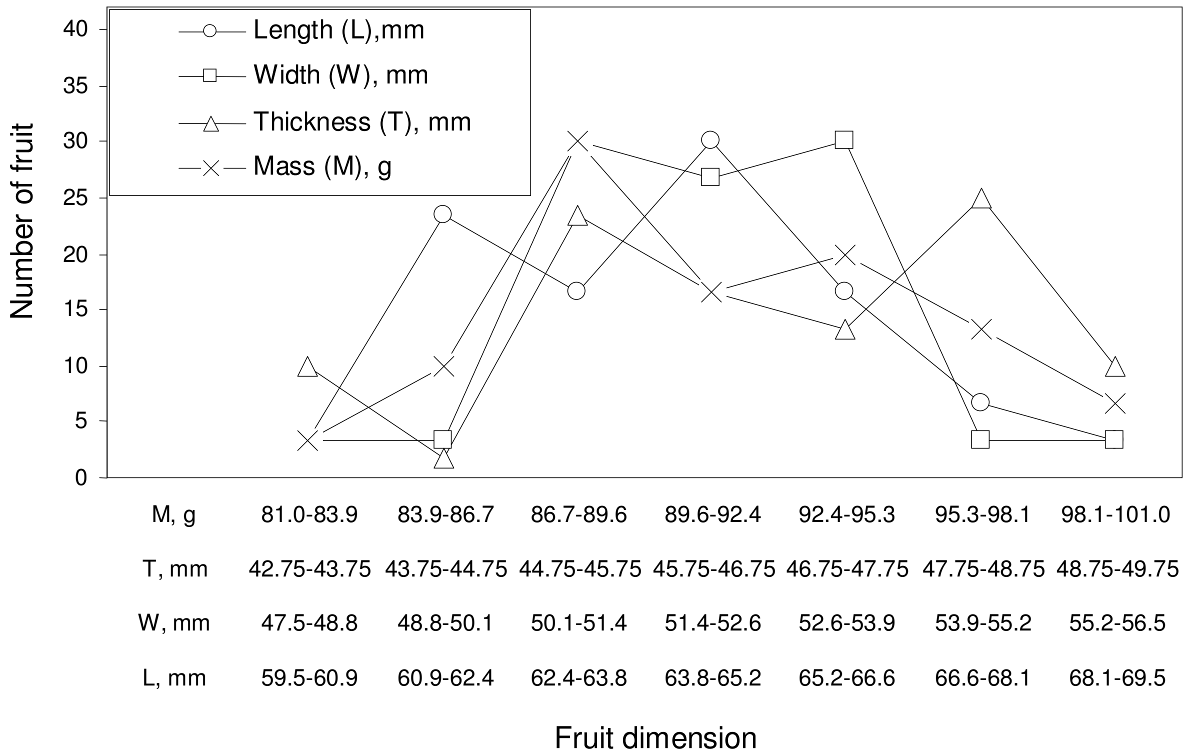

Figure 1. Frequency distribution curves of kiwifruit length, width, thickness and fruit mass at physiological maturity of kiwifruit cv. 'Hayward'.

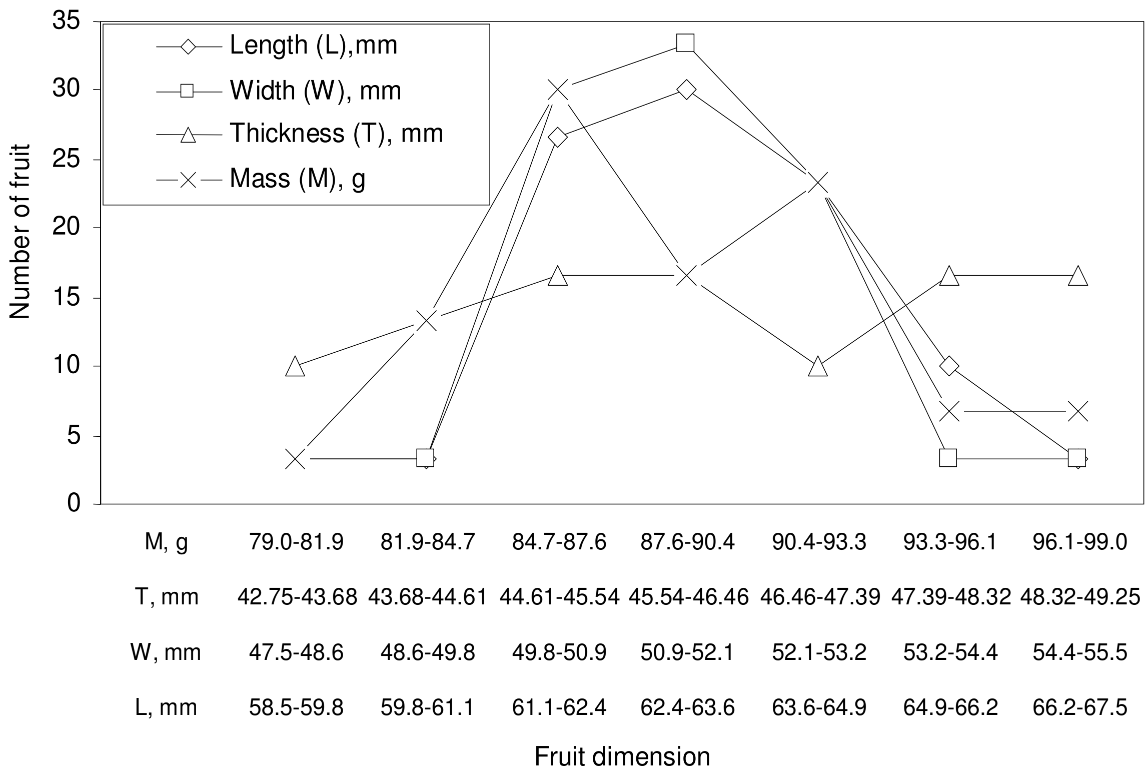

Figure 2. Frequency distribution curves of kiwifruit length, width, thickness and fruit mass at ripening period of kiwifruit cv. 'Hayward'.

Table 2. The correlation coefficients of kiwifruit cv. 'Hayward' at physiological maturity and ripening period.

Kiwifruit	Particular	Ratio	Degree of freedom	Correlation coefficient (R)
Physiological maturity	*L/W*	1.235	98	-0.270**[a]
	L/T	1.371	98	-0.090[ns c]
	L/M	0.702	98	0.298**
	L/Dg	1.197	98	0.371**
	L/S	0.767	98	-0.833**
	L/Φ	0.711	98	0.370**
	L/V	0.786	98	0.369**
Ripening period	*L/W*	1.228	98	-0.368**
	L/T	1.363	98	-0.045[ns]
	L/M	0.708	98	0.251*[b]
	L/Dg	1.192	98	0.297**
	L/S	0.753	98	-0.808**
	L/Φ	0.716	98	0.297**
	L/V	0.801	98	0.296**

[a] **Significant at 1% level; [b] *significant at 5% level; [c] [Ns]non significant. L, Length; W, width; T, thickness; M, mass; Dg, geometric mean diameter; S, surface area; Φ, sphericity; V, volume.

Table 3. Some physical properties at physiological maturity and ripening period of kiwifruit cv. 'Hayward'.

Physical property	Physiological maturity		Ripening period	
	Mean	Standard deviation	Mean	Standard deviation
Length, L (mm)	64.14	2.04	63.16	1.75
Width, W (mm)	51.95	1.60	51.45	1.48
Thickness, T (mm)	46.79	1.73	46.34	1.74
Geometric mean diameter, D_g (mm)	53.59	0.96	52.98	0.91
Sphericity, Φ (%)	83.60	2.51	83.90	2.35
Fruit mass, M (g)	91.38	4.45	89.24	4.30
Bulk density, ρ_b (kg/m^3)	374.46	9.29	397.71	24.77
Fruit density, ρ_t (kg/m^3)	1014.6	35.74	1047.77	20.66
Porosity, ε (%)	63.20	1.60	61.11	2.00
Surface area, S (cm^2)	90.24	3.40	88.19	3.03
Biological test device				
Skin firmness, *X-axis* F_{sx} (N)	95.51	16.91	25.31	5.24
Skin firmness, *Y-axis* F_{sy} (N)	98.80	14.12	20.82	6.24
Flesh firmness, *X-axis* F_{fx} (N)	50.05	19.97	11.94	1.87
Flesh firmness, *Y-axis* F_{fy} (N)	58.90	14.36	9.05	0.92
Hand penetrometer				
Skin firmness, (N)	91.95	11.64	23.11	8.95
Flesh firmness (N)	61.64	11.24	20.27	8.92
Projected area, cm^2				
X-axis	9.66	1.17	-	-
Y-axis	13.10	0.86	-	-
Z-axis	12.01	0.66	-	-

Table 3. Cont....

Colour properties					
	*L**	47.41	1.11	46.88	1.60
Skin	*a**	2.08	1.39	3.45	1.57
	*b**	27.63	2.05	22.08	1.36
	*L**	60.24	0.78	48.42	2.10
Flesh	*a**	-20.69	0.53	-15.08	0.74
	*b**	40.22	1.39	26.65	1.88
	*L**	82.79	1.34	75.29	3.99
Core	*a**	-6.89	0.74	-7.79	1.26
	*b**	24.83	2.15	26.46	3.09
	*L**	62.16	2.99	46.41	5.52
Two sides of core	*a**	-13.54	1.16	-9.65	1.48
	*b**	29.70	1.98	19.88	3.48
Coefficient of friction					
Glass		0.284	0.0031	0.324	0.002
Rubber		0.390	0.0020	0.419	0.005
Galvanized metal		0.318	0.0027	0.342	0.002
Chipboard		0.373	0.0380	0.411	0.047
Plywood		0.365	0.0310	0.402	0.039

0.173 and 0.190 for galvanized steel sheet, rubber, polyethylene and plywood, respectively.

The *L** and *b** values of skin color of kiwifruit decreased from physiological maturity to ripening period of kiwifruit with values from 47.41 to 46.88 (1.12% decrease) and 27.63 to 22.08 (20.09% decrease), respectively (Table 3). The *L*, a** and *b** values of kiwifruits on core and two sides of core of fruit decreased from physiological maturity to ripening period with values from 82.79 to 75.29 (9.06%) and -6.89 to -7.79 (13.06% decrease), respectively (Table 3). The skin colour of kiwifruit 'Hayward' determined as *L*, a** and *b** values was 43.94, 5.51 and 24.04, respectively (Celik et al., 2007). Costa et al. (2006) reported the flesh colour for cv. 'Hayward' as *L** of 56.41, *a** of -17.47 and *b** of 32.35, respectively.

Skin firmness of kiwifruits punctured along X- and Y-axis decreased between physiological maturity to ripening period from 95.51 to 25.31 N and from 98.80 to 20.82 N, respectively. Flesh firmness of kiwifruits X- and Y- axis decreased between physiological maturity to ripe-ning period from 50.05 to 11.94 N (X-axis) and from 58.90 to 9.05 N (Y-axis), respectively. The measured firmness values using a drill-mounted penetrometer ranged from 91.92 to 23.11 N and from 61.64 to 20.27 N for skin and flesh kiwifruits in physiological maturity and ripening period, respectively (Table 3). Celik et al. (2007) reported that the skin and flesh firmness of 'Hayward' were 95.05 and 78.28 N, respectively, at physiological maturity of kiwifruit.

Conclusion

The chemical and physical properties measured serve to design the equipment used in postharvest processing and to improve the quality of kiwifruit ('Hayward'). The following conclusions are drawn from the investigation on chemical and physical properties of kiwifruits: (1) the total antioxidant value was higher at physiological maturity than at ripening period, whereas total phenolic and total sugar contents were higher at ripening period than at physiological maturity; (2) all the relations between length and width, thickness, fruit mass, geometric mean diameter, sphericity, surface area and volume of kiwifruit at physiological maturity and ripening period relations, except for L/T, have been found to be statistically significant; (3) the average sphericity, bulk density, fruit densities and porosity, except for surface area, increased from physiological maturity to ripening period of kiwifruit. The rubber surface offered the maximum static coefficient of friction followed by chipboard, plywood, galvanized metal and glass; (4) the skin and flesh firmness of kiwifruits along Y-axis is higher than the X-axis. *L** and *b** values of skin colour of kiwifruit decreased, whereas *a** value increased from physiological maturity to ripening period.

REFERENCES

Association of Official Analytical Chemists (1984). Officials methods of analysis. 14th ed. Arlington. VA: Association of Official Analytical Chemists.

Bal E, Kok D (2006). Effects of different calcium carbite doses some quality criteria of kiwifruit (*Actinidia deliciosa*). (in Turkish). J. Tekirdag Agric. Fac. 3(2): 213-219.

Bartolome AP, Ruperez P, Fuster C (1995). Pineapple fruit: Morphological characteristics, chemical composition and sensory analysis of Red Spanish and Smooth Cayenne cultivars. Food Chem. 53: 75–79.

Benzie IFF, Strain JJ (1996). Ferric reducing ability of plasma (FRAP) as a measure of antioxidant power: The FRAP assay. Anal. Biochem. 239: 70-76.

Boukouvalas S, Chouliras V (2005). Factors affecting storage life in kiwi fruit. Agro Thesis. 3(1): 26-32

Celik A, Ercisli S, Turgut N (2007). Some physical, pomological and nutritional properties of kiwifruit cv. Hayward. Int. J. Food Sci. Nutr. 58: 411-418.

Costa SB, Steiner A, Correia L, Empis J, Moldao-Martins M (2006). Effects of maturity stage and mild heat treatment on quality of minimally processed kiwifruit. J. Food Engr. 76: 616-625.

Dawes HM, Keene JB (1999). Phenolic composition of kiwifruit juice. J. Agric. Food Chem. 47: 398-403.

Fathollahzadeh H, Rajabipour A (2008). Some mechanical properties of barberry. Int. Agrophysics, 22: 299-302.

Ferguson AR (1999). New temperate fruits: *Actinidia chinensis* and *Actinidia deliciosa*.. In: J. Janick (ed.). Perspectives on new crops and new uses. ASHS Pres. Alexandria. VA. pp. 342–347

Food and Agriculture Organization (2007). www.FAO.org/statistics.htm.

Hasey JK, Juonson SR, Gran JA, Reil WO (1994). Kiwifruit growing and handling. In: Proc. Univ. Of Californa Dvision of Agr. And Natural Resources, California, USA p.122

Jha SN, Kingsly ARP, Sangeeta C (2005). Physical and mechanical properties of mango during growth and storage for determination of maturity. J. Food Engr. 72: 73-76.

Marsh K, Attanayake S, Walker S, Gunson A, Boldingh H, Macrae E (2004). Acidity and taste in kiwifruit. Postharvest Biol. Technol. 32: 159-168.

Mohsenin NN (1970). Physical properties of plant and animal materials. Gordon and Breach Science Publishers. New York.

Nishiyama I, Fukuda T, Shimohashi A, Oota T (2008). Sugar and organic acid composition in the fruit juice of different Actinidia varieties. Food Sci. Tech. Res. 14: 67–73.

Ozgen M, Reese RN, Tulio AZ, Miller AR, Scheerens JC (2006). Modified 2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) method to measure antioxidant capacity of selected small fruits and comparison to ferric reducing antioxidant power (FRAP) and 2,20-diphenyl-1-picrylhydrazyl (DPPH) methods. J. Agric. Food Chem. 54: 1151–1157.

Park YS, Jung ST, Gorinstein S (2006). Ethylene treatment of 'Hayward' kiwifruits (*Actinidia deliciosa*) during ripening and its influence on ethylene biosynthesis and antioxidant activity. Sci. Horticult. 108: 22–28.

Razavi SM, Parvar MB (2007). Some physical and mechanical properties of kiwifruit. Int. J. Food Engr. 3(6,3): 1-14.

Sanz ML, Villamiel M, Martinez-Castro I (2004). Inositols and carbohydrates in different fresh fruit juices. Food Chem. 87: 325-328.

Singleton VL, Rossi JL (1965). Colorimetry of total phenolics with phosphomolybdic- phosphotungstic acid reagents. Am. J. Enol. Viticul. 16: 144–158.

Teixeira ARN, Ferreira RMB (1993). Ripening and fruit: In: Encyclopedia of food technology and nutrition. Macrae R, Robinson RK, Sadler MJ (ur). London, Academic Press, 5: 3933-3940

Whittaker DJ, Smith GS, Gardner RC (1997). Expression of the ethylene biosynthetic genes in *Actinidia chinensis* fruit. Plant Mol. Biol. 34: 45-55.