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Evaluation of Some Physical Properties of Cucumber (*Cucumis sativus* L.)

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Abstract: Cucumber is one of the important vegetables in many countries. Information about physical properties of cucumber is necessary for designing, grading, sorting and processing operations. In this study, some physical properties such as diameter, length, height, and weight of three varieties of cucumber (Green Gold, Dharwad, and Super Dominus) were measured. The results revealed that there was no significant difference (P<0.01) in the density values of the studied varieties, but regarding other physical properties there were a significant difference (P<0.01) among them. The average density for Green Gold, Dharwad and Super Dominus were 0.98, 0.95 and 0.94 g/cm^3, respectively. Green Gold cucumber had the highest diameter, volume, weight, flesh diameter, geometric mean diameter and sphericity. Dharwad and Super Dominus varieties with 15.49 cm length and 4.61 length to diameter ratio had the highest length and length to diameter ratio, respectively. Smallest skin thickness (1.48 cm) was for Super Dominus. Surface area of Green Gold, Dharwad and Super Dominus were 192.29, 192.4 and 131.2 cm^2. As well as there was a high and positive correlation between weight and volume in the studied varieties. There was a non-significant and low correlation (0.56) between diameter and length in Super Dominus. There was also a high and positive correlation between diameter and geometric mean diameter in all the varieties.

Key words: Cucumber, physical properties, green gold, super dominus, Dharwad.

1. Introduction

Cucumber (*Cucumis sativus* L.) is one of the popular vegetables in many countries. It belongs to the family of cucurbitaceae which has 118 genera and 825 species [1]. The fruit of this plant is green in color and depending on the variety; it can be small or large. Water is the main component (96%) of the crop and there are a lot of vitamins, minerals and organic acids in this produce which makes it a nutritious product [2]. Regarding different properties of cucumber such as diameter, length, color, skin thickness, etc., it can be used as a fresh produce by the consumers or can be processed further to manufacture different products, for example, pickled cucumber or in salads [3]. According to Food and agriculture organization (FAO) [1], Iran is the third producer of cucumber in the world but doesn't have high amounts of exports for this important vegetable. Due to failures in harvesting techniques and poor quality of post-harvest technologies, about 30% of this produce is wasted [4].

To reduce the waste figures, it is necessary to have good designed equipment for harvesting, grading, sorting, and processing of cucumber [5-7]. Knowledge of cucumber physical properties plays an important role in the design and optimization of its machinery. As a result, the sale price of this produce will be decreased and its quality will be improved which helps to reduce the wastage [7]. In a study [3], different cucumbers are

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classified based on their shape and color into obliged group with a green and white color, elongated and average size group, and cone-shaped cucumbers with dark green color. Unfortunately, there is very limited information and published data about the physical and engineering properties of cucumber and our work is one of the first studies of its kind. Our main objective was to measure different physical properties of this produce and to develop some correlations between these properties. The results can be well used in the design of the related equipment.

2. Materials and Methods

2.1 Field Operation

After cultivation of three most common varieties of cucumber, namely Green Gold, Dharwad and Super Dominus (Fig. 1) in Gorgan University of Agricultural Science & Natural Resources research farm (2007) in Iran, we harvested the produce. Then, we measured their physical properties including length, diameter, height, weight, volume, density, skin surface area, flesh thickness, skin thickness, geometric mean diameter and number of internal seeds [1, 6, 8, 9].

2.2 Measuring of Dimension and Weight

Depending on cucumber harvesting criteria (length & diameter), we selected 50 samples from each variety randomly and measured their dimensions by a digital micrometer (GUANGLU, Germany). The largest dimension was chosen as length and the smallest one as diameter. Then, the height was considered as perpendicular to diameter. The weight of the samples was measured by an electronic scale (Sartorious, Germany, TE313S). Finally, the dry matter content of samples was analyzed by placing them in an oven (Memmert, Gmbh+Catky, Germany) at 85 ℃ for 48 hours. This method was conducted individually for the skin and flesh of the samples.

2.3 Measuring of Surface Area, Flesh Thickness and Skin Thickness

Fig. 1 Fruit shape of Green Gold, Dharwad and Super Dominus cucumber cultivars.

For the determination of surface area, we used millimeter paper. First we peeled the samples carefully and then, the separated skin was placed on the millimeter paper to obtain their surface area. The flesh thickness and skin thickness was also analyzed by a digital micrometer.

2.4 Measuring of Density

The density of the samples was measured and calculated by the following formula [7]:

$$Density\left(\frac{g}{cm^3}\right)=\frac{Sample\ weight\ in\ air\ (g)}{Sample\ volume\ (cm^3)} \quad (1)$$

$$Sample\ volume\ (cm^3)=\frac{Sample\ weight\ in\ water\ (g)}{Water\ density\left(\frac{g}{cm^3}\right)} \quad (2)$$

2.5 Measuring of Geometric Mean Diameter, Sphericity and Length to Diameter Ratio

Determination of geometric mean diameter, sphericity and length to diameter ratio was calculated according to the following method [10]:

$$Geometric\ mean\ diameter = (length \times diameter \times height)^{1/3} \quad (3)$$

$$Sphericity=\frac{geometric\ mean\ diameter}{length}\times 100 \quad (4)$$

$$Length\ to\ diameter\ ratio=\frac{length}{diameter} \quad (5)$$

2.6 Statistical Analysis

The samples were selected randomly and the mea-

surements were done on 50 replications. For the comparison between results, least significant difference (LSD) analysis (P<0.05) was used and all analyzes performed by SAS software.

3. Results and Discussion

3.1 Determination of Physical Properties

By conducting an ANOVA (Table 1) on different physical properties among three cucumber varieties (Green Gold, Dharwad, Super Dominus), the results revealed that these varieties only differ significantly in density, and there is no significant difference (P<0.01) in other physical properties.

Results show that Green Gold had the highest values in diameter, volume, weight, flesh thickness, geometric mean diameter and sphericity (as shown in Table 2). Dharwad variety had the highest length which was 15.49 cm. In Super Dominus, the highest length to diameter ratio was 4.61.

Also, there was no significant difference (P<0.01) between Green Gold and Dharwad in terms of fruit surface area, skin thickness and dry matter content. As shown in Table 2, smallest skin thickness was for Super Dominus (1.48 cm). Therefore, this variety can be susceptible to physical impacts during harvesting and transportation and it is necessary to reduce these

Table 1 ANOVA of physical properties of Green Gold, Dharwad and Super Dominus cucumber cultivars.

S.O.V	df	Volume (cm^3)	Weight (g)	Height (cm)	Diameter (cm)	Length (cm)	Flesh diameter (mm)	Surface area (cm^2)
Treatment	2	**33996.02	**34354.01	**41.28	**40.66	**194.62	**118.12	**14924.1
Error	147	855.37	795.5	0.15	0.17	0.64	0.47	589.44

S.O.V	df	Density (g/cm^3)	Sphericity (%)	Geometric mean diameter (mm)	Length to diameter ratio	Skin diameter (mm)	No. of Seeds	Skin dry matter (%)	Flesh dry matter (%)
Treatment	2	^{ns} 0.005	**11226.8	**12.58	**40.99	**1.47	**338.05	**5.63	**3.88
Error	147	0.004	6.21	0.248	0.145	0.021	3701.4	0.23	0.42

** Significant at 1% level, ns: Not significant.

Table 2 Comparison of physical properties of Green Gold, Dharwad and Super Dominus cucumber cultivars.

S.O.V	Green gold	Dharwad	Super dominus	LSD 5%
Volume (cm^3)	180.21a	151.62b	77.11c	24.29
Weight (g)	177.7a	144.97b	73.15c	23.42
Height (cm)	6.55a	3.88b	2.99c	0.32
Diameter (cm)	6.48a	3.92b	2.91c	0.34
Length (cm)	7.66c	15.49a	13.21b	0.66
Flesh diameter (mm)	13.52a	9.56b	7.33c	0.57
Surface area (cm^2)	192.29a	192.4a	131.2b	20.16
Density (g/cm^3)	0.98a	0.95a	0.94a	0.05
Sphericity (%)	91.16a	39.87b	36.72c	2.07
Geometric mean diameter (mm)	6.87a	6.17b	4.85c	0.41
Ratio of lenghth to diameter	1.14c	3.99b	4.61a	0.316
Skin diameter (mm)	2.06a	2.11a	1.48b	0.12
Seed number	209.3b	474.2a	163.2b	50.53
Skin dry matter (%)	8.3a	8.44a	7.19b	0.40
Flesh dry matter (%)	5.63b	6.24a	5.1b	0.54

Means followed by the same letter are not significantly different at 5% by LSD.

damages because they can bring about discoloration of fruit and reduce the quality of the produce [4].

3.2 Density

By ANOVA, there was no significant difference among the densities of the three varieties. The average density for Green Gold, Dharwad and Super Dominus were 0.98, 0.95 and 0.94 g/cm^3, respectively. Since the density of these varieties is less than 1.00, therefore cucumber can be sorted by floating in brine solutions [7]. Also, it is possible to remove the "farm heat" from cucumbers by floating them in cool water which is more efficient than cooling by air blast coolers [11, 12]. This is an important step in post-harvest processing of fruits and vegetable, because delay in cooling or not appropriate cooling of harvested produce leads to an increase in their respiration activity and production of more heat in the stored crops. These conditions are favorable for the growth of fungi which can reduce significantly shelf-life of the produce [4]. Furthermore, it has been a common practice to calculate porosity from density [13].

3.3 Number of Seeds

The results showed that Dharwad variety contained highest number of seeds (474 seeds) in each cucumber. As well as there is a positive and high correlation (P<0.01) between the number of seeds and weight of fruit in Dharwad and Green Gold (Tables 3 and 4), which can highlight the influence of seeds on the fruit development and growth. This is in agreement with previous finding, which reported there is a positive correlation between weight and number of seeds in melon [14]. Also, in other research it is concluded that internal seeds of cucumber are rich in auxin and there is a strong and positive relationship between seeds and weight increase [15]. Interestingly, there was not such a correlation in Super Dominus variety which can be due to parthenocarpy property in this variety as we observed. It should be noted that this correlation between seeds and fruit weight is not common in all types of fruits, for instance, in pomegranate there is not this correlation [5]. Although some researchers have reported a relationship between the number of internal seeds and skin thickness, for example in pomegranate [8], we could not find such a relationship in cucumber.

3.4 Correlation Results of Physical Properties

Correlation results (Tables 3 and 4) revealed that in Dharwad and Super Dominus varieties, there were a positive and significant correlation between diameter and skin thickness and weight of fruit. In Dharwad variety, there was only a positive correlation between skin thickness and weight, which is similar to the results of skin thickness of pea that is an important parameter affecting its other properties because there is a high correlation between skin and weight in pea [7]. But this correlation could not found in pomegranate (correlation=-0.59) [8]. There was a strong and positive correlation between fruit length and its weight in all the studied varieties. This trend could be seen in greenhouse cucumbers too, because when they are being harvested, they have the maximum length and so, the highest weight [9]. Furthermore, the results revealed that surface area of Green Gold (192.29 cm^2) and Dharwad (192.4 cm^2) were significantly higher than Super Dominus (131.2 cm^2). On the base of this research, Green Gold variety had the highest weight (177.79 g) and volume (180.21 cm^3). Also, there was a very strong and positive correlation (P<0.01) between weight and volume in all the varieties. Fruit expansion in cucumber includes an exponential growth which follows by a gradual decrease and increase in wet weight of cucumber is totally correlated with growth in its volume [16]. This trend is in agreement with our data on length and diameter.

Others correlation results showed that in different varieties of cucumbers, the correlations in their physical properties are not the same (Tables 3 and 4). In Green Gold, there was no correlation between fruit diameter and other properties such as volumes surface area, number of seeds, skin thickness, sphericity and

Table 3 Correlation among some physical properties of Green Gold, Dharwad and Super Dominus cucumber cultivars.

Physical property	Cultivar	Length	Diameter	Volume	Weight	Surface area	Flesh diameter	No. of seeds	Skin diameter	Geometric mean diameter	Sphericity
Length	Green Gold	1									
	Dharwad	1									
	Super Dominus	1									
Diameter	Green Gold	0.65*	1								
	Dharwad	**0.81	1								
	Super Dominus	0.56	1								
Volume	Green Gold	**0.76	0.25	1							
	Dharwad	**0.87	**0.96	1							
	Super Dominus	**0.83	**0.89	1							
Wight	Green Gold	**0.79	0.22	**0.99	1						
	Dharwad	**0.85	**0.96	**0.99	1						
	Super Dominus	*0.63	**0.89	**0.92	1						
Surface area	Green Gold	**0.89	0.3	**0.95	**0.98	1					
	Dharwad	**0.90	**0.94	**0.94	**0.94	1					
	Super Dominus	*0.58	**0.74	*0.66	0.51	1					
Flesh diameter	Green Gold	**0.80	0.13	**0.91	**0.95	**0.97	1				
	Dharwad	-0.09	0.34	0.22	0.23	0.24	1				
	Super Dominus	0.26	0.22	0.27	0.22	0.26	1				
No. of seeds	Green Gold	**0.76	0.02	**0.82	**0.88	**0.92	**0.96	1			
	Dharwad	**0.79	**0.83	**0.83	**0.82	**0.86	0.21	1			
	Super Dominus	0.22	*-0.57	-0.23	-0.39	-0.28	0.002	1			
Skin diameter	Green Gold	0.01	0.57	-0.20	-0.28	-0.25	-0.44	-0.49	1		
	Dharwad	0.48	**0.71	*0.61	*0.60	**0.71	0.22	0.53	1		
	Super Dominus	0.50	*0.58	0.55	0.34	*0.70	0.29	-0.32	1		
Geometric mean diameter	Green Gold	**0.86	**0.94	0.51	0.50	*0.59	0.44	0.35	0.36	1	
	Dharwad	**0.80	**0.99	**0.96	**0.96	**0.95	0.36	**0.83	**0.71	1	
	Super Dominus	*0.69	**0.98	**0.95	**0.91	**0.75	0.25	-0.48	*0.61	1	
Sphericity	Green Gold	**-0.84	-0.51	0.48	-0.52	**-0.65	*-0.58	*-0.63	-0.23	*-0.69	1
	Dharwad	0.30	**0.80	*0.69	**0.70	*0.63	*0.66	0.53	*0.68	**0.81	1
	Super Dominus	0.01	**0.83	0.52	*0.64	0.52	0.12	**0.86	0.39	**0.73	1

* and ** significant at 5% and 1%, respectively.

Table 4 Correlation equation of physical properties for Green Gold, Dharwad and Super Dominus cucumber cultivars.

Trait	Cultivar	Correlation equation coefficients	Diameter	Volume	Weight	Surface area	Flesh diameter	Seeds number	Skin diameter	Geometric mean diameter	Sphericity
Length	Green Gold	a	2.708	-48.41	45.332	-167.7	3.041	121.78	2.06	1.978	131.33
		b	0.492	29.82	29.106	46.96	1.367	11.429	0.0005	0.638	-5.239
	Dharwad	a	-2.865	-438.2	-403.2	-270.8	11.006	-446.17	0.796	-1.906	27.438
		b	0.438	38.06	35.38	29.90	-0.093	59.404	0.0849	0.521	0.797
	Super Dominus	a	-0.42	-165.5	-125.9	-18.76	5.74	-77.427	0.0967	-0.234	35.97
		b	0.252	18.354	15.058	11.35	0.12	18.207	0.1048	0.385	0.057
Diameter	Green Gold	a		93.318	107.44	51.09	11.58	206.64	1.928	0.886	119.01
		b		13.401	10.846	21.78	0.3002	0.423	-0.02	0.923	-4.294
	Dharwad	a		-154.0	-143.6	-34.11	7.199	24.308	1.203	1.48	24.676
		b		77.79	73.43	57.65	0.601	114.51	0.231	1.194	3.845

(to be continued)

	Super Dominus	a	-50.71	-63.97	37.249	6.666	472.11	0.693	1.287	20.034
		b	43.925	47.122	32.309	0.2289	106.14	0.271	1.226	5.736
Volume	Green Gold	a		9.981	-44.19	6.318	152.56	2.09	5.117	105.08
		b		0.931	1.312	0.04	0.315	-0.0001	-0.0097	-0.077
	Dharwad	a		2.756	83.55	8.806	257.53	1.74	3.99	33.55
		b		0.938	0.718	0.005	1.429	0.0025	0.014	0.041
	Super Dominus	a		-4.17	86.05	6.892	230.39	1.075	2.984	31.011
		b		1.002	0.586	0.0057	-0.87	0.0053	0.024	0.074
Weight	Green Gold	a			-62.11	5.61	144.95	2.101	5.072	107.17
		b			1.431	0.044	0.362	-0.0002	0.01	-0.09
	Dharwad	a			82.31	8.767	259.04	1.739	3.96	33.319
		b			0.759	0.0055	1.484	0.0026	0.015	0.0446
	Super Dominus	a			100.59	7.014	263.88	1.257	3.279	30.53
		b			0.419	0.0043	-1.375	0.0031	0.021	0.0847
Surface area	Green Gold	a				7.559	159.62	2.089	5.295	105.88
		b				0.031	0.258	-0.0001	0.0082	-0.076
	Dharwad	a				8.196	102.1	1.385	2.591	30.216
		b				0.0071	1.934	0.0038	0.0186	0.0497
	Super Dominus	a				6.517	322.01	0.497	2.01	25.78
		b				0.0062	-1.209	0.0075	0.0217	0.0834
Flesh diameter	Green Gold	a					94.775	2.161	14.27	120.08
		b					8.47	-0.0072	0.192	-2.137
	Dharwad	a					313.11	1.707	3.785	22.33
		b					16.85	0.042	0.249	1.825
	Super Dominus	a					159.37	0.513	2.568	30.303
		b					0.528	0.132	0.3119	0.876
Seeds number	Green Gold	a						2.254	3.237	146.69
		b						-0.0009	0.017	-0.265
	Dharwad	a						1.515	2.742	30.968
		b						0.0013	0.0072	0.0186
	Super Dominus	a						1.614	5.388	42.043
		b						-0.0008	-0.0033	-0.032
Skin diameter	Green Gold	a							-13.547	201.26
		b							9.892	-53.336
	Dharwad	a							0.541	18.217
		b							2.666	10.215
	Super Dominus	a							2.418	27.94
		b							1.644	5.929
Geometric mean diameter	Green Gold	a								131.61
		b								-5.884
	Dharwad	a								19.743
		b								3.247
	Super Dominus	a								17.006
		b								4.0617

weight. In Dharwad, there is a significant correlation between sphericity and weight. In Green Gold, there is a positive and significant correlation (P<0.01) between flesh thickness and the properties of diameter, volume, weight, surface area, and number of seeds. On the other hand, there was a negative and significant correlation between sphericity and mentioned properties in Green Gold. We could not find such a correlation between flesh thickness and other properties in two other varieties (Dharwad and Super Dominus).

As it can be seen in Table 3, there is a positive and high correlation between diameter and geometric mean diameter in all the varieties (P<0.01). Also, there is a positive and significant correlation between diameter and sphericity in Dharwad and Super Dominus, but this correlation was negative and not significant in Green Gold. Similar results have been obtained for hackberry (*Celtis australis* L.) [6]. Researchers reported that there is a strong and significant correlation between diameter and length, diameter and weight, diameter and sphericity in wild meldar (*Mespilus germanica* L.) [17]. It can be seen that length, weight, surface area, geometric mean diameter, and sphericity are directly correlated with diameter. In spite of this trend, there is a non-significant and low correlation (0.56) between diameter and length in Super Dominus which could be due to parthenocarpy in this variety of cucumber. In fact, with increase in length of the fruit, diameter is not increasing significantly in Super Dominus. Hence, fruit shapes of different varieties of cucumber are not the same and for harvesting, individual varieties should be studied and considered. For example, researchers found that for Xoshinari variety of cucumber, optimum dimensions for harvesting are 20.95 cm in length, 3.28 cm in diameter, and 143.53 g in weight [9, 18-20]. In another work, Beit alpha optimum conditions for harvesting are 16 cm in length and 3.81 cm in diameter [18]. For Dutch varieties of cucumber which are elongated, they are harvested when their length is 27.94 cm and their diameter is 3.17-4.44 cm. In the Green Gold, there is no correlation between diameter and weight, and diameter and surface area. While, there is a negative correlation (-0.51) between diameter and sphericity which could be due to fruit shape of this variety and high number of internal seeds. According to Table 1, Super Dominus variety had the highest length to diameter ratio (4.61), but Green Gold and round fruits in general had the lowest ratio (1.14).

4. Conclusions

The results of this study revealed that there is no significant difference (P>0.01) in the density values of the studied varieties (Green Gold, Dharwad, Super Dominus), but regarding other physical properties, there is a significant difference (P<0.01) among the three varieties. There is a high and positive correlation between weight and volume in the studied varieties. There is also a high and positive correlation between diameter and geometric mean diameter in all the varieties. The findings of our study can be used to determine the optimum conditions of cucumber varieties for harvesting. Also, these physical properties can be helpful in breeding programs and design of related equipment.

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