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RESEARCH NOTES

Cantaloupe Volume Determination through Image Processing

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ABSTRACT

Cantaloupe (*Cucumis melo*) volume was measured using water displacement and image processing methods. The volume determined from image processing method was compared to the volume determined by the water displacement method using the paired samples *t*-test and the Bland-Altman approach. The paired samples *t*-test results showed that the volume determined by image processing method was not significantly (P> 0.05) different from the volume measured through water displacement method. The mean and standard deviation of the volume difference between the two methods were -81.1 cm^3 and 237.4 cm^3, respectively (95% confidence interval: -212.5 and 50.4 cm^3, P= 0.207). The average percentage difference between the two methods was 7.60%. The Bland-Altman approach was also indicated to be a satisfactory, image processing method suitable for volume estimation of almost all size cantaloupe. Accordingly, image processing provides an accurate, simple, rapid and non-invasive method to estimate fruit volume and can be easily implemented in monitoring fruit growth as well as in sorting of fruits during postharvest processing.

Keywords: Cantaloupe, Fruit sorting, Image processing, Volume.

INTRODUCTION

Cantaloupe (*Cucumis melo*) is a subtropical fruit of the family Cucurbitaceae. Its spread from Italy to other parts of the world was rapid due to its climatic requirements being of an ordinary nature. Cantaloupe is considered as one of the most desirable fruits due to its high nutritive values. Besides a rich source of vitamin A and C, it contains a fair amount of nutrients (Calcium, Magnesium, Phosphorus, Potassium and Iron) as well as vitamins (B_1, B_3, B_5 and B_6). Cantaloupe's constituents are comprised of: 55-59% edible portion, 87-92% moisture contents, 0.1-0.2% oil, 0.60-1.0% protein and 6.3-10.3% total soluble solids (Arabsalmani, 1996).

Iran produces 750,000 tons of cantaloupes (Iranian Ministry of Agriculture, Statistical Yearbook, 2005), but Iranian cantaloupe is not duely exported because of variability in size and shape along with a lack of proper mode of packaging.

Fruit size is one of the most determining quality parameters for evaluation as judged by consumer preference (Sadrnia *et al.*, 2007). Consumers prefer fruits of equal weight, and uniform shape (Waseem *et al.*, 2002). An estimation of mean fruit size is important in meeting quality standards, increasing market value, monitoring fruit growth, predicting fruit yield as well as proper sorting of fruits (Wilhelm *et al.*, 2005). Fruit size estimation is also helpful in planning packaging, transportation and marketing operations (Tabatabaeefar *et al.*,

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2000). The size of an agricultural produce is frequently represented by its mass because it is relatively simple to measure. However, volume-based sorting may provide a more efficient method than mass sorting. In addition, the mass of agricultural produce can be estimated from volume if the density known.

Two common methods of volume measurement include gas displacement and water displacement. Gas displacement method does not harm the fruit but it is time-consuming. While water displacement method takes less time, it may have degrading effects on the produce. Both methods are best performed indoors and may not be of adequate practicality (Ngouajio *et al.*, 2003).

Another method to determine fruit volume is the use of outer dimensions (Hall *et al.*, 1996; Ngouajio *et al.*, 2003). However, measuring dimensions using a caliper, subject to human error, may not be an efficient and practical approach in estimating volume, particularly in sorting large quantities of fruit in distribution terminals (Sadrnia *et al.*, 2007).

Nowadays, the use of image processing is gaining interest for the surface area and volume determination of fruit. Sabliov *et al.* (2002) used an image processing algorithm to determine surface area and volume of axisymmetric agricultural products. Wang and Nguang (2007) used the methodology developed by Sabliov *et al.* (2002) to measure the surface area and the volume of agricultural products. They created a representation of the produce with a set of elementary cylindrical objects and estimated the volume by summing up the elementary volumes of individual cylinders. Both Sabliov *et al.* (2002) and Wang and Nguang (2007) reported that the method successfully estimated the surface area and the volume of lemons, limes and peaches. Koc (2007) used image processing to determine the volume of watermelons. Rashidi *et al.* (2007) reported that image processing successfully estimated the volume of kiwifruits. Bailey *et al.* (2004) demonstrated an image processing approach which estimated the mass of agricultural products rapidly and accurately. They used two perpendicular views to estimate fruit volume, and then used the volume information to calculate mass through a closed-loop calibration.

The image processing estimation methods reported in literature were successfully applied to such agricultural produce as limes, lemons, peaches, watermelons and kiwifruits. All these products are more regularly shaped than cantaloupe (Rashidi and Seyfi, 2007). An estimation of cantaloupe volume is important in size sorting as well as in monitoring growth development under various management practices. Image processing can also provide an alternative to estimate the volume of cantaloupe. The aim of this study was to estimate cantaloupe volume through image processing while utilizing standard softwares for data handling and analysis.

MATERIALS AND METHODS

Plant Material

Fifteen randomly selected cantaloupes (*Cucumis melo cv.* Samsouri) of various sizes were picked up from their storage piles. Fruits were selected for freedom from defects by careful visual inspection, transferred to the laboratory and held at 5±1˚C and 90±5% relative humidity until use.

Experimental Procedure

The dimensions (Figure 1), i.e. length (L), major diameter (D_1) and minor diameter (D_2), were measured using a digital caliper. The mass of each cantaloupe was determined using a digital balance with ±5.0 g accuracy. The volume of each cantaloupe was measured using water displacement method. Each cantaloupe was submerged in

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a container full of water, and the volume of displaced water was determined using a 250 cm^3 capacity graduated cylinder. Water temperature during measurements was kept at 25˚C.

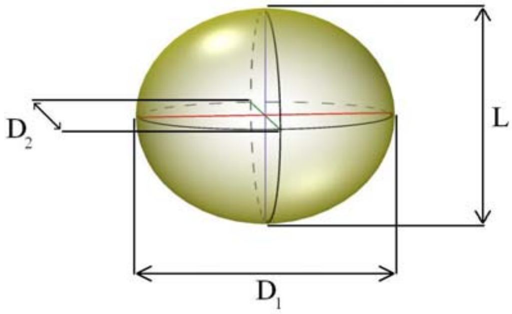

Figure 1. The dimensions of a cantaloupe.

The image processing system consisted of a digital camera with USB connection, a fluorescent ring light source (40 W) and a personal computer (PC) equipped with Adobe Photodhop 8.0 (Version 2003), Compaq Visual Fortran 6.5 (Version 2000) and Microsoft Excel (Version 2003) programs. A white cardboard was placed on the table to provide a white background. The digital camera was placed at the center of the fluorescent ring light source. The light source and camera were mounted on an adjustable frame attached to the measurement table. A schematic picture of the image acquisition system is presented in Figure 2. The distance between the measurement table surface and the camera was set at 45 cm. Each cantaloupe was placed at the center of the camera's field of view and two RGB color images were captured before and after manually rotating the cantaloupe 90˚ around the lateral axis.

The original RGB color image of each cantaloupe was converted to a grayscale image. Grayscale intensity represents 256 different shades of gray from black (0) to white (255). Using threshold technique, the selected region of interest on the grayscale image was then converted to a black-and-white image with pixel values of 0 or 255. From the grayscale image, pixel values less than 155 were converted to 0 (black) and pixel values higher than 155 converted to 255 (white), producing a black-and-white image for each cantaloupe. The threshold level of 155 was determined experimentally. Edge detection technique was then used to identify the cantaloupe edge in each image. Pixels showing the cantaloupe outline had the value of 0 and the remainder of the pixels in the image had the value of 255. Examples of the original RGB color, grayscale, black-and-white and outline images of a cantaloupe are shown in Figure 3. The original RGB color, grayscale and black-and-white images were recorded as a

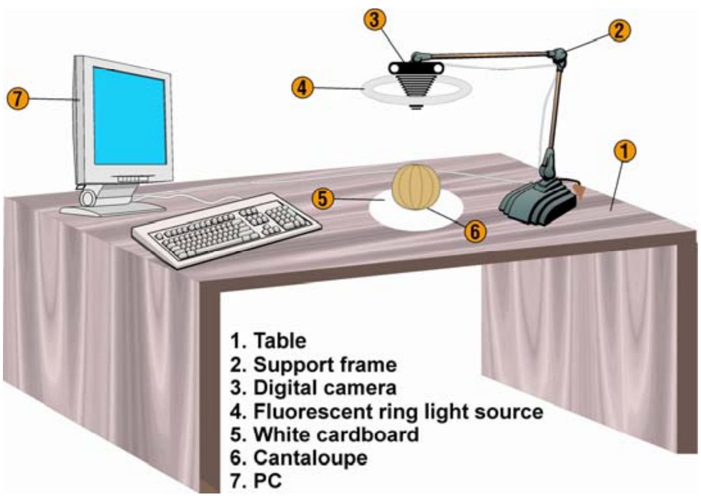

Figure 2. Image acquisition system.

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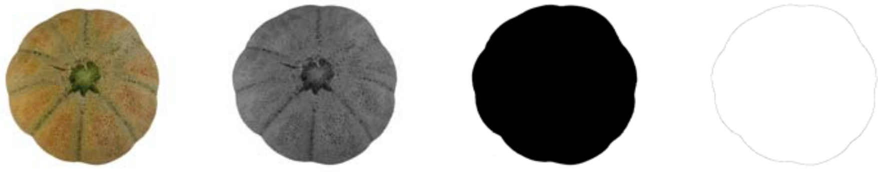

(I) (II) (III) (IV)

Figure 3. (I) Original RGB color; (II) Grayscale; (III) Black-and-white, and (IV) Outline images of a cantaloupe.

bitmap file while the cantaloupe outline image was recorded as a DAT file with a two-dimensional array. The purpose of processing and converting the original RGB color images to black-and-white and outline images was to reduce the file size and processing time during volume calculation using the computer software.

Dimensional Calibration

Each cantaloupe was placed at the center of the camera's field of view. Cantaloupe major and minor diameters were found *via* a digital caliper. Without changing the position of the fruit, the first surface image was captured through the image acquisition system. The number of pixels representing the major and minor diameters of the cantaloupe were measured on the first captured image. Then, the cantaloupe was manually rotated 90˚ around the latitudinal axis and its length measured *via* a digital caliper. Again, without changing the position of the fruit, the second surface image was captured and the number of pixels representing the length of the cantaloupe measured. The dimensions in millimeters were divided by the dimensions in pixels and a mean conversion factor obtained for each cantaloupe. The mean conversion factor for a number of 15 cantaloupes was averaged and a single conversion factor determined. The same conversion factor was later used to estimate the volume of each and other cantaloupe.

Volume Evaluation from Surface Images

The outline images of each cantaloupe as shown in Figure 3 (IV) were employed to calculate volume using the disk technique (Riddle, 1979). Each two-dimensional outline image of cantaloupe was assumed to be composed of individual rectangular elements as shown in Figure 4.

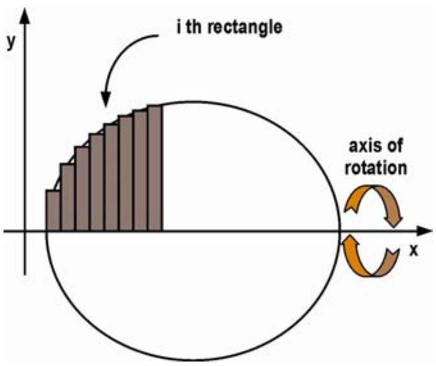

Figure 4. The outline image of cantaloupe was assumed to be composed of individual rectangular elements.

Revolving the height of each rectangular element around the x-axis produces a cylindrical disk with a diameter of Δy as shown in Figure 5. The volume of each cylindrical disk (V_i) shown in Figure 5 is equal to the cross sectional area of the disk (A_i) times the thickness of the disk (Δx). Equation (1) shows the cross-sectional area of a cylindrical disk and Equation (2) the volume of the same disk.

$$A_i = \pi(\frac{\Delta y}{2})^2 \quad (1)$$

$$V_i = A_i \Delta x \quad (2)$$

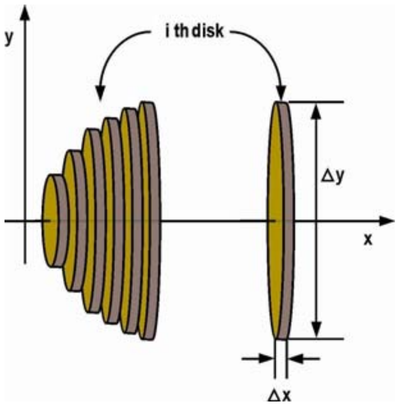

Figure 5. Revolving each element around the x-axis generated cylindrical disks.

The program developed in Compaq Visual Fortran considered each disk as having a thickness of 1 pixel and used an algorithm to determine the major and minor diameters and calculate the mean diameter of each disk. Using the mean diameter, the volume of each disk was calculated. The volume of each disk was then summed up to estimate the total volume as shown in Equation (3). Finally, the same conversion factor was used to estimate the volume of each and every cantaloupe.

$$V = \sum_{i=1}^{n} V_i \quad (3)$$

Statistical Analysis

A paired samples *t*-test and the mean difference confidence interval approach were used to compare the volume determined from image processing method with the one obtained through water displacement method. The Bland-Altman (1999) approach was also used to plot the agreement between cantaloupe volumes determined through image processing and the water displacement methods. The statistical analyses were performed using Microsoft Excel.

RESULTS AND DISCUSSION

Dimensional Calibration Results

The dimensional calibration was determined by measuring cantaloupe length, major and minor diameters in millimeters using a digital caliper and determining these parameters in pixels using image processing from the outline images. The dimensions measured by use of the digital caliper and *via* image processing are shown in Table 1. From the digital caliper and image processing measurements, a conversion factor of 1 pixel to 1.62 mm was determined. This conversion factor was used to estimate the volume of each cantaloupe using image processing.

Comparison of Image Processing Method with Water Displacement Method

The paired samples *t*-test results (Table 2) show that the volume determined through image processing is not significantly

Table 2. Paired sample t-test analyses on a comparison of volume measurement methods.

Size	df	Average Difference (cm^3)	Standard deviation of difference (cm^3)	P value	95% confidence intervals for the difference in means (cm^3)
15	14	-81.1	237.4	0.207	-212.5 , 50.4

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Table 1. Mass, dimensions and volumes of cantaloupes used in the study.

Sample number	Mass(g)	Dimensions: Through digital caliper (mm)			Dimensions: Through image processing (pixel)			Volume (cm^3)	
		Length	Major diameter	Minor diameter	Length	Major diameter	Minor diameter	Water displacement method	Image processing method
1	1245	123	139	136	78	81	80	1218	1010
2	1285	133	145	132	79	86	79	1333	1264
3	1340	127	151	144	78	89	87	1446	1400
4	1380	142	144	136	84	89	83	1456	1373
5	1390	145	155	123	87	93	75	1448	1287
6	1470	136	152	140	83	92	86	1516	1553
7	1540	140	152	150	87	92	91	1672	1605
8	1630	136	160	158	83	99	99	1800	1860
9	1695	144	160	152	91	99	93	1834	1784
10	1795	140	170	162	86	105	101	2019	2130
11	2035	155	182	162	97	112	101	2393	2492
12	2150	157	179	160	96	110	98	2355	2732
13	2300	161	181	171	101	115	111	2609	2719
14	2755	172	190	185	108	123	121	3166	3665
15	3380	183	205	186	117	134	124	3654	4260

(P>0.05) different from the volume measured *via* water displacement. The mean volume difference between the two methods is -81.1 cm^3 (95% confidence interval: -212.5 and 50.4 cm^3, P = 0.207). The standard deviation of the volume differences was 237.4 cm^3. A plot of the volumes determined by image processing method (IPM) and water displacement method (WDM) with equality line (1.0: 1.0) is shown in Figure 6. As shown in Figure 7, the volume differences between image processing and water displacement methods were normally distributed and 95% of the volume differences were expected to lie between $\mu - 1.96\sigma$ and $\mu + 1.96\sigma$, known as 95% limits of agreement (Bland and Altman, 1999). The 95% limits of agreement for comparison of volumes determined with water displacement and image processing were calculated to be -546.4 and 384.3 cm^3. Figure 7 also shows that for small-sized cantaloupe, the volume estimated through image processing is less than the volume measured *via* water displacement (WDM-IPM> 0). As the size of cantaloupe increases, an overestimation of volume occurs, when assessed through image processing (WDM-IPM< 0). This is because of the change in distance between the digital camera and the cantaloupe surface. Since the distance between the digital camera and the

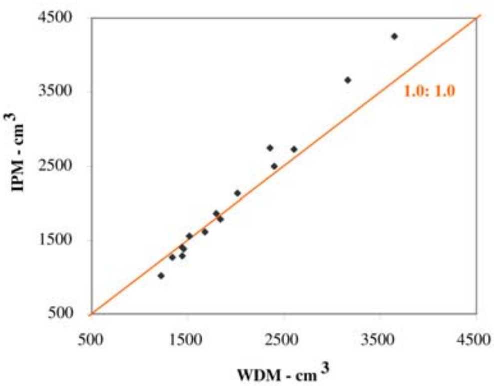

Figure 6. Cantaloupe volume measured using water displacement method (WDM) and image processing method (IPM) with equality line (1.0: 1.0).

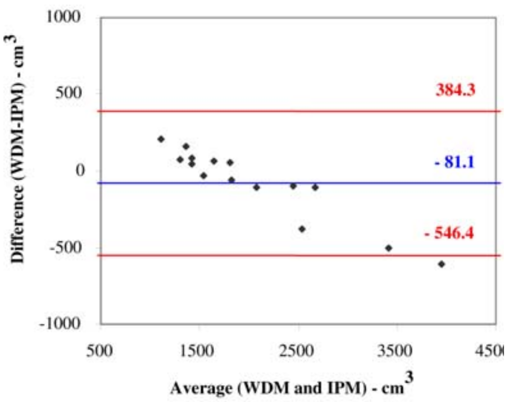

Figure 7. Bland-Altman plot for a comparison of cantaloupe volume measured through water displacement method (WDM) vs. image processing method (IPM); outer lines indicate the 95% limits of agreement (-546.4, 384.3) while center line showing the average difference (-81.1).

stand table is constant, the distance between cantaloupe and the digital camera becomes less with increasing cantaloupe size.

The average percentage difference for volume estimation through image processing and *via* water displacement was 7.60%. As in this study image processing method was based on the assumption that each cantaloupe was axisymmetric in shape, the accuracy of the determining volume depended on the uniformity of the fruit having the presumed shape. With misshapen cantaloupes, which are not axisymmetric in shape set aside, image processing provides an accurate, simple, rapid and non-invasive method to estimate the fruit volume. This method can be easily adopted in monitoring the growth and development of the fruit under various management practices, in estimating the weight of individual cantaloupes and thus in sorting of cantaloupe during postharvest processing operations.

CONCLUSIONS

Image processing method with the disk approximation technique was employed to estimate the volume of cantaloupes of varying sizes from sets of two surface images as captured with a digital camera. The volumes estimated using this method was statistically compared to the volumes measured through the water displacement method. The paired samples *t*-test results indicated that the difference between the volumes estimated through image processing vs. and water displacement was not significant (P> 0.05). The Bland-Altman approach also showed that, for all sized cantaloupe, image processing method satisfactorily estimated cantaloupe volume. Accordingly, image processing provides an accurate, simple, rapid and non-invasive method to estimate cantaloupe volume and can be easily implemented in monitoring growth development under various management practices as well as sorting of cantaloupe during postharvest processing.

REFERENCES

1. Arabsalmani, K. 1996. Evaluation of Flowering, Fruiting, and Effect of Seed Extraction Time on Seed Quality Characters of Cantaloupe (*Cucumis melo*), M. Sc. Thesis, University of Tabriz, Iran.
2. Bailey, D. G., Mercer, K. A., Plaw, C., Ball, R. and Barraclough, H. 2004. High Speed Weight Estimation by Image Analysis. *In: "Proceedings of the New Zealand National Conference on Non Destructive Testing"*. 27-39 July 2004, New Zealand.
3. Bland, J. M. and Altman, D. G. 1999. Measuring Agreement in Method Comparison Studies. *Stat. Methods Med. Res.*, **8**: 135-160.
4. Hall, A. J., McPherson, H. G., Crawford, R. A. and Seager, N. G. 1996. Using Early Season Measurements to Estimate Fruit Volume at Harvest in Kiwifruit. *J. Crop Hort. Sci.*, **24**: 379-391.
5. Koc, A. B. 2007. Determination of Watermelon Volume Using Ellipsoid Approximation and Image Processing. *J. Postharvest Biol. Technol.*, **45**: 366-371.
6. Ngouajio, M., Kirk, W. and Goldy, R. 2003. A Simple Model for Rapid and Nondestructive Estimation of Bell Pepper Fruit Volume. *J. Crop Hort. Sci.*, **38**: 509-511.
7. Rashidi, M. and Seyfi, K. 2007. Classification of Fruit Shape in Cantaloupe Using the Analysis of Geometrical Attributes. *World J. Agri. Sci.*, **3**: 735-740.
8. Rashidi, M., Seyfi, K. and Gholami, M. 2007. Determination of Kiwifruit Volume using Image Processing. *J. Agri. Biol. Sci.*, **2**: 17-22.
9. Riddle, D. F. 1979. *Calculus and Analytic Geometry*. Wadsworth Publishing Company, Inc., Belmont, CA, USA.
10. Sabliov, C. M., Boldor, D., Keener, K. M. and Farkas, B. E. 2002. Image Processing Method to Determine Surface Area and Volume of Axisymmetric Agricultural Products. *Int. J. Food Prop.*, **5**: 641-653.
11. Sadrnia, H., Rajabipour, A., Jafary, A., Javadi, A. and Mostofi, Y. 2007. Classification and Analysis of Fruit Shapes in Long Type Watermelon Using Image Processing. *Int. J. Agric. Biol.*, **1**: 68-70.
12. Tabatabaeefar, A., Vefagh-Nematolahee, A. and Rajabipour, A. 2000. Modeling of Orange Mass Based on Dimensions. *J. Agr. Sci. Technol.*, **2**: 299-305.
13. Wang, T. Y. and Nguang, S. K. 2007. Low Cost Sensor for Volume and Surface Area Computation of Axisymmetric Agricultural Products. *J. Food Eng.*, **79**: 870-877.
14. Waseem, K., Ghaffoor, A. and Rehman, S. U. 2002. Effect of Fruit Orientation on the Quality of Litchi (*Litchi chinenesis* Sonn) Under the Agro-climatic Conditions of Dera Ismail Khan-Pakistan. *Int. J. Agric. Biol.*, 4: 503-505.
15. Wilhelm, L. R., Suter, D. A. and Brusewitz, G. H. 2005. *Physical Properties of Food Materials. Food and Process Engineering Technology, ASAE*, St. Joseph, Michigan, USA.

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تعیین حجم طالبی با استفاده از پردازش تصویر

م. رشیدی ،م. غلامی و س. عباسی

چکیده

حجم طالبی با استفاده از دو روش جابه‌جایی آب و پردازش تصویر تعیین گردید. در مقایسه حجم تعیین شده به روش پردازش تصویر و حجم اندازه‌گیری شده به روش جابه‌جایی آب، از آزمون t و شیوه بِلَند- اَلتمن استفاده گردید. نتایج حاصل از آزمون t نشان داد که حجم تعیین شده به روش پردازش تصویر با حجم اندازه‌گیری شده به روش جابه‌جایی آب، دارای اختلاف معنی‌دار نیست (P= 0.207). در این مطالعه میانگین و انحراف معیار اختلاف بین دو روش به ترتیب -81.1 cm^3 و 237.4 cm^3 (سطح اطمینان 95% : 50.4 cm^3 و -212.5 cm^3) و میانگین درصد اختلاف بین دو روش 7.60% بود. نتایج حاصل از شیوه بِلَند -اَلتمن نشان داد که روش پردازش تصویر، حجم اندازه‌های مختلف از طالبی را به طور رضایت‌بخشی تخمین می‌زند. بنابراین، پردازش تصویر یک روش دقیق، ساده، سریع و غیرتهاجمی برای تعیین حجم میوه فرآهم آورده و می‌تواند به سادگی در پایش رشد میوه‌ها و درجه‌بندی میوه‌ها پس از برداشت مورد استفاده قرارگیرد.

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