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Food item Volume Determination Using Image Processing Method

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Abstract: Food item (*Cucumis melo*) volume was measured using water displacement and image processing methods. The volume determined from image processing method (IPM) was compared to the volume determined by the water displacement method (WDM) 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 different from the volume measured by water displacement method (P = 0.207). The mean and standard deviation of the volume difference between two methods were -81.1 cm_3 and 237.4 cm_3, respectively (95% confidence interval: -212.5 and 50.4 cm_3). The average percentage difference between two methods was 7.60%. The Bland-Altman approach also indicated that for all sized food item, image processing method satisfactorily estimated food item volume. 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 and sorting of fruits during postharvest processing.

Key words: Food item Volume Image processing Fruit sorting

INTRODUCTION

Food item (*Cucumis melo*) is a subtropical fruit and belongs to the family Cucurbitaceae. Its spread from Italy known to other parts of the world was rapid due to its climatic requirements. Food item is considered as the best fruits due to its high nutritive value. Besides source of vitamin A and C, it contains a fair amount of nutrients (Calcium, Magnesium, Phosphorus, Potassium and Iron) and vitamins (B_1, B_3, B_5 and B_6). Food item contains 55-59% edible portion, 87-92% moisture, 0.1-0.2% oil, 0.60-1.0% protein and 6.3-10.3% total soluble solids [1]. Fruit size is one of the most important quality parameters for evaluation by consumer preference [2]. Consumers prefer fruits of equal and uniform shape [3]. The estimation of mean fruit size is important in meeting quality standards, increasing value, monitoring fruit growth, predicting fruit yield and volume determination of fruit. Sabliov *et al.* (2002) used an

a displacement method does not harm the fruit but it is timerich in vitamin A and C, it contains a fair amount consuming. While water displacement method takes less time, it may have harmful effects on the produce. Both methods are best performed indoors and may not be practical [6]. Another method to determine fruit volume is the use of outer dimensions [6, 7]. However, measuring dimensions using a calliper, subject to human error, may be an efficient and practical approach to estimate fruit size [1]. Fruit size is one of the most important parameters for evaluation by consumer preference [2]. Consumers prefer fruits of equal weight volume, particularly in sorting large quantities of fruit in packing houses [3]. The estimation of mean fruit size is distribution terminals [2]. Nowadays, the use of image processing is gaining interest for the surface area and volume determination of fruit. Sabliov *et al.* (2002) used an

sorting of fruits [4]. Fruit size estimation is also helpful in image processing algorithm to determine the surface area
planning packaging, transportation and marketing and volume of axisymmetric agricultural products [8].
operations [5]. The size of an agricultural produce is Wang and Nguang (2007) used the methodology
frequently represented by its mass because it is relatively developed by Sabliov *et al.* to measure the surface area
simple to measure. However, volume-based sorting may and volume of agricultural products [9]. They created a
addition, the mass of agricultural produce can be

representation of the produce with a set of elementary EXCEL (Version 2003) programs. A white cardboard
cylindrical objects and estimated the volume by summing was placed on a table to provide a white background. The
the elementary volumes of individual cylinders. Both digital camera was placed at the center of the fluorescent
Sabliov *et al.* and Wang and Nguang reported that the ring light source. The light source and camera mounted on
method successfully estimated the surface area and an adjustable frame was attached to the measurement
volume of lemons, limes and peaches [8, 9]. Bailey *et al.* table. A schematic picture of the image acquisition system
(2004) demonstrated an image processing approach which is presented in Fig. 1. The distance between the
estimated the mass of agricultural products rapidly and measurement table surface and the camera was set at
accurately. They used two perpendicular views to 45 cm. Each food item was placed at the center of the
estimate fruit volume and then used the volume camera's field of view and two RGB color images were
information to calculate the mass through a closed- loop captured before and after manually rotating the
calibration [10]. food item 90° around the lateral axis.
The image processing estimation methods reported The original RGB color image of each food item was
in the literature were successfully applied to agricultural converted to a grayscale image. Grayscale intensity
produce such as limes, lemons and peaches. All of these represents 256 different shades of gray from black (0) to
products are relatively smaller and more regularly white (255). Using the threshold technique, the selected
shaped than food item. The estimation of food item region of interest on the grayscale image was then
volume is important for size sorting and monitoring converted to a black-and-white image with pixel values of
growth development under various management 0 or 255. From the grayscale image, pixel values less than
practices. Image processing can also provide an 155 were converted to 0 (black) and pixel values higher
alternative method to estimate the volume of food item. than 155 were converted to 255 (white), producing a black-
The aim of this study was to estimate food item volume and-white image for each food item. The threshold level
by image processing and utilizing of standard software's of 155 was determined experimentally. The edge detection
for data handling and analysis. technique was then used to identify the food item edge
MATERIALS AND METHODS had the value of 0 and the remainder of the pixels in the
Plant Material: Fifteen randomly selected food items color, grayscale, black-and-white and outline images of a
(*Cucumis melo cv.* Samsouri) of various sizes were picked food item are shown in Fig. 2. The original RGB color,
up from their storage piles. Fruits were selected for grayscale and black-and-white images were recorded as a
freedom from defects by careful visual inspection, bitmap file while the food item outline image was
transferred to the laboratory and held at 5±1°C and 90±5% recorded as a DAT file with a two-dimensional array. The
relative humidity until use. purpose of processing and converting the original RGB
Experimental Procedure: The dimensions (length, major to reduce the file size and processing time during volume
diameter and minor diameter) were measured using a calculation using the computer software.
digital caliper. The mass of each food item was measured
using a digital balance with ±5.0 g accuracy. The minimum Dimensional Calibration: Each food item was placed at
and maximum food item mass was 1245 and 3380 g, the center of the camera's field of view. Food item major
respectively. The volume of each food item was and minor diameters were measured with a digital caliper.
measured using the water displacement method. Each Without changing the position of the fruit, the first
food item was submerged in a container full of water and surface image was captured with the image acquisition
the volume of the displaced water was measured using a system. The number of pixels representing the major and
250 cm capacity graduated cylinder. Water temperature minor diameter o $_3$f the food item was measured on the
during measurements was kept at 25°C. first captured image. Then, the food item was manually
The image processing system consisted of a digital rotated 90° around the latitudinal axis and food item
camera with USB connection, a fluorescent ring light length was measured with a digital caliper. Again, without
source (40 W) and a personal computer (PC) equipped changing the position of the fruit, the second surface

with ADOBE PHOTOSHOP 8.0 (Version 2003), COMPAQ image was captured and the number of the pixels
VISUAL FORTRAN 6.5 (Version 2000) and MICROSOFT representing the length of the food item was measured.
in each image. The pixels showing the food item outline
image had the value of 255. Examples of the original RGB
color images to black-and-white and outline images was
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Fig. 1: Image acquisition system
(I) (II) (III) (IV) assumed to be composed of individual rectangular
Fig. 2: (I) Original RGB color, (II) grayscale, (III) rectangular element around the x-axis produces a
black-and-white and (IV) outline images of a cylindrical disk with a diameter of y as shown in Fig. 4.
food item The volume of each cylindrical disk (V) shown in Fig. 4 is
Fig. 3: The outline image of the food item was assumed 1 pixel and used an algorithm to determine the major and
to be composed of individual rectangular elements minor diameters and calculate the mean diameter of each
The dimensions in millimeters were divided by the was calculated. The volume of each disk was then
dimensions in pixels and a mean conversion factor was summed to estimate the total volume as shown in
calculated for each food item. The mean conversion equation 3. Finally, the same conversion factor was used
factor of 15 food items was averaged and a single to estimate the volume of each food item.
conversion factor was determined. The same conversion
factor was later used to estimate the volume of each (3)
food item.
Volume Evaluation from Surface Images: The outline Statistical Analysis: A paired samples t-test and the
images of each food item as shown in Fig. 2 (IV) were mean difference confidence interval approach were used
used to calculate volume using the disk technique [11]. to compare the volume determined from image processing
Fig. 4: Revolving each element around the x-axis generated cylindrical disks
Each two-dimensional outline image of food item was
elements as shown in Fig. 3. Revolving the height of each
i
equal to the cross sectional area of the disk (A_i) times the
thickness of the disk (x). Equation 1 shows the
cross-sectional area of a cylindrical disk and equation 2
shows the volume of the same disk.
(1)
(2)
The program developed in COMPAQ VISUAL FORTRAN considered each disk as having a thickness of
disk. Using the mean diameter, the volume of each disk

method with the water displacement method. The standard deviation of the volume differences was
The Bland-Altman approach [12] was also used to plot the 237.4 cm . A plot of the volumes determined by image
agreement between food item volumes determined by processing method (IPM) and water displacement method
image processing method with the water displacement (WDM) with the line of equality (1.0: 1.0) is shown in
method. The statistical analyses were performed using Fig. 5. As shown in Fig. 6, the volume differences between
MICROSOFT EXCEL. image processing and water displacement methods were

RESULTS AND DISCUSSION comparing these two methods were calculated to be -546.4
Dimensional Calibration Results: The dimensional food item, the volume estimated by image processing is
calibration was determined by measuring food item less than the volume measured by water displacement
length, major diameter and minor diameter in millimeters (WDM-IPM > 0). As the size of food item increases, the
using a digital caliper and determining these parameters in image processing method overestimates the volume
pixels using image processing from the outline images. (WDM-IPM < 0). This is because of the change in
The dimensions measured with the digital caliper and with distance between the digital camera and the food item
image processing are demonstrated in Table 1. From the surface. Although the distance between the digital camera
digital caliper and image processing measurements, a and the measurement table is constant, the distance
conversion factor of 1 pixel to 1.62 mm was determined. between food item and the digital camera reduces with
This conversion factor was used to estimate the volume increasing food item size.
of each food item using image processing. The average percentage difference for volume
Comparison of Image Processing Method with Water was 7.60%. As in this study image processing method
Displacement Method: The paired samples t-test results was based on the assumption that each food item was

(Table 2) showed that the volume determined with image axisymmetric in shape, the accuracy of the determining
processing was not significantly different from the volume volume depended on the uniformity of the fruit having the
measured with water displacement (P = 0.207). The mean presumed shape. If we do not take into account
volume difference between the two methods was -81.1 cm misshapen food item, ^{3} which are not axisymmetric in
(95% confidence interval: -212.5 and 50.4 cm^3). shape, image processing provides an accurate, simple,
^{3}
normally distributed and the 95% limits of agreement in
and 384.3 cm^3. Fig. 6 also shows that for small-sized
estimation with image processing and water displacement

Table 1: Mass, dimensions and volumes of food items used in this study

Sample number	Mass (g)	Dimensions: Length (cm) with digital caliper	Dimensions: Major diameter (cm) with digital caliper	Dimensions: Minor diameter (cm) with digital caliper	Volume (cm^3) Water displacement method	Volume (cm^3) Image processing (pixel)	Major Length (pixel)	Minor diameter (pixel)
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

Table 2: Paired sample t-test analyses on comparing 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

Fig. 5: Food item volume measured using water displacement method (WDM) and image processing method (IPM) with the line of equality (1.0: 1.0)

Fig. 6: Bland-Altman plot for the comparison of food item volumes measured with water displacement method (WDM) and image processing method (IPM); outer lines indicate the 95% limits of agreement (-546.4, 384.3) and center line shows the average difference (-81.1).

rapid and non-invasive method to estimate food item
volume and can be easily implemented in monitoring
growth development under various management
practices, estimating the weight of individual food item
and sorting of food item during postharvest processing.

CONCLUSIONS

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

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