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FULL LENGTH ARTICLE

Study on an automatic sorting system for Date fruits

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Abstract In the present study, a machine vision based, online sorting system was developed, the aim being to sort Date fruits (Berhee CV.) based at different stages of maturity, namely Khalal, Rotab and Tamar to meet consumers' demands. The system comprises a conveying unit, illumination and capturing unit, and sorting unit. Physical and mechanical features were extracted from the samples provided, and the detection algorithm was designed accordingly. An index based on color features was defined to detect Date samples. Date fruits were fed on a conveyor belt in a row. When they were at the center of the camera's field of view, a snapshot was taken, the image was processed immediately and the maturity stage of the Date was determined. When the Date passed the sensor, positioned at the end of the conveyor belt, a signal was sent to the interface circuit and an appropriate actuator, driven by a step motor, was actuated, leading the Date toward an appropriate port. For validation of proposed system performance, entire samples were again sorted by experts visually. Detection rate of the system for Tamar and Khalal was satisfactory. Although the detection rate was insufficient for the Rotab stage, there was no a significant difference between system accuracy and that obtained by the experts. The speed of image processing system was 0.34 s. System capacity was 15.45 kg/h.

1. Introduction

Date is one of the non-oil export products of Iran that can play an important role in the country's economy. Every component of Date, such as flesh, stone, leaf, etc. can benefit the food supply chain if processed properly (Rohani, 1988).

Ripening process of the Date includes four principle stages, namely; Kimri (immature), Khalal (changing color, not mature), Rotab (mature) and Tamar (ripe) stages. In general, fruits at the Khalal stage are ready to market as "fresh" fruit but this is true only for those cultivars that are sweet, with a low amount of tannin and low astringency (Barreveld, 1993). Some of Date cultivars are suitable for marketing at the Khalal stage including "Barhee", "Bereim", "Hayany" and "Khalas" among which, Barhee is the most popular cultivar worldwide

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(Mortazavi et al., 2007). The Khalal fruits that usually harvested at the end of July are highly perishable and must be transported to the market as soon as possible (Glasner et al., 2002). Any transport delay or improper storage conditions may result in quick appearance of Rotab spots and surface wrinkling, accompanied by a loss of flavor and taste. Since, a Date fruit in the Khalal stage is physiologically mature, it would be very perishable if it contains moisture over 50% and undergoes fermentation (alcoholic) resulting from the microbiological activity. This is considered a limiting factor in terms of product marketing and storage (Mortazavi et al., 2007). Packing Dates at different stages of maturity, i.e. Khalal and Rotab, in a same package is not recommended because of adverse mutual effects; Paying attention to the consumer's life style is a prerequisite of the good marketing. For example, Khalal in the Barhee cultivar is more desirable in the south of Iran, whereas Rotab is more desirable in the north of Iran. Manual sorting method of Date fruits, currently practiced in Iran, is time consuming and costly. Also it relies on labor skills and its accuracy is affected by numerous factors, such as labor fatigue. To overcome these shortcomings, increase in the sorting efficiency, improving product quality and conserving energy, automatic sorting systems have been employed by a number of researchers. Hobani et al. (2003) developed a neural network classifier for Date fruit varieties using some physical attributes. Ismail and Al-Gaadi (2009) developed an electronic sensor for Date fruit sorting based on moisture content. Al-Janobi (1998) used the Co-occurrence matrix method to grade the Date. Fedal (2008) identified the Date varieties and did sugar content estimation by color analysis. Also he studied Probabilistic Neural Network (PNN) techniques and succeeded in developing an object classifier (Fedal, 2007). Picus and Kalman (2000) proposed an adaptive grading approach for Date fruits by ''prototype populations''. Lee et al. (2010) evaluated Date fruit quality using color mapping. Calpe et al. (1996) presented low cost machine vision system for fruit grading. Abdulrahman and Al-Janobi (2000) developed a color computer vision system consisting of a microcomputer together with an image frame grabber and a CCD color camera for sorting and grading Saudi Dates (Sifri variety).

In the present article, a new color space for grading Date fruit is proposed based on maturity stages. The Objectives of this work were:

i. Grading Dates according to consumer desire,
ii. separating Khalal from other Date fruits to avoid its deterioration due to the enzymatic activity of Khalal, and
iii. Performing the sorting task objectively by machine vision instead of a manually subjective sorting system.

2. Material and method

2.1. Selection of illumination and capturing system

To select an appropriate combination of illumination and capturing devices, two types of illumination sources were used, namely Power LED 12 V DC and fluorescent lamp examined in combination with two models of camera namely Proline and Telecam (No. Nck 41CV). A dome shaped lighting box was developed. Six Power LEDs were powered by a 12 V DC source, and a circular 40 cm diameter Fluorescent lamp was powered by 220 V AC source. The images were captured according to standard RAL white card, 10 replications per combination of camera/light source. The RGB values of images were extracted by Image processing toolbox of Matlab software. These values were then compared with standard card value i.e. 255 by SPSS software.

2.2. Design of feeder system

To convey fruits into a paddle wheel feeder, a 300 cm long and 45 cm wide belt conveyor was made and installed at 70 cm height off the floor. An inverter driven half a horsepower electro-gearbox was used for driving the conveyor. Inverter was set to 15 Hz so that the belt speed of 22.6 m per minute was acheived.

2.3. Design of electronic interface and actuators

Fig. 1 depicts the diagram of the sorting system. The images captured by camera were recalled immediately to the workspace of Matlab. The detection algorithm identified a stage of maturity for individual Date fruits within 0.67 s in average. Then the results from the detection algorithm were sent to the interface circuit. An optical sensor (Autonics, model BEN5M-MFR) was placed 2–3 cm away from the paddle wheel feeder, in such a way that it was able to sense the presence of passing fruit. A signal from the sensor was then sent to the actuator to activate a paddle wheel feeder in an appropriate time to move a fruit toward the right exit port. If detected fruit was raw (Khalal), then step motor 1 opened the normally closed port and the fruit dropped out of port (Fig. 2). If detected fruit was semi ripe (Rotab), step motor 2 rotated the paddle wheel by 90°CW (Fig. 2). If the fruit was completely ripe (Tamar), step motor 2 rotated the paddle wheel 90°CCW. Fig. 3 illustrates the prototype sorting system of Date fruits.

2.4. Detection algorithm

A comprehensive study of the physical properties of Date is necessary to develop appropriate sorting technologies. In this study, the Date fruit samples were selected randomly from the Barhee cultivar from the Date Research Institute in Ahvaz (located in the south of Iran). The samples were at 3 stages of maturity namely Khalal, Rotab and Tamar. The fruits were taken to a Laboratory. Both, offline and online experiments were carried out. During offline experiments for every stage, 50 samples were selected at random for feature extraction. The images of samples were captured by Telecam No.Nck 41CV and saved in a personal computer for processing. To simplify the algorithm, the size of the images were reduced

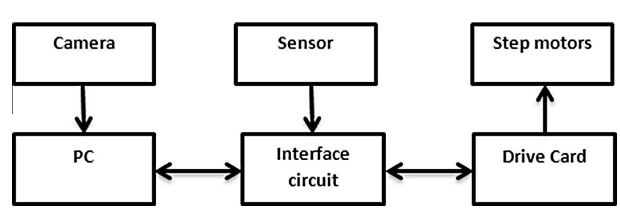

Figure 1 Schematic of sorting producer of Date fruit.

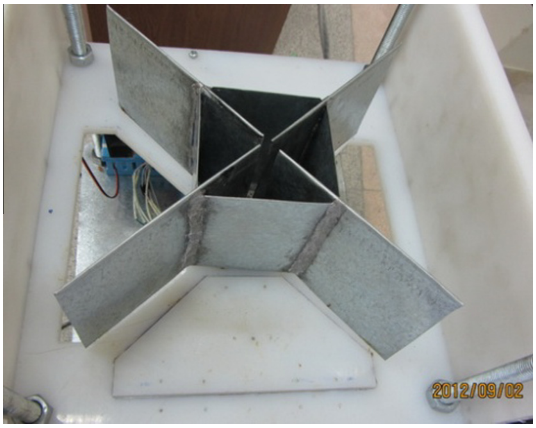

Figure 2 Top view of paddle wheel and a normally closed port used in the Date fruit sorting system.

Figure 3 A prototype sorting system for Date fruits.

from 883 * 556 to 300 * 300 pixels. Then the backgrounds of the images were removed. Color and textural features of objects such as contrast, entropy, nth moment and homogeneity were extracted by image processing toolbox of the Matlab software. Then each parameter was analyzed by statistical methods in the SPSS software. At the end, those parameters which were significantly different were selected to accomplish the sorting task. Among the investigated features, the color feature was significantly different from other parameters; so an index based on color components i.e. Red, Green and Blue was defined for detection algorithm. In order to compute the coefficients of each component of an index, the Taxonomy method was used. Taxonomy is a classification method on the basis of a multivariate analysis of observable differences and similarities between taxonomic groups. Classifications based on numerical taxonomy reflect degrees of evolutionary relationships.

During online experiments, 100 samples of fruits for each maturity stage were selected at random. Samples were fed onto a conveyor belt in a row. The speed of the conveyor belt was not controlled by a micro controller. There was a sensor before the illumination box; whenever the fruit passed the sensor, just after a pause, a snapshot was taken and the real time captured image was recalled to the workspace for processing. The size of the images was reduced to 300 * 300 pixels. Since the inverter imposed some noises on images, so the images were filtered by average filtering (Fig. 4). Then the images were processed according to the algorithm set up (Fig. 5).

2.5. Validation of sorting system

All the samples sorted by machine vision were re-sorted by 3 experts visually. The results from experts and machine vision were compared by the *t*-test.

3. Results and discussion

There were 4 combinations of light sources i.e. 12 V DC power LED and Fluorescent and cameras i.e. Telecam and Proline with 883 * 556 resolutions. Since the pixel values of standard white card were 255, 255, 255 for red, green and blue components respectively, to obtain a good quality image, the best combination of light source and camera should have the ultimate pixel value of 255. According to Tables 1–3, it is evident that LED along with Telecam was the best combination for red, green and blue components, because differences between obtained values with 255 are not significant.

Pourdarbani et al. (2008) investigated four types of light sources namely Halogen, Incandescent, Fluorescent and Miniature 3 mm LED. They found that miniature 3 mm LED gave the best results; however since the miniature LEDs were originally powered by an AC source, they could not obtain a constant output as DC battery. As a matter of fact, although the input voltage to miniature LED was DC (see Fig. 7), but as seen in Fig. 6, the voltage varies in harmony with AC source frequency. This means that, if a snapshot occurs at the peak voltage only, it will produce high quality image. See Fig. 6.

At the beginning of experiments offline tests were carried out for the determination of features for Date fruits at different stages of maturity. Color and textural features for 50 samples per stage were extracted by image processing with the Matlab software. This showed that color features were

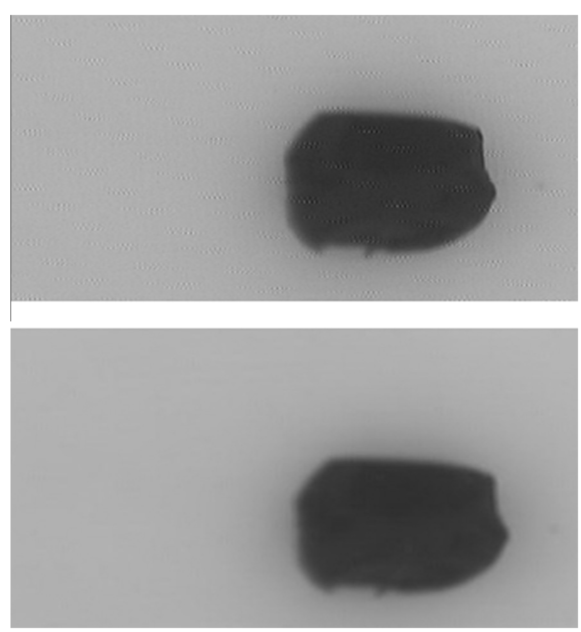

Figure 4 Top: original noisy image, bottom: filtered image.

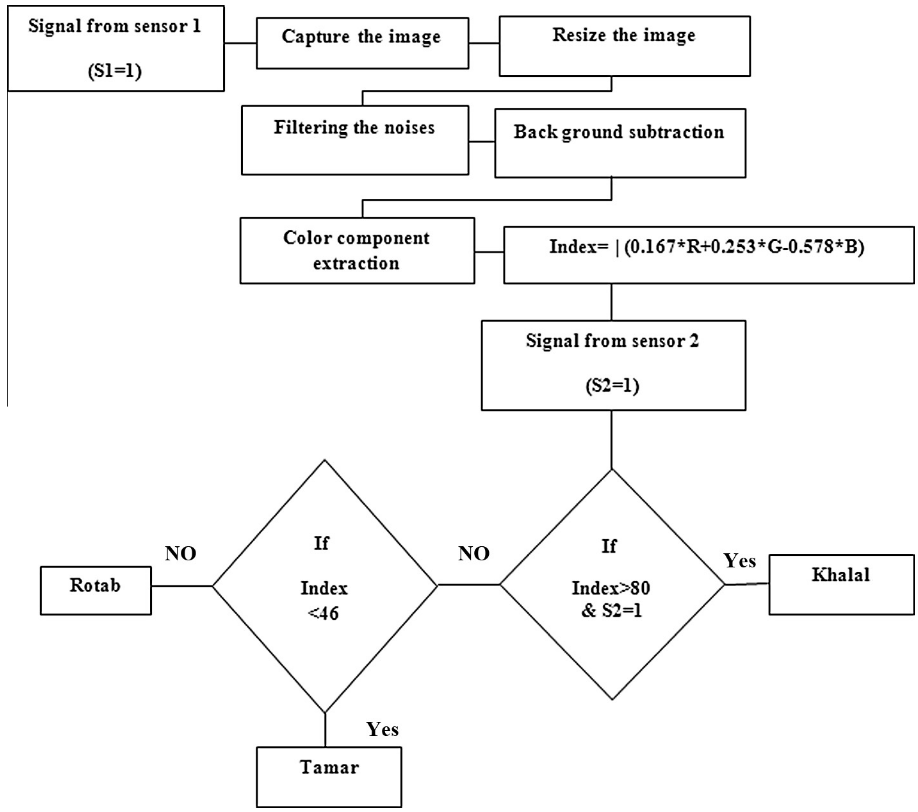

Figure 5 Flowchart of Date fruit sorting based on maturity stages.

Table 1 Mean pixel values for the Red component.

Camera	Light	*N*	Mean value	Std. deviation
Telecam	Flourescent	10	245.3463	3.06954
	LED	10	*254.8302*	.30109
Proline	Flourescent	10	143.1332	1.80798
	LED	10	188.5333	12.87662

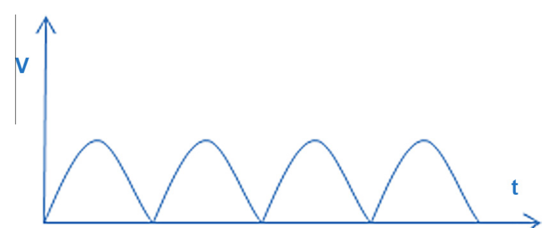

Figure 6 The nature of DC voltage output from AC to DC transformer.

Table 2 Mean pixel values for the Green component.

Camera	Light	*N*	Mean value	Std. deviation
Telecam	Flourescent	10	246.506	3.18821
	LED	10	*254.8443*	0.265
Proline	Flourescent	10	137.939	2.94295
	LED	10	185.5667	17.05405

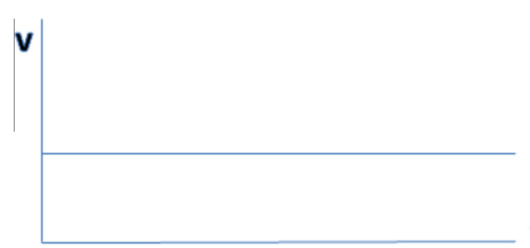

Figure 7 A nature of DC voltage output from 12 V DC battery.

Table 3 Mean pixel values for the Blue component.

Camera	Light	*N*	Mean value	Std. deviation
Telecam	Flourescent	10	234.7146	4.39468
	LED	10	*254.7175*	.39107
Proline	Flourescent	10	123.0709	2.72098
	LED	10	193.1000	19.597

significantly different at 3 different maturity stages (Tables 4–6). Therefore, the coefficients of color components were computed by the Taxonomy method. Coefficients for Red, Green and Blue were 0.167, 0.253 and 0.578, respectively.

It is worth mentioning that processing time is the key element in online applications. For example in the present

Table 4 Result of Duncan test for the Red component.

Treatment	*N*	Subset for alpha = 0.05		
		1	2	3
Tamar	50	136.8507		
Rotab	50		150.0335	
Khalal	50			204.6601

Table 5 Results of the Duncan test for the Green component.

Treatment	*N*	Subset for alpha = 0.05		
		1	2	3
Tamar	50	106.4310		
Rotab	50		116.4903	
Blue	50			179.9518

Table 6 Results of the Duncan test for the Blue component.

Treatment	*N*	Subset for alpha = 0.05	
		1	2
Khalal	50	85.4513	
Rotab	50	86.3799	
Tamar	50		92.9505

research, K-means method was used for Date fruit detection. It was not only time consuming (was) but also it could not detect the Dates correctly, while the processing time for the proposed method was 0.34s and it was more successful (Figs. 8 and 9).

Fig. 10 illustrates few samples of Dates at different stages of maturity. Note that Tamar and Rotab on the verge of Tamar look alike; this may lead to misclassification. At these kind of situations, even for human eyes, differentiation may not be possible.

In order to validate the proposed online system, the same samples were visually re-sorted by 3 experts. They did not use their sense of touch. The results of the online sorting system and experts are illustrated in Tables 7 and 8. The comparisons between human vision and machine vision are given in Table 9. As it is revealed from Table 9, human vision and machine vision did not have significant differences except for the Rotab stage. The principle reason for misclassification of the Rotab stage is that a Rotab starts to change its skin color from the top of the fruit down to the perianth (connection point to the tree), and this color change may have different intensities on two faces of a fruit (Fig. 11). So results will depend on which side is in front of the camera. In proposed sorting system fruits were not rotated in front of the camera, therefore, some errors occurred in the Rotab samples where images were captured from the face that had less color change compared to that of the other face, so they were misclassified as a Khalal. Also there was an error at the Khalal stage that was sorted as a Tamar in replication 1. The error occurred due to rolling of the fruit out of the camera's field of view on the conveyor belt; so the back ground image was captured and after back ground removal, the black image was produced. Since a pixel value of black was zero, it was recognized as a Tamar.

Since the receptors of a camera are less than receptors of a human eye (rods and cones of eye) so the eye can certainly recognize the details more precisely than camera. However, shortcomings of subjective judgment by labor, high cost of labor and fatigue, all make utilization of technologies such as machine vision unavoidable.

With respect to the obtained results, there were no significant differences between machine and human vision at the

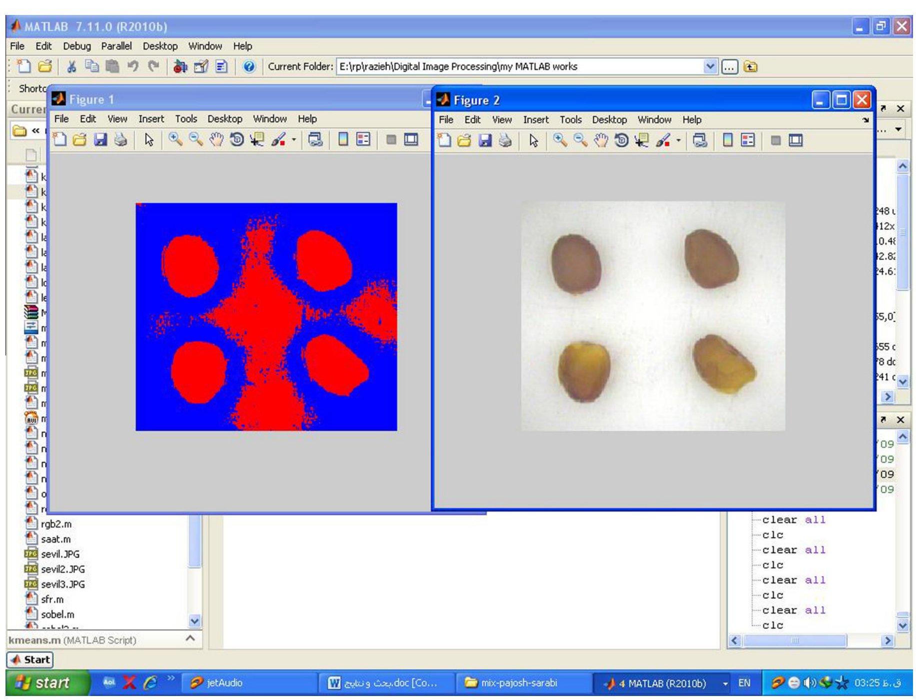

Figure 8 Results of K-means method in Date sorting.

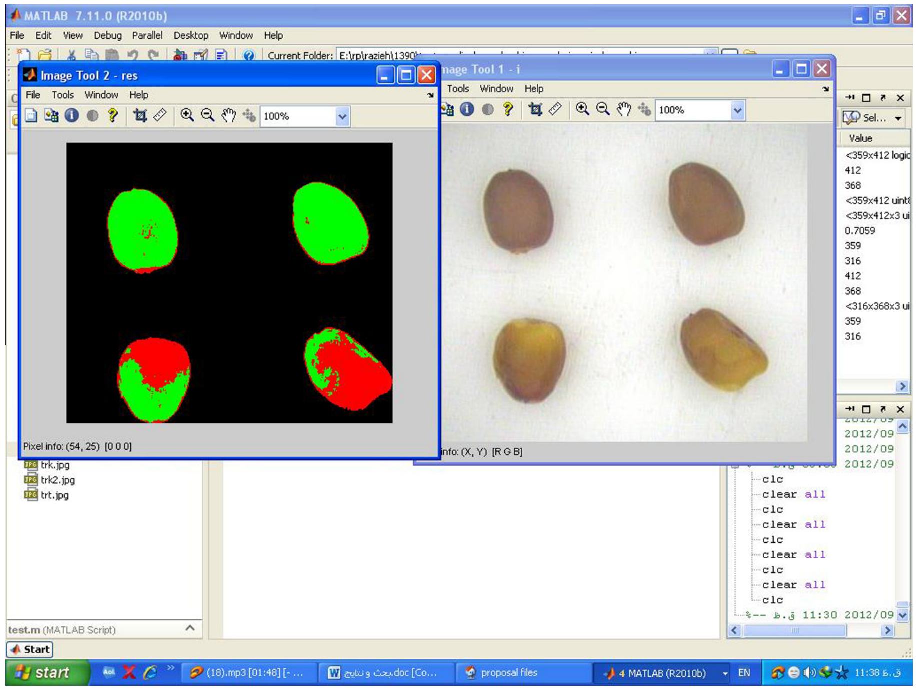

Figure 9 Results of the proposed method in Date sorting.

Figure 10 Samples of Dates at different stages of maturity.

Tamar stage sorting. The accuracy of sorting machine vision and human vision were 100% and 99%, respectively. Therefore the performance of proposed system was satisfactory. Although the detection rate of sorting of Rotabs on the verge of Tamar was not very satisfactory (65.33% for human vision and 56.66% for machine vision), but differences between

Table 7 Detection rate of the proposed Date sorting system during 3 replications.

Treatment	Repeat 1	Repeat 2	Repeat 3	Detection rate
Tamar	100	100	100	100
Rotab on the verge of Tamar	57	56	57	56.66
Rotab	98	97	96	97
Khalal	99	100	100	99.66
				88.33%

Table 8 Detection rate of Date sorting by experts.

Treatment	Expert1	Expert2	Expert3	Detection rate
Tamar	99	98	100	99
Rotab on the verge of Tamar	71	59	66	65.33
Rotab	100	100	100	100
Khalal	100	100	100	100
				91.08%

Table 9 Comparison between human vision and machine vision.

Treatment	Detection rate for machine vision	Detection rate for human vision	t-test at $\alpha = 0.05$
Tamar	100	99	0.158^{ns}
Rotab on the verge of Tamar	56.66	65.33	0.068^{ns}
Rotab	97	100	0.007^{*}
Khalal	99.66	100	0.374^{ns}

ns: no significant differences at $\alpha = 0.05$
* There are significant differences at $\alpha = 0.05$.

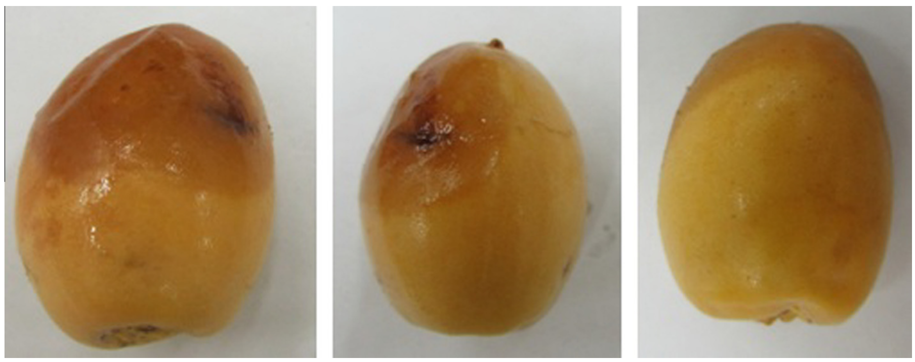

Figure 11 The images of different faces of a Rotab sample at 360° rotation.

results obtained from the machine vision system and the manual method were not significant. This means that an insufficient detection rate is not related to the weakness of the proposed system. In order to enhance the system, other technologies which use the sense of touch can be used, because the prime difference between Tamar and Rotab on the verge of Tamar is the softness of texture that cannot be sensed by machine vision. The accuracy of sorting in the Khalal stage for machine vision and human vision was 99.66% and 100%, respectively and differences between human and machine vision were not significant. Therefore the performance of the proposed system was satisfactory, bearing in mind that, detection of all Khalals accurately was one of our objectives. The accuracies of machine vision and human vision for sorting the Rotab stage were 97% and 100%, respectively and differences between human and machine vision were significant. The reason for misclassification of the Rotab stage was mentioned before (see Fig. 11). Lee et al. (2008) succeeded in obtaining a detection rate of 74.53% for yellow-head (Rotab) Date fruits. Therefore some improvement in algorithm is needed; otherwise some modification is necessary in the conveyor section of the system in such a way that all sides of a fruit could be exposed to a camera.

4. Conclusion

The performance of the proposed system was satisfactory in terms of sorting Tamar and Khalal. But an accuracy of the system for the detection of Rotab was insufficient. It is recommended that other varieties of Date are to be investigated. Also it is recommended to use more samples and replications to ensure repeatability of the system.

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