IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 9, Issue 11 Ver. I (Nov. 2016), PP 41-47
www.iosrjournals.org

A New Design of Olive Fruit Sorting Machine Using Color Image Processing

Akif Birol Dumanay[1], Raif Sakin[2], Ayhan İstanbullu[3]
[1]*(Edremit Vocational School, Department of Computer Technologies / Balıkesir University, Turkey)*
[2]*(Edremit Vocational School, Department of Mechanical and Metal Technologies / Balıkesir University, Turkey)*
[3]*(Computer Engineering Department, Engineering Faculty / Balıkesir University, Turkey)*

Abstract: *The food industry relies on a rapid and accurate separation and classification of fruits immediately after harvest before spoilage sets in. This study developed a prototype machine for olive fruit separation with image processing technology, founded on the changing hues of the olive fruit according to their level of maturity. The operating principle of the machine was based on a fruit-recognition software development using a USB3 camera functioning at 120 frames/s. Separation of the desired fruit is determined by first obtaining the color pattern from the camera image, which is then sent to the selected pattern as a clipboard and template. Detection of the fruit is then performed by comparing the color pattern of the fruit falling from a horizontal conveyor with the sinking color pattern, and location coordinates at the time of fall are determined. For image processing, an appropriate software parallel to our aim has been developed, establishing an algorithm through LabVIEW vision development. Digital output ports of a USB 6008 DAQ card were used to control the pneumatic valves. For lighting, the white LEDs were positioned at a particular angle. The separation process used pneumatic valves with a 1 ms response time. During the separation process, optimum values were determined for the primary parameters, such as the fruit falling angle with respect to the belt speed, pneumatic valve position and ideal camera angle. This prototype machine was determined to have a 98% success rate in separating olive fruit.*
Keywords: *Fruit color sorting, image processing, pattern matching*

I. Introduction

Fruit processing in the fruit industry is highly sensitive to time and speed. Thus, it is of great importance to select and separate fruits rapidly after harvest. Feng and Qixin (2004) studied an image processing system that could be used to separate fruit at high speeds. In this fruit separation process, the color tones of fruits were considered as a classification quality. The fruit separation process used Bayes classifier by applying the parameters obtained from another study. This separation system was tested on Crystal Fuji apples and an average 90% success was achieved. Zhang et al. (2014) studied a real-time algorithm, to automatically evaluate the quality of fruit surface. The approach relied on short-wave infrared imaging, obtaining satisfactory results with good image processing. The final quality grade of fruit in this study was defined according to the fruit size and the percentage of delaminated skin. An experiment was performed in a packing facility in Arizona, USA. Testing results showed the proposed method achieved a 95–98% grading accuracy for various grades. Yogitha and Sakthivel (2014) studied a computer-aided vision system for fruit sorting and grading at high speed. The development work involved dynamic capturing of an image signal from a camera when the objects were moving on a conveyor in real-time, based on synchronized trigger events. This process involved estimating color knowledge and geometrical parameters using library functions, such as filtering, histogram, color values, pixel averaging, dilate, erode, smoothing, filling, noise removal, detection of edges, and deblurring. Afkari-Sayyah et al. (2014) and Azarmdel et al. (2014) used image processing to classify olives as defective and sound, according to an artificial vision field (RGB and HSV color coordinates) and L*a*b* objective color parameters. Also, two types of lighting methods were used to investigate the effects of lighting on separation. Illumination based on fluorescent lamps (90%) was better at extracting the color parameters of the olive fruit than the light-emitting diode lamps. Eissa and Khalik (2012) developed a machine vision technique based on image processing techniques to estimate the quality of oranges and tomatoes based on their size, color, texture, and external blemishes. Moreda et al. (2009) reviewed various non-destructive electronic technologies capable of measuring fruit volume to determine the size of fruits and vegetables. It is challenging to develop a process that can accurately separate fruits based on their 3-D image and color. However, one of the most promising technologies in this area is 3-D multispectral screening. This approach links multispectral data with 3-D surface reconstruction, from which fruit volume and surface area can be calculated with a high accuracy. Riquelme et al. (2008) classified damaged olives into eight groups by using image analysis, considering the external appearance of the skin as the most decisive factor in determining the fruit quality. For the sound and damaged fruits, three aspects, including size, color, and morphology were analyzed. The application of three consecutive discriminant analyses resulted in the correct classification of 97 and 75% of olives during calibration and validation, respectively. However, these values varied widely, depending on the categories, ranging from 80-100% during calibration and 38-100% during validation. Blasco et al. (2007) proposed a region-oriented segmentation algorithm to define the common defects of citrus fruit peel that was tested on various varieties of oranges and mandarins. Assuming that most of the fruit surface corresponds to sound peel, the proposed algorithm was able to detect 95% of the defects evaluated correctly. Du and Sun (2006) highlighted the potential of learning techniques using computer vision, with a particular focus on artificial neural network, for food quality evaluation. Table olives are classified according to surface defects. However, the characteristics of each category are not defined. Thus, learning algorithms must be used to extract the quality information from batches previously classified by expert workers. Diaz et al. (2004) compared three algorithms to classify table olives into four categories by computer vision. The results showed that a neural network with a hidden layer could classify the olives with an accuracy of over 90%, while partial least squares discriminant and Mahalanobis distance were over 70%. Blasco et al. (2003) studied a machine vision system developed for on-line estimation of fruit quality grading. The classification system was tested on-line with apples obtaining a good performance when classifying the fruit in batches, and a repeatability in blemish detection and size estimation of 86 and 93%, respectively. Karakoç and Kavaklioğlu (2015) proposed a method that could successfully match images and decrease search time when image searching within another image. Image searching within another image is accomplished through the integrated use of image matching techniques and searching algorithms. During olive processing, it is important to separate the fruit according to their maturity. With the present technologies, separation process can be done by hand on a conveyor or through image processing techniques. However, the current operations have an 80% success and suffer from several limitations.

Hence, this study aims to develop a prototype machine for identifying and sorting olive fruits according to their level of maturity (color) through the use of image processing techniques. The operation principle of the machine relies on developing a fruit identification software by using a high-speed camera to capture images of the fruit as they move on a conveyor belt. The separation process is to be achieved using pneumatic valves without damaging the fruits and fulfilled by identifying olive fruit in free falling point (from the conveyor belt) according to its real image.

II. Materials and Method

In this study, olives of mixed color (Figure 1) were poured onto a speed-adjustable conveyor belt. A high-speed camera with a frame rate of 120 frames per second captured the location coordinates from the 2D images of the olives as the fall time from conveyor belt through a canal exposed to LED light within the closed system. As the olive samples previously introduced to the system by the camera were detected, the air nozzles opened and closed to realize the separation process. A data acquisition (DAQ) card was used to control the system. Six air valves were controlled with 5 V. The conveyor speed was measured by an external rotary encoder for feedback. A LabVIEW-based proportional–integral–derivative (PID) controller was used to enable real-time DC motor speed control.

Figure 1. Image of harvested olives before color sorting

Figure 2 shows the olive sorting machine equipped with a color image processing technique, designed for this study. The prototype specifically intends to analyze the color and defects of both fresh and pickled black and green olives. For this study, four different groups of olive fruit, including green (9XL), black (5XL), red (XL), and green (M) were used for the tests. The sizes or calliper classes of the olives are given in Table 1. The sizes of olives in Turkey, based on the number of olives per kilogram are given in Table 2. The number of olives per kilogram increase by 50 after 410. The number of olives is inversely correlated to the size of the olive. As the olives increase in size, the number of olives per kilogram decreases. Two consecutive calibers can be used connectively (Turkish Official Gazette, 2014). In these tests, five different conveyor belt speeds, 0.518, 0.691, 0.749, 0.806 and 0.864 m/s were used, respectively. Moreover, in response to the 6-bar operation pressure, three different nozzle output diameters, 2, 3, and 4 mm (ØN) were tested for the exit pressure from the nozzle. The stable and variable parameters used in the experimental study are detailed in Table 3.

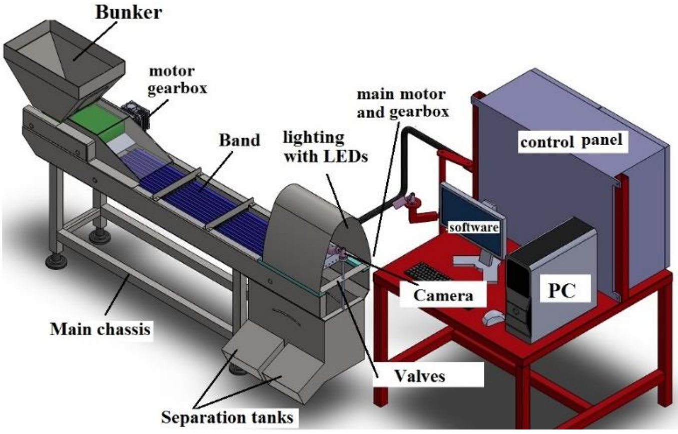

Figure 2. Design view of prototype of olive sorting machine

Table 1. The size of olives used in the tests (Turkish Official Gazette, 2014)

Olives	Color	Size	Number of olives per kg	Weight (g)	Dimension (mm) L x W
	green	9XL	89	11.217	34.5 x 22.5
	black	5XL	130	7.674	30.0 x 20.0
	red	XL	205	4.877	27.0 x 17.0
	green	M	267	3.747	24.0 x 15.5

Table 2. The size of olives, Turkish Official Gazette (2014)

Number of olives per kg	Size	Number of olives per kg	Size
60–70	11XL	181–200	2XL
71–80	10XL	201–230	XL
81–90	9XL	231–260	L
91–100	8XL	261–290	M
101–110	7XL	291–320	S
111–120	6XL	321–350	XS
121–140	5XL	351–380	2XS
141–160	4XL	381–410	3XS
161–180	3XL	…-…	…-…

Table 3. Technical features of olive sorting machine and the parameters used in the study

Parameter	Explanation
Operating voltage	220 V, 50 Hz
Total power	3 kW
Conveyor belt	With 6 canals, polymer material according to the FDA
Diameter of conveyor drum	55 mm
Camera	659x494 resolution, 120-frames/s speed, digital USB3
Camera angle	50–70 degree
Camera view range	50x150 mm, 250x750 pixel
PC	Windows Operating System, 4 ms detection speed
Data collection card	NI USB 6008 DAQ
Operating speeds	180–240–260–280–300 rpm
Conveyor belt speed	0.518–0.691–0.749–0.806–0.864 m/s
Pneumatic pressure connection	8 bar
Operating pressure	6 bar
Valves	6 items, pneumatic jet valve, 1000 induction/s
Air source	700 l/min
Flow rate	100 l/min
Nozzle output diameters (ØN)	2–3–4 mm
Machine weight	200 kg
Operating temperature	10–45°C
Sorting choices	Color sorting with 2 exits
Network	Remote control opportunity with internet connection
Capacity	1.5 ton/hour
User	Designed for small- and medium-scale enterprises

The image matching process included in the image processing techniques searches the location of a piece of image in another image. According to the pattern matching, which is one of the image matching methods included in digital image processing, a pattern image can be searched in an image and the locations of pattern images can be detected.

In this study, fruit identification software was developed via high-speed cameras. Color patterns from the defined locations on olive fruit were taken and saved in the study. Then, the saved patterns were searched and detected on the camera images that captured the olives falling from the conveyor belt. Olives instantaneously detected are interfered with by pneumatic valves having a response time of 1 ms. In this way, an olive grain whose flow direction is changed with pressurized air becomes separated from the other olives.

A photograph of the olive sorting machine is shown in Figure 3. This fruit sorting machine will be produced in Turkey. It is intended for small and medium-scale enterprises in Turkey to replace impractical and expensive imported machines while enabling a simpler and more cost-effective operation with improved accuracy rate. The pattern and color identification interface image of the program used in the study is given in Figure 4. Based on the fruit image, identification of the desired color tone and sensitivity degree can be saved by the developed software. With this method, sorting can be achieved at high sensitivity, and the success rate of the process is 98%. The user interface of software for olive sorting machine is shown in Figure 5.

Figure 3. Photograph of the olive sorting machine

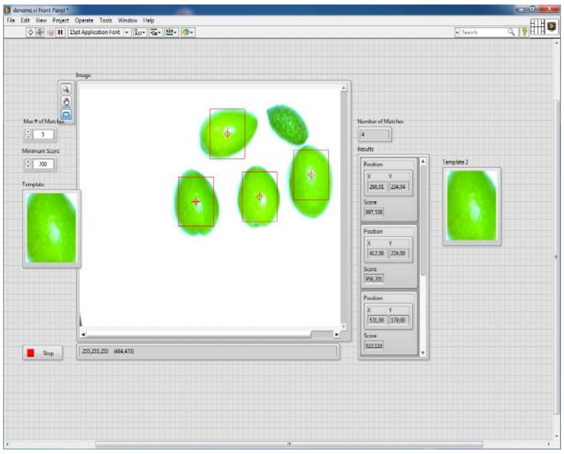

Figure 4. Pattern and color identification interface of software

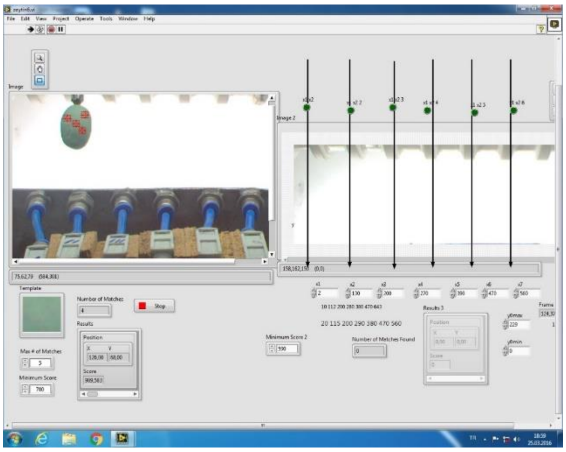

Figure 5. User interface of software

The average success rate of the sorting operation achieved with the conventional olive sorting machines is 80%. Under these circumstances, the rate of success must be increased. Essentially, the sensitivity of a particular image processing technique depends on the sorting software. The software used in this study obtains pattern recordings from the desired point or area on the real fruit image. The recorded image is compared with the camera images of all fruits moving on the conveyor belt. If the olive pattern matches the saved pattern, the olive is pushed into a second chamber by compressed air from the jet valve nozzle. The task of the pneumatic valve is to change the direction that the olive falls by blowing air over the olive at 6 bar in 8 ms. In this way, desired fruit color tones are collected in a separate chamber. The success rate of this sorting method increased by the sensitivity of color tones of the olive can be adjusted to 1/1000. The desired sensitivity rate can be selected in the fruit identification system using this method. Moreover, comparisons can be performed using the color codes from each point of a fruit image. Besides offering a potential alternative to manual separation processes performed using a traditional approach, the prototype in this study provides an innovative process for factories working at high capacity. Figure 6 shows the camera and pneumatic system used in the research. Freshly harvested olives, which were separated through image processing, are shown in Figure 7.

Figure 6. High-speed camera and pneumatic valves

Figure 7. Separated the olives by image processing technique

1.1. Experimental Study

The prediction and calculation of the orbit of the fruit falling from the conveyor belt is an important aspect of this study (Figure 8). Hastie and Wypych (2010), and Hastie et al. (2010) made several experimental studies about the prediction and calculation of the N4 distance (refer to Figure 8). Also, the Xmax distance is one of the important parameters concerning the construction of the fruit sorting machine, because it refers to the distance between the pulley center and the nozzle blowing point. The time at which the compressed air contacts the olive fruit according to the belt speed, and maximum and minimum nozzle distance values measured as a result of our experimental study are given in Table 4.

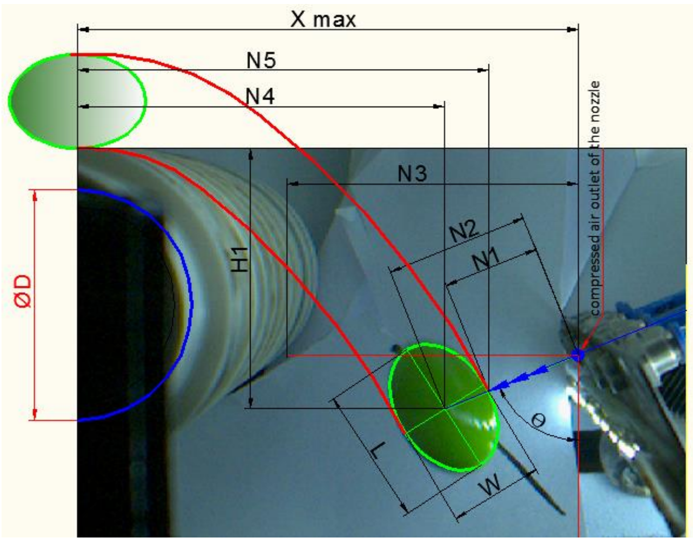

Figure 8. Basic dimensions (olive fruits falling from the belt and nozzle blowing photograph)

Table 4. Experimentally measured dimensions and effective parameters

Olives		ϴ	N1	N2	N3	N4	N5	H1	Nozzle distance (Xmin= N5)	Nozzle distance (Xmax=N5+30)
		(°)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Green (9XL)										
Belt speed (m/s)	0.518	68	23.2	34.5	70.0	88.2	99.0	62.2	99.0	129.0
	0.691	68	12.4	23.7	70.0	97.6	108.0	51.3	108.0	138.0
	0.749	67	6.9	21.3	70.0	100.1	113.3	50.9	113.3	143.3
	0.806	66	6.6	18.7	70.0	103.3	114.4	64.3	114.4	144.4
	0.864	66	2.5	15.8	70.0	106.0	118.2	49.9	118.2	148.2
Black (5XL)										
Belt speed (m/s)	0.518	68	26.8	36.0	70.0	85.2	93.6	56.2	93.6	123.6
	0.691	70	16.1	26.9	70.0	93.8	103.9	51.4	103.9	133.9
	0.749	67	12.2	23.1	70.0	97.3	107.2	51.3	107.2	137.2
	0.806	66	9.1	20.0	70.0	102.2	112.2	63.6	112.2	142.2
	0.864	66	6.0	18.2	70.0	103.9	114.9	65.0	114.9	144.9
Red (XL)										
Belt speed (m/s)	0.518	68	30.5	39.1	70.0	82.6	90.5	63.6	90.5	120.5
	0.691	69	20.6	28.0	70.0	90.9	97.2	52.4	97.2	127.2
	0.749	68	17.2	25.0	70.0	93.9	99.7	52.0	99.7	129.7
	0.806	65	15.6	24.5	70.0	97.8	105.8	65.7	105.8	135.8
	0.864	63	10.6	19.5	70.0	103.0	110.9	66.2	110.9	140.9
Green (M)										
Belt speed (m/s)	0.518	67	32.1	40.0	70.0	82.3	90.2	57.9	90.2	120.2
	0.691	67	23.6	31.3	70.0	87.9	94.9	65.8	94.9	124.9
	0.749	66	19.6	27.5	70.0	92.2	98.4	65.7	98.4	128.4
	0.806	65	17.1	24.9	70.0	97.4	104.7	67.9	104.7	134.7
	0.864	67	12.7	21.1	70.0	99.6	108.3	48.5	108.3	138.3

1.2. Comparison of the Developed System with the Present Technology

Comparisons between the olive color sorting prototype machine with the image processing system developed in this study and the present technology are detailed in Table 5.

Table 5. Comparison of the prototype olive sorting technology with the present technology

Conventional Systems	Developed System
The software generally identifies the color code of olive fruit on the camera image (RGB). The software detects and sorts the color codes (RGB) identified by the user's choice from the color scale present on the fruit grains. Under these conditions, a new identification is required for each region and each batch of products.	The user shows the desired olive grain to the camera once and enters a sensitivity code on the appearing screen. The user can change the desired sample for each fruit batch. Using this method, a new identification is not required for each region and each batch of products.
The olive grain moving on the conveyor is detected by the image processing technique using the RGB code and, via assigning the sorting time, is chosen by the pneumatic valves at the time of fall from the conveyor.	The system detects the olive grain in the space while falling from the conveyor belt. The sorting process operates at the desired sensitivity by determining the pattern, color or template on the fruit grain.
The system requires a contrast between the base color and the olive grain color for the color toning. Thus, the color of the conveyor belt should be clean and stainless. Worn and dirty belts must be changed annually. Thus, the business manager incurs an additional cost.	The system compares the point or regional images from the grains with the real images. Thus, the sorting process operates with high accuracy because the color ranges of each fruit group are identified in the system. Therefore, there is no need for different conveyor features and belt colors, minimizing the service requirements of the system.
The interfaces used in the present sorting system programs are quite complicated. It is difficult for the users to make adjustments for different products. Thus, the stability and capability of the system depend on the operator's ability.	The software interface is easy and practical. The operator introduces the olive to be separated to the camera. A template image is chosen on the olive grain. The system starts to operate automatically.
During the operation of this system, high-speed LED flashers are used. Cameras detect the fruit via these blinking/flashing LEDs.	The lightening is sufficient for the camera to sense because the system image identification is performed.
The costs of the commercially available designs are relatively high.	This domestic design is more affordable compared to its similar commercial models.

III. Results

Separation of four different olive classes, calibrated as green (9XL), black (5XL), red (XL) and green (M), was achieved from the experimental studies. The optimum parameters and results were attained in response to the five different belt speeds (0.518, 0.691, 0.749, 0.806 and 0.864 m/s).

- For the green (9XL) olive class, the optimum nozzle distance was between 129.0–148.2 mm.
- For the black (5XL) olive class, the optimum nozzle distance was between 123.6–144.9 mm.
- For the red (XL) olive class, the optimum nozzle distance was between 120.5–140.9 mm.
- For the green (M) olive class, the optimum nozzle distance was between 120.2–138.3 mm.

- For all classes, the optimum nozzle blow angle (ϴ) was between 65–70°.
- As the output diameter of compressed air (ØNz) increases, the blowing pressure and blowing force decrease.
- As the blow distance N1 increases, blowing pressure and blowing force decreases.
- As the belt speed increases, N4 (the distance of the pulley center to the fruit's center of gravity), and N5 (the fruit's last point distance) increase while N1 and N2 (the blowing distances effected by the nozzle) decrease. These values are relevant data for a productive machine construction.
- The average time before contact is made between the fruit and the compressed air or time of entrance to the blowing range is 0.158 s.
- The minimum conveyor belt speed should be 0.518 m/s or 180 rpm. When it runs at speed lower than 0.518 m/s, the compressed air exiting from the nozzle cannot push the olive grain. This decreases the capacity and productivity of the machine.
- The maximum conveyor belt speed should be 0.864 m/s or 300 rpm. The olive grains crash into the nozzle when this value is exceeded. As the speed increases, the capacity also increases. However, the machine's productivity decreases.
- Apart from the variable parameters above mentioned, the mechanical system, camera, pneumatic system, jet valves, DAQ and PC, and its synchronicity and fast performance also affect the productivity and accuracy of the color sorting machine.
- The prototype developed in this study is ideal to improve the process and reduce the costs of production. Within an hour and with high accuracy, it can fulfill the labor done by 30 workers in a day.

1.3. Suggestion

In the studies of fruit image processing and color sorting, besides the developed algorithm and the technology to be used, the operator's knowledge and ability are also of importance. Integrating artificial intelligence systems into the pattern and template searching systems of the image identification operations to be used in olive sorting seems to increase the stability of image identification studies and improve the ease of use.

Acknowledgments

This study was supported by the Scientific Research Project of Balıkesir University, (Project Codes: 2015/24 and 2015/182)

References

[1] **Feng, G. and C. Qixin (2004).** Study on color image processing based intelligent fruit sorting system. 5" World Congress on Intelligent Control and Automation, Hangzhou, P.R. China.

[2] **Zhang, D., D.-J. Lee, B. J. Tippetts and K. D. Lillywhite (2014).** "Date quality evaluation using short-wave infrared imaging." Journal of Food Engineering 141: 74-84.

[3] **Yogitha, S. and P. Sakthivel (2014).** "A distributed computer machine vision system for automated inspection and grading of fruits." International Journal of Computer Science and Mobile Computing 3(4): 522-527.

[4] **Afkari-Sayyah, A.-H., H. Azarmdel, M. Rasekh and T. Mesri-Gundoshmian (2014).** "Discriminating defected and sound fruits of olive according to external damage area using image processing techniques." International Journal of Farming and Allied Sciences 3(6): 647-652.

[5] **Azarmdel, H., A.-H. Afkari-Sayyah, H. Ghaffari and A. Alipasandi (2014).** "Olive classification according to RGB, HSV and L*a*b* color parameters using image processing technique." International Journal of Farming and Allied Sciences 3(6): 653-658.

[6] **Eissa, A. H. A. and A. A. Abdel Khalik (2012).** "Understanding color image processing by machine vision for biological materials." Structure and Function of Food Engineering 227-274.

[7] **Moreda, G. P., J. Ortiz-Cañavate, F. J. García-Ramos and M. Ruiz-Altisent (2009).** "Non-destructive technologies for fruit and vegetable size determination – a review." Journal of Food Engineering 92(2): 119-136.

[8] **Riquelme, M. T., P. Barreiro, M. Ruiz-Altisent and C. Valero (2008).** "Olive classification according to external damage using image analysis." Journal of Food Engineering 87(3): 371-379.

[9] **Blasco, J., N. Aleixos and E. Moltó (2007).** "Computer vision detection of peel defects in citrus by means of a region oriented segmentation algorithm." Journal of Food Engineering 81(3): 535-543.

[10] **Du, C.-J. and D.-W. Sun (2006).** "Learning techniques used in computer vision for food quality evaluation: a review." Journal of Food Engineering 72(1): 39-55.

[11] **Diaz, R., L. Gil, C. Serrano, M. Blasco, E. Moltó and J. Blasco (2004).** "Comparison of three algorithms in the classification of table olives by means of computer vision." Journal of Food Engineering 61(1): 101-107.

[12] **Blasco, J., N. Aleixos and E. Moltó (2003).** "Machine vision system for automatic quality grading of fruit." Biosystems Engineering 85(4): 415-423.

[13] **Karakoç, M. and K. Kavaklioğlu (2015).** "Image searching within another image using image matching and genetic algorithms." Pamukkale University Journal of Engineering Sciences 21(5): 182-193.

[14] **Turkish Official Gazette (2014)**. Turkish Food Codex Notification No 2014/33 on table olives.

[15] **Hastie, D. B. and P. W. Wypych (2010).** "Conveyor belt trajectories - comparing predicted to experimental results." Bulk Solids Handling 30(8): 438-445.

[16] **Hastie, D. B., P. W. Wypych and P. C. Arnold (2010).** "Influences on the prediction of conveyor trajectory profiles." Particulate Science and Technology 28(2): 132-145.