Assessment of the Damage in Ozoned Apricots by Fuzzy Logic

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Abstract: Standardization and quality evaluation of apricot and other food products should satisfy the consumer and manufacturers. However, consumer, manufacturer, farmer or experts because of human factor do not often make quality evaluation correctly. With technological advances, image processing and artificial intelligence (e.g. artificial neural networks, genetic algorithms, fuzzy logic, etc.) have found different applications in food industry, such as process monitoring and optimization, classification and quality control. This article reports on and discusses the results of some experiments conducted to measure the damage rate in ozoned apricots. The technique used in the experiments is based on fuzzy logic, which seems to offer a promising avenue in food engineering. The experimental data has been collected with image processing methods. Fuzzy logic model, which was created by expert food engineers' opinions, has a very good approach when comparing with sensory analysis.

Keywords: Apricot, Damage Rate, Fuzzy Logic, Image Processing

1. Introduction

The apricot (PrunusArmenica L.), which is classified under in the Rosaceae family, is one of the most important stone fruit of world(Naderi-Boldaji, Fattahi, Ghasemi-Varnamkhasti, Tabatabaeefar, & Jannatizadeh, 2008). It contains more water, less energy and protein than other fruits; but it has an important role in human health(Gezer, Haciseferoğulları, & Demir, 2003) (Igual, García-Martínez, Martín-Esparza, & Martínez-Navarrete, 2012). It is important for Turkey because of leading apricot producer in the world with annual about 811 thousand tons according toFAOSTAT, 2017. Main problem of apricot has a very short shelf life under the storage conditions at 0° C and 90% relative humidity for 1-2 weeks(Hui, 2006). Some methods are used for increasing of the shelf life of apricot and other food products. One of the main methods is the ozoned. Ozone, which is a powerful oxidant and an effective disinfecting agent, have using for extending the storage time of food products(Barboni, Cannac, & Chiaramonti, 2010). Ozone could be a good sanitizer for the food products. In addition, it shred microorganisms with oxidation of vital cellular components.In addition to increasing the shelf life, another important problem is the quality evaluation and standards of apricot and food products. Various sensors (electronic nose and electronic tongue, camera, etc.) and sensing analysis have been using for quality control processes of the food products(Curt, Hossenlopp, Perrot, & Trystram, 2002)(Baldwin, Bai, Plotto, & Dea. 2011)(Escuder-Gilabert & Peris, 2010)(Deisingh, Stone, & Thompson, 2004). However, they have many disadvantages, such as; time consuming, human factor, cost, and to be damaging for food products(Ramprabhu & Nandhini, 2014)(Maheshwari, 2013)(Brosnan & Sun, 2004)(Du & Sun, 2004)(Omid, Khojastehnazhand, & Tabatabaeefar, 2010).

In recent years, many researchers have focused on automated quality control systems to provide more efficient and accurate defining quality standards(Kodagali & Balaji, 2012)(Wang, Wang, Xie, & Zhang, 2012). Quality evaluation of food products have been easily defined with CV and Soft Computing methods. CV has very useful techniques for extracting features that are color, shape, size and other type properties of food products(Bakar, Hisham, Ishak, Shamsuddin, & Wan Hassan, 2013)(Davidson, Ryks, & Chu, 2001). They are evaluated by AI or Soft Computing methods for sorting, classification, grading, and other defining output of food products quality standards(Gill, Sandhu, & Singh, 2014)(Girolami, Napolitano, Faraone, & Braghieri, 2013)(Jadhav & Patil, 2013). Fuzzy Logic is one of the subfield of AI.Fuzzy Logic has been using for quality control, classification, defect detection, sorting, grading and processes analyzing of the different food industry applications that are time varying, nonlinear and complex(Sun & Brosnan, 2003b).Fuzzy Logic permits the use of linguistic values of variables and imprecise relationships for modeling system behavior(Hu, Gosine, Cao, & Silva, 1998)(Gunasekaran, 1996). The outputs are calculated according to input variables by membership functions and rules(Sun & Brosnan, 2003a).

In many studies show that the result of Fuzzy Logic and Computer Visionare rapid application period, success estimation in quality control, not expensive, notcomplicated, easy analyzing and without human factors. In this paper, Fuzzy Logic is used for measuring the damage in ozoned apricots according to the color changes, ozone rat and storage time. In addition, the results of Fuzzy Logic are compared with sensory analysis that is made by two foodengineering experts.

The following objectives of the present study were: (1) to extract RGB value using image processing techniques of the ozoned apricot (2) to analyze of apricot data (PPM, Storage Time, R, G and B values)using fuzzy logic and (3) to compare the results of fuzzy logic and sensory analysis.

2. Material and methods

2.1. Overview

In this paper, various ozone degrees were used for determining of effect on the shelf life. Features, which were calculated R (Red), B (Blue), G (Green) values by image processing, contained ozone degrees, storage time that were saved to database. These features were evaluated by Fuzzy Logic based on human experience. And, the results of Fuzzy Logic are compared with sensory analysis. The flow chart of system is shown in Fig. 1.



Figure 1: Flow chart for System

2.2. Apricot

Apricots, cultivars "Hasanbey", were provided in the Dardanos Research Center of Çanakkale Onsekiz Mart University. The samples transported to the laboratory at the same day and fruits were sorted according to damaged, color and size by experts.

2.3. Ozone

Ozone, which is a powerful oxidant and an effective disinfecting agent, have using for extending the storage time of food products. Ozone could be a good sanitizer for the food products. Also, it shred micro-organisms with oxidation of vital cellular components (Barboni, 2010).

Ozone gas was produced using industrial ozone generator (Model TKZ-H, Teknozon Ozone Systems LTD.ŞTİ., İzmir, Turkey). Ozone was applied to the apricot samples in gas form. O³ applications designed different concentrations and time. O³ applications were;

- 1) Control apricots, which weren't applied ozone, stored as natural.
- 2) Apricots were applied by ozone gas at 1 ppm in 5 min.
- 3) Apricots were applied by ozone gas at 1 ppm in 10 min.
- 4) Apricots were applied by ozone gas at 5 ppm in 5 min.

- 5) Apricots were applied by ozone gas at 5 ppm in 10 min
- 6) Apricots were applied by ozone gas at 10 ppm in 5 min
- 7) Apricots were applied by ozone gas at 10 ppm in 10 min
- 8) Apricots were applied by ozone gas at 20 ppm in 5 min
- 9) Apricots were applied by ozone gas at 20 ppm in 10 min 10^{10}

Apricot samples were stored in the refrigerator at 4⁰C after the ozone gas applied.

2.4. Image Processing Steps

The apricots are placed on image acquisition tool and captured them. Image acquisition tool is prepared size of 40 cm x 40 cm x 15 cm as shown in the Fig. 2. Diffuser 2 x 24 W fluorescent lighting fixtures are mounted to sub-base in order to ensure a homogeneous enlightenment. Above the floor covered with matte and white cardboard for preventing glare. Two polarizing filters at the horizontal and vertical direction are placed on the glass for being more uniform emission of light, and thus the shading is minimized. Moreover, the filters blocked scattering of light from the bottom and the glare effect of the flashlight of digital camera on the surface of products. Fujifilm 9800-model digital camera are used to capture and it is placed on tripod to prevent vibrations that may occur during the shooting.Ten apricots are captured each time.



image.

(x, y) = (1380, 390)

w = 1800 px, h = 1950 px

After, image is cropped according to specific coordinate for making easily preprocessing. Image cropping extracts specific area from original image. In this paper, original image size is 4048 x 3040 pixels. If origin point is (x, y) and area width (w) and height (h);





Figure 3: Croped Image

Background and original images are subtracted. Subtracted image is converted gray level image and find threshold

> Cropped Substracted Image

Figure 4: Image Substract

Subtracted image converted to Gray Image using Equation (*).Gray image (Fig. 5) defines that R, G, B color values have equal R, G, B values. So that;



Figure 5: RGB Image to Gray Image

Gray image is passed the threshold value for obtaining binary image (Fig. 6). Thresholding create binary image from a grayscale image for image segmantation. If $f_t(x, y)$ is a thresholded version of a f(x, y) at a global threshold T value,

$$f_t(x, y) = \begin{cases} 1 & if \ f(x, y) \ge 7\\ 0 & otherwise \end{cases}$$



Figure 6: Image Thresholding

Labeling of objects on a screen works by scanning a binary image because of identifying connected pixel areas (Fig. 7).



Figure 7: Labeling

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value. As shown in Fig. 4, background and original images are subtracted.

As shown in Fig. 3, these values arecalculated using original

Labeling each apricot in image is stored in computer shown in Table 1. according to PPM and storage time. The apricot samples are





2.5. Fuzzy Logic

Fuzzy Logic Model are created using Matlab[®] Fuzzy Logic Toolbox as shown Fig.8. The inputs are Red (R), Green (G), Blue (B), Ozone Degree, and Storage Time. The output is damage rate of apricot (Fig. 9). Membership function of inputs is trapes function and Mamdani model is chosen for defuzzification (Fig.10). 252 rules are defined for the rule base by using expert opinion of Food Engineers who expert in the field.

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Figure 8: Fuzzy Logic Model



(f) Output variable Damage (% rate)

[0 20]

(e) Input variable Storage (time)

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Figure 10: Fuzzy Rule Viewer

2.6. Sensing Analysis

In this study, Hedonic type scale system are used for sensory analyzing. Two food engineers, who are expert in the field, give opinions for all apricots one by one according to scale system. Experts do not know which apricot ozoned or not. Only they show all apricots one by one and give the point according to scale system. Every scale value of experts converts to upper system. Mean of their results gives the damaging rate of apricots. Table 2 is a sample of converting result of experts' opinion value.

| Table 2: Sensory Analyzing (| (Hedonic type scale system) |
|------------------------------|-----------------------------|
|------------------------------|-----------------------------|

| | | | | | | | Scale |
|---------|-----|---------|-------|---------|-----------|---------|---------|
| | | Group | Ozone | Scale | Scale (%) | Scale | (%) |
| Apricot | | of | Rate | (Expert | (Expert | (Expert | (Expert |
| Number | Day | Apricot | (PPM) | 1) | 1) | 2) | 2) |
| 1 | 1 | 1 | 1 | 4 | 80 | 5 | 100 |
| 2 | 1 | 1 | 1 | 4 | 80 | 5 | 100 |
| 3 | 1 | 1 | 1 | 4 | 80 | 5 | 100 |
| 4 | 1 | 1 | 1 | 4 | 80 | 5 | 100 |
| 5 | 1 | 1 | 1 | 4 | 80 | 5 | 100 |
| 6 | 1 | 1 | 1 | 3 | 60 | 5 | 100 |
| 7 | 1 | 1 | 1 | 3 | 60 | 5 | 100 |
| 8 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 9 | 1 | 1 | 1 | 4 | 80 | 5 | 100 |
| 10 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 11 | 1 | 1 | 1 | 4 | 80 | 5 | 100 |
| 12 | 1 | 1 | 1 | 4 | 80 | 5 | 100 |
| 13 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 14 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |

| 15 | 1 | 1 | 1 | 3 | 60 | 5 | 100 |
|----|---|---|--------|------|-------|------|-------|
| 16 | 1 | 1 | 1 | 4 | 80 | 5 | 100 |
| 17 | 1 | 1 | 1 | 5 | 100 | 4 | 80 |
| 18 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 19 | 1 | 1 | 1 | 5 | 5 100 | | 100 |
| 20 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 21 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 22 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 23 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 24 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 25 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 26 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 27 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| 28 | 1 | 1 | 1 | 4 | 80 | 5 | 100 |
| 29 | 1 | 1 | 1 | 4 | 80 | 5 | 100 |
| 30 | 1 | 1 | 1 | 5 | 100 | 5 | 100 |
| | | | Mean : | 4,43 | 88,67 | 4,97 | 99,33 |

- 1- Very Bad
- 2-Bad
- 3- Medium
- 4- Good
- 5- Very Good

3. Result and Discussion

Image samples of apricots changing according to storage time and ozonation degree show in the Table 1. Captured images convert to RGB values using image processing techniques. The sample results of Fuzzy Logic and Food Engineers sensing analysisare shownin Table 3.

Table 3: Fuzzy Logic and Sensing Analysis Results

| Storage Time | Ozone (PPM) | Ozone Time (Minutes) | <u>R_{mean}</u> | <u>G_{mean}</u> | <u>B_{mean}</u> | Scale Mean | Scale Mean (Expert2) | Scale % | Scale % | Scale % (Mean of Experts) | Fuzzy % <u>(Result)</u> |
|-------------------|----------------|----------------------------|-------------------------|-------------------------|-------------------------|---------------|----------------------------|--------------------------|-------------|---------------------------------|----------------------------|
| $\frac{(Day)}{0}$ | No Ozone | <u>(Williaces)</u> | 126.16 | 92.86 | 45.89 | <u>4.43</u> | <u>4.97</u> | <u>(Experti)</u> 88.7 | <u>99.3</u> | <u>94</u> | 95.1 |
| 1 | No Ozone | - | 116,33 | 82,24 | 42,69 | 4,97 | 5,00 | 99,3 | 100,0 | 100 | 94,6 |
| 5 | No Ozone | - | 115,39 | 79,79 | 40,69 | 4,10 | 5,00 | 82,0 | 100,0 | 91 | 93,1 |
| 10 | No Ozone | - | 115,09 | 77,79 | 40,16 | 5,00 | 4,93 | 100,0 | 98,7 | 99 | 95,1 |
| 15 | No Ozone | - | 112,44 | 75,71 | 40,21 | 5,00 | 4,90 | 100,0 | 98,0 | 99 | 93,6 |
| 20 | No Ozone | - | 111,94 | 75,7 | 39,05 | 5,00 | 5,00 | 100,0 | 100,0 | 100 | 93,4 |
| 0 | 1 | 5 | 127.69 | 77.89 | 41.01 | 4.87 | 4.97 | 97.3 | 99.3 | 98 | 94.3 |

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| 1 | 1 | 5 | 120,85 | 69,94 | 37,78 | 4,90 | 4,97 | 98,0 | 99,3 | 99 | 94 |
|----|----|---------|--------|----------------|-------|------|------|-------|-------|----------|--------------|
| 5 | 1 | 5 | 120,48 | 67,63 | 37,75 | 4,77 | 4,97 | 95,3 | 99,3 | 97 | 93,1 |
| 10 | 1 | 5 | 119,39 | 66,88 | 36,82 | 5,00 | 4,97 | 100,0 | 99,3 | 100 | 94,2 |
| 15 | 1 | 5 | 113,82 | 65,6 | 36,53 | 5,00 | 5,00 | 100,0 | 100,0 | 100 | 93,2 |
| 20 | 1 | 5 | 110,97 | 65,22 | 35,45 | 5,00 | 5,00 | 100,0 | 100,0 | 100 | 93,2 |
| 0 | 1 | 10 | 123,39 | 96,82 | 44,21 | 5,00 | 4,90 | 100,0 | 98,0 | 99 | 94 |
| 1 | 1 | 10 | 119,39 | 91,39 | 39,57 | 4,80 | 4,90 | 96,0 | 98,0 | 97 | 94,3 |
| 5 | 1 | 10 | 116,93 | 90,84 | 38,6 | 5,00 | 4,93 | 100,0 | 98,7 | 99 | 93,1 |
| 10 | 1 | 10 | 115,76 | 89,37 | 37,69 | 4,90 | 4,93 | 98,0 | 98,7 | 98 | 94 |
| 15 | 1 | 10 | 113,27 | 87,22 | 37,6 | 4,97 | 4,90 | 99,3 | 98,0 | 99 | 93,1 |
| 20 | 1 | 10 | 111,92 | 86,25 | 35,95 | 4,90 | 4,73 | 98,0 | 94,7 | 96 | 93,1 |
| 0 | 5 | 5 | 124,85 | 79,59 | 42,73 | 4,00 | 4,87 | 80,0 | 97,3 | 89 | 94,6 |
| 1 | 5 | 5 | 118,7 | 71,76 | 38,46 | 4,90 | 4,97 | 98,0 | 99,3 | 99 | 94 |
| 5 | 5 | 5 | 115,14 | 69,92 | 38,33 | 4,07 | 5,00 | 81,3 | 100,0 | 91 | 92,7 |
| 10 | 5 | 5 | 114,75 | 67,78 | 38,57 | 4,00 | 4,73 | 80,0 | 94,7 | 87 | 93,4 |
| 15 | 5 | 5 | 109,47 | 64,93 | 39,14 | 3,90 | 4,77 | 78,0 | 95,3 | 87 | 86 |
| 20 | 5 | 5 | 108,64 | 64,4 | 39,1 | 3,97 | 4,83 | 79,3 | 96,7 | 88 | 80 |
| 0 | 5 | 10 | 126,47 | 82,35 | 39,33 | 3,83 | 4,83 | /6,/ | 96,7 | 8/ | 84,6 |
| 1 | 5 | 10 | 121,41 | 73,99 | 37,42 | 3,13 | 4,57 | 62,7 | 91,3 | // | 84,2 |
| 5 | 5 | 10 | 120,94 | 71,3 | 36,62 | 3,27 | 4,40 | 65,3 | 88,0 | 77 | 82,7 |
| 10 | 5 | 10 | 120,61 | 70,76 | 35,13 | 3,27 | 4,83 | 65,3 | 96,7 | 81 | 83,1 |
| 15 | 5 | 10 | 115,81 | 68,11 | 36,81 | 3,53 | 4,70 | /0,/ | 94,0 | 82 | 83,2 |
| 20 | 5 | 10 | 110,04 | 67,95 | 35,05 | 3,00 | 4,93 | 60,0 | 98,7 | 79 | 71,4 |
| 0 | 10 | 5 | 126,94 | 84 | 40,75 | 2,97 | 4,20 | 59,3 | 84,0 | 12 | /3,9 |
| 1 | 10 | 5 | 113,79 | 70,53 | 37,94 | 3,/3 | 4,37 | /4,/ | 87,3 | 81 | 83,9 |
| 5 | 10 | 5 | 113,09 | 69,61 | 37,69 | 3,00 | 4,33 | 60,0 | 86,/ | /3 | 12,1 |
| 10 | 10 | 5 | 111,85 | 69,43 | 36,23 | 3,13 | 4,63 | 62,7 | 92,7 | /8 | 13 |
| 15 | 10 | 5 | 109,08 | 67,08 | 35,27 | 2,87 | 3,80 | 57,3 | /6,0 | 6/ | /8,6 |
| 20 | 10 |) 10 | 105,58 | 00,97 | 35,33 | 2,73 | 3,93 | 54,7 | /8,/ | 0/ | 08,0 |
| 0 | 10 | 10 | 123,19 | 04,01 75.20 | 42,72 | 5,00 | 4,00 | 28.7 | 92,0 | /0 65 | 62.0 |
| 5 | 10 | 10 | 110,48 | 73,39 | 38,00 | 1,95 | 4,35 | 50.2 | 90,7 | 03 79 | 03,9 72.7 |
| 10 | 10 | 10 | 115,79 | 73,10 | 37,00 | 2,97 | 4,07 | 58.0 | 827 | 70 | 73 |
| 10 | 10 | 10 | 108.64 | 67.88 | 36.18 | 2,70 | 4,15 | 54.0 | 86.0 | 70 | 78.6 |
| 20 | 10 | 10 | 107.64 | 66.98 | 35.95 | 2,70 | 4,30 | 57.3 | 81.3 | 69 | 78.6 |
| 0 | 20 | 5 | 122.07 | 83 | 44 74 | 2,07 | 4 37 | 54.7 | 87.3 | 71 | 74 |
| 1 | 20 | 5 | 109.3 | 70.53 | 39.6 | 1.80 | 3 53 | 36.0 | 70.7 | 53 | 64 |
| 5 | 20 | 5 | 106.77 | 68.14 | 39 54 | 1,00 | 3,33 | 33.3 | 69.3 | 51 | 52.7 |
| 10 | 20 | 5 | 105,77 | 67.9 | 39 38 | 2.80 | 3.93 | 56.0 | 78.7 | 67 | 63.4 |
| 15 | 20 | 5 | 99.45 | 65.55 | 38.6 | 1.83 | 4.20 | 36.7 | 84.0 | 60 | 67.9 |
| 20 | 20 | 5 | 94.01 | 64.92 | 37 77 | 2.93 | 4 63 | 58.7 | 92.7 | 76 | 78.5 |
| 0 | 20 | 10 | 123.59 | 86.94 | 44.25 | 1.70 | 3.57 | 34.0 | 71.3 | 53 | 54 |
| 1 | 20 | 10 | 110.54 | 74.22 | 40.44 | 1.80 | 3.90 | 36.0 | 78.0 | 57 | 54.8 |
| 5 | 20 | 10 | 107.23 | 72.49 | 39.94 | 1,73 | 3,30 | 34.7 | 66.0 | 50 | 52.7 |
| 10 | 20 | 10 | 107,23 | 70.14 | 39.58 | 1,73 | 3.87 | 34.7 | 77.3 | 56 | 53.2 |
| 15 | 20 | 10 | 97.79 | 67.57 | 38.15 | 1,10 | 2.50 | 22.0 | 50.0 | 36 | 38.5 |
| 20 | 20 | 10 | 88.83 | 65.13 | 37.68 | 1.00 | 1.97 | 20.0 | 39.3 | 30 | 38.5 |
| 20 | 20 | 10 | 00,05 | 00,10 | 21,00 | 1,00 | 1,27 | 20,0 | 57,5 | | 00,5 |

In this article, nine different group samples are used. Each groups are designed using different concentration and application time of O^3 . At the same time, each groups are evaluated by two expert food engineers with sensory analysis and fuzzy logic. Totally, number of apricot is 270

and each group has 30 samples. The sample results of Fuzzy Logic and Experts were compared as shown Table 3. In addition to, correlation of two methods is shown Fig.11 and R^2 value was found as 0,93.



Figure 11: Correlation of Fuzzy Logic and Sensing Analysis Results

4. Conclusion

The ozoned apricot was analyzed by Fuzzy Logic using RGB values that are collected by Image Processing techniques. Finding performance of Fuzzy Logic, the results were compared by sensory analysis that was made by two experts' food engineering. Fuzzy Logic approach provided to analyze easy, fast, high accuracy rate, minimum error and optimum solution without human factors or any physical and chemical analysis. Also, another contribution of Fuzzy Logic gives information best point of PPM and Storage Time. As shown in Table(*), the red fill row is the best point of storage and PPM value of the ozoned apricot. Fuzzy Logic analyze the ozoned apricot, and, the results of them are validated using sensory analysis.

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