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STUDY ON APPLE QUALITY NON-DESTRUCTIVELY USING LASER BEAM AS LIGHT SOURCE

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ABSTRACT

Texture and appearance are among the most important characteristics of food. In this paper, a 3 mW He-Ne laser beam has been used as light source to study apple properties. The purpose of the work was to look for the possibility to determine fiuit ripeness related properties in a non-destructive way.

Egyptian Apples (variety Jonagold) were monitored at different maturity stages using the laser source and a RGB camera at room temperature. The images of the laser light scattered by the fruit were captured and the total number of pixels in the image exceeding a threshold was taken as texture indicator. The pictures show significant differences for apples at different maturity stages. The apple side (background and blush) has significant effect on the image. The fruit firmness measured by non-destructive acoustic response showed a strong negative correlation with the laser image analysis.

NTRODUCTION

Colour of fruit is one of the most direct quality parameters attracting the consumers. Recently there has been an increasing interest in using computer-assisted image processing to aid quality control in non-contact and non-destructive way. Considerable research work has been done on applying machine vision system to inspect agricultural products quality. **Rehkugler and Throop (1986, 1989)** applied machine vision system for sorting apples. **Miller and Delwiche (1989)** reported a colour vision system to acquire peach color images and grade them. **Sarkar and Wolfe (1985a,b)** developed and evaluated a computer vision system to control the fresh tomato quality. Other applications have included cucumbers, potatoes, beef, kernels, and bell pepper **(Tillett, 1991)**. The above techniques rely on surface or near surface optical reflectance properties of the fiuit.

So far, only a few researchers applied laser beam as light source to study food quality. **Birth et al. (1978)** used the Helium Neon (He-Ne) laser beam to determine the fruit quality by studying the scatter coefficient. **Sun et al. (1983)** investigated the distribution of light transmitted through a piece of white potato flesh by using two light sources: (1) a 632.8 nm, 5 mW, He-Ne laser; (2) monochromatic light at 625 nm wavelength conveyed through a 6.2 nm diameter light guide.

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Duprat et al. (1995) studied ripeness of Golden apples based on laser light source machine vision. They found a nonlinear negative relation (r=-0.84) between the image size formed by the scattering of the laser beam and the firmness.

A number of researchers have used computer vision systems to evaluate grain quality factors. **Ounasekaran and Paulsen (1986)** evaluated several non-destructive testing techniques and concluded that computer vision is the most suitable form of automatic quality evaluations. Seed quality evaluations and seed contamination evaluations seem particularly well suited to analysis by machine vision. **Neurman, et al. (1989)** used colour image processing method to classify different wheat varieties with considerable success. **Zayas et al. (1990)** used a colour feature based pattern recognition technique to analyse corn defects. This technique was reported to be successful for detecting defects such as damaged corn and blue-eye mould. **Shearer and Holmes (1990)** used co-occurrence matrices from image matrices which included intensity, saturation, and hue, 33 colour texture features in total to identify plants with satisfactory accuracy.

The neural network is a new information processing technique that offer solutions to problems that have not been explicitly formulated. **Liao (1992)** developed a knowledge-based machine vision system for discrimination of corn kernels and used a Learning Vector Quantization algorithm to classify colour properties of white and/or yellow corn kernels. He also used a trained neural network classifier to differentiate between as many as seven cultivars of containerized nursery stock using up to 33 texture features. Results showed that computationally efficient neural network classifiers are capable of accuracy in the range of 77% to 97%. **Xu et al. (1995)** developed a neural network based machine vision system to classify barley and malts grades using shape and colour features witha successful classification rate of 90.1 %

In this work, it was tried to use He-Ne laser beam as light source to study the apple quality non-destructively by taking and analysing the scatting images of the laser beam. The fruit firmness was measured by the non-destructive acoustic response technique. The relation between the two methods was studied.

MATERIAL AND METHODS

Egyptian apples were purchased from a local market. Total of 50 apples were tested in this experiment. The measurements were done on both background and blush side of the fruit.

Apples were numbered and stored at room temperature at 20°C, 65% relative humidity. The experiment was carried out first using acoustic response acquisition followed by image measurement. The apples were monitored for 8 days at 2 days interval at the laboratory of Okayama University, Department of Agricultural Engineering, Okayama Japan.

Image Acquisition:

The experiment was performed in a dark room at environment temperature about 20°C. The experiment set up is shown in Fig. (1).

The sample holder can be turned around so that images can be taken from different points of the sample. The light source was a 670 nm (red light), 3 mW output He-Ne laser diode with 5 mm diameter of beam size and beam divergence <0.5 mrad. The angle between incident light and camera was 15°. The images were captured by a solid-state colour video camera (NC TK-I070E). The camera had three parallel ac-coupled analog outputs, red, green and blue (RGB) corresponding to the three National Television System Committee (NTSC) colour primaries.

The signal from the camera was digitised using a frame grabber (Truevision TARGA +, 32 bit) installed on a PC-AT486/66 DX2 with 16 Mb RAM. The digitized images were analysed by software written in Pascal language and meanwhile displayed on a 17-in colour monitor. The digitised image was also saved on a cassette for later reviewing.

The working distance from the camera lens to the sample was set at 50 cm. The position of the laser light source was adjusted such that the image displayed in the center of the monitor. Each apple was captured 4 times at different points around the equator. Four apples, two measurements of the background colour (green-yellow) side and the other two of blush (red) side were done. The camera was calibrated before the test.

Image Segmentation and analysis:

$r = R/(R+G+B)$ (1)

$g = G/(R+G+B)$ (2)

and

$b = B/(R+G+B)$ (3)

Each pixel on fruit has a Red (R), Green (G) and Blue (B) value between 0 and 255 resulting in 2553 distinct colours. The laser beam source was red light and the digitised colour image contains primary red colour. The mean $r \geq 0.7$ (and $g \leq O.l$) for the apples so that the image thresholding was carried out based on red data. The global thresholding ($r \geq 14$) was used to segment the apple image from the background of the image picture. The $r \geq 150$ was chosen to identity the high level intensity reflectance (Fig. 2).

The total number of pixels after thresholding, the total number of pixels in the inner part and in the outer part of the image were calculated as indicators of the fruit ripeness.

It is desirable to perform colour analysis without the effects of intensity variations. The normalized colour coordinates can be defined in RGB colour space as mentioned in the equations above.

Fruit Firmness Measurement:

The firmness of apple was measured with the non-destructive acoustic response technique **(Chen and De Baerdemaeker, 1993)**. The stiffness

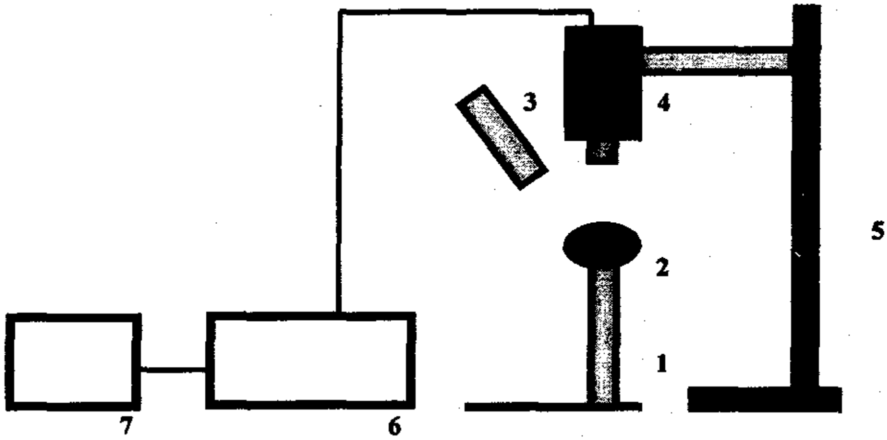

Fig. (1): Image acquisition system. 1-sample holder, 2-fruit sample, 3-leaser light source, 4-camera, 5-stand, 6-computer, 7-monitor.

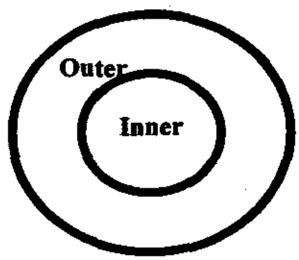

Fig. (2): Shape segmentation of scattered laser light on an apple fruit. (inner: 150£R£255, outer: 14£R£150, total pixels: pixels in the 14£R£255.)

factor was calculated as $f^2 m^{2/3}$ (f: peak frequency, H_z, m: mass of the apple, kg) and the average of the samples measurements on a fruit was taken as the result.

RESULTS AND DISCUSSION

The main factors affecting the scatter image measurement of apples are shown in Table (1). The storage time (day), side (background or red) and their interactions have significant effect on the number of total pixels captured. This means that the laser reflection can be used to study the apple ripeness evaluation during the storage. The images taken from background and red side were significantly different. The effect of side should be taken into account when analysing the apple image.

Table (1): General linear model analysis of main effects and interactions on total pixels of the Jonagold apple

Source of variance	DF	Significance testing
day	20	**
side	1	**
day* side	20	**

side: background (green-yellow) and blush (red), DF: Degree of Freedom
**: significant at the $P \leq 1\%$ level.

In the analysis of the apples, the mean total pixel numbers were taken as the ripeness indicator. The Duncan's multiple range test was carried out to see the differences.

The result is shown in Table (2). Significant differences in the image are observed with storage time when using 4 day interval and the background side image of the apple. Similar results can be derived if one takes the total average of the scatter images on the apple regardless of the side effect. The blush side image seemed less sensitive compared with the background side.

Table (2): Egyptian apple (jonagold) classified according to the background side and blush side

Background side (green-yellow)			Blush side(red)	
day	mean	difference	mean	difference
0	1081.7	C1	883.34	B
2	1126.8	C	915.28	B
4	1265.6	CB	1012.28	B
6	1447.0	AB	1167.15	A
8	1558.6	A	1293.40	A

1: Means with the same letter are not significantly different .

The scatter image analysis result is negatively correlated with the non-destructive acoustic response firmness measurement (Table 3). It is interesting to notice that the outer part of the image was the main contributor to the changes of the apple image. The increase of pixel number of the inner part image was less correlated with the total pixels than the outer part. The more significant change of the outer part pixel numbers may be due to the changes of apple structure as the apple ripens. The cellular structure of mature green apple tissue is compact with very small intercellular spaces which causes the light to be scattered and reflected within a small area. In red fruits the cells are engorged with fluid and there are more intercellular spaces which results in more light transmitted **(Hetherington and MacDougall, 1992)**. The increase of reflection, scattering and transmission resulted in the bigger radius of the image. Meanwhile the inner part, corresponding to the high intensity of the laser beam, has not changed much. The smoothness of apple surface is another factor to be considered. The fruit lost some water and the turgor pressure changes as the apple ripened resulting in a not smooth, but wrinkled skin. Therefore the reflection and scattering also increases in all directions.

Table (3): Correlation matrix of the apple

	Firmness	**Total pixel**	**Inner pixel**	**Outer pixel**	**Volume loss**
Firmness	1. 000	-0.927	-0.770	-0.923	-0.681
Total pixel		1. 000	0.769	0.999	0.649
Inner pixel			1. 000	0.746	0.659
Outer pixel				1.000	0.636
Volume loss					1. 000

Suppose the fruit density does not change much during the experiment, then the weight loss is proportional to the volume loss. The apple firmness has a negative correlation with volume loss. The scatter image has positive correlation with the volume loss.

The Egyptian apple stiffness measurements were negatively correlated (r= -0.96) with the image analysis which is shown in Fig. (3). It was preferred to use the total number of pixels on the background side to indicate apple ripeness.

In practice, the alternative method is to take the total image as a hole but this regardless the effect of background or blush side. The pixels in the outer part image have more importance for apple image classification.

The mean total pixel number of Egyptian apple images is positively correlated with the volume loss. The relation can be found from Fig. (4). This indicates the effect of weight loss resulting in a wrinkle apple surface and this loss of smoothness affects the image information.

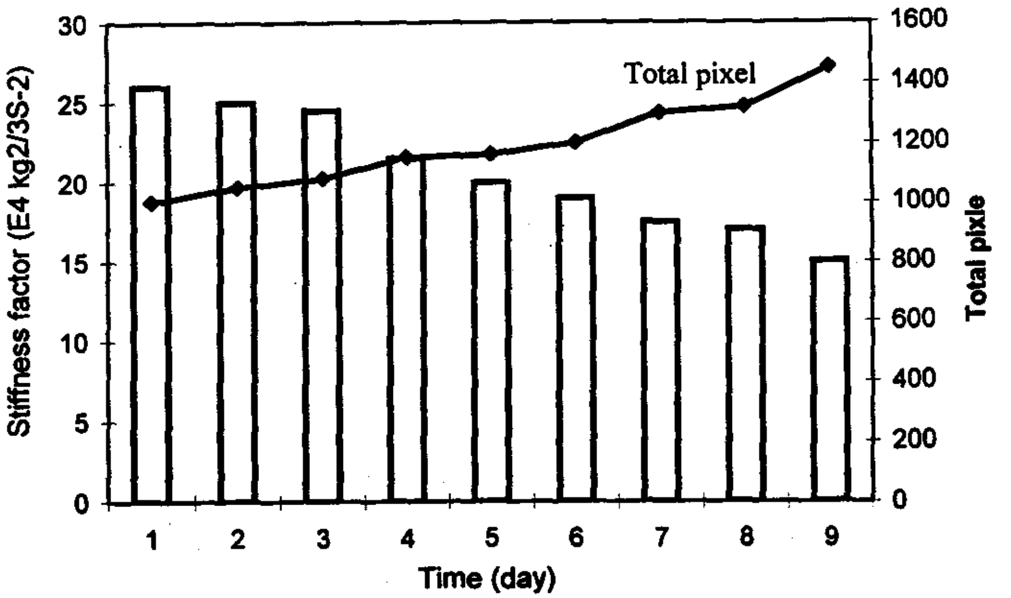

Fig. (3): Stiffness and total number of pixels in the scatter imge of Egyptian apples during storage at room temperature.

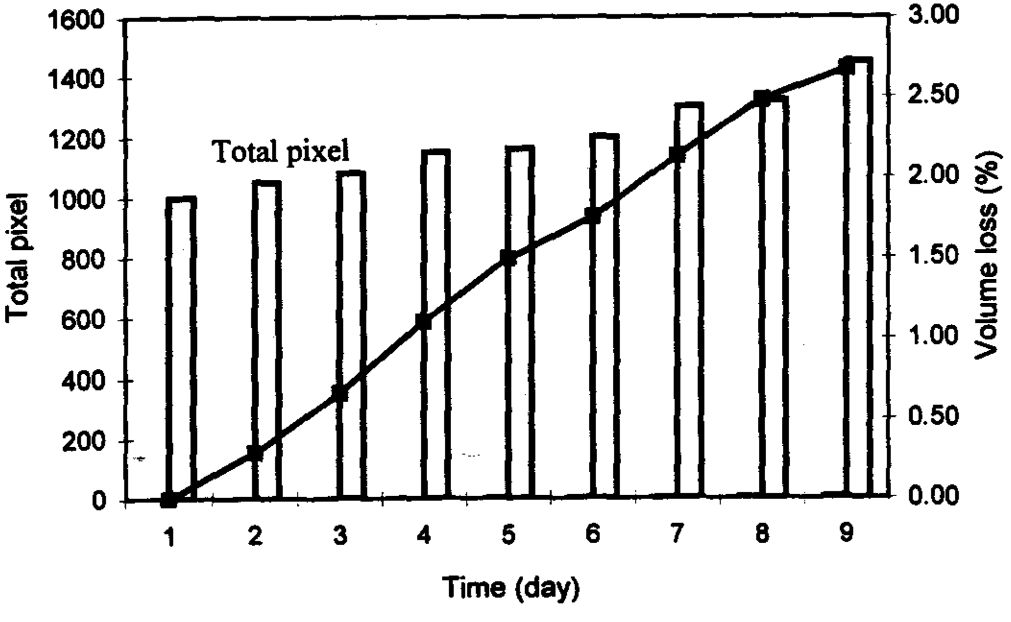

Fig. (4): Total number of pixels in the scatter image and volume loss of Egyption apples during storage at room temperature.

Another reason for the increase of the total number of pixels in the apple scatter image is the loss of chlorophyll during maturation. The apple with more chlorophyll shows stronger absorbance in the red light region and therefore the reflectance is relative lower **(Sitkei, 1986, Duprat et al. 1995).** As apple matured, the background colour turns to yellow due to loss of chlorophyll so that the reflectance increases and more pixel numbers are observed in the scatter image.

It is possible to monitor apple ripeness during storage and shelf life through the laser light image analysis. This method can be applied to fruit quality control as the reference critical level of the fruit texture is established.

CONCLUSIONS

A low power laser beam (3 mW) with a wavelength of 670 nm (red light) was used as the light source to study the apple quality in a non-destructive test. The total number of pixels in the image of scattered light was used as a texture indicator to distinguish apple ripeness.

The background or blush side of the laser beam illuminate on Egyptian apple has significant effect on the total pixel level in the scatter image. Projecting the laser beam on background side resulted in a more distinguishable image.

The non-destructive acoustic response firmness measurement results were negatively correlated with the image analysis. For Egyptian apple, a correlation coefficient of -0.967 was obtained. The methods provide valuable information about fruit quality.

The results showed a potential for using laser beam as light source to classify Egyptian apple according to quality. Different power laser beams may provide different information on textural properties under the skin, but this is the subject of future research.

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الملخص العربي

دراسة علي جودة التفاح المصري باستخدام حزمة من شعاع ليزر كمصدر للضوء

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باحث بمعهد بحوث الهندسة الزراعية – الدقي - الجيزة

المظهر الخارجي والقشرة هي صفات مهمة من ضمن صفات كثيرة مهمة في جميع الفواكه . باستخدام شعاع ليزر كمصدر للضوء تم تقييم نوعية التفاح المصري في هذه الدراسة . أما الهدف الأساسي في هذا البحث هو إمكانية تقدير نضج ثمرة التفاح باستخدام شعاع الليزر .

التفاح المصري كان يتم فحص نضجه عند مراحل نضج مختلفة باستخدام شعاع الليزر وكذلك كاميرا عند درجة حرارة غرفة البحث . تم استخدام خواص الألوان بطريقة RGB (احمر – اخضر – ازرق) لتحليل مراحل النضج عن طريق شكل القشرة الخارجية للتفاح .

ووضحت الصورة المأخوذة اختلاف معنوي للتفاح عند مراحل نضج مختلفة باستخدام التحليل الوصفي .كما ان صلابة الثمرة كان لها علاقة ارتباط سالبة بواسطة التحليل الوصفي بأشعة الليزر مما كان لة اثر واضح فى تحديد جودة التفاح .

تم استخدام شعاع الليزر بقدرة صغيرة في هذه الدراسة كمصدر للضوء هو الذي تم أخذه في الاعتبار في هذه الدراسة لتحديد الخواص الطبيعية كموشر لمعرفة مدي نضج التفاح من عدمه .

كما أوضحت الدراسة ان شعاع الليزر المستخدم كمصدر للضوء حدد بوضوح نوعية التفاح المصري وخاصة النضج .

كما يمكن القول انة باستخدام شعاع الليزر ذو قدرة اعلى من المستخدم فى هذه التجربة قد تعطي نتائج اخري وخاصة داخل الثمرة ٠