Proceedings of the 2003 IEEE/ASME
International Conference on
Advanced Intelligent Mechatronics (AIM 2003)

Judgment on Level of Maturity for Tomato Quality Using L*a*b* Color Image Processing

Yoshinori Gejima
Faculty of Agriculture,
Miyazaki University,
Miyazaki, Japan
ygejima@cc.miyazaki-u.ac.jp

Houguo Zhang
College of Food Science and
Nutritional Engineering,
China Agricultural University,
Beijing, China

Masateru Nagata
Faculty of Agriculture,
Miyazaki University,
Miyazaki, Japan
nagatam@cc.miyazaki-u.ac.jp

Abstract
*This paper was described the judgment of Maturity for Tomato quality using color image processing. The image analysis were used RGB and L*a*b* color system. As in analyzes, the pixels count of G(36) showed the highest correlation coefficient from tomato maturity. But, the average value of a* of the tomato upper surface was more accuracy maturity index than the radical regression curve of G(36).*

Keywords
Level of maturity, Tomato, Color system, RGB, L*a*b*

INTRODUCTION
Generally, fruits and vegetables are sorted to several grades before transporting to the market by using the human power and the weight grader shown in Fig.1. Recently, it is serious problems in Japan that farm workers are decreasing year by year and import of fruits and vegetables are increasing in Japan. And customers request safety and high quality foods.

Machine vision and image processing techniques have been found as useful tools and trend for increasing quality inspection [1]. Research in this area indicates the feasibility for improving quality and saving labor from a traditional sorting.

Fig. 1 Weight grader (for Tomato)

This paper presents judgment for tomato maturity using the image-processing technique.

COLOR SYSTEM
RGB and L*a*b* color systems were used in this study. This section explains the outline of these systems.

RGB color system
RGB color system is a theory based on three basic colors. The color is mixed of three basic colors. About 16.8million colors, including the colors of all kinds of gray and the colors of all kinds of hue and saturation, can be mixed out by the three basic colors on the personal computer (PC). The collected image data of this system can directly become source data without changing the color system.

L*a*b* color system
The L*a*b* color system, which can show the hue of object, is three-dimensional space. It is nearly to the sense of mankind. L* represents luminance, a* and b* corresponds to chroma. It can be calculated by the following formula:

$$L^*=116\times B-16$$
$$a^*=500\times(A-B)$$
$$b^*=200\times(B-C)$$

where:

$A=(X/X_0)^{1/3}$	$X/X_0>0.008856$
$A=7.787(X/X_0)+16/116$	$X/X_0\leqq 0.008856$
$B=(Y/Y_0)^{1/3}$	$Y/Y_0>0.008856$
$B=7.787(Y/Y_0)+16/116$	$Y/Y_0\leqq 0.008856$
$C=(Z/Z_0)^{1/3}$	$Z/Z_0>0.008856$
$C=7.787(Z/Z_0)+16/116$	$Z/Z_0\leqq 0.008856$

Generally, for the standard light (white light of NTSC color television system), $X_0=0.983$, $Y_0=1.000$ and $Z_0=1.183$. This system needs the formula of the XYZ color system as follows.

$$X=0.607\times R+0.174\times G+0.201\times B$$
$$Y=0.299\times R+0.587\times G+0.114\times B$$
$$Z=0.066\times G+1.117\times B$$
$$R = \text{Value of R} / 255$$
$$G = \text{Value of G} / 255$$

B = Value of B / 255

JUDGMENT OF TOMATO MATURITY BY USING IMAGE PROCESSING [4-8]

Generally, the harvested fruits and vegetables are treated according to their maturity. The fruits and vegetables with high maturity enter into nearby market or produced into juice and jam. While with low maturity were preserved or endure long-distance to be sold. Often, maturity degree means the extent of maturity, which is commonly judged by the outer color of the fruits and vegetables. Each manufacturer unit has own judgment criteria. Figure 2 is the criteria for tomato by JA Miyazaki. The work mainly depends on human judgment. But manual evaluation and sorting of fresh market tomatoes are costly and inherently unreliable due to its subjective nature.

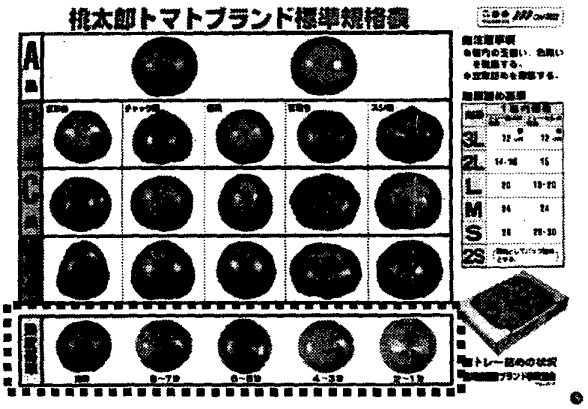

Fig. 2 Criteria of Tomato (JA Miyazaki, The maturity is showed in a dotted box.)

In 1985, a standard tomato color chart published by USDA distinguishes six stages of coloration, namely green, breaker, turning, pink, light red and red. Consultation with fresh market tomato growers in New Jersey showed that light red and red tomatoes are generally considered to be mature, while green, breaker, turning and pink tomatoes are taken as mature greens [2].

Cao and Nagata et al. (1998) concluded that the level of R, G and B in RGB color system were affected by illumination and that the level of a^* and b^* in L*a*b* color system were not affected by the illumination [3].

Therefore, this research tries to compare the RGB with L*a*b* color system to estimate tomato maturity.

MATERIALS AND METHODS

Samples

Tomatoes (*Lycopersicon esculentum*, variety: Momotarou) were collected from a tomato farm in Mayazaki pref. Farmers were asked to distinguish the samples into five grades according to their experience, namely 10-20%, 30-40%, 50-60%, 70-80% and fully mature. Every grade has ten samples.

Methods

The experiment setting used in this research is shown in Fig. 3. To create the natural light white fluorescent lamp (round) and high-frequency switching equipment were used. Through the diffusion filter, which was set at the front part of CCD camera (SONY, DXC-151A, CCD- IRIS/RGB COLOR VIDEO CAMERA, 380 thousand pixels) diffusion light was captured. The image processing board (HIMAWARI 50, input signal: RGB signal, frame memory: $512 \times 512 \times 8$ bit $\times$ 12 sheet) attached to the computer (NEC, PC-9821 Xv20, 200MHz) hardware freezes and grabs the tomato images placed under the CCD camera.

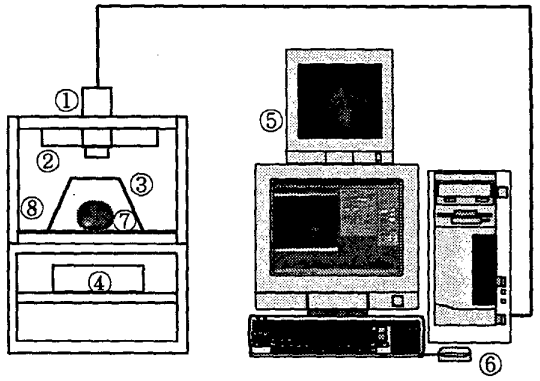

Fig. 3 Experimental Setup

1.CCD camera, 2.Fluorescent lamp, 3.Tracing paper, 4.High frequency switching setup, 5.Monitor, 6.PC, 7.Tomato, 8.Carpet (Black)

ANALYSIS AND RESULTS

Excluding the noise

To remove the influences of background, software were used. These software written in Visual C++ and MATLAB (The MathWorks, Inc.) converts the background into white. The condition of the background is as follows:

$$R<2 \text{ or } b^*<-3$$

where R (RGB color system) and b^* ($L^*a^*b^*$ color system) are the values of this point. Fig. 4 represents the two images before and after processing.

Correlation of the histogram and the maturity

To find out the differences among various kinds of tomatoes, the histograms of each color system values were made. Hence the correlation line is obtained between the histogram changing and the maturity. Therefore, the

numerical value of maturity has to set at 10-20% to 10%, 30-40% to 30%, 50-60% to 50%, 70-80% to 70% and fully mature to 90%.

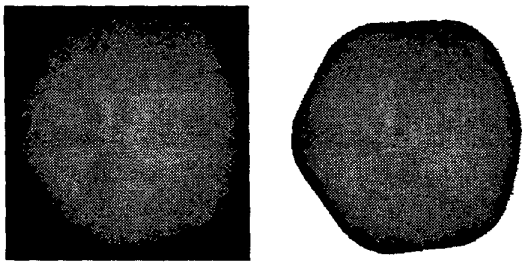

Fig. 4 Source and processed image

Figure 5 shows the correlation coefficients of RGB values, Fig. 6 shows the correlation coefficients of L*a*b* values. In Fig.5, the higher correlation coefficients were showed at G and R-value, which are 0.8658 at G(36) and –0.8213 at R(35). In Fig. 6, the highest correlation coefficient, which is 0.7694 of L*(50), is lower than above them correlation coefficient of G(36) and R(35).

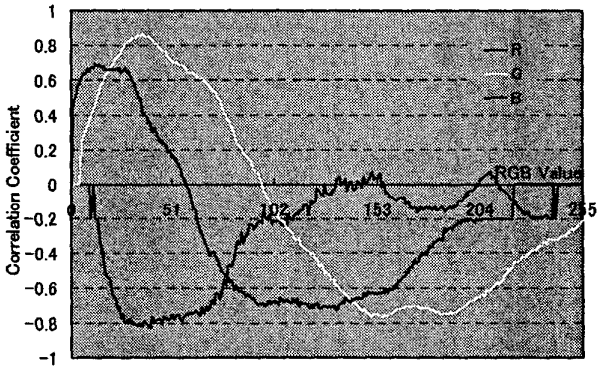

Fig. 5 Correlation coefficient of the maturity and the histogram of RGB values

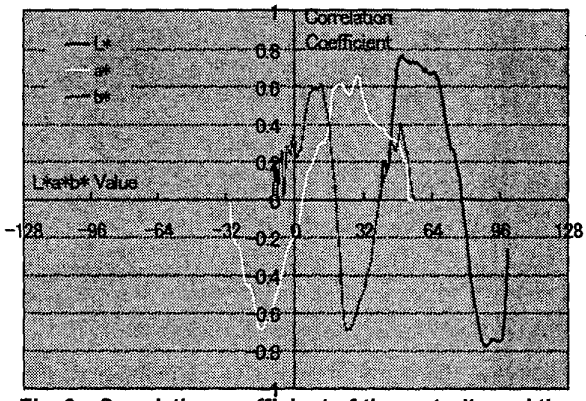

Fig. 6 Correlation coefficient of the maturity and the histogram of L*a*b*

So, the histograms were obtained by averaging ten samples. From Fig. 7 and 8, we can see that along with the increase of maturity the value of a* ascends accordingly, while the level of b* does not have clear change along with the increase of maturity. But for each curve of a* histogram, there is a peak when a* value equals zero. It is supposed that the reasons are due to the existence of calyx and the reflection, which has not been completely excluded.

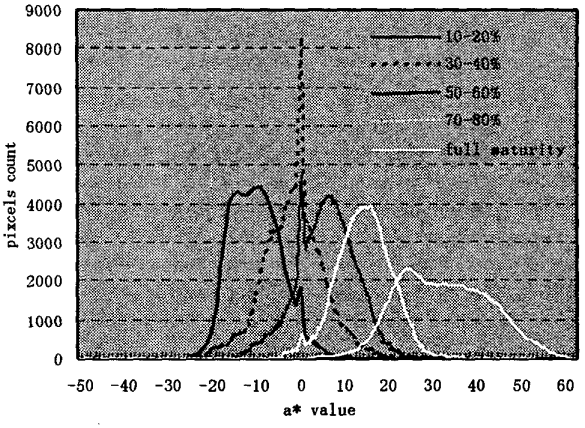

Fig.7 The histogram of a*

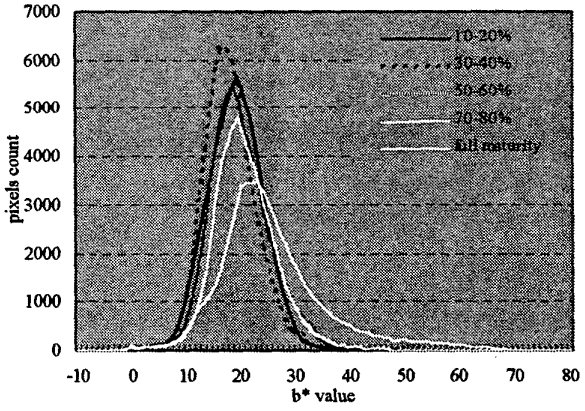

Fig. 8 The histogram of b*

Compare of maturity judgments

As analyzed above, pixels count of G(36) and average a* value are important factors in maturity judgment. The accuracy of judgment of each factor was compared.

Figure 9 is showed the graph between the maturity and pixels count of G(37). A black line is regression line and a white curve is radical regression, which is the highest correlation coefficient (=0.8935). From this, regression formula can required the tomato maturity from the count pixels. The dotted lines in figure are the borderline of 20, 40, 60 and 80% mature, which are required radical

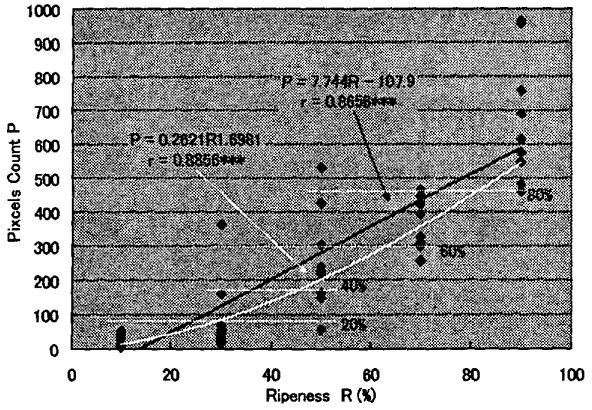

Fig. 9 Relationship between the maturity and pixels count of G(36)

regression curve. Above 80%, pixels count of fully mature tomato is correct judged. But, other judges were inaccurate (accuracy average 65%) under 80% maturity.

The average value of a* for every sample and for every stage of maturity was calculated. The results are shown in

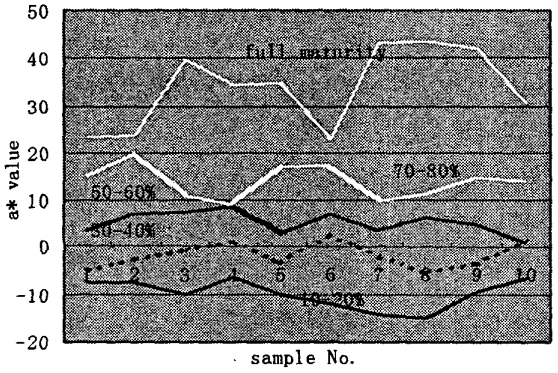

Fig. 10 Average value of a*

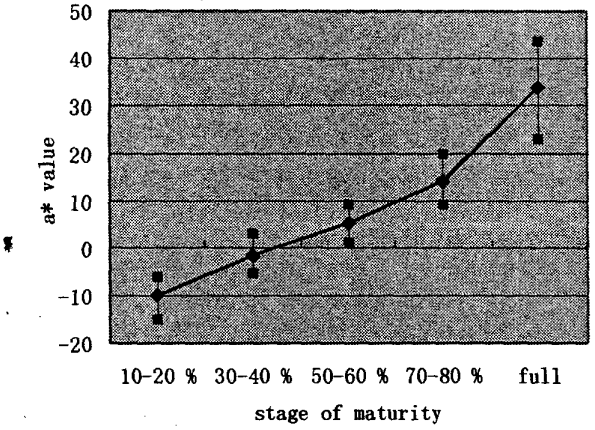

Fig. 11 Average value of a* for every stage of maturity

Fig.10 and 11. According to the figures, we can see that the average value of a* has a high relation with the maturity. So the value can be used to estimate maturity and make the following suggestion:

i) 10 – 20 % of fully maturity:
$a^* < -5.8$ ····· (1)
ii) 30 – 40 % of fully maturity:
$-5.8 \leqq a^* < 2.1$ ····· (2)
iii) 50 – 60 % of fully maturity:
$2.1 \leqq a^* < 9.2$ ····· (3)
iv) 70 – 80 % of fully maturity:
$9.2 \leqq a^* < 21.5$ ····· (4)
v) fully maturity:
$21.5 \leqq a^*$ ····· (5)

Table 1 Results of judgments

judgment by man	sample No.	average value of a*	new result
10-20%	1	-7.57	10-20
	2	-7.54	10-20
	3	-10.24	10-20
	4	-6.16	10-20
	5	-10.12	10-20
	6	-12.08	10-20
	7	-14.42	10-20
	8	-15.11	10-20
	9	-9.19	10-20
	10	-6.64	10-20
30-40%	1	-4.64	30-40
	2	-2.68	30-40
	3	-0.65	30-40
	4	1.14	30-40
	5	-3.44	30-40
	6	3.14	50-60
	7	-2.09	30-40
	8	-5.34	30-40
	9	-3.7	30-40
	10	1.59	30-40
50-60%	1	4.13	50-60
	2	7.46	50-60
	3	7.6	50-60
	4	9.09	50-60
	5	3.18	50-60
	6	7.55	50-60
	7	4.13	50-60
	8	6.51	50-60
	9	4.95	50-60
	10	1.12	30-40
70-80%	1	15.46	70-80
	2	19.88	70-80
	3	11.23	70-80
	4	9.4	70-80
	5	17.34	70-80
	6	17.31	70-80
	7	10.02	70-80
	8	11.55	70-80
	9	15.13	70-80
	10	14.4	70-80
fully maturity	1	23.45	fully maturity
	2	23.85	fully maturity
	3	39.83	fully maturity
	4	34.4	fully maturity
	5	34.77	fully maturity
	6	23.06	fully maturity
	7	43.14	fully maturity
	8	43.6	fully maturity
	9	41.89	fully maturity
	10	30.7	fully maturity

where a* is the average value of the upper surface of the tomato.

Now maturity can be judged according to a* value. But due to the limit of sample numbers the final classifications need to be modified. According to the above suggestion the samples were judged again and the results are shown in Table 1. Gray cells were showed the incorrect answer. The average of correct judgment was 96%.

CONCLUSIONS

This study is obtained the judgment of Maturity for Tomato quality using color image processing. The image analysis were used RGB and L*a*b* color system. The following conclusions are obtained from:

1. The pixels count of G(36) showed the highest correlation coefficient from tomato maturity.
2. The radical regression curve of G(36) was judged 70% average correct.
3. Along with the increase of maturity, the level of a* also rises accordingly, while the b* value has not so much change.
4. The average value of a* for the upper surface can be used for maturity index.

REFERENCES

[1] Ruming Fang, Jiangrong Cai and Li Xu., *Computer image processing technique and applications in agricultural engineers,* Tsinghua university publications (1999).

[2] N.Sarkar, R.R.Wolfe, *Feature extraction techniques for sorting tomatoes by computer vision,* TRANSACTIONS of the ASAE 28(3) 970-974 (1985).

[3] Cao, Masateru Nagata et al., *Studies on Grade Judgment of Tomato –Quality Feature Extraction Using Color Image Processing,* Bulletin of the Faculty of Agriculture Miyazaki University 45(1· 2) (127-133) (1998).

[4] Masateru Nagata, Pepito Menguito BATO, Masafui Mitarai, Qixin Cao, Takao Kitahara, *Study on Sorting System for Strawberry Using Machine Vision,* Journal of JSAM 62(1) (2000).

[5] S. Laykin, Y. Edan, V. Alchanatiset and R.Regev et al., *Development of a Quality Sorting Machine Using Machine Vision and Impact,* ASAE Paper No.993144, Toronto, Ontario, Canada July 18-21 (1999).

[6] Y.Tao, P.H.Heinemann, Z.Varghese, C.T.Morrow, H.J. Sommer, *Machine Vision for Color Inspection of Potatoes and Apples,* TRANSACTIONS of the ASAE 38(5): 1555-1561 (1995).

[7] Lifeng Liu and Stan Sclaroff. *Deformable Shape and Description via Model-Based Region Grouping,* BU CS TR98-017 rev. 2. To appear in Proc. IEEE Conf. on Computer Vision and Pattern Recognition, June (1999).

[8] R.R.Wolfe, M.Swaminathan. *Determining Orientation and Shape of Bell Peppers by Machine Vision.* TRANSACTIONS of the ASAE 30(6) (1987).