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# *Food Process Engineering in a Changing World*



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## Development of Citrus Grading System Using Image Processing

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### INTRODUCTION

Citrus production in Indonesia has been increasing to a yield of 17-25 tons/ha. However, the quality is still a serious problem. Most of the citrus produced from the production centers such as Pontianak and Medan enter domestic market with unattractive appearance with big varieties in size, color, and taste. For that reason, the quality improvement of citrus through the development of quality assurance system using new technologies is necessary. Many postharvest handling technologies such as waxing and modified atmosphere packaging can be applied, but uniformity in size, color, and taste is very important in marketing the products.

One of the advanced technologies that can be used for sorting and grading fruits is an automatic grading system with image processing for quality measurement. Image processing technology is a technology developed to obtain information from image by modifying the image into a desired and more informative one and analyzing it, or translate the meaning into an action in machine vision. Image processing technology has been applied to detect cherry tomato in a bunch of cherry tomato plants by recognizing object with different color. The method was integrated in the harvesting robot for cherry tomato cultivated in a greenhouse [1]. Another example of image processing application is in mushroom harvesting robot, to detect the mature mushroom to harvest [2] and in watermelon harvester to do the same task [3].

The objectives of this study were to develop software using image processing to grade citrus based on their weight and color, and to develop a real-time grading machine prototype.

### MATERIALS AND METHODS

Data of the area of each citrus in image obtained from a CCD camera attached to a grading machine prototype was transformed to the weight of citrus, and was used for classifying the citrus conformed to SNI grades.

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The machine prototype was designed and constructed consisting of a rotating fruit feeder with two pneumatic solenoids that open and close one after another to release one fruit at a time, a belt conveyor, a color CCD camera, four openings with three pneumatic solenoids, four collecting boxes, a logic control panel, and a computer.

Eight hundred and fifty of Pontianak citrus, composed of 125 grade A fruits, 125 grade B fruits, and 200 fruits each for grades C, D, E respectively, were used as samples. The samples



were graded manually based on size. The results of image processing classification was then compared to the ones from manually grading, while the performance of the machine was observed through its capacity.

## RESULTS AND DISCUSSION

In grading the citrus based on size, it is important to use Indonesian standard (SNI 01-3165-1992) as reference by re-grading the samples into a new grades by direct measuring using a digital balance. This re-grading of 850 fruits resulting 91 fruits as grade A, 269 fruits as grade B, 467 fruits as grade C, and 23 fruits as grade D. No grade E in Indonesian standard for citrus.

The results show that out of 850 samples used in this experiment, there were 323 fruits (38%) which were not compromised to SNI based on direct weight measuring using a digital balance. It can be seen from the same table that manual grading agreed with SNI in grade A by 100%, in grade B by 46%, in grade C by 19%, and in grade D by 0%. In average, manual grading agreed with SNI in all grades by 41%, which is very low. It can be said that, manual grading was done in a random way and not using Indonesia standard as reference, or done subjectively.

Furthermore, the same samples were graded based on size of fruit, or area projection of the fruit in image using the developed computer program. In the computer program, the borders of each grade in weight (g), were converted into threshold values (pixel), based on equation.  $y=205x+7018$ , with y as area projection (pixel) and x as weight (g). The results of grading using the machine and its conformity to SNI is shown in Table 1.

Table 1. Variance of grading by image processing to SNI 01-3165-1992 citrus grade

SNI Citrus Grade	Grading by Image Processing				Amount
	A	B	C	D	
A	84 (92%)	7 (8%)	0 (0%)	0 (0%)	91
B	2 (1%)	263 (98%)	4 (1%)	0 (0%)	269
C	0 (0%)	17 (4%)	436 (93%)	14 (3%)	467
D	0 (0%)	0 (0%)	0 (0%)	23 (100%)	23
Total fruit	86	287	440	37	850

## CONCLUSION

The developed prototype for automatic grading machine with image processing as quality evaluation method had been performed successfully to the designed function. The results indicated that citrus graded by image processing conformed to SNI at a degree of 96% compared to 41% performed by manual grading. However, the capacity of the grading machine was 700 fruits/hr, thus it needed further improvements, especially in speed, before the implementation in the field.

## REFERENCES

- [1] Kondo, N., Nishitsuji Y, Ling, P. & Ting, K.C. 1996. Visual Feedback Guided Robotic Cherry Tomato Harvesting. Transactions of the ASAE, 39 (6), 2331-2338.
- [2] Reed, J.N., He, W. & Tillett, R.D. 1995. Picking Mushrooms by Robot. International Symposium on Automation and Robotics in Bioproduction and Processing, Vol.1. Kobe, Japan, 22 September 1995. Proceedings p. 27-34.
- [3] Tokuda M., Namikawa K., Sugari, M., Umeda, M., & Iida, M. 1995. Development of Watermelon Harvesting Robot (1): Machine Vision System for Watermelon Harvesting Robot. International Symposium On Automation And Robotics In Bioproduction And Processing. Vol. 2. Kobe, Japan, 22 September 1995. Proceedings p.9-16.