Multiple Parameters for Prediction of Translucent Flesh in Mangosteens

[1]Sontisuk Teerachaichayut, [2]Anupun Terdwongworakul and [2]Siwalak Pathaveerat
[1]Department of Food-processing Engineering, Faculty of Agro-Industry, King Mongkut's Institute of Technology Ladkrabang, Ladkrabang, Bangkok 10520, Thailand
[2]Department of Agricultural Engineering, Faculty of Engineering at Kamphaeng Saen, Kasetsart University, Kamphaeng Saen Campus, Nakhonpathom 73140, Thailand
([1]Corresponding: E-mail: ktsontis@kmitl.ac.th)

ABSTRACT

Translucent flesh in mangosteen is a main defect that obstructs the exporting growth and prompts the need for non-destructive inspecting technique. The physical and chemical parameters of 257 mangosteen samples were determined as a ratio of maximum diameter and minimum diameter (RMM), a ratio of calyx weight and fruit weight (CWW), Specific gravity (SC), averaged pericarp moisture content (AMC), and differential pericarp moisture content (DMC). Discriminant analyses were performed on the parameters to evaluate the accuracy of translucency classification validated by leave-one-out cross validation. The overall accuracy of classification was achieved using all parameters presenting 78.9% compared with 72% when using only SC for samples without yellow gumming and hardening pericarp disorder. The pericarp hardening samples and yellow gumming samples were found to decrease the accuracy of the analysis. The results indicated that the multiple parameters that objectively imitated the subjective indices employed by manual sorter could be applicable to evaluate the translucent flesh.

Keywords: Prediction, translucent flesh, mangosteen, discriminant analysis, Thailand

1. INTRODUCTION

Mangosteen (*Garcinia mangostana* L.) has claimed a place as one of the most important tropical fruits. Physiological disorders that hinder a growing export market include irregular shape, damage caused by insects with symptoms of decay, fruit cracking, yellow gumming, hardening of the pericarp and the most center of attention in recent years, translucent flesh (Pamplona and Garcia, 2001). There were many studies to determine reasons for the disorders. A drop higher than 10 cm could cause significant damage to pericarp, following which hardening at the point of impact would be apparent (Tongdee and Suwanagul, 1989 and Ketsa and Atantee, 1998). Pankasemsuk *et al.* (1996) showed that specific gravity of translucent flesh fruit was greater than one and was less than one for fruit with normal flesh. Also, fruit exhibiting translucent flesh disorder had lower titratable acid percentage and soluble solids concentration than normal fruit. Moreover, heavy rain during development and growth or water infiltration induces excessive water uptake into the flesh resulting in the translucent flesh disorder. Furthermore, translucent flesh fruit had significantly higher pericarp and flesh water content than normal flesh fruit. At present, detection of translucent disorder in mangosteen fruit is carried out by carefully cutting open the fruit and visually inspecting the flesh.

A number of techniques were investigated to predict disorders in mangosteens. Moisture determination in mangosteens as related to flesh translucent disorder was studied using microwave technique with overall accuracy of 79% (Tongleam *et al*., 2004). Arunrungrusmi *et al.,* (1999) produced 2 D cross-sectional image of mangosteen from near infrared transmission information and showed 70% accuracy for mangosteen hardness classification. X-ray CT and NMR imaging were applied for detecting the rotten flesh of mangosteen and identifying the translucent flesh of mangosteens (Yantarasri *et al*., 1996). Floating in water, which is presently applied in real practice, is another technique used in sorting out the translucent flesh fruits and the specific gravity is to be used instead. However, this technique obtained a low accuracy of prediction. Total sorting efficiency of normal and translucent fruit, using a specific gravity value of one, averaged 71% from four year data (Sornsrivichai *et al.,* 2000). Thus, a more reliable technique for translucent mangosteen prediction is still needed.

Many research projects have been carried out for an internal quality prediction in other fruits by using a parameter such as capacitance for watermelon (Kato, 1997), phase shift of laser Doppler for kiwifruit, peach and Japanese pear (Muramatsu *et al*., 1999), density for kiwifruit (Jordan *et al*., 2000), magnetic resonance imaging for apples (Gonzalez *et al*., 2001), or acoustic impulse response for seedless watermelon (Diezma-Iglesias *et al*. 2004). In addition, internal quality predictions in tropical fruits were reported such as Brix value of mango using near infrared spectroscopy (Saranwong *et al*., 2001) and internal quality in watermelon by acoustic impulse response (Diezma-Iglesias *et al*., 2004). Past research used only one parameter per technique. Alternatively, it is interesting that a consideration of multiple parameters may improve the accuracy of internal quality prediction in fruits. Recent researches turned to the application of multivariate analysis (Abu-Khalaf *et al*., 2004 and Kazemi *et al*., 2005).

In the packing house of mangosteen for export, many experienced inspectors have been checking defects in mangosteen by considering a co-relation of its features such as sphericity, calyx-stem attribute, weigh-size, and water-ring on skin of each fruit in order to separate out low quality fruit including those having translucent flesh. Therefore, the objective of this research was to propose the use of simple physical and chemical parameters, which derived from the subjective means of manual sorting, for multivariate prediction of the translucent flesh in mangosteen.

2. MATERIALS AND METHODS

2.1 Sample Set

A set of 257 intact mangosteen samples harvested from an orchard in Nakhonnayok Province, eastern area of Thailand, was used for this study. The plantation was controlled by providing the excess water in order to force the production of more translucent flesh in mangosteen for this research. Each sample was evaluated for both non-destructive tests, which included specific gravity, weight, and external dimensions and the destructive measurement (*i.e*. pericarp water content). Following the non-destructive measurements, the fruit was cut open at the equator line to investigate internal defects. Mangosteen having normal flesh, yellow gumming disorder, hardening pericarp disorder, and translucent flesh disorder were grouped by visual consideration (Figure 1).

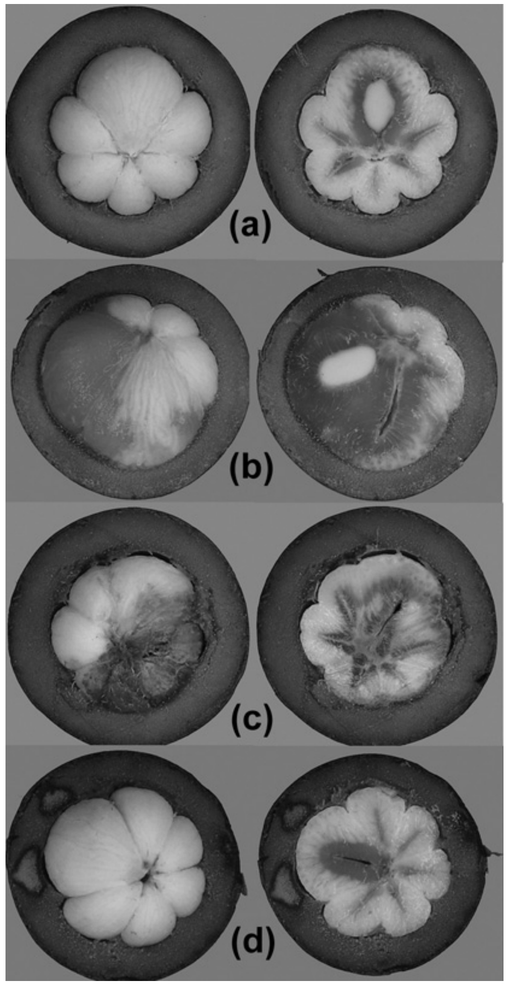

Figure 1. Picture of mangosteen samples (a) normal mangosteen flesh (b) translucent flesh disorder (c) yellow gumming disorder (d) normal mangosteen flesh with hardening pericarp disorder.

2.2 Non-destructive Physical Measurements

A number of translucency predicting parameters were derived from subjective means used by experienced inspectors. For non-destructive method, the inspectors evaluate the translucency from whether the fruits are out of shape, which was defined as a sphericity or a ratio of maximum and minimum diameter. The size of the calyx compared with the fruit size is another subjective parameter that could be translated into weight ratio between calyx and the fruit. Weight-size relation could be defined as its specific gravity. Each sample was weighed

(W_1) by using a digital scale (AND, HR-200, 210 g capacity, 0.1 mg readability, Japan). Archimedes' principle was used to determine the weight of the displaced water by submerging the fruit into water by means of a sinker rod. The reading of the scale with the fruit submerged (W_2) subtracted by the container weight (W_3) was the weight of the displaced water. The specific gravity of each sample was calculated as outlined in Mohsenin (1984) and expressed as follows:

$$\text{Specific gravity} = W_1/(W_2 - W_3) \quad (1)$$

The maximum and minimum diameters of each sample were measured using a vernier caliper (Mitutoyo 530-312, 150 mm ± 0.03 mm). A weight of the calyx of each sample was also measured.

2.3. Pericarp's Moisture Content

Visual inspection on the internal pericarp of cut-open mangosteen showed that the biggest segment of the flesh was normally translucent. The internal color of the pericarp adjacent to the translucent flesh additionally appeared darker than other part of pericarp (Figure 2). The hypothesis was that the moisture content in the pericarp next to the translucent flesh would be greater than other pericarp since excessive water might be taken up in the pericarp at the site of translucent aril. Thus it was believed that the difference of pericarp moisture contents would be better parameter to specify the translucency of the flesh than sole pericarp moisture content.

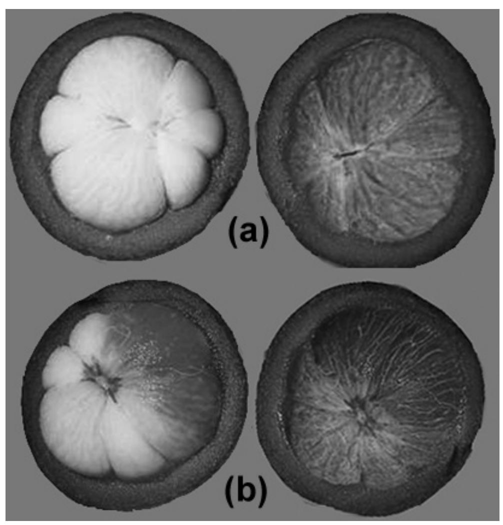

Figure 2. The internal surface of pericarp presentation in mangosteen without translucent flesh (a) and with translucent flesh (b).

Two parts of the pericarp of each sample were cut and each part was divided into two pieces of about 1.20 grams. One part of the pericarp (Part I) was cut at the area of translucent flesh or at the site of the biggest edible aril for non-translucent mangosteen. The other part of pericarp (Part II) was cut at the opposite site of part I. The moisture content of each piece was determined by microwave drying using a 950 W microwave (DAEWOO, KOR-4125, Korea), which is a standard technique explained by Gay *et al*. (2003). The pericarp's differential moisture content of each sample was calculated with the averaged moisture content of Part I subtracted by the averaged moisture content of Part II.

2.4 Data Analysis

The translucency predicting parameters of 257 mangosteen samples were determined as a ratio of maximum diameter and minimum diameter (RMM), a ratio of calyx weight and fruit weight (CWW), the specific gravity (SC), the averaged pericarp moisture content (AMC), and differential pericarp moisture content (DMC). To imitate the way the experienced inspectors used to judge the defect by practically considering various parameters aforementioned prior to making the decision, the analysis for prediction will be based on multivariate analysis. The SPSS® program (SPSS Inc., Chicago, USA) version 11.5 was used to perform a discriminant analysis for leave-one-out cross validation by the canonical discriminant function to evaluate discriminant power of multiple physical parameters in prediction of translucency.

3. RESULTS AND DISCUSSION

The specific gravity as a single predictive parameter was firstly attempted to evaluate the translucency of the flesh in mangosteens. The overall accuracy for prediction of translucency for all samples and samples without yellow gumming and pericarp hardening defects are 68.5 % and 72.0 % respectively as shown in Table 1.

Table 1. Classification for the translucent flesh using single parameter of the specific gravity for the discriminant analysis

Acquisition		Number of normal mangosteen	Number of translucent flesh mangosteen	Total number of mangosteen	Classification accuracy (%)
A	Total	188	69	257	68.5
	Correct	117	59	176	
	Incorrect	71	10	81	
B	Total	126	49	175	72.0
	Correct	84	42	126	
	Incorrect	42	7	49	

A: Prediction was performed by consideration of all samples and using a single parameter of the specific gravity for analysis.
B: Prediction was performed by consideration of the samples excluding yellow gumming and hardening pericarp disorder and using a single parameter of the specific gravity for analysis.

The accuracy of the separate prediction for the normal flesh group and the translucent flesh group were 62.2 % and 85.5 % respectively when considering all samples. Likewise, the accuracy of the separate prediction for the normal flesh group and the translucent flesh group were 66.7 % and 85.7 % respectively when considering the samples without yellow gumming and hardening pericarp. The prediction was based on the criteria that the translucent flesh mangosteen had the specific gravity greater than one (Pankasemsuk *et al*., 1996). However, in practice, the experienced sorter judges the defect by evaluating several parameters subjectively. Thus, multiple parameters were used to analyze. The next analysis using multiple parameters was performed. Another potential parameter was the pericarp moisture content as reported by Pankasemsuk *et al.* (1996). The translucency was reported to occur due to excess water that resulted in greater moisture content in the pericarp. It was nevertheless hypothesized that the relative value of the pericarp moisture content would be better predictor than the absolute value since the pericarp at the translucent aril was observed to appear wetter than the opposite. All parameters used in the analysis included a ratio of maximum diameter and minimum diameter (RMM), a ratio of calyx weight and fruit weight (CWW), the specific gravity (SC), averaged pericarp moisture content (AMC) (*i.e.* an average of moisture content from the translucent pericarp and the opposite), and the differential pericarp moisture content (DMC). As shown in Figure 3, the sorting of the normal mangosteen and the translucency mangosteen was done using both the averaged pericarp moisture content (AMC) and the specific gravity (SC). Sufficient separation was noticed using these two parameters. However the specific gravity seemed to contribute to the separation more than the averaged pericarp moisture content. Two groups of the the normal mangosteen and the translucency mangosteen were more separated by the horizontal line. The specific gravity of the normal fruit was significantly different from defect fruit (95% confidence). Significant difference was also found for the average moisture content as shown in Table 2.

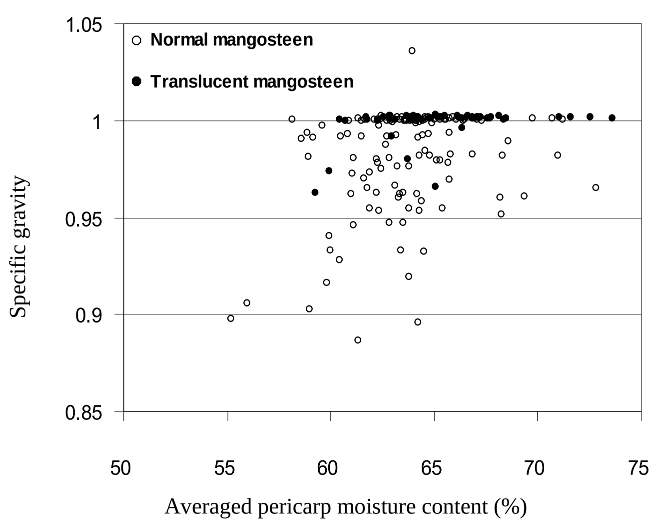

Figure 3. Mangosteen samples were separated by average pericarp moisture content and the specific gravity.

Table 2. The average of the pericarp moisture content and the specific gravity of the normal and defect mangosteen

	Normal mangosteen	Translucent flesh mangosteen
The specific gravity*	0.981 (0.027)	0.999 (0.009)
Average pericarp moisture content (%)*	63.67 (2.57)	66.52 (2.96)

*Significance at 95% confidence
(number in parenthesis is standard deviation)

To improve the separation, the discriminant analysis was performed using RMM, CWW, SC., AMC, and DMC as input parameters. The prediction of the canonical discriminant function was evaluated by leave-one-out cross validation. The overall accuracy for the prediction of the translucency for two cases of classification using both all samples and samples without yellow gumming and the pericarp hardening defects are 73.2 % and 78.9 % respectively as indicated in Table 3. In the former case, the prediction accuracy for the normal mangosteen was 94.1% (177 out of 188) and 15.9% (11 out of 69) accuracy for translucent flesh mangosteen. As for the latter case, when discarding samples having yellow gumming and pericarp hardening defects, the prediction accuracy for translucent flesh mangosteen was improved to 38.8% (19 out of 49). The effect of the yellow gumming disorder on the classification of the translucent flesh mangosteen partly coincided with report by Sornsrivichai *et al.* (2000). They found that by using specific gravity to separate translucent pulp mangosteen, the efficiency was 22.7% and dropped to 17.4% when sorting mangosteen with translucent flesh and yellow gumming for 1997 season.

Table 3. Classification for the normal and the translucent flesh mangosteen using the discriminant analysis and leave-one-out cross validation.

Acquisition		Number of normal mangosteen	Number of translucent flesh mangosteen	Total number of mangosteen	Classification accuracy (%)
A	Total	188	69	257	73.2
	Correct	177	11	188	
	Incorrect	11	58	69	
B	Total	126	49	175	78.9
	Correct	119	19	138	
	Incorrect	7	30	37	

A: For all samples
B: For samples without yellow gumming and pericarp hardening defects

Table 4 shows comparison between the standardized canonical discriminate function coefficients for both cases. Using all samples in prediction, DMC and AMC played an important role compared with DMC and SC when using samples without yellow gumming and pericarp hardening defects. The coefficients indicated that the yellow gumming and pericarp hardening defects influenced the specific gravity measurement (-0.059 compared to 0.521). The DMC variable however gave the most and consistent contribution to the prediction for both cases. The coefficients of DMC were greater than those of AMC especially when discarding the samples with defects of yellow gumming and pericarp hardening. The results suggested the potential of DMC over AMC in terms of prediction performance. This could be explained that DMC parameter was relative value that would not be affected by change in environment conditions compared with the absolute value of AMC parameter.

Table 4. Standardized canonical discriminant function coefficients of the functions for prediction translucency in mangosteen using all samples and samples without gamboge and rind hardening defects.

Input variables	All samples	Samples without yellow gumming and pericarp hardening defects
Averaged pericarp moisture content (AMC)	0.643	0.387
Ratio of calyx weight and fruit weight (CWW)	-0.019	-0.055
Differential pericarp moisture content (DMC)	0.719	0.629
Specific gravity (SC)	-0.059	0.521
Ratio of maximum diameter and minimum diameter (RMM)	-0.303	-0.111

The analyses showed that multiple parameters could be implemented to evaluate the translucency in flesh more accurate than a single parameter.

4. CONCLUSIONS

Using discriminant analysis, multiple parameters related to the subjective indices for prediction of translucent flesh were showed to give better performance than a single parameter (78.9% against 72%). The classification error could be reduced by sorting out samples affected by yellow gumming and pericarp hardening prior to evaluation. The best predictive parameter was differential pericarp moisture content for samples with or without yellow gumming and pericarp hardening. Further research is thus needed for evaluation of yellow gumming and pericarp hardening in mangosteen.

5. ACKNOWLEDGEMENTS

The authors acknowledge the support by the Postgraduate and Research Development Project in Postharvest Technology at Kasetsart University and Kasetsart University Research and Development Institute (KURDI) for research funding, and would like to thank Mr. Jumraj and Mrs. Upa Teerachaichayut for their kind facility help and use of their orchard.

6. REFERENCES

Abu-Khalaf, N., B. Bennedsen and G. Bjorn. 2004. Distinguishing Carrot's Characteristics by Near Infrared (NIR) Reflectance and Multivariate Data Analysis. *Agricultural Engineering International: the CIGR Ejournal*, vol. VI. Manuscript FP 03 012.

Arunrungrusmi, S., D. Khawparisuth, K. Chamnongthai, M. Okuda and S. Ozawa. 1999. Nondestructive 2D cross-sectional visualization of a mangosteen. *Fifth International Symposium on Signal Processig and its Applications*, 443-445. Brisbane, Australia, 22-25 Aug.

Diezma-Iglesias, B., M. Ruiz-Altisent and P. Barreiro. 2004. Detection of Internal Quality in Seedless Watermelon by Acoustic Impulse Response. *Biosystems Engineering* 88 (2): 221–230.

Gay, S. W., R. Grisso and R. Smith. 2003. *Determining forage moisture concentration.* Virginia: Department of Crop and Soil Environmental Sciences.

Gonzales, J. J., R. C. Valle, S. Bobroff, W. V. Biasi, E. J. Mitcham and M.J. Mccarthy. 2001. Detection and monitoring of internal browning development in 'Fuji' apples using MRI. *Postharvest Biology and Technology* 22: 179-188.

Jordan, R. B., E. F. Walton, K. U. Klages and R. J. Seelye. 2000. Postharvest fruit density as an indicator of dry matter and ripened soluble solids of kiwifruit. *Postharvest Biology and Technology* 20: 163–173.

Kato, K. 1997. Electrical Density Sorting and Estimation of Soluble Solids Content of Watermelon. *Journal of Agricultural Engineering Research* 67: 161 – 170.

Kazemi, S., N. Wang, M. Ngadi, and S. Prasher. 2005. Evaluation of Frying Oil Quality Using VIS/NIR Hyperspectral Analysis. *Agricultural Engineering International: the CIGR Ejournal*, vol. VII. Manuscript FP 05 001.

Ketsa, S. and S. Atantee. 1998. Phenolics, lignin, peroxidase activity and increased firmness of damaged pericarp of mangosteen fruit after impact. *Postharvest Biology and Technology* 14: 117-124.

Mohsenin, N. N. 1986. *Physical properties of plant and animal materials*. New York: Gordon and Breach Science Publishers.

Muramatsu, N., N. Sakurai, N. Wada, R. Yamamoto, T. Takahara, T. Ogata, K. Tanaka, T. Asakura,Y. Ishikawa-Takano and D. J. Nevins. 1999. Evaluation of fruit tissue texture and internal disorders by laser Doppler detection. *Postharvest Biology and Technology* 15: 83–88.

Pamplona, P. P. and M. E. Garcia. 2001. *Handbook on Mangosteen: Production Practices in the ASEAN*. Kabacan, Cotabato, The Philippines: University of Southern Mindanao.

Pankasemsuk, T., Jr. J. O. Garner, F. B. Matta and J. L. Silva. 1996. Translucent flesh disorder of mangosteen fruit (*Garcinia mangostana* L.). *HortScience* 31: 112-113.
Saranwong, S., J. Sornsrivichai and S. Kawano. 2001. Improvement of PLS calibration for Brix value and dry matter of mango using information from MLR calibration. *The Journal of Near Infrared Spectroscopy* 11: 287-295.
Sornsrivichai, J., R. Podee, K. Saengnil and T. Yantarasri. 2000. Nondestructive method for sorting of gamboge and translucent pulp in mangosteen by specific gravity. *Precision and efficiency in Quality Assurance in Agricultural produce: ACIAR Proceedings 100 edited by Johnson*, 158-163. Australia.
Tongdee, S. C. and A. Suwanagul. 1989. Postharvest mechanical damage in mangosteen. *ASEAN Food Journal* 4: 151-155.
Tongleam, T., N. Jittiwarangkul, P. Kumhom and K. Chamnongthai. 2004. Non-Destructive grading of mangosteen by using microwave moisture sensing. *International Symposium on Communications and Information Technologies*, 650-653. Sapporo, Japan, 26-29 Oct.
Yantarasri, T., C. Sivasomboon, J. Uthaibutra and J. Sornsrivichai. 1996. X- ray and NMR for nondestructive internal quality evaluation of durian and mangosteen fruits. *Acta Hort. (ISHS)* 464: 97-101.