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Effect of Water Content on Backscattering Parameters

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ABSTRACT

Water content is one of the parameters that used to determine fruit quality. In this study, the effect of water content on the changes of backscattering parameters was investigated. The experiment was conducted on 240 bananas which vary from ripening stages 2 to 4. About half of the samples were stored at 6°C to induce chilling injury symptoms while the other were stored at 13°C and used as a control samples. The water content values were measured destructively on each sample based on the wet basis method. The results were compared with backscattering data that acquired using backscattering imaging. Results indicated there were significant differences ($P<0.05$) on the water content values and backscattering parameters as ripening stages increased. Results also revealed there were significant differences on the collected data as chilling injury developed. Hence, backscattering imaging is potentially useful for determining water content values and textural properties of fresh produce.

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INTRODUCTION

Water content is one of the main quality attributes for fruits and vegetables. Similar to other biochemical components such as lipid, cell wall composition, particle size and shape, this attribute contributes to the textural properties of fresh produce (Sams, 1999). It was used to indicate chilling injury symptoms in many fresh produce such as cucumber, grapes, citrus, etc. Theoretically, as chilling injury develops, water losses become greater due to cellular breakdown, deterioration of membrane integrity as well as loss of epicuticular wax (Kasim, 2011). As a result, the fruits showed surface pitting symptom which indicate the development of chilling injury on the fruits.

Increased demand for objectivity, consistency, and efficiency in defect detection has necessitated the introduction of optical imaging methods which are automated, non-destructive, precise and cost effective. Essentially, optical imaging methods are based on the interaction between light and samples. The lights used in optical imaging methods ranged from the ultraviolets (UV, 10-400 nm) to the visibles (400 nm to 700 nm) and was often extended to include the near infrareds (NIR, 700 to 2500 nm) (Abbott, 1999; Ruiz-Altisenta, 2010). Theoretically, when light hits a fruit about 4% of the light would be reflected at the fruit surface while the rest enters the fruit tissue and is absorbed, transmitted, or scattered back (diffused reflectance) from the region close to the incident point (Birth, 1976). The interaction between the fruit tissue, the apparent intensity and the pathlength of light from incident point until total attenuation provided information on the structural and chemical characteristics of the fruit (Abbott, 1999).

Backscattering imaging is a new innovative method based on spatially-resolved readings, combining vision system and spectral readings by which the image is produced from the interaction between light and the fruit (Lu, R., 2004). The method has been used to detect many fruits attributes such as firmness (Lu, 2000) sugar content (Lu, 2000; Qing,2007), soluble solids content (Qing, 2007) colour (Romano, 2012; Hashim, 2013) and moisture content on dried banana slices (Romano, 2008). Therefore, this study was conducted to investigate the potential of this method to detect the changes of water content that related to the development of chilling injury symptoms in bananas.

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Methodology:

A total of 240 bananas consisting of 60 bananas for each of the ripening stages 2 to 5 were measured for this study. Out of the 60, 30 were grouped as chill-treated samples and another 30 were grouped as control samples. The chill-treated and control samples were stored at 6 °C and 13 °C respectively with relative humidity of 90-95% for two days. Data collections were measured at before and after storage. Water content determination was carried out by weighing the peel slices using electronic balance and stored into oven for 24 hours with drying temperature of 60 °C (Romano, 2008). The dried skins were weighed again after removal from the oven and the water content is calculated by expressing the mass difference as a percentage of the mass before storage.

The backscattering images were acquired using own-developed backscattering imaging system. Since water is the main absorber at near infrared region (Abbott, 1999), laser diode emitting light at 785 nm wavelength was applied in this study. The backscattering images whose sizes were 720x576 pixels were acquired in a dark room and the incident angle of light beam was set at 15° from the vertical to get distortion-free images and minimal direct reflection back to the camera. Each banana was placed under the CCD camera in the same orientation and position.

The backscattering parameters were obtained by plotting the light intensity against the diametral pixels. From the backscattering profile, the backscattering parameters, i.e., the inflection point (IP), the slope after inflection point (SA), the full-width-half-maximum (FWHM) and the saturation radius (RSAT) were determined. The backscattering parameter values obtained from the analysis were then transferred as text files to Matlab or MS Excel for further statistical analysis.

RESULTS AND DISCUSSIONS

(i) Changes of Water Content during Chilling Injury:

Fig. 1 indicates that for each ripening stage, there were significant differences in water content from before to after storage. At before storage, both the control and the chill-treated samples had high values of water content. This is because the fruits were still intact and not subjected to any treatment. The values then decreased after storage. For control samples, the decreased could be related to the respiration and transpiration process as the fruits continued ripen when stored at ambient temperature. For chill-treated samples, the decreased could be related to the development of many open pores due to the damage of membrane cells in the skin that allowed uncontrollable transpiration process.

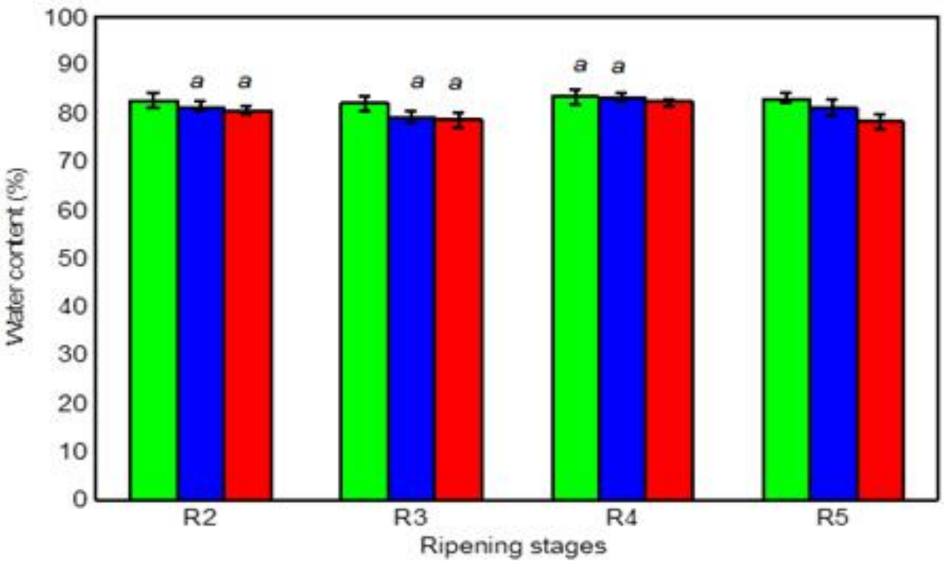

Fig. 1: Water content of bananas at different ripening stages. Green: Before storage (20 °C), Blue: After stored at control temperature (13 °C), Red: After stored at chilling temperature (6 °C). Bars represent mean ± standard deviation. The letter *a* indicates values that are not significantly different ($p>0.05$).

Table 1: ANOVA of water content in bananas subjected to experimental factors.

Factor	F-values	P-values
Temperature	103.13	<0.0001
Ripening stages	64.00	<0.0001
Temperature*Ripening stages	9.83	<0.0001

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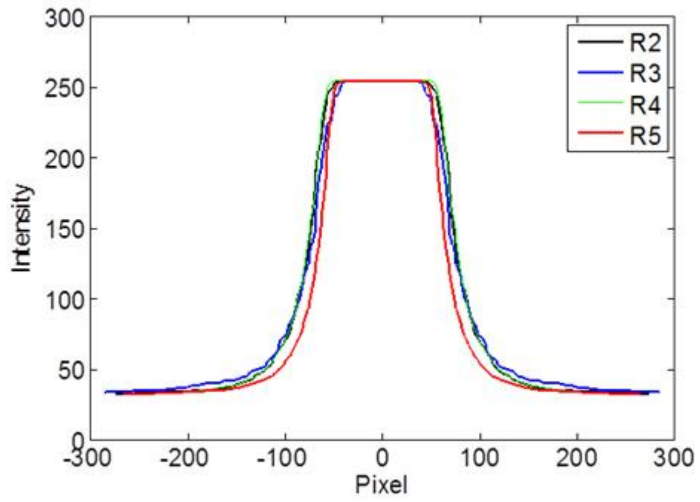

Fig. 2: The backscattering profile of 785 nm at different ripening stages before storage.

Table 2: ANOVA of backscattering parameters subjected to experimental factors.

Factor	Parameter	F-values	P-values
Temperature	*IP*	1898.84	<.0001
	SA	1057.40	<.0001
	FWHM	3211.56	<.0001
	RSAT	662.67	<.0001
Ripening stage	*IP*	312.14	<.0001
	SA	130.51	<.0001
	FWHM	365.18	<.0001
	RSAT	852.79	<.0001
Temperature*Ripening stage	*IP*	9.74	<.0001
	SA	17.29	<.0001
	FWHM	21.36	<.0001
	RSAT	12.49	<.0001

Therefore, it can be concluded that there was a change in water content values as the samples were exposed to 6 °C and 13 °C storage. This was confirmed by the ANOVA result which showed that there were significant effects of temperature, ripening stage and their interaction on water content in bananas (Table 1). Temperature had the most influence on the water content values by showing the highest F-values.

(ii) Effect of Water Content on Backscattering Parameters:

Fig. 2 shows the pattern of backscattering profile at different ripening stages. It can be seen that R5 obtained the lowest RSAT values while curve fitting for the other ripening stages overlapping to each other. Since theoretically water content increases as the ripening stage advances, the more pronounced decreased in backscattering area for R5 could be due to the increases in the absorption of the 785 nm light by the higher water content in the fruits.

As chilling injury developed, the ripening process was inhibited and the tissue showed decay symptoms that lead to increase water losses. When the water content is reduced, air replaced water in the intracellular space making the distance between solids decreased (Romano, 2008), resulting an increased in firmness or hardness of the fruits during chilling injury. As a consequence, light penetration into the tissues became more difficult. Photons took a straight trajectory and more direct reflection occurred. The effects of experimental factors on the backscattering parameters are as shown in Table 2. Results indicated all experimental factors and their interactions were significant. The highest F-values was shown by FWHM with 21.36.

Summary:

The results of this study show that backscattering imaging could be used to detect water content in fresh produce. The area of the backscattering images increased as water content decreased, affecting the backscattering parameters, IP, SA, FWHM and RSAT. All the backscattering parameters showed significant changes as chilling injury developed. This indicated that backscattering imaging could be used to detect water content values in chilled injured bananas and potentially could be also applied on other fresh produce.

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