QUANTIFICATION OF STARCH CONTENTS IN APPLES USING IMAGE ANALYSIS AND THEIR RELATIONSHIPS TO PHYSICOCHEMICAL PROPERTIES

Y. J. Cho[1], W. Jun[1], B. S. Ko[1], C. T. Kim[1], C. J. Kim[1], D. M. Kim[1]and J. K. Kim[2]

[1]Korea Food Research Institute
San 46-1, Baekhyun-dong, Bundang-ku, Songnam-si 463-420, Korea
[2]Dept. of Horticultural Science, Chung-Ang University
San 40-1, Naeri, Daeduckmyun, Ansung-si 456-756, Korea
E-mail: yjcho@kfri.re.kr

ABSTRACT

At harvest, the starch contents of apples, which were related to their maturity, were quantified by using image analysis. The stained area was measured by a computer vision system when an apple slice was stained with KI/I_2 solution. The stained area ratio of the stained area of the apple slice to its whole area, or the starch index, was defined as an indicator of starch content. When *Tsugaru* apples were manually sorted into immature, turning and mature groups, their starch indices were 0.374, 0.312 and 0.129, respectively. Meanwhile, the starch index had correlation to various physicochemical properties of *Tsugaru* apples. At the statistically significant level of 0.1%, it was correlated with the pH value, bio-yield force, rupture force and color of intact and skin-removed apples. At the 1% significant level, it had the correlation with the density and moisture content.

Key Word : Starch Content, Apple, Image Analysis, Physicochemical Properties

INTRODUCTION

The information on fruit maturity can be utilized to decide the time of harvest and establish the plan of storage and marketing. Immature fruits may be underpriced whereas overmature ones are not appropriate for long-term storage because the maturity is related to their taste and physicochemical properties.

Some physicochemical properties of apples may change according to their maturation. Knee et al. (1989) investigated various indicators of maturity for harvest of apple fruit intended for long-term storage. They reported that starch and firmness at apple harvest indicated a different maturity order.

A chemical titration of starch content is hardly used in the field of apple production because it is difficult and time-consuming. Traditionally, starch in a plant tissue has been stained with an iodine solution. This procedure is not quantitative and

qualitative.

In this study, a starch index numbered by a simple and rapid procedure using image analysis was proposed to quantify starch contents relating to apple maturity. Also, the relationships of the starch index with various physicochemical properties were investigated.

MATERIALS AND METHODS

APPLE

Tsugaru apples were harvested from a local apple orchard on August 31, 1999. The harvested apples were manually sorted into immature, turning and mature groups. 75 apples were randomly selected from three maturity groups for test.

STARCH QUANTIFICATION

Starch contents of apples were quantified by using image analysis which was performed with a computer vision system consisted of a 2/3" one-chip color CCD camera (Model TMC-74, PULNiX) and a color frame grabber (Model Oculus-TCX, Coreco). First, sliced apples were thermally processed at 60°C for 20 minutes and stained with the KI/I_2 solution. Fig. 1 shows that the degrees of stain are different with maturity. Then, the stained and whole areas of sliced apples were measured with the image analyzer. In this study, the ratio of the stained area to the whole area was defined as a starch index.

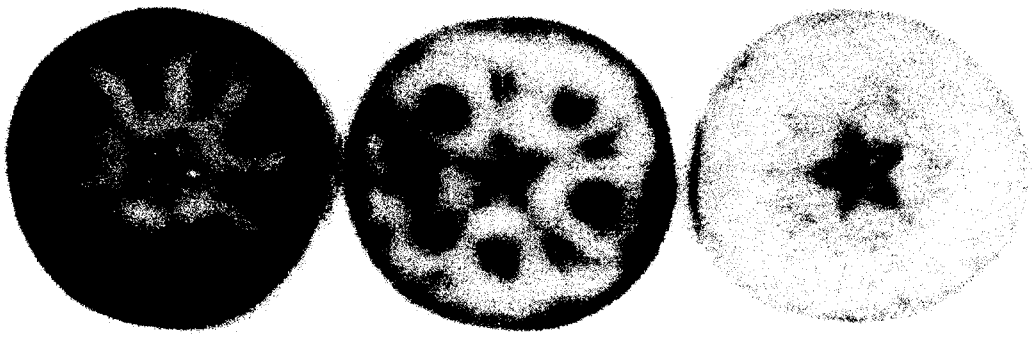

Fig. 1. The degrees of stain of apples with maturity (from left, immature, turning and mature).

An image processing procedure used in this study for starch quantification is as follows. A color image having red, green and blue frames was captured from a stained apple slice. The RGB color system of the image was converted to the color system with hue, intensity and saturation components. Because the color stained with the KI/I_2 solution was blue, the frame of hue was segmented by the threshold value of pure blue.

Then, the segmented and whole areas were measured. Finally, a ratio of the stained area to the whole area, or a starch index, was calculated.

MEASUREMENT OF PHYSICOCHEMICAL PROPERTIES

Moisture content, soluble solids content and pH of apple flesh, density of an intact apple, and compressive properties and color of intact and skin-removed apples were measured.

Moisture content was measured by an oven method under the condition of 70°C and 20 hours. Soluble solids contents and pH values were measured a refractometer and pH meter, respectively. Density was obtained by a platform scale method. Bio-yield and rupture points were collected by using a compression tester with a plat plunger with 5 mm diameter. In compression test, loading speed was 5 mm/min. Values in Hunter's color system were measured with a spectrophotometer and color distribution was analyzed by using a computer vision system.

RESULTS AND DISCUSSION

STARCH INDEX

Fig. 2 shows an apple slice stained with the KI/I_2 solution (left) and a binary image indicating starch (right). In this study, a starch index that was a ratio of the stained area of an apple slice to its whole area was defined.

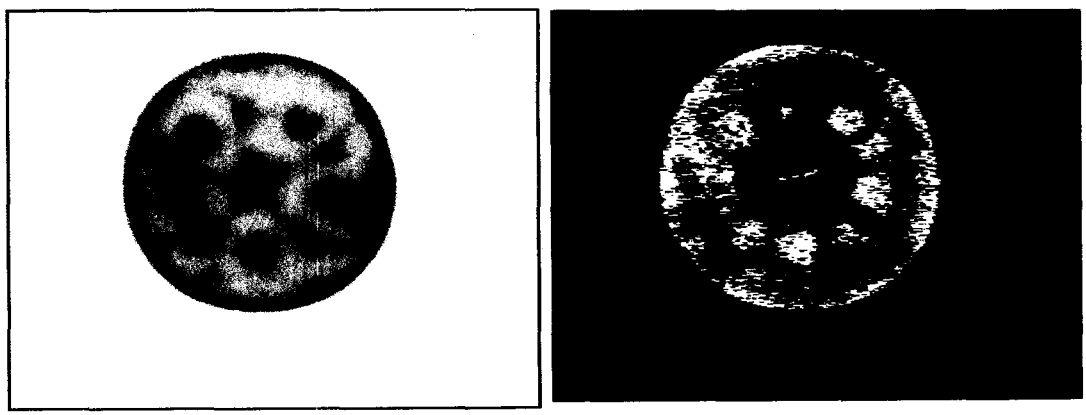

Fig. 2. An apple slice stained with the KI/I_2 solution (left) and a binary image indicating starch in an apple (right).

Table 1 shows that the starch indices of *Tsugaru* apples were different with maturity. When apples were manually sorted in the immature, turning and mature groups, their starch indices were 0.374, 0.312 and 0.129, respectively.

Table 1. The starch indices of *Tsugaru* apples with maturity

Maturity	Starch index [1)]
Immature	0.374 [2)]
Turning	0.312
Mature	0.129

Notes: [1)] Ratio of the stained area of an apple slice to its whole area
[2)] An average of 25 apples in each maturity group

RELATIONSHIP OF STARCH INDEX TO PHYSICOCHEMICAL PROPERTIES

Various physicochemical properties of apples have interrelationships when maturity is considered. For example, starch content, firmness, color, moisture content, and so on are interrelated regarding maturity or ripeness (Mohsenin, 1986; Van Woensell et al., 1987; Knee et al., 1989; Cho and Hwang, 1998). In this study, the starch indices of *Tsugaru* apples were related to various physicochemical properties.

Table 2 shows the correlation coefficients of the starch indices of *Tsugaru* apples with their various physicochemical properties. As shown in Table 2, at the 0.1% significant level, the starch index had the high correlation with the pH value, bio-yield force, secant slope, rupture force and Hunter's color value a of *Tsugaru* apple flesh. Also, the bio-yield force, rupture force, Hunter's color value a of the intact apples had the high correlation with the starch index at this statistical level.

At the 1% significant level, the density, moisture content and secant slope within bio-yield of *Tsuagru* apple flesh had the correlation with the starch index. Meanwhile, the rupture deformation and Hunter's color value b of the intact apples and the bio-yield deformation and rupture deformation of the apple flesh had the correlation with it at the 5% significant level.

From the above results, the highest correlation coefficient was –0.666 which appeared between the starch index and the pH value of the apple flesh, following by 0.642 between the starch index and the bio-yield force of the intact apples. The latter agrees with the study of Knee et al. (1989) that starch content and firmness were indicators for apple maturity

Table 2. The correlation coefficients of the starch indices of *Tsugaru* apples with their various physicochemical properties

Property			Correlation coefficient	Significant probability
Height			-0.057 [1)]	0.6292
Width			-0.014	0.9018
Height/width ratio			-0.036	0.7562
Density of an intact apple			0.373**	0.0011
Moisture content of apple flesh			-0.367**	0.0013
Soluble solids content of apple flesh			0.063	0.5895
pH of apple flesh			-0.666***	0.0001
Intact apple	Bio-yield deformation		0.227	0.0511
	Bio-yield force		0.642***	0.0001
	Secant slope within bio-yield		0.361**	0.0016
	Rupture deformation		0.260*	0.0252
	Rupture force		0.611***	0.0001
	Hunter's color value	L	0.135	0.2491
		a	-0.447***	0.0001
		b	0.285*	0.0136
Skin-removed apple	Bio-yield deformation		0.237*	0.0414
	Bio-yield force		0.498***	0.0001
	Secant slope within bio-yield		0.391***	0.0006
	Rupture deformation		0.284*	0.0139
	Rupture force		0.589***	0.0001
	Hunter's color value	L	-0.096	0.4157
		a	-0.431***	0.0001
		b	-0.039	0.7379
Hue of color of intact apple	Mean		-0.097	0.4074
	Standard deviation		-0.458***	0.0001

Notes: *, ** and * mean 5%, 1% and 0.1% significant levels, respectively.**

[1)] The correlation coefficients were calculated with 75 apples.

CONCLUSIONS

The starch content of apples is known as an indicator of their maturity. Its chemical quantification procedure is difficult as well as time-consuming. For the starch content to be an effective indicator in the field of apple production, a rapid and simple technique for evaluating the starch content of apples is needed.

In this study, an image analysis technique was developed to evaluate the starch content of apples. When an apple slice was stained with the KI/I_2 solution, the starch index, or the ratio of the stained area to the whole area, was defined, because only starch in the apple slice was dyed.

When the technique developed in this study was applied to *Tsugaru* apples sorted in immature, turning and mature groups by a farmer, the starch indices were 0.374, 0.312 and 0.129, respectively.

Meanwhile, the stained area ratio had the high correlation to various physicochemical properties of *Tsugaru* apples. At the statistically significant level of 0.1%, it was correlated with the pH value, bio-yield force, rupture force and color of intact and skin-removed apples. At the 1% significant level, it had the correlation to the density and moisture content.

Therefore, the image analysis procedure developed in this study is expected to be a technique for evaluating apple maturity.

ACKNOWLEDGEMENTS

Appreciation is extended to Agricultural R&D Promotion Center, Korea for sponsoring this project.

REFERENCES

1. ASAE S368.2. 1994. Compression test of food materials of convex shape. ASAE Standards, Engineering Practices, and Data, 41st Ed. pp. 472-475, ASAE, St. Joseph, MI, USA.
2. Cho, Y. and J. Hwang. 1998. Physicochemical factors for evaluating freshness of apple and tomato. Journal of Korean Society for Agricultural Machinery 23(5):473-480.
3. Knee, M., S. G. S. Hatfield and S. M. Smith. 1989. Evaluation of various indicators of maturity for harvest of apple fruit intended for long-term storage. Journal of Horticultural Science 64(4):403-411.
4. Mohsenin, N. N. 1986. Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publisher, New York.
5. Van Woensel, G., A. Wouters and J. De Baerdemaeker. 1987. Relation between mechanical properties of apple fruit and sensory quality. Journal of Food Process Engineering 9(3): 173-189.