Effects of meteorological factors on fruit qualities of 'Fuji' apple in Korea

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Summary: 'Fuji' apples from five different growing regions in Korea were analyzed for internal and external quality attributes which included fruit shape, color and sugar. Significant relationships were observed between final fruit color (a*) and air temperature in August. Red color was poorly developed where the average temperature in August was over 25 oC. The sugar composition was significantly different depending on region. The sucrose content decreased with increasing temperature above 16 oC during the harvest season. The fruit shape was not affected by agro-climatic conditions in this study.

Introduction

Apples are one of the major fruit crops in Korea. Apple production can be found in many parts of the country from 36 to the 38 N latitude (the upper part of South Korea), but the main concentration is in KyungSang Pook Do Province (*Proctor* & *Lee*, 1981; *Syn* & *Ryo*, 1995). *Since* 1970 'Fuji' has been widely planted and accounts for 77% of total apple production in this major apple-producing area. Fruit color is one of the most important factors for final fruit quality for 'Fuji' apple because the price is dramatically affected by the color grade in Asian markets.

Several studies have been done investigating the effect of different climatic conditions on fruit quality of apple and other fruits (*Spano* et al, 1997; *Toldam-Andersen* & *Hasen*, 1998). From these studies it has been found that temperature during ripening has a major influence on fruit metabolism which can lead to differences in the development of fruit color and internal quality factors. It has been concluded that cool nights followed by warm days when UVB and light are incident leads to the red blush on 'Granny Smith' apple (*Reay*, 1999). In grapes, warm climate during ripening leads to high sugar but limited acid content, whereas a cool climate limits the sugar but leads to high acid content and secondary substances like aroma and color (*Jackson* & *Lombard*, 1993). *Tomana* & *Yamada* (1988) reported that the rate of glucose synthesis was decreased by low temperature in cool areas but the rate of sucrose synthesis was increased by low temperature in apple. However, no such information is available for 'Fuji' apple quality and it is still a question that how it depends on agro-climatic conditions.

This study considers the response of external (skin color) and internal (sugar composition) 'Fuji' quality to different agro-climatic areas during fruit growth. The objective of this research is to improve our understanding of fruit quality on agro-climatic conditions and to suggest proper sites for 'Fuji' apple production in the future.

Material and methods

The experiments were carried out in five different apple growing areas, Euisung, Munkyung, Pohang, Taegu and Yungduk in Korea. Three commercial orchards were selected in each of the five areas.

Fifty 'Fuji' apples were randomly collected at the commercial harvest (Oct 31, 1996) from each orchard in

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order to determine the effects of the agro-climate on fruit quality in terms of fruit shape, color and sugar composition. The fruit shape expressed by D/L index was determined by the average of the largest and smallest transverse diameter (D) over longitudinal length (L) in each fruit.

Fruit color was measured with a NR-3000 Handy Colorimeter (Japanese Electronic Co, Japan) and fruit chromaticity (color) was recorded in Commission Internationale d'Eclairage (C. I. E.) L*, a* and b* color space coordinates (*Hunter*, 1975). In this system of color representation the values L*, a* and b* describe a uniform three-dimensional color space, where L* value corresponds to a dark-bright scale and represents the relative lightness of colors. The a* and b* value correspond to the measure of redness and yellowness, respectively.

To analyse sugar composition, apple juice was centrifuged at 4000 rpm and filtered through Miracloth (Calbiochem, U.S.A.). Analysis of sugar composition was done using high performance liquid chromatography (HPLC; Soinadzu LC-10A, Japan) with a Shodex SC1011 column and conditions as described by *Syn* et al. (1997).

The air temperatures were obtained from the nearest local meteorological center to each orchard from May to harvest dates.

Results and discussion

The comparison of agro-climatic conditions among the five different areas was shown in *Fig. 1* and *Fig. 2*. Among the five different areas, Taegu area recorded the highest average air temperature during the fruit growth periods. Toward harvest season the air temperature in Taegu was 3.1 1C higher than Munkyung area in the October *(Fig. 1)*. The natural precipitation was not significantly different among the five different areas except Munkyung area. In June, rainfall was significantly increased overall areas and decreased after this month in the all areas except for Munkyung, where the rainfall in July was significantly higher than other areas *(Fig. 2)*.

Fruit quality, in terms of D/L index, skin color (a*) and sugar composition was significantly different among the five areas *(Table 1)*. The fruits in Taegu and Munkyung areas were flatter than those in other areas, however the difference was small. The areas which were chosen in this study based on the variation in their agro-climatic conditions and consequently showed wide variation in fruit colors. The

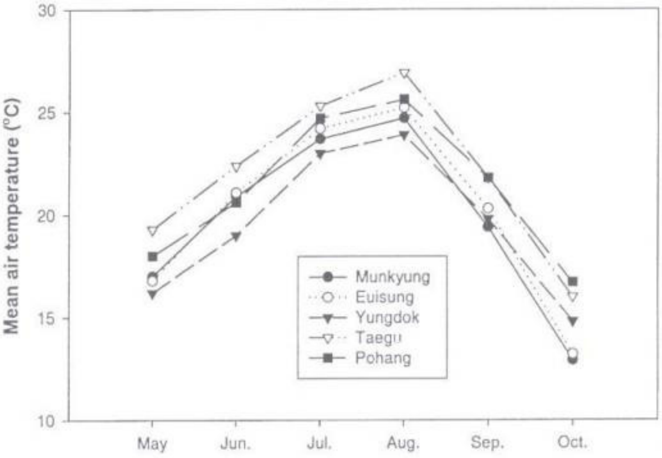

Fig. 1 Mean air temperature during fruit growing season in the five different regions in Korea in 1996.

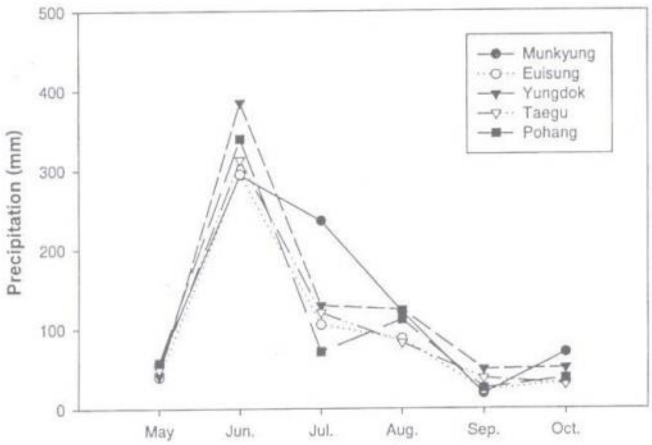

Fig. 2 Precipitation during fruit growing season in the five different regions in Korea in 1996.

highest L* value (at commercial harvest dates) was obtained from fruits in Taegu (52.8) followed by those in Euisung (48.1) area. The a* value (a measure of redness) was significantly different among the areas. The fruits in Munkyung area had the highest value (33.0), however the lowest value was found on fruits form Taegu (20.2). However, the b* value (a measure of yellowness) was not different among the areas. In the comparison of sugar composition, fructose was the most prevalent sugar followed by sucrose and glucose regardless of the area except for Taegu area where the glucose contents was higher than

Table 1 Comparison of D/L index, skin color and each sugar composition in the fruits produced in five different regions in Korea.

Regions	D/L index	Skin Color			Sugar composition (g/100ml)			
		L*	a*	b*	Sucrose	Glucose	Fructose	Sorbitol
Munkyung	1.20az	44.3c	33.0a	18.8a	5.01ab	1.99bc	5.36a	1.25a
Euisung	1.15b	48.1b	32.3ab	17.7a	5.26a	1.89c	5.83a	1.30a
Yungdok	1.15b	45.3c	30.6b	19.5a	4.01b	2.33b	5.87a	0.92ab
Taegu	1.22a	52.8a	20.2c	21.0a	2.99b	3.65a	6.43a	0.88ab
Pohang	1.16b	44.1c	28.9b	17.8a	3.75a	2.56b	6.24a	0.87ab

*Means followed by same letter are not significantly different at the 5% level by Duncan=s Multiple Range Test.

sucrose. Sucrose, glucose and sorbitol contents were significantly different in apples from different area whereas fructose was not. Fruits from Euisung and Taegu had the highest and lowest sucrose contents, respectively. In contrast to sucrose contents, the glucose contents were reversed in general. Fruits from Munkyung and Eusung, where the orchards are located on hillsides had the highest sorbitol values.

The average air temperature during the fruit growth periods affected the quality characteristics of fruits. The correlation between temperature and fruit quality is shown in *Table 2*. Although the soil and climatic conditions at a given orchard site are critically important for fruit shape (Syn et al., 1997), the D/L index in this study was not correlated with average monthly air temperature through the entire fruit growth periods. This suggests that differences in air temperature among five areas were not enough to affect fruit shape in this study.

The a* values were significantly influenced by air temperature especially in August (r= -0.826) when the fruit begins to turn red (Table 2). Furthermore, the quadratic regression of the air temperature on a* value of fruits for different areas at commercial harvest provided a coefficient of determination (R^2) of 0.975 *(Fig. 3)*. As reported by Creasy (1969) for 'McIntosh' apple, it is concluded that the temperature at the beginning of the period when 'Fuji' begins to turn red is very important for red pigment development. The data in this study showed that the red color is poorly developed where the average air temperature is over 25 °C in August such as fruit from Pohang and Teagu areas.

Glucose and fructose contents were positively correlated with mean temperature in October *(Table 2)*. However, sucrose and sorbitol were negatively corrected with mean temperature in harvest month. The quadratic regression of the air temperature on sucrose content provided a coefficient of determination (R^2) of 0.875 *(Fig. 4)*. The data suggested that increasing temperature during the harvest period decreased the sucrose content.

Temperature is a normal environmental variable which can influence the degree of red coloration and sugar contents of 'Fuji' apples. The amount of red color on the cultivar is significant in its marketing desirability in Asia. For high quality 'Fuji' apple (in term of red color) it should be grown in areas with mean temperature below 25 °C in August when the red color begin to develop. To produce high sucrose content in 'Fuji' apple, mean temperature should be below 16 °C during the weeks before optimum harvest maturity.

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Table 2 Correlation coefficients between mean air temperature during fruit growth periods and final fruit quality (D/L index, skin color and sugar composition) in overall fruits produced in five different regions in Korea

	Correlation coefficients					
	May	Jun.	Jul.	Aug.	Sep.	Oct.
D/L index	0.685	0.710	0.485	0.602	0.196	0.064
Skin color						
L	0.660	0.725	0.637	0.751	0.470	0.196
a	-0.885*	-0.616	-0.743	-0.826*	-0.763	-0.683
b	0.059	0.309	0.226	0.390	0.207	0.302
Sugars						
Sucrose	-0.728	-0.244	-0.524	-0.577	-0.747	-0.887*
Glucose	0.871	0.536	0.694	0.774	0.758	0.744
Fructose	0.745	0.380	0.728	0.725	0.934*	0.883*
Sorbitol	-0.494	0.082	-0.302	-0.314	-0.667	-0.937*

*Significant at 5% level, respectively.

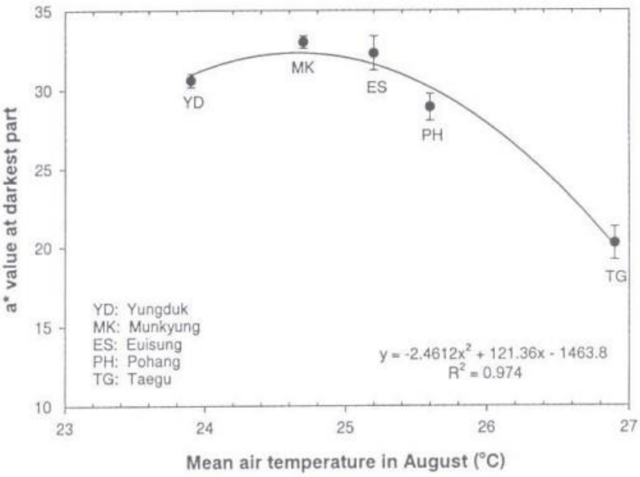

Fig. 3 Quadratic regression of a* value at the darkest part of fruits and mean average temperature in August of 1996 under 5 different growing regions in Korea. Vertical bars represent SE.

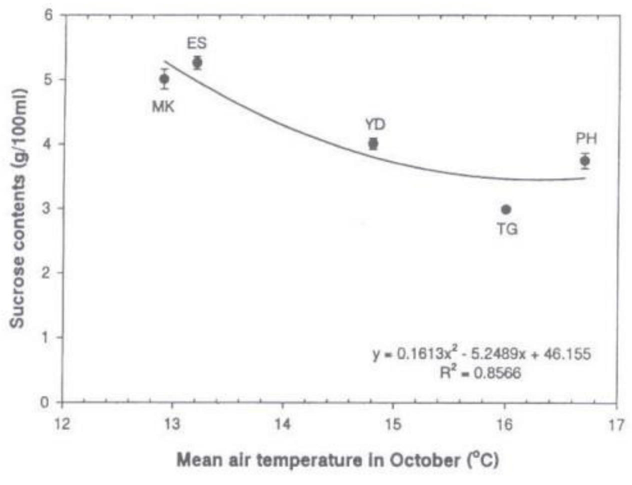

Fig. 4 Quadratic regression of sucrose contents of the fruits and mean average temperature in October of 1996 under 5 different growing regions in Korea. Vertical bars represent SE. Refer to Fig. 3. for abbreviation.

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