Changes in physicochemical properties of the fruit of lulo (*Solanum quitoense* Lam.) harvested at three degrees of maturity

Cambios en las propiedades fisicoquímicas de frutos de lulo (*Solanum quitoense* Lam.) cosechados en tres grados de madurez

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Abstract

The changes in the physicochemical properties of lulo (*Solanum quitoense* Lam) were evaluated in the present research at three degrees of maturity. 300 fruits were used for maturity degree and it was determined the physical characteristics (weight, volume, density, equivalent diameter, sphericity index, performance of pulp and peel) and chemical characteristics (pH, acidity, soluble solids, Maturity Index (MI) and content of vitamin C). The results indicate that maturity does not significantly affect the physical variables, but if done with the chemical properties of fruits. The pH, soluble solids, MI and content of vitamin C was statistically increased (from 2.89 to 2.94, $P < 0.01$) (6.58 to 9.04 °Brix, $P < 0.001$), (1.83 - 2.84, $P < 0.001$), (4.17 and 11.95 mg ascorbic acid/100 g of fresh pulp, $P < 0.001$) with maturity changes, respectively, in contrast the acidity decreased (3.78 to 3.21 g citric acid /100 g of fresh pulp, $p < 0.001$).

Key words: Maturity index, soluble solids, Tropical fruit, vitamin C.

Resumen

En la investigación se evaluaron los cambios en las propiedades fisicoquímicas de frutos de lulo (*Solanum quitoense* Lam.) en tres grados de madurez. Se utilizaron 300 frutos por grado de madurez y se determinaron las características físicas (peso, volumen, densidad, diámetro equivalente, índice de esfericidad, rendimiento de pulpa y cáscara) y químicas (pH, acidez, sólidos solubles, índice de madurez (IM) y contenido de vitamina C. Los resultados mostraron que la madurez no afecta significativamente las variables físicas, pero sí las propiedades químicas de los frutos ($P < 0.01$), de la forma siguiente: el pH (2.89 - 2.94), los sólidos solubles (6.58 - 9.04 °brix), el IM (1.83 - 2.84) y el contenido de vitamina C (ascórbico) (4.17 - 11.95 mg/100 g de pulpa fresca); por el contrario, la acidez (cítrico) disminuyó de 3.78 para 3.21 g/100 g de pulpa fresca ($P < 0.01$).

Palabras clave: Fruta tropical, índice de madurez, propiedades fisicoquímicas del fruto, sólidos solubles, vitamina C.

Introduction

Lulo (*Solanum quitoense* Lam.) is a fruit native to the Andes, cultivated and consumed mainly in Ecuador, Colombia and Central America (Acosta *et al.*, 2009). It is an important source of vitamins, proteins and minerals with considerable nutritional potential (Gancel *et al.*, 2008). The fruit is a golden yellow berry, of 2-6 cm in diameter, covered with stinging hairs, juicy green pulp, generally used in juices, nectars, ice cream, candies, jams, jellies, dressings, sauces and sorbets (Diaz and Manzano, 2002; Gancel *et al.*, 2008). The growing interest in markets has encouraged in recent years the production of this promising Andean fruit.

In 2011, in Colombia this crop occupied an area of 6,748 ha with a production of 57.070 t (Agronet, 2011), being septentrionale and quitoense the most important botanical varieties of lulo in the country; the first is characterized by the presence of thorns on the stem and leaves, while the second has no thorns and the fruit is usually less acid than in the first (Casierra-Posada *et al.*, 2004).

Knowledge of the physicochemical properties of the fruit is important for producers, marketers and processors to schedule and plan the tasks of harvesting, post-harvest management, selection of the processing unitary operations and packaging design. Caicedo (1999) found that during the ripening process the skin of the fruit changes from dark to light green, subsequently acquires yellow hues on the sides to reach the characteristic yellow color of ripe fruits of the variety. Casierra-Posada *et al.* (2004) found that during the maturation occurs an increase in soluble solids and a reduction of thickness of the texture of the fruit. Gancel *et al.* (2008) and Acosta *et al.* (2009) evaluated some physicochemical properties of lulo ripe fruits grown in Ecuador and Costa Rica, and Giraldo-Gomez *et al.* (2010) determined the thermophysical properties of concentrated lulo juice. However, in the literature there are few studies on evaluation of the physicochemical properties of the lulo fruit during ripening. The objective of this research was to evaluate changes in the physicochemical properties of lulo fruit harvested in three degrees of maturity.

Materials and methods

Origin of the fruits

The fruits of lulo used in the study were obtained from a commercial crop located west of the department of Valle del Cauca, at 1,640 meters, 3° 50' 53" N and 76° 34' 36.4" W, with an average temperature of 18° C and a precipitation of 2,000 mm. The fruits were harvested 110 days after the start of flowering in three levels of maturity, depending on the color changes of the skin. Grade 1 (M1) corresponds to green between 75g and 100%, grade 2 (M2) at 50% green and grade 3 (M3) between 0g and 15% green. In the crop three uniform fields were identified, in which random samples of 20 fruits were taken from each field by degree of maturity, for a total of 60 fruits per sampling and 300 fruits in five samplings. The fruits harvested were taken for analysis in the laboratory of Fruit and Vegetable Technology, at the Universidad Nacional de Colombia, Palmira.

Physicochemical analysis

In a subsample of 20 fruits weight (g), volume (cm^3), density (g/cm^3), the equivalent diameter (cm) and the pulp and peel yield (%) of the fruit were measured in accordance with the methodology proposed by Salazar *et al.* (2007). The sphericity index (%) was estimated according to Aydın and Özcan (2002). The chemical characteristics were established in the pulp of each of the sub-samples, pH, total acidity and soluble solids were determined according to the Colombian Technical Standards NTC 4592 (1999a), NTC 4623 (1999b) and NTC 4624 (1999c) and the results were expressed in grams of citric acid/100 g of fresh pulp and Brix degrees, respectively. The maturity index (MI) was evaluated by the ratio between soluble solids and total acidity. The vitamin C content in samples was set out according to the method proposed by Oboh (2006), mixing 5 g of pulp in 100 ml distilled water and taking 10 ml of this mixture to add 25 ml of glacial acetic acid at 20% for titration with 2.6-dichlorophenolindophenol. Results were expressed in mg of ascorbic acid/100 g of fresh pulp from a standard concentration of ascorbic acid. All determinations were performed in duplicate.

Statistical analysis

The assessment of changes in the physicochemical properties of the fruits of lulo in the three degrees of maturity was conducted through a randomized block design. The significance among samples was established using ANOVA and significant differences by Tukey test ($P < 0.01$) using the statistical software SPSS 18 for Windows.

Results and discussion

Physical properties

Table 1 shows that the physical properties of the fruit did not change as a result of maturity ($P > 0.01$). This behavior is mainly due to the condition of the fruit at harvest time, where physical changes are imperceptible because at this stage chemical changes affecting some organoleptic properties as the external color, flavor, aroma and texture occur.

The weights of the fruit in the three degrees of maturity were higher than those found by Gancel *et al.* (2008). The volume ranged between 119.59 and 123.04 cm^3 and density between 0.92 and 0.93 g/cm^3, being the first higher values than those found by Alvarado *et al.* (2007) and the second similar to those found by the same researchers. The range of equivalent diameter of the fruit (4.6 to 4.69 cm) is estimated within the values found by Diaz and Manzano (2002).

The sphericity index between 95.71 and 95.86% confirms that lulo is spherical, a major variable in the design of classification systems, waxing, packaging and cooling. In the three degrees of maturity the pulp yield varied between 62.52g and 64.50% and in peel between 35.06g and 35.71% values similar to those reported by Salazar *et al.* (2007).

Chemical properties

The pH increased from 2.89 to 2.94 as the

Table 1. Physicochemical properties in three degrees of maturity in lulo fruits.

Properties	Degree of maturity			Significance
	M1	M2	M3	
Physical				
Weight (g)	114.72±8.27	114.59±9.74	111.11±7.70	NS
Volume (cm^3)	123.04±8.46	122.68±10.15	119.59±7.92	NS
Density (g/cm^3)	0.93±0.10	0.93±0.01	0.92±0.01	NS
Equivalent diameter (cm)	4.69±0.13	4.67±0.18	4.60±0.13	NS
Sphericity index (%)	95.86±0.58	95.74±0.46	95.71±0.60	NS
Pulp yield (%)	63.01±1.56	62.52±1.79	64.50±3.10	NS
Peel yield (%)	35.19±1.36	35.71±1.71	35.06±2.27	NS
Chemical				
pH	2.89±0.03 b[a]	2.91±0.04 ab	2.94±0.03 a	P<0.01
Total acidity (g citric acido/100 g of pulp)	3.78±0.20	3.52±0.30	3.21±0.38	P<0.001
Soluble solids (°Brix)	6.57±0.27 c	7.89±0.46 b	9.03±0.63 a	P<0.001
Maturity index	1.83±0.32 c	2.26±0.26 b	2.84±0.38 a	P<0.001
Vitamin C (mg ascorbic acid/100 g of pulp)	4.16±1.49 c	7.36±1.02 b	11.95±2.78 a	P<0.001

a. Maturity index: M1 degree corresponds to green between 75 y 100%, degree 2 (M2) to 50% green and degree 3 (M3) between 0 y 15% green.

[a] Values in the same row followed by different letters difer significantly ($P < 0.01$), according to Tukey's test.

maturity grew; on the contrary, the acidity was reduced from 3.78 to 3.21 (P <0.01) (Table 1 and Figure 1). In the work of Caicedo and Higuera (2007), Salazar *et al.* (2007), Ospina-Monsalve *et al.* (2007) and Mejia *et al.* (2012), pH values higher than those found in this study were estimated. Furthermore, the total acidity was similar to that observed for Caicedo and Higuera (2007) and superior to that obtained by Salazar *et al.* (2007) and Mejia *et al.* (2012) working with lulo fruits.

The reduction in the acidity of the fruit during maturation has been corroborated by Casierra-Posada *et al.* (2004) in lulo, Guadarrama (1983) in acerola (*Malpighia punicifolia* L.), Schwartz *et al.* (2009) in pomegranate (*Punica granatum*), Schweiggert *et al.* (2011) in papaya (*Carica papaya* L.), Jimenez *et al.* (2011) in purple passion fruit (*Passiflora edulis* S.) and Palafox-Carlos *et al.* (2012) in mango (*Mangifera indica* L). This reduction may also result from degradation of the organic acids in the process of respiration, vital mechanism that occurs during the fruit ripening stage.

Soluble solids increased (P <0.01) as the fruit reached the highest degree of maturity (Table 1 and Figure 2), results that are consistent with the findings of Mustaffa *et al.* (1998) in banana (*Musa cavendishii* L.), Gomez *et al.* (2002) and Schweiggert *et al.* (2011) in papaya, Bashir *et al.* (2003) in guava (*Psidium guajava*), Usenik *et al.* (2008) in plum (*Prunus domestica* L.), Jimenez *et al.* (2011) in gulupa, Mejia *et al.* (2012) in lulo and Palafox-Carlos *et al.* (2012) in mango. The soluble solids content was similar to those reported by Diaz and Manzano (2002), Caicedo and Higuera (2007), Ospina-Monsalve *et al.* (2007) and Mejia *et al.* (2012). According to Gomez *et al.* (2002) and Fisk *et al.* (2006) the increase in soluble solids during the ripening of climacteric fruits is the result of the activity of the sucrose phosphate synthase enzyme (SPS), which is responsible for hydrolyzing the starch granules; on the other hand, the cell wall protopectins hydrolyze to soluble pectins and contribute to the increased soluble solids concentration during the ripening process (Prasanna *et al.*, 2007).

The MI increased (P <0.01) with the highest degree of maturity of the fruits (Table 1), consistent with findings from Casierra-Posada *et al.* (2004) and Caicedo and Higuera (2007). This behavior is a consequence of the reduction of acidity and the increment of the soluble solids during fruit ripening of lulo (Figures 1 and 2).

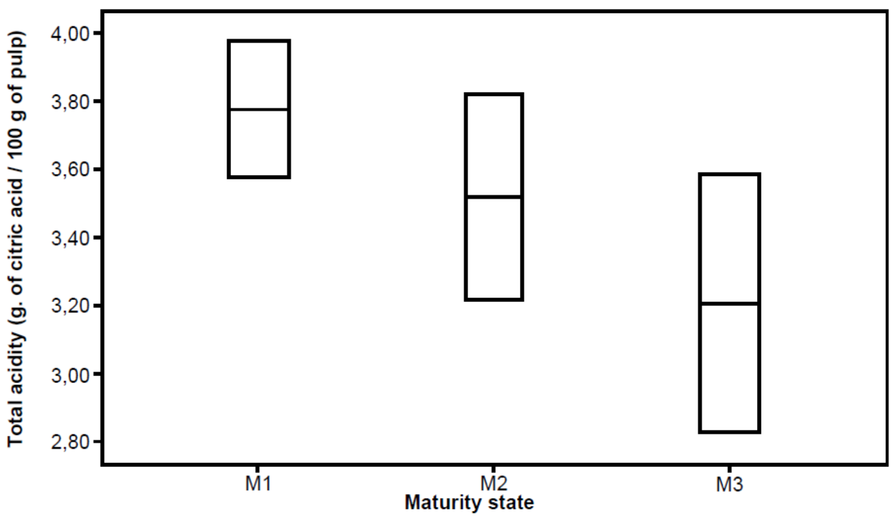

Figure 1. Total acidity of lulo fruits in three degrees of maturity

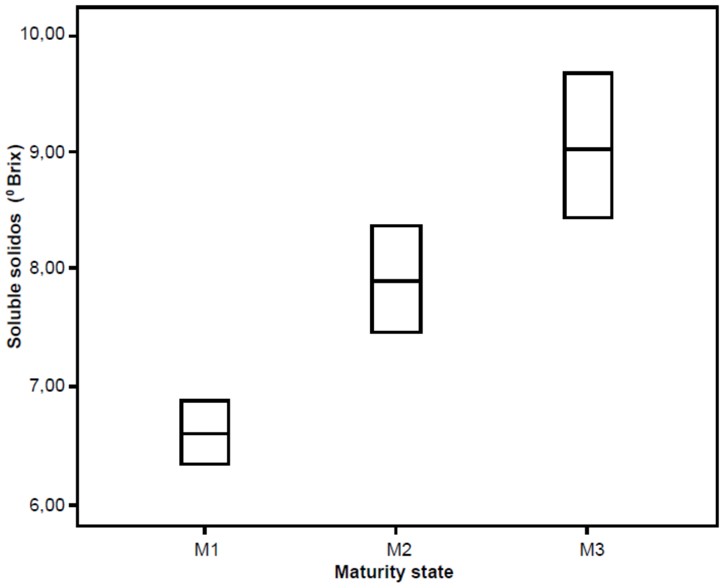

Figure 2. Soluble solids of lulo fruits in three degrees of maturity.

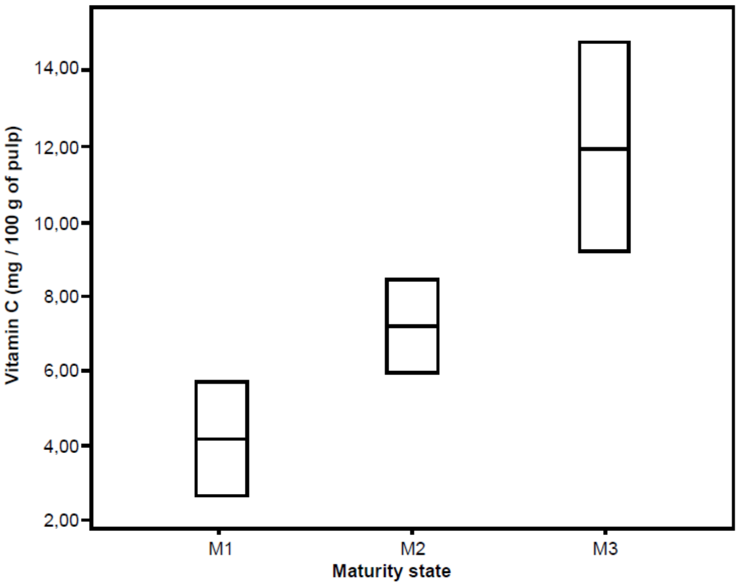

Figure 3. Vitamin C concentration of lulo fruits in three degrees of maturity.

The concentration of vitamin C increased ($P < 0.01$) as the fruits reached a higher maturity state (Table 1 and Figure 3). These concentrations are similar to those found by Acosta *et al.* (2009) in mature lulo fruits and higher than those found by Contreras-Calderon *et al.* (2011) in several tropical fruits. The increment of this bioactive compound during maturity in other climacteric fruits was previously described by Bulk *et al.* (1996) who found increments of 300% in the ascorbic acid concentration in five guava cultivars when they reached the highest degree of maturity; Mustaffa *et al.* (1998) reported significant changes of ascorbic acid in banana with a high degree of maturity and Yahia *et al.* (2001) found an increment in this antioxidant during tomato ripening.

Yahia *et al.* (2001), suggest that the low enzymatic activity of the ascorbic acid oxidase in the fruits allows reaching higher concentrations of vitamin C, as this is responsible for the oxidative degradation of ascorbic acid in the plant tissues during the maturation processes (Arellano-Gomez *et al.*, 2005. Matarazzo *et al.*, 2013), which explains the findings in this regard in the present study.

Conclusions

- The physical properties of the fruit of lulo (Solanum quitoense Lam) (weight, volume, density, equivalent diameter, sphericity index, pulp and peel yield) were not affected by the degree of maturity; on the contrary, the chemical properties (pH, soluble solids, and maturity index and Vitamin C) increased; while the acidity decreased.
- High concentrations of soluble solids and vitamin C and low level of acidity in the fruits of lulo with maturity grade 3 show its high agro-industrial potential in the production of pulp, juices, nectars and concentrates, since high values of these attributes chemicals are related to the organoleptic and nutritional quality of the derivatives of this tropical fruit.

References

Acosta, O.; Pérez, A. M.; and Vaillant, F. 2009. Chemical characterization, antioxidant properties, and volátile constituents of naranjilla (*Solanum quitoense Lam.*) cultivated in Costa Rica. Arch. Latinoam. Nutr. 59(1):88 - 94.

Alvarado, J.; Muñoz, S.; Medina, S.; and Alvarado, J. D. 2007. Propiedades físicas del fruto, pulpa y jugo de la naranjilla Iniap-Palora (*solanum quitoense x solanum sessiliflorum*). Ambato Ecuador. VI Congreso Iberoamericano de Ingeniería en Alimentos CIBIA.

Agronet. Producción de lulo en Colombia-1992 - 2011. Available in :http://www.agronet.gov.co/www/htm3b/ReportesAjax/parametros/reporte16_ 2011.aspx?cod=16, 04-11-2013

Arellano-Gómez, L. A.; Saucedo-Veloz, C.; and Arévalo-Galarza, L. 2005.Cambios bioquímicos y fisiológicos durante la maduración de frutos de zapote negro (*diaspros digyn* Jacq.). Agrociencia 39:173 – 181.

Aydın, C. and Özcan, M. 2002.Some physico-mechanic properties of terebinth (*Pistacia terebinthus* L.) fruits. J. Food Engin. 53:97 - 101.

Bashir, H. A. and Abu-Goukh, A. B. 2003. Compositional changes during guava fruit ripening. Food Chem. 80(4):557 - 563.

Bulk, R. E.; Babiker, F. E.; and El Tinay, A. H. 1996. Changes in sugar, ash and minerals in four guava cultivars during ripening. Plant Foods for Human Nutrition 49(2):147 - 154.

Caicedo, D. 1999. Cosecha y poscosecha. In: Gómez, C. *et al.* (eds.). Manejo integrado del cultivo del lulo. Convenio Corpoica-Plante-Sena. Ibagué. Tecnimpresos. p. 85 - 96.

Caicedo, O. O. e Higuera, B. L. 2007. Inducción de polifenoloxidasa en frutos de lulo (*solanum quitoense*) como respuesta a la infección con *colletotrichum acutatum*. Acta Biol. Col. 12(1):41 – 54.

Casierra-Posada, F.; García E. J.; and Ludders, P. 2004. Determinación del punto óptimo de cosecha en el lulo (*Solanum quitoense* Lam.) Var. *quitoense* y *septentrionale*. Agron. Col. 2(1):32 - 39.

Contreras-Calderón, J.; Calderón-Jaimes, L.; Guerra- Hernández, E.; and García-Villanova, B. 2011. Antioxidant capacity, phenoliccontent and vitamin C in pulp, peel and seed from 24 exotic fruits from Colombia. Food Res. Intern. 44:2047 – 2053.

Díaz, J. G. and Manzano, J. E. 2002. Calidad en lulo (*Solanum quitoense* L.) Almacenados a diferentes temperaturas. Interam. Soc. Trop. Hort. 46:27 - 28.

Fisk, C. L.; McDaniel, M. R.: Strik, B. C.; and Zhao, Y. 2006. Physicochemical, sensory, and nutritive qualities of hardy kiwifruit (*Actinidia arguta*) 'Ananasnaya' as affected by harvest maturity and storage. J. Food Sci. 71(3):S204 - S210.

Gancel, A. L.; Alter, P.; Dhuique-Mayer, C.; Ruales, J.; and Vaillant, F. 2008. Identifying carotenoids and phenolic compounds in naranjilla (*Solanum quitoense* Lam.) var. Puyo hybrid, an andean fruit. J. Agric. Food Chem. 56(24):11892 - 11899.

Gómez, M.; Lajolo, F.; and Cordenunsi, B. 2002. Evolution of soluble sugars during ripening of papaya fruit and its relation to sweet taste. J. Food Sci. 67(1):442 - 447.

Giraldo-Gómez, G. I.; Gabas, A. L.; Telis, V. R. and Telis-Romero, J. 2010. Propiedades termofísicas del jugo concentrado de lulo a temperaturas por encima del punto de congelación. Ciencia y Tecnologia de Alimentos. 30 (Suppl. 1):90 - 95.

Guadarrama, A.1983. Algunos cambios químicos durante la maduración de frutos de semeruco *(Malpighia punicifolia L.*). Rev. Facultad de Agronomía 12(1 - 4):111 - 128.

NTC 4592 1999a. Instituto Colombiano de Normas Técnicas. Productos de Frutas y Verduras. Determinación del pH. Bogotá. Icontec. 4 p.

NTC 4623 1999b. Instituto Colombiano de Normas Técnicas. Productos de Frutas y Verduras. Determinación de la acidez titulable. Bogotá. Icontec. 6 p.

NTC 4624 1999c. Instituto Colombiano de Normas Técnicas. Jugos de Frutas y Hortalizas. Determinación del contenido de sólidos solubles. Método refractométrico. Bogotá. Icontec. 9 p.

Jiménez, A. M.; Sierra, C. A.; Rodríguez-Pulido, F. J.; González-Miret, M. L.; Heredia, F. J; and Osorio, C. 2011. Physicochemical characterisation of gulupa (*Passiflora edulis* Sims. foedulis) fruit from Colombia during the ripening. Food Res. Intern. 44:1912 – 1918.

Matarazzo, P. H.; De Siqueira, D. L.; Salomao, L. C.; Da Silva, D. F.; and Cecon, P. R. 2013. Desenvolvimento dos frutos de lulo (*Solanum quitoense* Lam.) em Viçosa-MG. Rev. Bras. Frutic. 35(1):131 - 142.

Mustaffa, R.; Osman, A.; Yusof, S.; and Mohamed, S. 1998.Physico-chemical changes in cavendish banana (*Musa cavendishii* L var Montel) at different positions within a bunch during development and maturation. J. Sci. Food Agric. 78 (2):201 - 207.

Mejía, C. M.; Gaviria, D. A.; Duque A. L.; Rengifo R. M.; Aguilar, E. F.; and Hernán, A. A. 2012. Physicochemical characterization of the lulo (*Solanum quitoense* Lam.) castilla variety in six ripening stages.Vitae 19(2):157 - 165.

Oboh, G. 2006. Antioxidant properties of some commonly consumed and underutilized tropical legumes. European Food Res. Techno. 224:61 - 65.

Ospina-Monsalve, D. M.; Ciro Velásquez, H. J.; and Aristizabal Torres, I. D. 2007.Determinación de la fuerza de la fractura superficial y fuerza de firmeza en frutas de lulo (*solanum quitoense* x *solanum hirtum*). Revista Facultad Nacional de Agronomía 60(2):4163 - 4178.

Palafox-Carlos, H.; Yahia, E.; Islas-Osuna, M. A.; Gutierrez-Martinez, P.; Robles-Sánchez, M.; and González Aguilar, G. A.2012. Effect of ripeness stage of mango fruit (*Mangifera indica* L.) cv. Ataulfo on physiological parameters and antioxidant activity. Sci. Hortic. 135:7 - 13.

Prasanna, V.; Prabha, T. N.; and Tharanathan, R. N. 2007. Fruit ripening phenomena-an overview. Critical Rev. Food Sci. Nutr. 47 (1):1 - 19.

Salazar, R.; Piedra D.; and Escarabay, P. 2007.Propiedades físico-químicas de cinco frutas de la zona sur del Ecuador para su industrialización. Alimentos, Ciencia e Ingeniería 16 (2):20 - 24.

Schweiggert, R. M.; Steingass, C. B.; Mora, E.; Esquivel, P.; and Carle, R. 2011.Carotenogenesis and physicochemical characteristics during maturation of red fleshed papaya fruit (*Carica papaya* L.). Food Res. Intern. 44:1373 – 1380.

Shwartz, E.; Glazer, I.; Bar-Yaakov, I.; Matityahu, I.; Bar-Ilan I.; Holland, D.; and Amir, R. 2009. Changes in chemical constituents during the maturation and ripening of two commercially important pomegranate accession. Food Chem. 115:965 – 973.

Usenik, V.; Kastelec, D.; Veberič, R.; and Štampar, F. 2008. Quality changes during ripening of plums (*Prunus domestica L.)*. Food Chemistry 111(4):830 - 836.

Yahia, E. M.; Contreras-Padilla, M.; and Gonzalez-Aguilar, G. 2001. Ascorbic acid content in relation to ascorbic acid oxidase activity and polyamine content in tomato and bell pepper fruits during development, maturation and senescence. LWTFood Sci. Techn. 34(7):452 - 457.