Determining optimal harvest point for champa (*Campomanesia lineatifolia* R. & P.) fruit based on skin color

Determinación del punto óptimo de cosecha de frutos de champa (Campomanesia lineatifolia R. & P.) con base en el color de la epidermis

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RESUMEN

Se desconoce el punto óptimo de cosecha de los frutos de champa; por lo tanto, los frutos se cosechan en diferentes estados de madurez, lo que disminuye la calidad del producto. Con el objetivo de determinar el punto óptimo de cosecha del fruto de champa, se evaluó la calidad poscosecha de seis tratamientos correspondientes a diversos estados de madurez del fruto con base en el color de la epidermis, así: 100% verdes (V) con madurez fisiológica, 25% amarillo (A), 75% V, 50% A - 50% V, 75% A - 25% V, 100% A y un testigo (frutos recolectados del suelo). Los frutos fueron cosechados en el municipio de Miraflores (Boyacá). Al final del almacenamiento se encontró que los frutos pueden ser cosechados 100% V con madurez fisiológica los cuales presentaron una duración de 7,6 días; cosechar frutos más maduros reduce significativamente la vida útil. Estos mismos frutos continuaron con el proceso de maduración durante la poscosecha y conservaron por más tiempo características como firmeza, peso, sólidos solubles totales y acidez total titulable. En general se observó que al cosechar los frutos 100% V se prolonga la vida poscosecha de los mismos; los demás tratamientos maduran normalmente, pero la duración poscosecha es inferior.

Palabras clave: índice de madurez, color de la epidermis, poscosecha, vida útil.

ABSTRACT

Optimal perfume guava fruit harvest point is unknown; fruits are therefore harvested at different ripening stages which reduces product quality. Postharvest quality was assessed in six treatments regarding different fruit ripening stages based on skin colour aimed at determining the optimal harvest point as follows: 100% green (G) being physiologically mature, 25% yellow (Y) 75%G, 50%Y-50%G, 75%Y-25%G, 100%Y and a control (fruit collected from the ground). The fruit was harvested in the municipality of Miraflores (Boyacá, Colombia). At the end of storage it was found that the fruits could be harvested 100%G, being physiologically mature, and had a 7.6 day shelf-life; harvesting riper fruits significantly reduced shelf-life. The same fruits continued to ripen during storage maintaining characteristics such as firmness, weight, total soluble solids and total titratable acidity for a longer time. It could be observed that the fruit's postharvest life became extended by harvesting fruit 100%G; the other treatments ripened normally but their postharvest life was shorter.

Keywords: Maturity index, skin colour, postharvest, shelf-life.

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Introduction

Perfume guava (*Campomanesia lineatifolia* R. & P.), known locally as champa, is a fruit species from the Amazon region (Villachica, 1996) belonging to the *Myrtaceae* family (Bonilla *et al*., 2005); it is extensively cultivated in the Lengupá region, Boyacá. The fruit is highly perishable, having an attractive flavour and aroma and the pulp is abundant and juicy, sweet and acidulated; the fruit has good marketing potential and can compete with already-known species (Álvarez-Herrera *et al*., 2009). The fruit is consumed fresh and the pulp can be used in preparing juices, creams, candies, jams, desserts, liquors and jellies (López and Rodríguez, 1995; Villachica, 1996). Perfume guava fruit is generally collected from the ground (López and Rodríguez, 1995; Villachica, 1996) and sometimes harvested directly from the trees but at different ripening stages; some fruit are disposed of as they do not comply with consumer or trader quality demands thereby leading to the producers' economic losses (Balaguera *et al*., 2009). According to Álvarez-Herrera *et al*., (2009), no maturity index has been determined for scheduling harvests for this species; the fruit thus becomes wasted or its marketing becomes limited to regional centres near the place of production in most cases.

Maturity in harvesting is one of the most important factors determining postharvest behaviour and final quality; it is related to consumers and traders' prerequisites (Delwiche, 1987; Santamaría *et al*., 2009). The fruit is hand-picked like many agricultural products, implying that the harvester has to be able to decide when a product has reached harvest maturity (Kader, 2002). Perfume guava fruit continue to ripen after harvest due to their climacteric

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nature (Álvarez *et al*., 2009) thereby enabling harvest to be anticipated (Altube *et al*., 2001) as soon as they have reached physiological maturity.

Different indexes can help establish objective harvest criteria (Kader, 2002; Kays, 2004); skin colour is one of the best suited (Kader, 2002) as it correlates well with other product quality physical, chemical and sensory indicators (Mendoza *et al*., 2006), is easy to use, non-destructive and low cost, but has to be used in conjunction with other indexes for more objective determination. Casierra-Posada *et al*., (2004) determined that optimal harvest point for two lulo (*Solanum quitoense*) varieties occurred at ripening stages three (50% green and 50% yellow) and four (25% green and 75% yellow). Colour is also used as maturity index in blackberry fruits (*Rubus glaucus*) (Sora *et al*., 2006), Cape gooseberry (*Physalis peruviana* L.) (Novoa *et al*., 2006), yellow cactus fruit (pitaya) (*Selenicereus megalanthus* Haw.) (Rodríguez *et al*., 2005), guava (*Psidium guajava*) (Azzolini *et al*., 2004) and tomato (*Solanum lycopersicum* L.) (Casierra-Posada and Aguilar-Avendaño, 2008).

This study was aimed at determining perfume guava fruit's optimal harvest point in the municipality of Miraflores, Boyacá, based on skin colour to establish technical criteria to be used for scheduling harvests and guarantee that fruit are harvested directly from the tree having appropriate maturity, thereby benefitting producers, industrialists, traders and consumers.

Experimental development

The fruit were harvested on the "El Mango" farm in the Ayatá area in the municipality of Miraflores, Boyacá, Colombia, which is located at 5°11'40" N and 73°08'44" E, at 1432 masl, having 22.3°C average temperature and 80% relative humidity. The laboratory phase was carried out at the Universidad Nacional de Colombia's Agronomy Faculty's Plant Physiology and Postharvest laboratories in Bogotá.

A randomised experimental design was used involving six treatments at skin colour-based ripening stages (Table 1) where each treatment had three replicates, giving 15 experimental units (EU). Each EU consisted of 1,300 g of fruit. The fruit was collected directly from the trees using completely healthy homogeneous-sized EU. Table 1 shows each treatment's fruit characteristics at harvest point. Colour difference between consecutive ripening stages was calculated following Mendoza *et al*.'s methodology (2006) to ensure that each treatment's fruit colour was actually different. The fruit was taken to the laboratory and placed into LMR 351 storage chambers having 22°C average temperature, 80% relative humidity and 12 hours' light for simulating Miraflores' environmental conditions.

The sensory analysis methodology used by Aguayo et al., (2006) and Sora *et al*., (2006) was adapted for determining the number of days during which fruit continued being suitable for consumption. Weight loss (%) was determined by measuring fresh weight in a 100g sample of fruit using a 0.001g resolution precision scale. CIELab system L*, a* and b* parameters were determined using a Minolta CR-400 colorimeter for skin colour; three equidistant readings were taken on each fruit on the equatorial area. Firmness (N) was measured on the equatorial part of the fruit with a 0.05 N resolution digital PCE-PTR 200 penetrometer. Total soluble solids (TSS) were measured as °Brix and total titratable acidity (TTA) was expressed as citric acid percentage according to Álvarez *et al.*'s methodology (2009).

The Shapiro-Wilk's test was used for ascertaining data normality and Levene test for homogeneity of variance; data complying with the above-mentioned assumptions was subjected to variance analysis (Anova). The remaining variables (pH on postharvest days 1 and 3 and firmness on postharvest days 2 and 3) were previously transformed using $\sqrt[2]{x}$. Tukey's multiple comparison test (5%) was also used with SAS v. 8.1e (Cary, N.C) statistical package.

Table 1. Skin colour-based description of perfume guava fruit collected at different maturity stages

Treatment (color %)		Skin color			Δ+ Color	Pulp color			Δ Color	FW (g)	ED (mm)	PD (mm)	V (cm^3)
Yellow	Green	L*	a*	b*		L*	a*	b*					
0	100	66.9	-17.6	39.8		66.9	1.1	23.6		20.7	35.7	27.5	24.5
25	75	76.9	-12.0	48.8	12.1	76.9	5.6	25.2	11.0	23.2	37.3	29.1	27.3
50	50	72.6	-8.6	44.9	5.8	72.6	4.3	29.8	6.4	24.3	39.3	28.9	28.0
75	25	70.3	-7.9	50.4	9.1	70.3	5.4	34.8	5.5	24.2	38.3	29.0	28.5
100	0	76.2	-3.4	51.3	4.8	76.2	4.8	33.8	5.9	23.4	36.3	28.7	27.7
Control++		64.1	-4.6	46.8	5.3	64.1	3.6	23.1	16.2	23.3	37.1	29.2	27.9

+ colour difference regarding prior treatment, if the difference was >4 then colour was perceived as being different; FW, fresh weight; ED: equatorial diameter; PD: polar diameter; V: volume. ++ ripe fruit collected from the ground

Results and Discussion

Postharvest life

The ripening stage had a differential effect on the fruit's postharvest life; it was found that the more advanced the harvest ripening stage, the shorter the fruit's shelf-life. Fruit collected directly from the ground (traditional harvesting method) had a short life lasting about two days, a time statistically equal to that exhibited by 100% yellow fruit harvested from the tree (Table 2). Even so, fruit can be harvested 100% green but physiologically mature leading to significantly extending their shelf-life by almost eight days, such time providing greater marketing and industrialisation potential. This could lead to making better use of this fruit thereby contributing to reducing postharvest losses which, according to López and Rodríguez (1995), can be as high as 97% in the Lengupá region in Boyacá.

Table 2. Skin colour-based postharvest life of perfume guava fruits collected at different ripening stages

Treatment		Postharvest life (days)
Yellow color (%)	Green color (%)	
0	100	7.6 a
25	75	5.1 b
50	50	3.7 c
75	25	3.3 c
100	0	2.5 d
Control		1.9 d

Mean values followed by letters show statistical differences according to Tukey's test (5%)

Perfume guava is a climacteric fruit (Álvarez et al., 2009) having increased respiration rate and ethylene production during ripening (Kader, 2002); such fruit can be harvested from the moment of physiological maturity and continue ripening until reaching consumption maturity, as happens with fruit harvested 100%G; it has also been found in guava that fruit harvested green have had a longer life than those harvested ripe (Azzolini *et al*., 2004). However, harvesting fruit with the aforementioned maturity involves certain disadvantages such as reduced productivity resulting from fruit not yet having reached their full size. When to harvest would thus depend on product benefit-cost ratio or its destination. It is thus recommended taking into account factors such as supply/demand ratio, availability of manpower and storage rooms to determine during which ripening stage it is more advisable to harvest perfume guava fruit.

Firmness

Statistical differences were observed at all sampling points; fruit harvested 100% green kept their firmness longer followed by 75% green fruit, while fruit harvested 100% yellow and the control had the least favourable results (Figure 1A). These agreed with known lulo (Casierra-Posada *et al*., 2004) and guava fruit results (Azzolini *et al*., 2004). The practical implication involved in loss of firmness is that fruit manipulation, distribution and marketing become impeded (Lima *et al*., 2009). Harvesting 100% green fruit guarantees that fruit softening is less than in ripening fruits thereby providing fruit with greater resistance during postharvest tasks. Álvarez *et al*., (2009) have mentioned that perfume guava fruit can tolerate around 2N forces without sustaining damage during the first three days postharvest; a force of more than 1N would cause negative effects on quality after such period.

The enzymes involved in fruit softening through cell wall and starch reserve degradation (Kays, 2004) lead to slower perfume guava fruit ripening regarding fruit harvested during early ripening stages, maybe due to not enough ethylene concentration being available for such enzymes' complete activation and fruit at an earlier ripening stage can have higher protopectine concentration (Hernández *et al*., 2007) providing tissue with greater consistency. This might explain less firmness loss in fruit harvested at an earlier ripening stage. Turgor pressure may have had a greater effect because riper fruit also had the highest weight loss percentages until day 5 postharvest (Figure 1B); the results agreed with reports from studies regarding other species (Shackel *et al*., 1991; Vicente *et al*., 2007).

Statistical differences regarding weight loss were only found on day 5 postharvest; however, green fruit lost less weight until day 7 postharvest and had a 30.82% accumulated weight loss by day 9 (Figure 1B). A similar pattern was found in guava fruit (Azzolini *et al.,* 2004). Plant cells' hydric status is one of the main factors determining perishable products' quality and postharvest life. Burg (2004) has reported that, depending on the species, the product loses its freshness when it transpires more than 3% to 10% of its fresh weight and, therefore, fruit harvested when less ripe would keep their freshness longer. Kader (2002) has stated that water loss is the main cause of fruit deterioration because it results in a direct reduction of fresh weight and quality and shortens shelf-life due accelerated ripening and senescence. This is probably what happened in fruit harvested during advanced ripening stages. Fruit harvested during an earlier ripening stage sustained more weight loss, possibly due to longer exposure to the environment (Casierra-Posada *et al*., 2004; Casierra-Posada and Aguilar-Avendaño).

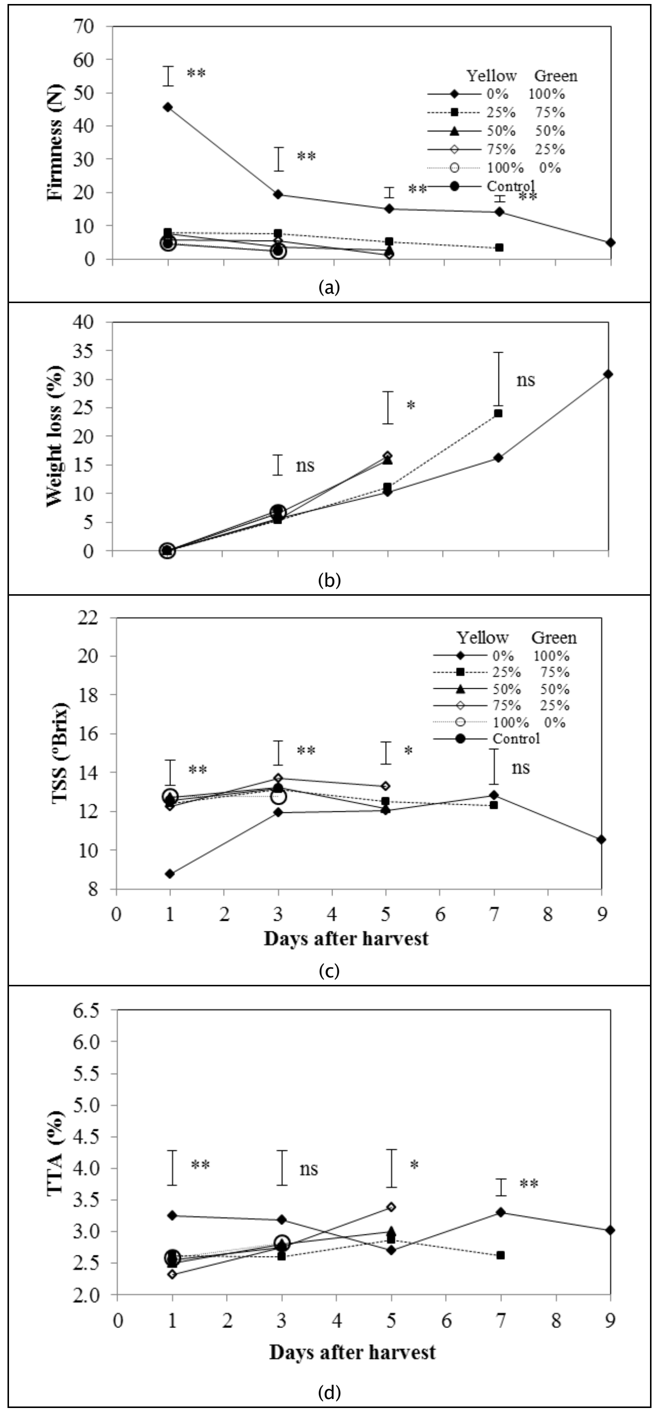

Figure 1. Firmness A, weight loss B, total soluble solids (TSS) C, and total titratable acidity (TTA) D for perfume guava fruit harvested at different ripening stages based on skin colour for determining optimal harvesting point. The bar represents the statistical value for the least significant difference (LSD) used to compare means with Tukey's test. If the difference between two means at each sampling point was bigger than the LSD value, there would be α = 0.05 difference. * means 5% statistical difference, ** means 1% statistical difference, ns means no difference

Higher weight loss in riper fruits until day 5 postharvest was probably caused by greater cell disintegration meaning that weak cell walls and membranes would allow water leakage by transpiration to take place at a higher rate and the fact that they had already reached the climacteric stage; respiration would thus have accelerated senescence and used fruit reserves to a greater extent, mainly as organic acids and sugars (Kays, 2004). Green fruit had lower loss during the first days, probably due to less tissue deterioration; moreover, the dermal system seems to be more efficient in green fruit, as it consists of external protective covering such as cuticle, epidermal cells, stomata, guard cells and trichomes regulating water loss in fruit (Kader, 2002). Sora *et al*., (2006) have reported greater weight loss in blackberry fruit harvested during more advanced ripening stages.

Total soluble solids

Statistical differences were found on days 1, 3, and 5 postharvest. Fruit in a more advanced ripening stage when the experiment began had a greater amount of TSS; 100% green fruit had lower TSS values throughout almost the whole storage period. Increased TSS could also be observed during the first days, followed by reduction (Figure 1C).

Increased TSS was probably due to starch hydrolysis and polysaccharides in cell walls producing soluble sugars (Kays, 2004; Menéndez *et al*., 2006) while the resulting reduction could be attributed to increased respiration (Kays, 2004); this was clearly observed in 100% green fruit. Fruit continued to ripen during the postharvest period and achieved TSS values similar to those of fruit harvested at organoleptic maturity. The above implied that fruit could be harvested 100% green as long as they had achieved physiological maturity allowing them to enjoy a longer postharvest life and greater chance of being consumed and processed, thus reducing postharvest loss. The other treatments led to optimal TSS accumulation but their shelf-life was inversely proportional to their maturity. Anzzolini *et al*., (2004) have reported similar results in guava where ripening fruit had increased TSS than fruit at an earlier ripening stage.

Total titratable acidity

Statistical differences were found at all sampling points, with the exception of day 3 postharvest when fruit having a higher percentage of yellow increased TTA during storage. However, 100% green fruit had the lowest TTA on day 3, while the highest TTA values were obtained on the other days (Figure 1D). It has also been determined that green pitaya fruit have higher TTA values than ripening fruit during storage (Rodríguez *et al*., 2005). It has also been found in guava fruit that the ripening stage has affected TTA differentially, being higher in fruit harvested unripe having increased TTA at the beginning of the postharvest period (Azzolini *et al*., 2004). Novoa *et al*., (2006) determined that Cape gooseberry fruit being harvested during an earlier ripening stage (green yellow) had higher TTA during storage compared to those harvested during more advanced ripening stages (yellow), as observed in perfume guava fruit. This indicated that unripe fruit had a better postharvest pattern because they had more organic acids available to be used as respiratory substrate, thereby promoting longer shelf-life expectancy.

Skin colour

Statistical differences were encountered in L* value on days 5 and 7. It could be observed that L* increased in fruit which changed from green to yellow, indicating that skin brightness increased; as soon as the latter was obtained, L* value decreased in 100% green fruit, while decrease in L* occurred later on in 75% green 25% yellow (Figure 2A), these fruits thus remained brilliant for longer. There were significant statistical differences in a* value at all samplings. As a* value increased green decreased in fruit; it could be observed that fruit having higher green percentage on skin had lower a* values and took longer to increase it (Figure 2B). b* value statistical differences were observed on days 5 and 7 postharvest where positive values indicated yellow which is why all values were positive; however, it was found that b* value decreased in fruit having the highest ripening stage. This value increased until days 5 and 7 in 75% green 25% yellow and 100% green fruit, respectively, which was the moment when they became totally yellow; b* value then decreased (Figure 2C).

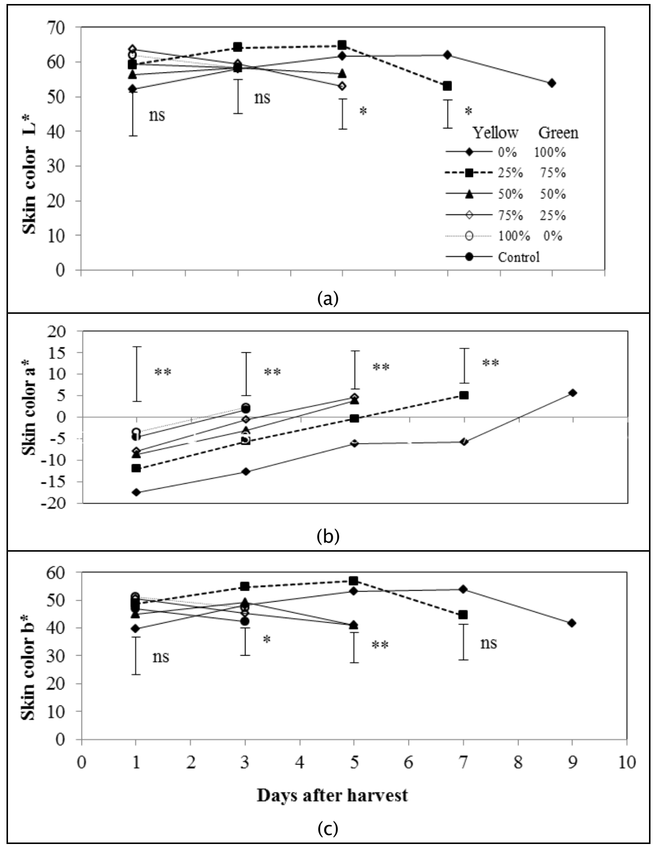

Figure 2. Skin colour pattern for perfume guava fruits harvested at different ripening stages based on skin colour for determining optimal harvest point. A. L* value; B. a* value and C. b* value. The bar represents the statistical difference for the least significant difference (LSD) used to compare means by Tukey's test. If the difference between two means at each sampling point was bigger than the LSD value there would be $\alpha = 0.05$ differences. * means 5% statistical differences, ** means 1% statistical differences, ns means no differences

The perfume guava fruit results were similar to those obtained by Santamaría *et al*., (2009) who found that papaya fruit harvested at a more advanced ripening stage had higher and faster increase in a* value, the difference lying in their increased b* values at all stages, the smallest increases occurring in the most unripe fruit. Colour intensity and uniformity affect fruit quality because chlorophyll loss, the synthesis of new pigments such as carotenoids and the exposure of pigments previously formed during fruit development may be observed in many fruit (Ferrer *et al*., 2005). It was observed in the present study that 100% green fruit needed more postharvest time for chlorophyll degradation and synthesis or show pigments causing yellow toning. Colouring during storage was not the same as when fruit directly matured on trees because L* value was lower at ripening (7 days postharvest for this treatment) and had higher green colouring, although yellow tone was high.

Silva *et al*., (2009) stated that a reduction in plants' green colour is associated with chlorophyll degradation. It could be thought that chlorophyllase action would be lower during early ripening stages and thus loss of green would not be as evident as in fruit harvested during more advanced ripening stages, probably because ethylene synthesis and action is less in fruit harvested during early ripening stages. Reduced b* value indicated the beginning of loss of yellow giving place to yellow-brownish tones typical of aging and which was reflected by riper fruit, thereby showing much faster reduction. It could be observed that this was accompanied by a loss in luminosity reflected in lower L* value. Increased L* value was observed at the beginning of papaya fruit ripening, together with increased b* values (yellow) but without change in a* values, still indicating the presence of green (Santamaría *et al*., 2009).

Conclusions

Perfume guava ripening dynamics were closely related to maturity stage at the moment of harvest, being slower in fruits harvested at an earlier maturity stage. Perfume guava fruits could thus be harvested 100% green and physiologically mature because they had a significantly longer 7.6 day postharvest life and maintained firmness, weight, colour, total soluble solids and total titratable acidity for a longer time. However, fruit could be harvested even 100% yellow in the absence of postharvest and/or transformation limitations because organoleptic characteristics are optimal at the moment of harvest even if shelf-life is considerable shorter.

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