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Effect of calcium acetylide on fruit ripening in two banana cultivars

Efecto del acetiluro de calcio sobre la maduración de fruta en dos cultivares de plátano

Jaime Vera Chang
Ph.D Universidad Técnica Estatal de Quevedo (UTEQ), Quevedo, Los Ríos, Ecuador
jverac@uteq.edu.ec, ORCID: 0000-0001-6127-2307

Byron Merchán Sánchez
Ph.D Graduated from Universidad Técnica Estatal de Quevedo (UTEQ), Quevedo, Los Ríos, Ecuador.
byron.merchan@uteq.edu.ec, ORCID: 0000-0001-5552-2277

Diego Tuarez Garcia
Ph.D Universidad Técnica Estatal de Quevedo (UTEQ), Quevedo, Los Ríos, Ecuador
dtuarez@uteq.edu.ec, ORCID: 0000-0001-5153-1889

Antonio Bustamante González
Ph.D National Institute of Agricultural Research (INIAP), Mocache, Los Ríos, Ecuador
antonio.bustamante@iniap.gob.ec, ORCID: 0000-0003-1924-1843

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Corresponding Author
Jaime Vera Chang
jvera@uteq.edu.ec
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Abstract

The irrational use of ripening agents can cause damage to banana composition. Therefore, the objective of this research was to analyze the use of calcium acetylide in fruits of Musa paradisiaca L., Dominico and Barraganete varieties. A completely randomized design (CRD) with factorial arrangement A x B x C was used, with twelve treatments and three replications, for the determination of differences between means Tukey was used (p≤ 0.05). The variables evaluated were: ripening time, dry matter content, moisture, pH, energy, brix degrees, acidity, pulp hardness, peel dry matter, peel moisture and peel color, for which a total of 36 boxes were used, which were sampled at two times: 48 and 72 hours after the calcium acetylide was applied. Regarding the results, it should be noted that, regardless of the variety, both in physical and qualitative parameters in fruit pulp, all treatments exposed to calcium acetylide were outstanding. However, within chemical parameters such as energy and dry matter content, the controls stood out, respectively. In conclusion, there was a marked influence of calcium acetylide as an artificial ripening agent over natural ripening in the other aspects evaluated, especially in the

ripening time variable, where the treatments exposed to it were able to obtain an advantage of more than 50% of time in relation to the controls.
Key words: banana, postharvest, acetylene, quality, shelf life

Resumen
El uso irracional de agentes maduradores puede provocar daños en la composición del plátano. Por ello el objetivo de esta investigación fue analizar el uso del acetiluro de calcio en frutos de Musa paradisiaca L., en las variedades Dominico y Barraganete. Se utilizó un diseño completamente al azar (DCA) con arreglo factorial A x B x C, con doce tratamientos y tres repeticiones, para la determinación de diferencias entre medias se utilizó Tukey ($p \leq 0,05$). Las variables evaluadas fueron: tiempo de maduración, contenido de materia seca, humedad, pH, energía, grados brix, acidez, dureza de pulpa, materia seca de la cáscara, humedad de la cáscara y color de la cáscara, para lo cual se utilizó un total de 36 cajas, las cuales fueron muestreadas en dos tiempos: a las 48 y 72 horas de haber sido aplicado el acetiluro de calcio. En relación a los resultados se podría destacar que, independientemente de la variedad tanto en parámetros físicos como en parámetros cualitativos en pulpa de fruta, sobresalieron todos los tratamientos expuestos al acetiluro de calcio. Sin embargo, dentro de parámetros químicos como el contenido de energía y materia seca sobresalieron los testigos respectivamente. En conclusión, se denoto una marcada influencia del acetiluro de calcio como agente madurante artificial sobreponiéndose a la maduración natural en los demás aspectos evaluados, sobre todo en la variable tiempo de maduración, donde los tratamientos expuestos a este supieron obtener una ventaja de más del 50% de tiempo en relación a los testigos.
Palabras clave: Plátano, postcosecha, acetileno, calidad, vida útil

Introduction

Banana production is significantly important in Ecuador, and its importance in the external market is such that domestic production accounts for about 32% of Ecuador's trade in bananas. (Solano et al., 2022)The importance of banana production in the external market is such that national production represents about 32% of world trade. (Álvarez et al., 2020). In 2020, about 145,501 hectares were cultivated nationally, reaching a production of 722,298 MT, of which about 600,000 MT were marketed, which would indicate a significant imbalance in traceability, according to SIPA data. (SIPA, 2020).

This is due to the fact that the production chain of this important product involves a number of links that affect its price, such as: producers and the conditions present in the period between planting and harvesting, as well as intermediaries, transporters, distributors and finally wholesalers and retailers, who are responsible for setting the retail price, taking into account its size, quality and appearance. (Quintero & Jiménez, 2015).

The harvest of the product is carried out according to its appearance (Escalante & Fuenmayor, 2020) and the harvest index is the fruit filling; in technified crops the age since flowering is fixed as an index; postharvest studies of banana have shown numerous changes in the chemical composition and postharvest behavior during ripening. (Mejia, 2013). The physiological maturity (ripening) of this climacteric fruit has a marked influence on physical quality, organoleptic characteristics, shelf life and respiration rate, the latter being an indicator of the rate of deterioration of the product. (Kader, 2014).

The natural ripening process is a combination of physiological, biochemical and molecular processes, which involves a different metabolic coordination, with the activation and deactivation of several genes that can trigger a series of changes in color, sugar content, acidity, fruit texture, taste and aroma (Belew et al., 2016),(Sogo-Temi et al., 2014). However, this ripening process can be artificially induced using different chemical agents such as ethanol, methanol, glycol, ethephon and calcium acetylide. (Islam et al., 2018).

Calcium acetylide (CaC2) is a synthetic material made from limestone, which when in contact with water generates acetylene, another gas with a similar effect to ethylene. Its use is very common among banana wholesalers. However, it is banned in many countries because it also generates phosphide (a toxic gas) and the dust it leaves behind may contain arsenic, which is also highly toxic. (CENTA, 2018).

In spite of this, the use of this component is a very common practice among local traders, who empirically use acetylide as a plantain ripening agent, which can have irreparable repercussions on public health. Therefore, the main objective of this research is to evaluate the use of calcium acetylide in different doses and exposure times in two plantain cultivars (dominico and barraganete) present in the germplasm bank of the Tropical Experimental Station Pichilingue of INIAP, in order to determine the differences between the results obtained in the physical and chemical characteristics, and how these are contrasted to the fruits obtained by natural ripening.

Methodology

The research was carried out on the grounds of the "La María" campus of the UTEQ, located in the canton of Mocache, province of Los Ríos, with geographical coordinates: 01°04'46'' South latitude and 79° 30'09'' West longitude, at an altitude of 69 meters above sea level. The fruits belonging to the two plantain cultivars (dominico and barraganete) were collected at the Pichilingue Tropical Experimental Station of INIAP, located at Km 5 on the Quevedo - El Empalme road.

The site where the trial was established presented the following agroclimatic conditions: mean temperature of 24.8 °C, relative humidity of 84%, annual rainfall of 2252.20 mm, heliophany of 894 (hours of light/year) and an ecological zone of humid-tropical forest (bh-T).

A completely randomized design (CRD) with a trifactorial arrangement A x B x C was used, with twelve treatments and three replications; the means obtained were subjected to Tukey's test (≥ 0.05 p). Factor A corresponded to the plantain cultivars (Dominico and Barraganete), factor B to the doses of acetylide used (control, 10 g per kg/fruit, 30 g per kg/fruit) and factor C corresponded to the exposure time (48 and 72 hours). Table 1 shows the analysis of variance scheme.

Table 1. *A analysis of variance*

Source of variation		Degrees of freedom
Treatments	t-1	
Factor A	a-1	1
Factor B	b-1	
Factor C	c-1	1
AxB Interation	(a-1)(b-1)	
AxC Interation	(a-1)(c-1)	1
Interaction BxC	(b-1)(c-1)	
Interaction AxBxC	(a-1)(b-1)(b-1)(c-1)	
Experimental error	axbxc(r-1)	
Total	**axbxc.r-1**	

Three boxes were used, with 5 kg of banana inside each one, for each treatment, giving a total of 36 boxes. Sub-samples were taken for subsequent analysis at two different times: 48 and 72 hours after the application of calcium acetylide in the different treatments, after the respective exposure time for each treatment had elapsed.

After the treatment, the bags (chambers) were opened and kept open for 3 days, during which time it was possible to observe the total ripening of the treatments exposed to acetylide, but not of the control treatments, from which subsamples were also extracted, so that a comparison could be made between natural ripening and the use of acetylide as a banana ripening agent at different doses through the respective laboratory analyses. Table 2 below shows the identification and coding of each treatment.

Table 2. *Identification and coding of treatments*

Trat	Description	Rep	EU	Total
T1	dominico+ 10 g/kg calcium acetylide + 48 hours		5	
T2	dominico+ 10 g/kg calcium acetylide + 72 hours		5	
T3	dominico+ 30 g/kg calcium acetylide+ 48 hours		5	
T4	dominico+ 30 g/kg calcium acetylide + 72 hours		5	
T5	barganete + 10 g/kg calcium acetylide + 48 hours		5	
T6	barganete + 10 g/kg calcium acetylide + 72 hours		5	
T7	barganete + 30 g/kg calcium acetylide + 48 hours		5	
T8	barganete + 30 g/kg calcium		5	

	acetylide + 72 hours	
T9 (witness 1)	dominico+ natural ripening + 48 hours	5
T10 (witness 2)	dominico+ natural ripening + 72 hours	5
T11 (witness 3)	barraganete + natural ripening + 48 hours	5
T12 (witness 4)	barraganete + natural maturation + 72 hours	5
Total		

Rep: repetitions; EU: experimental units; TREAT: treatment; EU: experimental units.

Ripening time (days). The ripening time was determined in days, from the placement of the plantain fingers to ripen until 100% of the fruit presented a yellow color throughout its peel. In addition, the ripening color scale implemented by Hidalgo (2012) was used.(Hidalgo, 2012)which was proposed by Von Loesecke and adapted by Cayón et al. and describes the following stages: dark green (V), light green (VC), yellow green (V-A), yellow (A) and very yellow (M-A).

Dry matter content (g). For the analysis of this variable, it was necessary to implement the AOAC standard method (934.01). (Rodríguez et al., 2013). Regarding the preparation of the samples, they went through an initial drying at 60°C for 24 hours and a subsequent drying at 105°C also for 24 hours, until the samples reached a constant weight (Binder ED 115-UL,Germany). (BINDER, 2017).

Moisture (%). To determine the moisture percentage, the samples were dried at a temperature of 105°C, a process recommended by the AOAC 977.04 standard. (FAO & OMS, 1999).

pH. By means of the implementation of a potentiometer, the pH in the pulp and peel was stipulated.

Energy (kcal). With respect to the determination of energy (kcal), a calorimetric pump was implemented to carry out an oxidation process.

Brix degrees. For the determination of this variable, the clusters of each treatment were chosen with a razor, a cut was made and the sample was extracted, then it was evaluated through the refractometer to determine the percentage of fructose in the sample.

Titratable acidity (%). Regarding the titratable acidity variable, a titration with sodium hydroxide (10% of normality) (NaOH 0.1N) was performed.

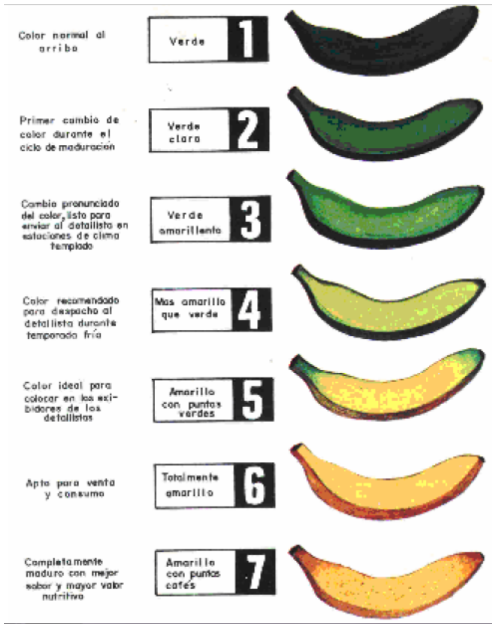
Pulp hardness. This was done through observation and palpation based on personal experience and a scale of values was created, where 1 corresponded to a consistent pulp, 2 corresponded to a soft pulp and 3 to an excessively soft pulp.

Peel dry matter (%). For the analysis of this variable, it was necessary to implement the standard AOAC method (934.01) (FAO & OMS, 1999). Regarding the preparation of the samples, they went through an initial drying at 60°C for 24 hours and a subsequent drying at 105°C also for 24 hours, until the samples reached a constant weight (Binder ED 115-UL,Germany). (BINDER, 2017).

Peel moisture (%). To determine the percentage of shell moisture, the samples were dried at a temperature of 105°C, a process recommended by the AOAC 977.04 standard. (FAO & OMS, 1999).

Peel color. To classify the color of the peels of the different experimental units, Figure 1 was implemented, corresponding to a standard ripening scale, which shows the different levels of maturity of the fruit with their respective colors. (Ordóñez, 2005).

Figure 1. Peel colors according to maturity level.



Source: (Ordóñez, 2005).

Results

Ripening time (days). The interaction of the three factors A (banana cultivars) x B (dose) x C (exposure time) resulted in significant differences between factors, with a coefficient of variation of 11.17%, with the best treatments that were subjected to calcium acetylide (T1, T2, T3, T4, T5, T6, T7 and T8) obtaining a ripening between 4 to 5 days, T2, T3, T4, T5, T6, T7 and T8) obtained a maturation of 4 to 5 days, while treatments T9, T10, T11 and T12 (controls) obtained a slower maturation, prolonging the maturation time by 10 to 15 days. As for the simple effect of factor A (banana cultivars), the best treatment was the barraganete with a maturation of 7 days, while in factor B (dose) the best treatments were those subjected to doses of 10 and 30 g/kg of acetylide with 5 days, as for factor C (exposure time) there were no statistical differences.

This would indicate that treatments T1, T2, T3, T4, T5, T6, T7 and T8, regardless of variety, calcium acetylide doses and exposure time, matured in less time, saving between 9 to 10 days compared to the controls. This shows a reduction in time of up to 66% in the case of the dominico variety and approximately 55% in the case of the barraganete variety, through the use of calcium acetylide (10 and 30 g/kg) on the green fruit.

Dry matter content (g). In the dry matter content, significant differences were found in factor B (dose), highlighting natural ripening with 0.78%, while in factor C (exposure time), 48 hours stood out over 72 hours with 0.79%; as for factor A (plantain cultivars), there were no significant differences (≤0.05). According to the analysis of variance, the interaction of factors A (plantain cultivars) x B (dose) x C (exposure time), showed highly significant differences ($p \leq 0.05$), with a coefficient of variability of 9.59%, the best treatment being T11 (control 3) with a value of 0.66%, this due to the fact that the lower the dry matter content, the greater the degree of ripening of the fruit. This was followed by T1, T3, T5 and T7 (treatments that were exposed to calcium acetylide for a range of 48 hours), with values less than 1 in dry matter. While T2, T4, T6 and T8 (treatments exposed to calcium acetylide for 72 hours), showed values greater than 1 in dry matter, this would indicate that the period of exposure of banana varieties to calcium acetylide would cause different effects on dry matter content.

Moisture (%). According to the analysis of variance of the moisture variable, it was found that there were highly significant differences in factor B (dose), highlighting the doses of 10 and 30 g/kg of calcium acetylide on natural ripening, while in factor C (exposure time) the highest value was 63.97 at 72 hours; the opposite occurred in factor A (varieties) where no differences were recorded. As for the interaction between factors A (banana cultivars), B (dose) and C (exposure time), the treatments that obtained the highest moisture content were T8 and T2 with 67.74 and 67.22% respectively, followed by the other treatments (T1, T3, T4, T5, T6, T7) exposed to calcium acetylide (regardless of dose, time and variety) with values greater than 60%. On the other hand, the control treatments obtained lower percentages, with T9 (control 1) being the treatment with the lowest percentage of the trial with 56.31%.

pH. For the variable pH, according to Tukey's test (≤0.05), significant differences were found in factor A (banana cultivars) with the best treatment being barraganete with 6.22%, as for factor B (dose), the best treatment was the inclusion of 10 g/kg of calcium acetylide with 5.80%, while in factor C (exposure time) no significant differences were recorded. With respect to the interaction between factors A (banana cultivars) x B (dose) x C (exposure time), significant differences were found, the best treatment being T8 with 5.60, which would indicate that the presence of calcium acetylide tends to decrease the pH of the fruits, which did not occur in T9, T10, T11 and T12 (controls), with natural ripening, which registered values close to neutral pH with 7.23, 7.20, 7.10 and 7.00, respectively.

Energy (kcal). According to the ANOVA, there were highly significant differences ($p \leq 0.05$) in factor A (banana cultivars) with the dominico variety standing out with 3738.81 Kcal, while in factor B (dose) natural ripening obtained the highest value with 3845.57 Kcal and in factor C (exposure time), the best value was recorded at 48 hours with 3693.64 Kcal. As for the interactions between factors A (banana cultivars) x B (dose) x C (exposure time), T9 (control 1 = dominico + natural ripening + 48 hours) stood out with 3925.58 Kcal, while the worst treatment was T6 (barraganete + 10 g/kg calcium acetylide + 72 hours) with 3528.19 Kcal. In general, it could be estimated that the natural ripening treatments whose variety was dominico registered values between 3800 and 3900 Kcal, and that values lower than these meant the use of calcium acetylide as an artificial ripening agent. A similar case is shown in the natural ripening treatments with barraganete plantain, which registered values between 3700 and 3800 Kcal, and that when they registered values ranging between 3500 and 3600 Kcal, they indicated the use of the ripening agent.

Brix degrees. According to the analysis of variance in factor A (banana cultivars), there was no significance, while in factors B (dose) and C (exposure time) the opposite occurred, the best dose being 10 g/kg of acetylide with 30.91 ^{0} brix and the best exposure time 48 hours with 21.25 ^{0} brix. Meanwhile, to the interactions between factors A (banana cultivars) x B(dose) x C (exposure time), significant differences were shown, with the best treatment being T5 (barraganete + 10 g/kg calcium acetylide + 48 hours) with 32.80 ^{0} brix, followed by the other treatments exposed to calcium acetylide (T1, T2, T3, T4, T6, T7 and

T8) with records exceeding 29 °, while those with the lowest values were T9, T10, T11 and T12 (controls) with 1.75, 2.00, 2.05 and 1.65⁰ brix respectively.

Titratable acidity (%). According to the ANOVA, there were no significant differences in factor A (banana cultivars), the opposite occurred in factors B (dose) and C (exposure time), highlighting natural ripening with 0.08 titratable acidity % and a time of 72 hours with 0.16%. While in the interactions between factors A (banana cultivars) x B (dose) x C (exposure time), it was shown that the best treatments were T7 and T5 with 0.45 and 0.41 % respectively, followed by the other treatments exposed to calcium acetylide, whose acidity was higher than 0.10. The opposite occurred with the naturally ripened controls (T9, T10, T11 and T12) whose acidity levels did not exceed 0.10.

Pulp hardness. According to the analysis of variance (p ≤0.05), both in factor A (banana cultivars) and factor C (exposure time) no significant differences were found; however, in factor B (dose) significant differences were found, highlighting the treatments exposed to acetylide over the naturally ripened ones. In the interactions between factors A (banana cultivars) x B (dose) x C (exposure time), there were significant differences, the best treatments being T1, T2, T3, T4, T5, T6, T7 and T8 with a mean of 2.00, which means that their pulp is soft, while the control treatments with natural ripening (T9, T10, T11 and T12) registered a score of 1.00 corresponding to a consistent pulp.

Dry matter in peel (%). According to the analysis of variance and Tukey's test (p ≤0.05) in factor A (plantain cultivars), factor B (dose) and factor C (exposure time), high statistical significance was found. As for the interactions between factors A (plantain cultivars) x B (dose) x C (exposure time), the best results were obtained by T3 (dominico + 30 g/kg calcium acetylide + 48 hours) with 4.11%, while the lowest value was obtained by T9 (control 1 = dominico + natural ripening + 48 hours) with 2.03%.

Peel moisture (%). According to the analysis of variance and Tukey's test (p ≤0.05), high statistical significance was found in factors A (plantain cultivars), B (dose) and C (exposure time), the best being the Dominican plantain with 70.71%, the best dose was 10 g/kg acetylide with 70.27% and the best exposure time was at 48 hours with 71.66%. In the interactions between factors A (plantain cultivars) x B (dose) x C (exposure time), a variation index of 7.20% was obtained, which shows that there were significant differences, the best treatment being T4 (dominico + 30 g/kg calcium acetylide + 72 hours) with 67.55.

Peel color. According to Tukey's test ($p \leq 0.05$), factor A (plantain cultivars) and C (exposure time) did not show significance, while factor B (dose) showed high statistical significance, the best doses were 10 and 30 g/kg acetylide with 6 points on the ripening scale, which means fully ripe. In turn, in the interactions between factors A (banana cultivars) x B (dose) x C (exposure time), a variation index of 6.63% was revealed, showing significant differences, highlighting T1, T2, T3, T4, T5, T6, T7 and T8 (treatments with the application of acetylide), with a result of 6 points on the scale of peel color which means fully ripe, while the worst treatments were those obtained by natural ripening: T9, T10, T11 and T12 (controls) with 3 points meaning yellowish green.

The values obtained in the ripening time showed greater efficacy with acetylide in contrast to other ripening substances such as ethrel, which can take between 3 to 6 days longer to ripen (Woldu et al., 2015). Therefore, it could be determined that the use of the doses and exposure times of the fruit with calcium acetylide in the present research obtained the expected results. Valverde et al, (Valverde et al., 1986) indicate that, if doses higher than these are implemented, it can cause overripening or predispose the fruits to the development of pathogens, which would affect fruit quality.

On the other hand, the results obtained for dry matter content agree with the data obtained by Martínez et al. (2016) (César Martínez et al., 2016) who emphasize that this variable is conditioned by the maturity stage of the fruit, presenting lower levels when the fruit is ripe.

This means that the higher the moisture content, the higher the ripening stage, and the higher the percentage of moisture in the fruit, the lower the presence of dry matter (Espinosa, 2013). This phenomenon is described in the research conducted by Von Loesecke, who states that during the ripening process the moisture content of the pulp increases, due to the hydrolysis of starch and the osmotic movement of water from the peel to the pulp and the faster concentration of sugars in the pulp (Arrieta et al., 2006), finding an increase in total soluble solids (brix degrees) and titratable acidity (Quiceno et al., 2014). It should be noted that if what is sought is to give greater commercial value to banana productions of both the dominico and barraganete varieties, it is advisable to obtain an adequate percentage of moisture in the harvested product (green fruit), and that this prevails for a considerable time, mainly if they are destined for the fried products industry, where they always seek materials with less water to avoid the penetration of oil in the product, for which has established a moisture range between 57-61% (Lucas et al., 2012). In addition, a high moisture content of banana contributes to a decrease in its shelf life during storage, as well as to a high economic loss after harvest (Sogo-Temi et al., 2014).

The pH results obtained show that the naturally ripened treatments in both the dominico and barraganete varieties did not noticeably decrease their pH levels, unlike those obtained by the treatments ripened with calcium acetylide (10 and 30 g/kg), which means that the treatments exposed to this mineral obtained a higher degree of ripening than those ripened naturally. This increase in organic acidity is due to the expected formation of Krebs cycle acids (Famiani et al., 2015), which causes the degradation of starches into reducing sugars and their conversion into pyruvic acid (Torres et al., 2013). In addition, it has been found that the lower the pH level, the greater the accumulation of malic acid in the fruit (Guzmán, 2014). This coincides with that reported by Wills et al. (Quiceno et al., 2014), who state that the increase of this acid occurs at an accelerated rate during the change from light green to intense yellow, a process that is highly related to the flavor of the fruit during ripening due to the concentration of acidity, total and reducing sugars in the pulp (Quiceno et al., 2014). In the case of banana peel, the pH varies according to the degree of ripening of the fruit, when it is immature (green peel) the pH will be alkaline, while when it is ripe (yellow peel) its pH decreases significantly to acid, this is possibly due to the fact that organic acids decrease as the fruit ripens by transforming them into sugars (Giraldo et al., 2014).

The overall analysis of the results obtained in energy shows a favorable trend in energy content for naturally ripened treatments, this is due to the starch content of the fruit as it matures (Torres et al., 2013). Starch is the main reserve carbohydrate in most plants. In the first hours after banana harvest, starch is hydrolyzed, which may be related to an increase in moisture content in the pulp after harvest, indicating that as time passes and the ripening process occurs either naturally or artificially, the lower the starch content and the higher the total soluble solids (sugars) content (César Martínez et al., 2016b). In addition, it is important to note that carbohydrate metabolism can be altered under certain environmental conditions such as exposure to temperature (Espinosa, 2013).

Regarding brix degrees, it is possible to appreciate the tendency of treatments ripened with calcium acetylide to increase the total soluble solids content (Brix degrees), as opposed to treatments exposed to natural ripening. This phenomenon seems to be related to that described by Solis (2015) (Solis, 2015), who in his research determined that the decrease in starch levels in the fruit is due to the degradation process, which allows the accumulation of fructose, sucrose and glucose, the main sugars that make up the total soluble solids (Brix), essential to determine the ripening criteria of the fruit. This process occurs due to an increased production of ethylene in the fruit, which initiates an increase in the respiration rate and can be influenced by climatic conditions (Espinosa, 2013). In the specific cases of T1, T2, T3 and T4, treatments composed of banana of the Dominico variety and exposed to doses of 10 and 30 g/kg of acetylide in periods of 48 and 72 hours in the present investigation, records ranging from 29.50 to 30, 75 ° brix were obtained in a maximum period of 3 days, while by natural ripening of this same variety it takes about more than 20 days to reach a record similar to those obtained.

Regarding titratable acidity, it behaved according to that reported by Martínez & Bermúdez (2016), who state that organic acids in the pulp tissues of most banana cultivars decrease during ripening or as ripening progresses. On the other hand, it is important to note that the acidity of the fruit is produced precisely by the combination of these acids with those fatty acids such as palmitic and linoleic. This is related to that indicated by Fernández and Martínez (2015) who emphasize that organic acids are closely linked to the respiration process and therefore fruit ripening (Fernández & Martínez, 2015).

On the other hand, it is known that fruit firmness depends on the effect of enzymes on pectin and starch; during this process, protopectin is degraded to lower molecular weight fractions that are more soluble in water, which causes fruit softening. The softening of banana tissues is due to changes that occur in the cell wall composed of long-chain carbohydrates divided into pectic substances (protopectin), hemicelluloses and celluloses. In these chains, calcium is an important component of the unions between the carboxylic groups, reinforcing the structural components of the cell (Mejia, 2013); producing sucrose and galacturonic acid, which generate flexibility in the material (Beltrán et al., 2010).

This means that the greater the dry matter in the peel, the greater the ripening of the fruit, which is due to what was reported by Dadzie and cited by Martínez and Bermúdez (2016) (Carlos Martínez & Bermúdez, 2016), during ripening the moisture content of the peel decreases, while that of the pulp increases, because the peel loses water releasing it both to the atmosphere, as well as to the pulp. However, these changes will depend on the cultivar under study (Reynoso, 2019), which is consistent with the results obtained in factor A, where the barraganete variety outperforms the dominico.

The lower the value of the moisture content of the peel, the greater the ripening, as indicated by Lustre cited by Kulkarni (2011) (Kulkarni et al., 2011) in his research, in which he demonstrates that the moisture content of the pulp increased during ripening, while that of the peel decreased. This event takes place through carbohydrate decomposition and osmotic transfer from the peel to the pulp. Which would indicate that osmotic removal of moisture from the peel has a very significant effect on the net increase in pulp moisture content (Allcca, 2017). Similar results to those achieved in the present investigation were obtained by Guanasekara (2015) (Gunasekara et al., 2015), where the treatment that obtained the lowest moisture content in the banana peel was the one exposed to calcium acetylide, even above the treatment treated with Ethephon, this would indicate a greater effectiveness of the mineral under study over other alternatives to artificial ripening such as Ethephon.

Finally, the color in the peel changes from green to yellow during the ripening stage, these changes are due to the decrease of chlorophyll content precisely in the decrease of chlorophyll b, by enzymatic activity hydrolyzing from chlorophyllide and phytol, and the decrease of color intensity is associated with the decrease of chlorophyll a, because chlorophyll b has a similar structure to chlorophyll a, but the 3-methyl group is substituted by the 3-formyl group, this small difference produces changes in the visible absorptions (Mejia, 2013), this whole process allows the increase in the synthesis of yellow pigments (carotenoids and anthocyanins) (Beltran et al., 2010). This result is in agreement with the literature present in most research, in that ripening agents allow ripening (change of peel color) faster than when it is done naturally. However, it is important to rescue what was stated by Sogo-Temi (2014) (Sogo-Temi et al., 2014), who indicates that calcium acetylide is one of the most effective ripening agents since it can induce ripening in 24 hours in the same period of time as other ripening agents such as ethylene, in addition to the fact that it is more affordable, which makes it a more popular ripening agent among banana sellers, especially in developing countries such as Ecuador.

Conclusions

The use of calcium acetylide as an artificial ripening agent obtained significant differences on the physical parameter peel color, evaluated in the two banana varieties (Dominico and Barraganete), in which treatments T1, T2, T3, T4, T5, T6, T7 and T8 stood out with a score of 6 (maximum value on the Von Loesecke scale). The opposite occurred in treatments T9, T10, T11 and T12, which correspond to natural ripening.

With respect to the evaluation of chemical parameters, great variability was observed, with different treatments with exposure to calcium acetylide standing out in variables such as: Moisture, Brix degrees, Acidity, pH, Peel dry matter and Peel moisture. The opposite occurred in the variables Energy and Dry Matter Content, where T9 and T11, corresponding to treatments with natural ripening, prevailed.

Finally, the pulp hardness and ripening time variables clearly showed a predominance in the treatments exposed to calcium acetylide, obtaining a greater softness and at the same time reducing the ripening time to 5 days in the case of treatments T1, T2, T3, T4, T5, T6, T7 and T8, over a range of 10 to 15 days for the natural ripening of the two varieties.

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