

Effect of Calcium Carbide Treatment on Ripening Time and Physicochemical Properties of Mango (*Mangifera indica* L.) Variety “Kent”, Côte d’Ivoire

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Authors’ contributions

This work was carried out in collaboration among all authors. Author MC conceived and designed the study, wrote the protocol. Authors YS and ADSK performed the statistical analysis, carried out the protocol and wrote the first draft of the manuscript. Authors MC and CN supervised the findings of this work. All authors provided critical feedback and helped shape the research, analysis and contributed to the final manuscript.

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ABSTRACT

Aims: this study aims to find out appropriate method of application and the optimum dose of calcium carbide required to initiate ripening of mango var. “Kent”.

Study Design: The experimental set-up was of a completely randomized design.

Place and Duration of Study: This study was performed in the Department of Genetic and Biochemistry, at the Laboratory of Food Biochemistry of University Peleforo Gon Coulibaly, Korhogo, Côte d’Ivoire, May 1, 2020.

Methodology: Seventy uniform, mature green and healthy mangoes were bought from a local company and divided into five groups. The groups were divided into different calcium carbide levels as follows: 0 (control), 1 g/kg and 3 g/kg, CaC₂ per fruit; 1 g/L and 3 g/L, CaC₂ in distilled

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water to induce ripening at room temperature. The physicochemical analysis was carried out on both the unripe and ripened fruits.

Results: The results obtained revealed that calcium carbide reduce significantly fruit ripening time from 6 days (naturally ripened fruit) to 3 days (3 g/kg) and 4 days (1 g/kg). The present study showed also that calcium carbide by spraying is not effective on mango ripening time. The physicochemical analysis indicated that CaC_2 may induce negative changes on some quality parameters like firmness, pH, acidity, total soluble solids (3 g/kg, CaC_2 per fruit) and vitamin C. However, the fruits subjected to 1 and 3 g/kg, exhibited an increase of skin brightness and yellowness whereas 1 g/kg increase slightly in TSS when compared to the control. Moreover, the study established that the ripening time and changes in quality parameters are dose and method dependent.

Conclusion: The present investigation showed that the artificial ripening using calcium carbide could not keep quality physicochemical characteristics intact.

Keywords: *Mango (Mangifera indica L.); calcium carbide; physicochemical parameters; artificial ripening.*

1. INTRODUCTION

Fruits provide vital nutrients in human diet such as vitamins, minerals, complex carbohydrates, proteins, lipids, and antioxidants essential for maintaining normal health [1–3]. They are largely distributed in nature, commercially and nutritionally important and can be consumed raw. Among the fruits, mango (*Mangifera indica* L.), belonging to Anacardiaceae family widely found in tropical and subtropical regions, is one of the most important commercial crops worldwide in terms of production, marketing, and consumption. Mango acquires its organoleptic and nutritional qualities after ripening. Ripening is the final stage of development of fruit which involves series of physiological and biochemical process leading to changes in colour, flavour, aroma and texture that make the fruits both attractive and tasty. Mango fruits ripen rapidly after harvest. Mango can ripen naturally or artificially using artificial agents including ethylene gas (expensive), ethephon, calcium carbide (cheaper), etc. Calcium carbide (CaC_2) accelerates ripening rate by releasing acetylene gas in presence of moisture [4,5]. Thus, in Côte d'Ivoire, the mango sector is facing to artificial ripening phenomenon using calcium carbide to accelerate fruit ripening. The key reasons that justify this practice by mango sellers include high demand of seasonal fruit (particularly at the beginning of the season) and possible economic loss during fruit storage. In addition, calcium carbide is cheaper and available and artificially ripened fruits may develop uniform and attractive surface colour but poor in taste. Certainly, artificial ripening accelerates the rate of the process but affects the nutritional quality, sensory and safety of the fruits and the fruit

generally have shorter shelf life [6]. The method of calcium carbide application in commercial practise is critical because, calcium carbide produces some impurities such as phosphorous hydride and arsenic hydride which could cause health hazards [7]. Hence, it is appropriate to take precautions like to avoid the contact of fruits with calcium carbide after acetylene release because these hydrides are fat soluble and may dissolve in the wax layer of fruits. Therefore, this study was investigated to find out appropriated method of application and the optimum dose of calcium carbide required to initiate ripening of mango var. "Kent".

2. MATERIALS AND METHODS

2.1 Material

Seventy-five uniform, mature green, undamaged and healthy fruits of Kent mango variety were purchased from Comako company, Korhogo, Côte d'Ivoire. The fruits were then packed into plastics baskets and conducted to the laboratory of the Department of Biochemistry and food technology, UFR of Science, Peleforo Gon Coulibaly University and kept at room temperature before treatment. The fruits were washed with water to remove the latex, shade dried until no moisture was visible on the fruit surfaces and randomly divided into five groups of 15 fruits. Four group were submitted to four calcium carbide levels (1 g/kg and 3 g/kg, g calcium carbide per kg of fruits; 1 g/L and 3 g/L, calcium carbide per distilled water). Calcium carbide was bought from a Korhogo market and used as the ripening agent. The experiment was conducted in May 2020.

2.2 Methods

2.2.1 Calcium carbide treatment

The calcium carbide was weighed using a precision balance (Denver Instrument, SI-234MAX 230 g model) and divided into the weight requirement of each treatment group (1 g/kg and 3 g/kg, calcium carbide per fruit; 1 g/L and 3 g/L, calcium carbide per distilled water; and naturally ripen). For 1 g/kg and 3 g/kg, CaC_2 per fruit; calcium carbide was wrapped in a paper towel and kept at the bottom of a cardboard. The fruits were packed according to treatment, the calcium carbide was then moistened with drops of distilled water to release the acetylene gas and covered tightly with a newspaper to prevent leakage of the gas produced. After 24 hours, the packets of calcium carbide were removed from the containers, and the fruits were uncovered and allowed to ripen. For 1 g/L and 3 g/L, CaC_2 per distilled water; calcium carbide requirement was dissolved in water in Erlenmeyer flask using magnetic stirrer for two minutes. The fruits were placed in cardboard, sprayed with 70 mL of CaC_2 solution using sprayer and covered with newspapers. After 24h, fruits were uncovered and left to ripen. Control fruits were packed in cardboard for 24h and uncovered to ripen naturally.

2.2.2 Ripening time, shelf life and rot rate

Fruit ripening was characterized by change of colour from green to yellow and when fruit gives off mango characteristic aroma with relatively low firmness. The fruit ripening time was measured as the time it took the whole fruits to change colour from green to yellow and release mango characteristic aroma. The rot rate and shelf life of the fruits were assessed by regular visual inspection of fruits as described by Dadzie and Orchard [8]. Shelf life calculated as the period (in days) between ripening and the end of saleable life or of edible life of fruit (appearance of shrinkage, wrinkles and discolouration). The rot rate was determined by counting rotten fruits during experimental period.

2.2.3 Determination of physicochemical properties

The method described by AOAC [9] was adopted to determine dry matter content and based on drying in an oven at 105°C during 24 h to constant weight. Firmness was measured using a digital penetrometer (FC GAUGE PCE - FM 200 model, Milan, Italie) by Yao et al. [10]

method and expressed in Newton (N). Colour was measured in the colour space L^* , a^* and b^* using a Konica Minolta colorimeter model CR-10plus, Japan. Four determinations were performed on different sides of fruits from each treatment. For total soluble solids (TSS) and acidity determination, four fruit peels from each treatment were removed and the juice of pulp was separately extracted using a juice extractor model Kuvings D9900, South Korea. The TSS and acidity were measured with a digital refractometer double scale Brix-acid (PAL-BX-ACID91, ATAGO) Japan) at 25°C following manufacturer directions. While pH of extracted juice was assessed using pH meter model 206-pH1, Testo, UK, after calibrating. Ascorbic acid was determined by the titration method following the procedure of Pongracz [11] and expressed as mg/100 g fresh pulp.

2.2.4 Statistical analysis

The results were expressed as Mean \pm Sd. Statistical difference between the different groups was evaluated using one-way ANOVA with Bonferroni post-hoc test. The values were considered significant when $P < .05$. Data was analysed using version 3.6.1 R software.

3. RESULTS AND DISCUSSION

3.1 Ripening Time, Shelf-Life, Rot Rate

The Table 1 exhibits the ripening time, shelf life and decay incidence. Calcium carbide treatment reduce significantly ripening time from 6 (naturally ripened) to 3 days (3 g CaC_2 per 1 kg of fruit) or 4 (1 g CaC_2 per 1 kg of fruit). This reduction of ripening time by calcium carbide is due to acetylene gas released after its contact with water. Our study was corroborated by Gbakon et al. [4] which registered 2 to 3 days as ripening time of mango containing in plastic bag using calcium carbide. The calcium carbide action on ripening time is affected by the nature of fruit container (plastic or paper bags). The results revealed also that application of CaC_2 by spraying does not influence the ripening time. This can be attributed to a release of acetylene gas during dilution or spraying. According to concentration, calcium carbide removes completely (3 g CaC_2 /L of water, 1 g/kg, and 3 g/kg, CaC_2 per fruit) or partially (1 g CaC_2 /L of water) microbial development. The averages of rot rate vary from 26,67% to 66,67% after storage. The highest rot rates were recorded in spraying treatment and the lowest rate of spoilage was observed in 1 g CaC_2 /kg of fruit.

This might be attributed to moisture generated by spraying in storage container furthering fungi development.

3.2 Physical Properties

3.2.1 Colour

Mango skin colour is an important selection criterion for consumers. Also, it is one of the reasons that lead sellers to calcium carbide use for mango ripening. Parameters L^* (luminance which varies from white to black) and a^* (designed green/red axe) values increase significantly with calcium carbide treatment depending on concentrations (Fig. 1). The increase of a^* value is associated to both of chlorophyll degradation, carotenoids and xanthophylls biosynthesis [12]. According to Ornelas-Paz et al. [13], degradation of chlorophyll pigments during ripening period is due to conversion of chloroplast to chromoplast, which consists of carotenoids and xanthophylls. The highest loss of green colour (a^*) of skin and lightness (L^*) of skin and flesh observed after the exposition of fruits to 3 g CaC_2 per 1 kg of fruit means that the calcium carbide would act as a stimulator of chlorophyllase activity and carotenoids biosynthesis process. L^* values in 1 g/kg of fruit and natural samples are similar. The

greatest b^* (blue/yellow axe) values were found in naturally ripened mango and treated to 3 g/kg of fruit and lowest in 3 g/L distilled water. The flesh colour values (Lab) are nearly similar for different samples.

3.2.2 Firmness

The firmness decreases with storage time. The rate of change of fruit firmness is higher in the treated mango as compared to naturally ripened mango samples. This decrease could be attribute to the breakdown of insoluble pectic substances to soluble forms by a series of reactions caused by the action of pectic enzymes i.e. Esterases and polygalacturonidase [14]. That is followed by the membrane permeability resulting in progressive loss of fruit tissue firmness. In artificial ripening samples, 3 g and 1 g of calcium carbide per kg of fruit samples have the lowest skin firmness values ($42,48 \pm 8,63$ N and $39,20 \pm 11,56$ N respectively) whereas the highest flesh firmness values were been registered in 3 g of CaC_2 per kg of fruit and 3 g of CaC_2 per litre ($13,48 \pm 2,21$ N and $15,43 \pm 4,23$ N respectively) after ripening. The strong firmness loss noted in treated fruits can be due to calcium carbide that hastens polygalacturonase enzyme activity [5]. These results agree with those reported by Gandhi et al. [15].

Table 1. Effect of Calcium carbide on ripening time, shelf-life and rot rate

Treatments	Ripening time (day)	Shelf-life	Rot rate (%)
3g/kg	3 ^a	5 ^a	0 ^a
1g/kg	4 ^{ab}	7 ^{ab}	0 ^a
3g/L	6 ^b	8 ^b	0 ^a
1g/L	6 ^b	8 ^b	26,66 ^c
Natural	6 ^b	8 ^b	13,33 ^b

Values in a column with the same letter were not significantly different ($P < .05$)

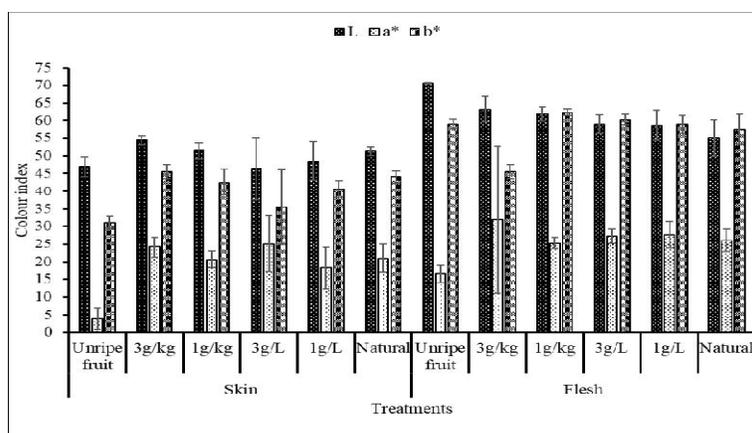


Fig. 1. Effect of Calcium carbide on colour after ripening

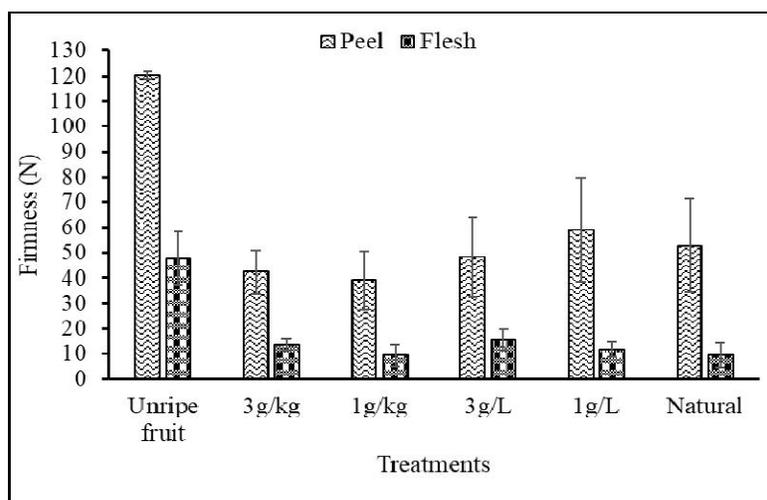


Fig. 2. Effect of Calcium carbide on fruit firmness after ripening

3.3 Biochemical Properties

Table 2 presents the results for proximate composition of the fruits ripened with different concentrations of calcium carbide CaC_2 . The total soluble solids and pH increase whereas acidity and ascorbic acid decrease over ripening. The highest TSS was found in 1 g/kg of fruit treatment ($18,35 \pm 1,01\%$) while the lowest TSS was recorded in 3 g CaC_2 per kg of fruit treatment ($15,62 \pm 1,65$). The TSS increases more with spraying treatment than when calcium carbide pieces were introduced in storage container. The statistical analysis revealed a significant difference in TSS content between treatment models. The reaction of starch breakdown into soluble sugars that is responsible to the increase of TSS values could be accelerated by calcium carbide per acetylene releasing. This is in accordance with Muthal et al. [16] which reported that chemical ripening agents increase the rate of starch breakdown of banana. The lowest TSS recorded in 3 g per kg of fruit could mean that calcium carbide (at high dosage) acts essentially on skin of the fruit. Acidity and pH evolution can be associate to organic acids (malic acid, acetic acid) in fruits. Thus, acidity decreases from $0,51 \pm 0,02\%$ for unripe fruit to $0,48 \pm 0,10$; $0,46 \pm 0,10$; $0,42 \pm 0,04$; $0,38 \pm 0,06$ and $0,38 \pm 0,09\%$ in artificially ripened fruits (3 g/L ; 3 g/kg ; 1 g/kg ; 1 g/L and naturally ripened fruits respectively. In addition, statistical analysis shown no significant difference at 5% signification. The decline of acidity and pH increase could be due to the use of organic acids as substrates for respiration, gluconeogenesis

and biogenesis of flavour compounds. [5,17]. The vitamin C values ranged from $42,07 \pm 2,09$ (naturally ripened) to $30,02 \pm 3,62$ mg/100g FM (3 g/L; CaC_2 per water). Spraying treatment influence more ascorbic acid content than CaC_2 pieces introduction in storage container. The ascorbic acid content in the mango fruits decreased significantly during the ripening storage period for all models. This reduction in vitamin C content may be due to the susceptibility of ascorbic acid to oxidative destruction. In addition, ascorbic acid (vitamin C) is very soluble in water and its decrease can be attributed to water loss through stomata by transpiration or evaporation depending on temperature, relative humidity, and cellular wall state. The decrease of vitamin C content during ripening was reported by many authors as Adeyemi et al. [18]; Cissé et al. [19]; Gbakon et al. [4]; Gill et al. [14]; Othman and Mbogo [20]. Dry matter contents were not varied significantly during ripening. Hence, it varies from $16,00 \pm 4,10$ (unripe fruit) to $19,95 \pm 1,53$ mg/100g FM (3g/kg, CaC_2 per fruit). Also, spraying of 3g of CaC_2 dissolved in one litre of water resulted to a decrease of dry matter. During ripening, dry matter evolution is particularly linked to water movement and slightly to TSS content. In fact, the TSS increase lead to movement of water from peel to pulp through osmotic process resulting to declining of dry matter content. It is known that a low relative humidity induces an important movement of water from peel to environment by transpiration or evaporation. So, the quantity of water out will find out the dry matter content of pulp.

Table 2. Effect of Calcium carbide on biochemical properties during ripening

Samples	TSS (°Brix)	Acidity (%)	Ph	Vitamin C (Mg/100g FM)	Dry Matter (Mg/100g FM)
Unripe Fruit	06,00±0,30 ^a	0,51±0,02 ^a	3,65±0,23 ^a	63,77±2,09 ^d	16,00±4,10 ^a
3g/Kg	15,62±1,65 ^b	0,46±0,10 ^a	3,79±0,07 ^{ab}	33,63±3,62 ^{ab}	19,95±1,53 ^a
1g/Kg	18,35±1,01 ^b	0,42±0,04 ^a	3,95±0,04 ^{bc}	39,66±2,09 ^{bc}	16,90±2,73 ^a
3g/L	18,60±1,21 ^b	0,48±0,10 ^a	3,88±0,13 ^{ab}	30,02±3,62 ^a	15,93±3,10 ^a
1g/L	17,20±1,77 ^b	0,38±0,06 ^a	3,86±0,21 ^{ab}	31,22±2,09 ^a	17,33±2,00 ^a
Naturally Ripe	17,00±0,26 ^b	0,38±0,09 ^a	4,08±0,17 ^c	42,07±2,09 ^c	19,80±0,92 ^a

Each observation is a mean ± SD of four replicate experiments (n = 4). Values in a column with the same letter were not significantly different (P = .05). TSS = Total Soluble Solids; FM = Fresh Matter

4. CONCLUSION

This present study shown that firmness, colour, vitamin C, titrable acidity, total soluble solids, ripening time, shelf life and rot rate change significantly in artificially ripened mango compared to naturally ripened mango. These properties change following calcium carbide concentrations. The titrable acidity and total soluble solids of chemically ripened mango were higher than the naturally ripened mango. While naturally ripened mango presents more vitamin C content and firmness as compared to artificially ripened mango. Artificially ripened fruits are recorded the most brightness which is search by sellers. Calcium carbide was reduced the ripening time from 6 days for natural ripened to 3 or 4 days for 3 g and 1 g CaC₂ per 1 kg of fruit. Moreover, the study established that the ripening time and changes in quality parameters were dose dependent. In other words, a high calcium carbide level produces a great adverse effect. This study shown that calcium carbide by spraying is not effective on mango ripening time. The fruits treated with 1g CaC₂ per 1 kg of fruit are registered the physicochemical parameters near to those of naturally ripened fruits. Consequently, we recommend naturally ripening to mango sellers that is safer way. If necessary, 1 g/kg (g of CaC₂ per kg of fruit) can be used for artificial ripening by sellers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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