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Research Article
Calcium Carbide Treatment on Some Physiochemical Characteristics of Broken and Mummy Mango Fruits

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Abstract
Background and Objective: Calcium carbide is a corrosive and dangerous chemical containing traces of arsenic and phosphorus hydride as impurities. The effects of calcium carbide treatment on the fruits of two relatively new mango varieties (*Mangifera indica L.*) namely: Broken and Mummy, grown in Benue State, Nigeria was investigated. **Materials and Methods:** Sixty uniform, mature green, undamaged and healthy fruits were harvested and the fruits of each variety divided into four groups. Each variety was subjected to different levels of calcium carbide treatment as follows: 0, 2, 4 and 6 g calcium carbide per kg of fruit to induce ripening at room temperature. The pulp was extracted after ripening and used in the biochemical analysis. Data was analyzed by one-way ANOVA followed by Bonferroni *post hoc* test. The results revealed that Broken and Mummy mango fruits could be artificially ripened by calcium carbide and it was more effective in early ripening when compared to natural ripening. **Results:** The study showed significant differences between calcium carbide-ripened mangoes and the untreated mangoes. This study also provided evidence that ripening of mangoes by calcium carbide induced significant negative changes in some of the investigated physical characteristics: fruit weight, physiological weight loss, firmness and biochemical constituents such as pH, tiratable acidity, total soluble solids and vitamin C in all the three groups. The calcium carbide-treated fruits, especially the groups subjected to 4 and 6 g of calcium carbide per kg of fruit exhibited a trend in higher physiological weight loss, less total soluble solids, drastic decrease in Vitamin C and higher acid content than the fruits that ripened naturally. The differences between the two varieties noticed in response to calcium carbide treatment were probably due to their genetic dissimilarities. **Conclusion:** The present study established that the calcium carbide-ripened fruits could not keep the investigated physicochemical characteristics intact.

Key words: Calcium carbide, artificial ripening, mango fruits, physicochemical parameters, fruit ripening time

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Fruits provide vital nutrients in human diet by supplying the necessary growth regulating factors such as vitamins, minerals, complex carbohydrates, proteins, lipids and antioxidants essential for maintaining normal health[1-3]. They are widely distributed in nature, a commercially important and nutritionally essential food commodity and can be consumed raw. Apart from the consumable part of the fruits, the by-products, such as the fruit peels and the seeds represent excellent components for food, medicinal or cosmetic purposes.

Among the fruits, mango (*Mangifera indica* L.) in the 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 fruits ripen rapidly after harvest. The fruits are also susceptible to diseases[4]. They perish quickly due to ripening and softening which limit the storage, handling and transport potential of the fruits[5]. Mango fruits are therefore harvested when they are immature and mature green. Post-harvest treatment of mango fruits is a key challenge in Nigeria[2]. Ripening is done naturally or artificially and this leads to fruit maturity before consumption or processing[6]. The key factors that influence the practice of artificial ripening include high demand of seasonal fruit and possible economic loss during fruit storage and distribution[7]. The common practice currently is harvesting these mango fruits in bulk in a single picking, including fruits of different stages of maturity. As a result of this practice, there are postharvest losses of up[4] to 40-60%. To overcome these problems, mango fruits can be exposed to chemical ripening agents such as calcium carbide, acetylene gas and ethephon among others for a short period in order to activate ripening[7,8].

Natural fruit ripening is a combination of physiological, biochemical and molecular processes[9,10]. It involves coordination of different metabolisms with activation and deactivation of various genes, which leads to changes in colour, sugar content, acidity, texture and aroma volatiles[9,11]. The change in colour during the fruit ripening process is a result of the unmasking of pigments by degradation of chlorophyll, synthesis of different types of anthocyanins and their accumulation in vacuoles and accumulation of carotenoids. Production of complex mixture of volatile compounds and other related compounds enhance the flavour and aroma of the fruit. Sweetness increases because of increased gluconeogenesis, hydrolysis of polysaccharides, decreased acidity and accumulation of sugars and organic acids. Furthermore, textural changes resulting in the softening of fruits occur due to enzyme-mitigated alteration in structure and composition of the cell wall[11]. Through these changes, fruits become ripe with distinctive characteristics: sweetness, colour, softness and palatability.

Preliminary studies in Benue state, the central mango growing area of Nigeria, indicated the indiscriminate commercial application of calcium carbide on the different varieties of mango fruits to enhance ripening. During transportation, the naturally ripened fruits may become over-ripened and inedible. Sometimes fruit sellers chemically ripen the immature fruits in order to avoid loss, meet the high demand and make high profit. Fruits ripened with calcium carbide may develop a uniform and attractive surface colour but are poor in flavour and the inside may remain unripe. Though the use of calcium carbide accelerates ripening, it may affect the physicochemical characteristics of the fruits.

Research concerning the action of calcium carbide as a ripening agent for the different varieties of mango fruits in Nigeria is quite limited. In this study, investigation was carried out to determine the changes and trend behaviour in some of the physicochemical characteristics of the two relatively new varieties of mango fruits in Benue state of Nigeria (namely, Broken and Mummy) when ripening was induced by the application of calcium carbide.

MATERIALS AND METHODS

Forty uniform, mature green, undamaged and healthy fruits of Broken mango variety were randomly harvested from a mango orchard in Mbaikon settlement of Tsambe Ward in Vandeikya Local Government Area (LGA), while 20 fruits of Mummy mango variety were obtained from an orchard in Lessel, Ushongo LGA, Benue State-Nigeria on 4th August, 2017. The weight of the mango fruits was recorded using analytical weighing scale RS 232, Adam model. The 60 fruits were washed with water to remove the latex and shade dried until no moisture was visible on the fruit surfaces. The fruits were then packed into wooden baskets and transported to the laboratory of the Department of Chemistry, Faculty of Science, Benue State University Makurdi and kept at room temperature. Calcium carbide was bought from a welding materials store at the Makurdi Modern Market and used as the ripening agent. The analysis was conducted from 18th August to September, 2017.

Treatment of mango fruits with calcium carbide: The 40 Broken and 20 Mummy mango fruits were each divided into four groups. The Broken variety was subsequently labelled B1, B2, B3 and B4 while the Mummy variety was designated M1, M2, M3 and M4. Each variety was subjected to three levels of calcium carbide treatment as follows: 2, 4 and 6 g calcium carbide per kg of fruit to induce ripening; with B1 and M1 being the controls (without calcium carbide) for Broken and Mummy respectively. Calcium carbide was crushed into small pieces and weighed using analytical weighing balance PW 184 Adam model.

Rao[12] method was used in this study to quicken the ripening process of the mango fruits. When fully ripened, the fruit peels were removed and the pulp from each treatment was separately fed into a China-made Qlink Blender model QBL-20L330 and then homogenized. The resulting pulp from each group of fruits was pooled to form eight respective composite samples (B1, B2, B3, B4 and M1, M2, M3, M4). The resulting pulp (juice) was thereafter introduced into plastic bottles, properly labelled and preserved in a refrigerator at 15°C for biochemical analysis.

Determination of physicochemical characteristics of the mango fruits: The physical and biochemical characteristics of the broken and mummy mango fruits were determined as follows:

Fruit weight and physiological weight loss: The weight of mature green (unripe) and ripe fruits (final weight) were measured on a digital scale (grams) and recorded. Physiological weight loss (PWL) was calculated according AOAC[13].

Fruit length and girth: Fruit length and girth were measured (cm) with an English-made Dean Fiberglass Tape and recorded. Three fruits from each group were randomly selected, measured and the dimensions recorded.

Moisture content: The method described by AOAC[13] was adopted to determine the moisture content and based upon the removal of water from the sample and its measurement by loss of weight.

Firmness: Firmness was measured with a penetrometer using a piston 4 mm in diameter and a 30 mm min^{-1} speed. Firmness in kilogram force (kgF) was determined every two days until the fruits ripened.

pH: pH was determined by AOAC[13] method using pH meter.

Titratable acidity (TA): The TA was determined according to the method as described by Mazumdar and Majumder[14].

Total soluble solids (TSS): The TSS was measured according to the method described by Mazumdar and Majumder[14] using digital bench refractometer and the reading appearing on the screen was directly recorded as total soluble solids (°Brix).

Vitamin C: Vitamin C (also known as Ascorbic acid) was determined by the titration method following the procedure of AOAC[13].

Statistical analysis: The results were expressed as Mean±SEM. Statistical difference between the different groups was evaluated using one-way ANOVA with a Bonferroni *post hoc* test. The values were considered significant when $p<0.05$. Data was analyzed using version 18 software (SPSS Science, Chicago, Illinois, USA).

RESULTS

The results obtained from the analysis carried out on calcium carbide treated and untreated mango fruits are presented in Table 1 and Fig. 1-5. The result showed that the weights, length, girth and moisture content of Broken mangoes in the different treatment groups were not significantly different from one another. However, values of these parameters were significantly lower in comparison to Mummy mangoes (Table 1).

Table 1: Some physical characteristics of Broken and Mummy ripened by calcium carbide

Groups	Weight (g)	Length (cm)	Girth (cm)	Weight loss (%)	Moisture (%)
B1	732.80±4.84*	13.22±0.07*	34.57±0.05*	9.96±0.02#	86.46±0.02*
B2	743.20±1.32*	13.24±0.02*	34.35±0.14*	10.16±0.07#	86.45±0.01*
B3	741.80±0.92*	13.10±0.06*	34.11±0.05*	11.50±0.01#	86.47±0.01*
B4	740.40±0.51*	13.13±0.05*	34.53±0.05*	12.11±0.05#	86.30±0.19*
M1	1351.00±0.45	18.96±0.02	40.72±0.24	9.66±0.00#	89.37±0.01
M2	1345.60±6.66	18.97±0.01	40.86±0.02	9.32±0.06#	89.38±0.01
M3	1335.40±0.24	19.12±0.04	40.68±0.05	10.69±0.02#	89.37±0.02
M4	1343.00±1.55	19.08±0.05	40.62±0.04	10.88±0.01#	89.39±0.03

N = 5, *Significant compared with Mummy mangoes on same day at $p<0.001$, #Significant compared with all other groups on same day at $p<0.001$

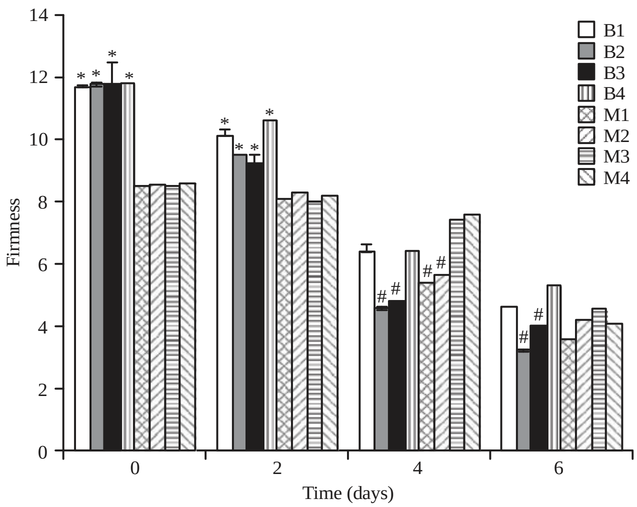

Fig. 1: Effect on firmness of mangoes treated with different doses of calcium carbide

N = 5, *Significantly firmer than Mummy mangoes at p<0.001, #Significantly softer than untreated mango of same variety on same day at p<0.001

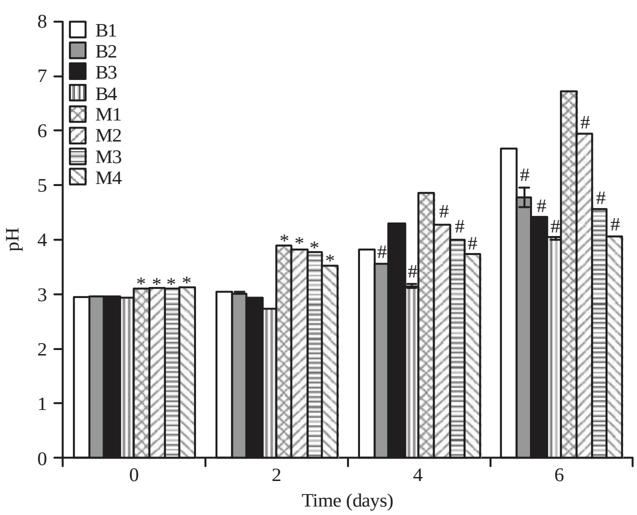

Fig. 2: Pulp pH of mangoes as influenced by different doses of calcium carbide

N = 5, *Significantly lower than value in broken mangoes at p<0.001, #Significantly lower than pH in untreated mangoes of same species at p<0.005

Mangoes showed weight loss, which was dose-dependent: Mangoes treated with lower concentration of calcium carbide had significantly (p<0.001) lower weight loss, while those treated with higher doses of calcium carbide lost more weight in both varieties. The untreated mangoes had significantly lower weight loss than those treated with calcium carbide.

Days taken for the mango fruits to ripen: The results of the present study showed that calcium carbide caused early

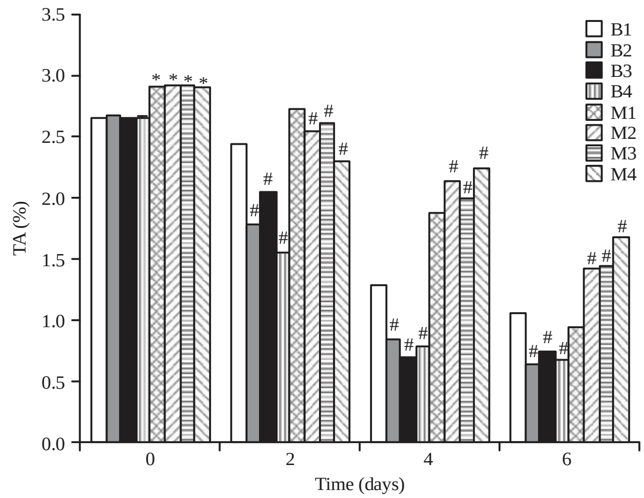

Fig. 3: Status of titratable acidity of mangoes as influenced by different doses of calcium carbide

N = 5, *Significantly higher than Mummy mangoes at p<0.001, #Significantly different from untreated mangoes of the same variety at p<0.001

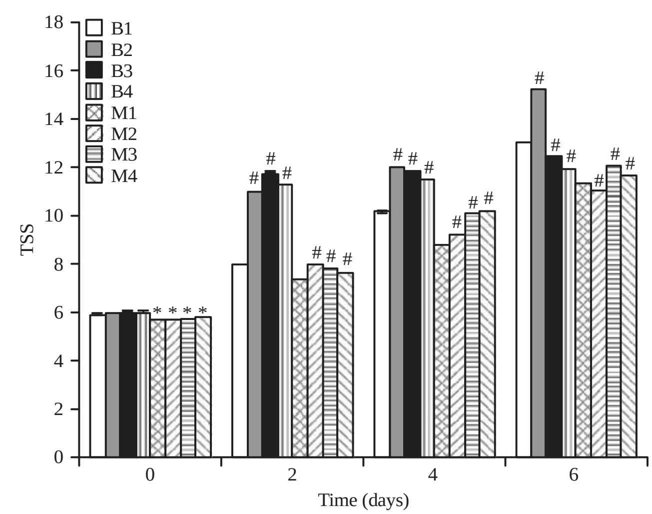

Fig. 4: Effect of different doses of calcium carbide treatment on TSS of the mangoes

N = 5, *Significantly lower than broken mangoes at p<0.001, #Significantly different compared with mangoes of same variety at p<0.001

ripening compared to natural ripening in both varieties. The untreated fruits ripened in nine to ten days after harvest, while the treated fruits ripened in 5-7 days after harvest.

Firmness: On day 0, the Broken mangoes were significantly firmer than Mummy mangoes. By day 2, however, there was reduction in the firmness in both varieties. For Broken mangoes, reduction in firmness was not dose dependent as mangoes treated with lower doses of calcium carbide became

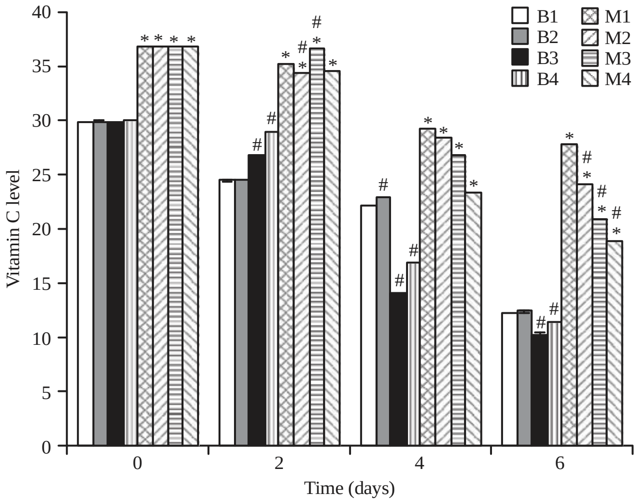

Fig. 5: Effect of calcium carbide treatment on vitamin C content of mangoes

N = 5, *Significantly higher than that in broken mangoes at p<0.001, #Significantly different from untreated mangoes of same species at p<0.001

significantly (p<0.001) softer than those treated with the highest dose of calcium carbide. Furthermore, by day 2, Broken mangoes without treatment were significantly softer than mangoes treated with the highest dose of calcium carbide (Fig. 1).

By day 4, both varieties of mangoes became softer than the value observed on day 2. For Broken mangoes, treatments at doses of B2 and B3 significantly (p<0.001) reduced the firmness of the mangoes relative to the untreated B1, while the firmness of mangoes treated with the highest dose of calcium carbide was not significantly different (p>0.05) from the untreated. In the case of Mummy mangoes, the untreated were significantly (p<0.001) softer than the treated at the different concentrations of calcium carbide and those treated with higher concentrations of calcium carbide were firmer than those treated with lower concentrations.

By day 6, Broken mangoes treated with the lowest dose of calcium carbide were significantly (p<0.001) softer than all other groups, while those treated with the highest dose of calcium carbide were significantly (p<0.001) firmer than the untreated Broken mangoes and those treated with lower doses of the drug. For Mummy mangoes, the untreated were significantly softer than those treated with calcium carbide.

When firmness was considered based on varieties of mangoes, Broken mangoes were significantly firmer than Mummy by day 0; but by day 4, the Broken mangoes were significantly (p<0.001) softer than Mummy and by day 6, there was no significant difference between the firmness of both varieties of mangoes.

When reduction (%) in firmness was considered, by day 2, Broken mangoes treated with calcium carbide at the dose of B3 of fruit had the highest percentage decrease in firmness (21.43±0.29%), while Mummy mangoes treated with calcium carbide at the dose M2 of fruit had the least reduction in firmness. By days 4 and 6, Broken mangoes at dose of B2 of mango fruit had the highest reduction in firmness: 61.23±0.13% and 72.79±0.06, respectively. By day 6 however, Mummy mangoes treated with calcium carbide at dose M3 had the least reduction in firmness. Based on variety of mangoes, the overall reduction (%) in firmness was greater in Broken than Mummy mangoes.

Pulp pH: The pulp pH of Broken mangoes without treatment by day 0 (2.95±0.00) was significantly higher (p<0.001) than that of Mummy mangoes (3.11±0.00). The pulp pH of all treated groups of Broken mangoes was significantly higher (p<0.001) than Mummy mangoes (Fig. 2).

By day 2, there was reduction in pulp pH in B1, B2 and all groups of Mummy mangoes. The pH levels of Broken mangoes were still significantly (p<0.001) higher than in Mummy mangoes.

By day 4, the pH of all the mangoes had reduced compared with the value observed on day 0. For Broken mangoes, the untreated mangoes had a significantly (p<0.001) higher reduction in pH than B2 and B4. While for Mummy mangoes, the pH of the untreated mangoes was significantly lower than those treated with calcium carbide.

By day 6, the pH of the untreated Broken mangoes was significantly (p<0.001) lower than all Broken mangoes treated with calcium carbide and pH was significantly (p<0.001) lower in mangoes treated with lower concentrations of calcium carbide than those treated with higher doses of calcium carbide. Likewise, in Mummy mangoes, the untreated had significantly lower pH than the treated and pH was significantly (p<0.001) lower in mangoes treated with lower concentration of calcium carbide than in those treated with higher concentrations of the ripening agent.

The pulp pH of both varieties continued to decrease as they ripened. The untreated Mummy mangoes had the highest reduction in pH (116.63±0.13%) by day 6; the reduction was significantly higher than those treated with calcium carbide. The reduction in pH in untreated Broken mangoes (91.27±0.16%) was also significantly higher than the treated. The higher the dose of calcium carbide, the higher the pH was in both varieties of the mangoes.

Titratable acidity (TA): The TA was 2.66±0.00 in untreated Broken mangoes by day 0, while it was significantly higher (p<0.001) in untreated Mummy mangoes (2.91±0.00) on same day. Treatment with calcium carbide did not cause any significant difference in TA in Broken or Mummy mangoes on day 0 (Fig. 3).

By day 2, there was reduction in TA of the mangoes: In Broken mangoes, the reduction was significantly (p<0.001) more in mangoes treated with the highest dose of calcium carbide and the least reduction was in the untreated Broken mangoes. Similarly, in Mummy mangoes, the highest reduction was found in mangoes treated with the highest dose of calcium carbide and the least reduction was found in the untreated. By days 4 and 6, the results were varied. However, Broken mangoes treated with calcium carbide significantly reduced TA in a rather dose-dependent manner.

Total soluble solids (°Brix) content: Total soluble solids (TSS) content was 5.92±0.05 in untreated Broken mangoes on day 0 and was significantly higher than the value in untreated Mummy mangoes (5.66±0.05) on same day. The TSS increased in both varieties of mangoes by day 2. By day 4, TSS there was a further increase in TSS. The TSS in Broken was significantly higher at lower calcium carbide concentrations. On day 6 similar increase in the TSS of mangoes was observed. Based on the two mango varieties, there was increase in TSS from 0-6 days and the value of TSS was significantly higher in Broken mangoes (Fig. 4).

Vitamin C content: Results showed that vitamin C content of Mummy mangoes was significantly higher than that of Broken mangoes by day 0. The vitamin C content in both varieties of mangoes significantly reduced as they ripened. It was obvious by days 4 and 6 that calcium carbide significantly reduced the vitamin C content of treated mangoes and this occurred in a dose-dependent fashion, such that the reduction in vitamin C content was lower at a lower concentration of calcium carbide and higher at a higher concentration. Mummy had higher vitamin C content and the reduction (%) in vitamin C of calcium carbide-ripened mangoes was higher in Broken than in the Mummy variety (Fig. 5).

DISCUSSION

There were several changes in the physicochemical characteristics of the mango fruits ripened by calcium carbide such as weight, ripening time, firmness, pH, titratable acidity, total soluble solids and vitamin C.

Effect on weight of fruits: The mangoes showed weight loss, which was calcium carbide dose-dependent: mangoes treated with lower concentration of calcium carbide had significantly (p<0.001) lower weight loss, while those treated with higher doses of calcium carbide had higher weight loss in both varieties. The untreated mangoes had significantly lower weight loss than those treated with calcium carbide.

The differences in weight and fruit size reported in this study may be due to the mango varietal difference as these parameters depend on the type, environment and cultivation conditions. Some researchers have indicated that factors like respiration and transpiration are responsible for the physiological weight loss in mango during ripening[15]. The accelerated weight loss in this study for treated mango fruits may be due to the induced ripening by calcium carbide.

Ripening time of the fruits: Delay in ripening by calcium salts like calcium chloride treatments has been reported by several workers[16,17]. In the present study calcium carbide hastened the ripening of fruits by 3-4 days, compared to control. Some studies have reported ripening of untreated mango fruits within 9-12 days post-harvest at ambient temperature depending on variety and stage of fruit maturity at harvest[18]. The ripening agent may have prompted the enzymatic action in the fruits resulting in the quick ripening. This is in agreement with research work by Pandarinathan and Sivakumar[6], Nagaraj *et al.*[19]. Acetylene gas released from calcium carbide when it reacted with water accelerated the ripening.

Effect on firmness: Firmness is a crucial factor for consumer acceptance of fruits and it is also very important from a commercial viewpoint. This is because softening limits the post-harvest life of fruits by enhancing physical damage during handling and increasing the fruits' susceptibility to diseases[10]. Therefore, firmness is an indicator of maturity and also an important parameter for judging quality[11,20]. It is known that an inverse relationship between fruit size and flesh firmness exists. Smaller fruits are generally firmer than larger fruit and this might be due to having more cell wall material per unit volume[21]. In this study, Broken fruits which are smaller in size were firmer than the bigger Mummy fruits and this, as stated, might be due to having more cell wall material per unit volume. Pulp firmness decreased with increased ripening due probably to decrease in pectin content. This is in agreement with previous work[21]. The fact that treated mangoes had various degrees of fruit firmness as the level of calcium carbide increased may be an indication of interference of the toxic ripening agent with the cell wall degrading enzymes acting upon protein and carbohydrates.

Effect on pH: The present study indicates that pH of Broken was lower than that of Mummy. This might have been due to genetic dissimilarities between the two varieties. The treated mangoes also recorded lower pH, with mangoes on the highest dose of calcium carbide having the lowest pH. Similar results were obtained by other researchers[6]. This phenomenon might be possible to oxidation of acids during ripening. Natural fruit ripening involves multiplicity of biochemical pathways and the application of calcium carbide as a chemical ripening agent in this study may probably have interfered with these biochemical pathways which thus affected the pH of the mango fruits.

Effect on titratable acidity (TA): Result showed a decrease in TA as the mangoes ripened. However, based on the variety of mangoes, Broken mangoes had a significantly greater reduction in TA than Mummy mangoes. The changes in TA are significantly affected by the rate of metabolism especially respiration, which consumed organic acid and thus declined acidity. Malic acid is the main organic acid in mango and decrease in titratable acidity with ripeness might be due to their utilization as substrates for respiration[21]. The comparatively high values of TA in the calcium carbide-ripened mango fruits may be negatively linked with the flavour.

Effect on total soluble solids (TSS): The TSS is an important quality for many fresh fruits because solids include the soluble sugars – sucrose, glucose fructose and acid. Increase of TSS is due to the hydrolysis of starch to soluble sugars. During the ripening and softening process, starch is broken down in to the simple soluble sugars and soluble pectin which increases fruit softening[21]. Ripened fruits generally become sweeter and more acceptable. The increase in sweetness is mainly due to the conversion of starch to sugars. Sugars are primarily found in the cell vacuole and are usually a major component of soluble solids in the cell sap[22]. TSS of fruits is correlated to the texture and composition. The This may be due to the degradation of cell walls and hydrolysis of starch to sucrose during ripening[6].

In agreement with previous research, total soluble solids content and titratable acidity (TA) followed the expected trends during the ripening period. While the TSS content in the fruits increased, the TA decreased. There was a consistent increase in total soluble solids content during ripening. Calcium carbide-treated mangoes produced less soluble solids as compared to control. The change in TSS was slow with advancing ripening period due to the fact that there was less of substrate remaining. This was probably due to more rapid and partial breakdown of non-reducing sugars and other polysaccharides and their subsequent conversion to reducing sugars in the course of fruit ripening.

Effect on vitamin C content: Findings clearly indicate that vitamin C also known as ascorbic acid decreased during the ripening at ambient temperature. The reduction in vitamin C content of the fruits during ripening may be due to the susceptibility of ascorbic acid to oxidative destruction. The present findings strongly agree with the results reported by Prasanna *et al.*[18], Shivashankara *et al.*[23], Thomas and Oke[24], Padmini and Prabha[25], Mamiro *et al.*[26], Mannan *et al.*[27], Pandarinathan and Sivakumar[6]. The higher decrease in the treated groups compared to the untreated is most probably due to the accelerated action of calcium carbide during the ripening process.

CONCLUSION

Calcium carbide altered the natural physicochemical properties of the mango fruits. The results established the nutritional inadequacy of the treated Broken and Mummy mangoes as exhibited in higher weight loss, more acid content, in addition to less total soluble solids and lower vitamin C than the control. The study established that the ripening and changes in both varieties of mango were dose-dependent, with the highest calcium carbide level producing the most adverse effect.

SIGNIFICANCE STATEMENT

The study discovered that calcium carbide has the ability to decrease the nutritional quality of mango fruits regardless of the variety of mango treated with this ripening agent. Apart from the health hazards of consuming calcium carbide ripened mango fruits as has been reported in study, this study elucidated that treated fruits may not provide adequate nutritional benefits to communities that are experiencing malnutrition such as is common in rural villages of developing countries. The baseline data on the Broken and Mummy mango varieties provided by this study which had hitherto been lacking can add to the related existing literature for further research. It is desirable that simple mango fruits ripening technologies be developed and promoted in local communities so as to maintain the natural nutritional composition of fruits during ripening for the benefit of consumers.

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REFERENCES

1. Hayes, D.P., 2005. The protective role of fruits and vegetables against radiation induced cancer. Nutr. Rev., 63: 303-311.
2. Rossato, S.B., C. Haas, M.D.C.B. Raseira, J.C.F. Moreira and J.A.S. Zuanazzi, 2009. Antioxidant potential of peels and fleshes of peaches from different cultivars. J. Med. Food, 12: 1119-1126.
3. Ubwa, S.T., M.O. Ishu, J.O. Offem, R.L. Tyohemba and G.O. Igbum, 2014. Proximate composition and some physical attributes of three mango (*Mangifera indica* L.) fruit varieties. Int. J. Agron. Agric. Res., 4: 21-29.
4. Onyeani, C.A., S.O. Osunlaja, O.O. Owuru and O.S. Sosanya, 2012. Mango fruit anthracnose and the effects on mango yield and market values in Southwestern Nigeria. Asian J. Agric. Res., 6: 171-179.
5. Amarakoon, R., D.C.K. Illeperuma and K.H. Sarananda, 1999. Effect of calcium carbide treatment on ripening and quality of Velleicolomban and Willard mangoes. Trop. Agric. Res., 11: 54-60.
6. Pandarinathan, S. and S. Sivakumar, 2010. Studies on biochemical changes in mangoes due to artificial ripening. Int. J. Agric. Sci., 1: 347-355.
7. Dhembare, A.J., 2013. Bitter truth about fruit with reference to artificial ripener. Arch. Applied Sci. Res., 5: 45-54.
8. Islam, M., M.Z.H. Khan, M.A.R. Sarkar, N. Absar and S.K. Sarkar, 2013. Changes in acidity, TSS and sugar content at different storage periods of the postharvest mango (*Mangifera indica* L.) influenced by Bavistin DF. Int. J. Food Sci., Vol. 2013. 10.1155/2013/939385.
9. Lizada, C., 1993. Mango. In: Biochemistry of Fruit Ripening, Seymour, G.B., J.E. Taylor and G.A. Tucker (Eds.). Chapman and Hall, London, pp: 255-271.
10. Brady, C.J., 1987. Fruit ripening. Annu. Rev. Plant Physiol., 38: 155-178.
11. Ellong, E.N., S. Adenet and K. Rochefort, 2015. Physicochemical, nutritional, organoleptic characteristics and food applications of four mango (*Mangifera indica*) varieties. Food Nutr. Sci., 6: 242-253.
12. Rao, D.S., 2012. Method of fruits ripening. Indian Institute of Horticultural Research (ICAR), India.
13. AOAC., 1995. Official Methods of Analysis of the Association of Official Analytical Chemists. Association of Official Analytical Chemists, Washington, DC.
14. Mazumdar, B.B. and K. Majumder, 2003. Methods on Physicochemical Analysis of Fruits. Daya Publishing House, Darya Ganj, Delhi, ISBN: 9788170352884, Pages: 187.
15. Narayana, C.K., R.K. Pal and S.K. Roy, 1996. Effect of pre-storage treatments and temperature regimes on shelf-life and respiratory behaviour of ripe *Baneshan* mango. J. Food Sci. Technol., 33: 79-82.
16. Yuen, C.M.C., S.C. Tan, D. Jovce and P. Chettri, 1993. Effect of postharvest calcium and polymeric films on ripening and peel injury in Kensington Pride mango. Asean Food J., 8: 110-113.
17. Gafur, A., M.Z. Shafique, M.O.H. Helali, M. Ibrahim, M.M. Rahman and M.S. Alam, 1997. Studies on extension of postharvest storage life of mango (*Mangifera indica* L.). Bangladesh J. Scient. Ind. Res., 32: 148-152.
18. Prasanna, V., T.N. Prabha and R.N. Tharanathan, 2007. Fruit ripening phenomena-an overview. Crit. Rev. Food Sci. Nutr., 47: 1-19.
19. Nagaraj, P., K.V.R. Ramana and B.A. Prasad, 1984. Effect of calcium carbide on ripening and quality of Alphonso mangoes. J. Food Sci., 21: 278-282.
20. Hossain, M.A., M.M. Rana, Y. Kimura and H.A. Roslan, 2014. Changes in biochemical characteristics and activities of ripening associated enzymes in mango fruit during the storage at different temperatures. BioMed Res. Int. 10.1155/2014/232969.
21. Medilcott, A.P. and A.K. Thompson, 1985. Analysis of sugars and organic acids in ripening mango fruits (*Mangifera indica* L. var Keitt) by high performance liquid chromatography. J. Sci. Food Agric., 36: 561-566.
22. Rahman, M.M., N. Absar and M.A. Ahsan, 2011. Correlation of carbohydrate content with the changes in amylase, invertase and ?-Galactosidase activity of ripe mango pulp during storage under different temperatures. Bangladesh J. Scient. Ind. Res., 46: 443-446.

23. Shivashankara, K.S., S. Isobe, M.I. Al-Haq, M. Takenaka and T. Shiina, 2004. Fruit antioxidant activity, ascorbic acid, total phenol, quercetin and carotene of Irwin mango fruits stored at low temperature after high electric field pretreatment. J. Agric. Food Chem., 52: 1281-1286.
24. Thomas, P. and M.S. Oke, 1980. Vitamin C content and distribution in mangoes during ripening. Int. J. Food Sci. Technol., 15: 669-672.
25. Pudmini, S. and T.N. Prabha, 1997. Biochemical changes during acetylene-induced ripening in mango (var. Alphorns). Trop. Agric. (Trinidad), 74: 265-271.
26. Mamiro, P., L. Fweja, B. Chove, J. Kinabo, V. George and K. Mtebe, 2007. Physical and chemical characteristics of off vine ripened mango (*Mangifera indica* L.) fruit (Dodo). Afr. J. Biotechnol., 6: 2477-2483.
27. Mannan, M.A., S.A.K.U. Khan, M.R. Islam, M.S. Islam and A. Siddiqa, 2003. A study on the physico-chemical characteristics of some mango varieties in Khulna region. Pak. J. Biol. Sci., 6: 2034-2039.