ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 3
March 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2023; 23(3):22871-22892 https://doi.org/10.18697/ajfand.118.22485

EFFECT OF VARIED CALCIUM FORMULATIONS AND TIME OF APPLICATION ON POSTHARVEST QUALITY AND ORGANOLEPTIC ACCEPTABILITY OF MANGO FRUITS

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Volume 23 No. 3
March 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

Mango (Mangifera indica L.) is a highly perishable fruit with a short shelf life at ambient conditions, which may lead to post-harvest losses approximated to be 40-45%. This reduces returns to farmers significantly. The problem is compounded by the fact that most farmers do not have access to cold storage facilities. Nutrient management has been shown to affect postharvest characteristics of fruits. Calcium particularly plays a critical role in cell membrane integrity, tissue firmness and delays lipid catabolism. Previous studies have indicated a deficiency of calcium in some mango growing regions in Kenya. A field study was carried out to determine the effect of varied calcium formulations applied at various stages of growth on mango fruits post-harvest quality and organoleptic acceptability. The study was carried out in Embu County Eastern Kenya during seasons 2017/2018 and 2018 /2019 using "Van Dyke" cultivar, aged approximately 10 years. The experiment was set up in a randomized complete block design with a split-split plot arrangement, three trees per replication, replicated thrice. Three calcium formulations: calcium chloride, calcium nitrate and Easygro™ were applied at rates of 0%,1.0%, 1.5% and 2.0% at fruit set, 30 days after fruit set and 30 days to physiological maturity. The calcium sources formed the main plots, the timing of application formed the subplots while the rates of application formed the sub-sub plots. Total soluble solids (TSS) and percentage titratable acidity (TA) were assessed at harvest and after 12 days of storage under ambient conditions (25±2ºC, 70±5% relative humidity) using standard procedures. Selected fruits' sensory attributes were also evaluated after storage using a hedonic scale. Analysis of data was done using the 14th Edition of the Genstat software. The differences among the means of the treatments were compared using Fisher's Protected LSD test at 5% probability level. Fruits sprayed with calcium chloride, 2.0% at fruit set had higher TSS (6.8 º brix and 6.3º brix) (10.47 º brix and 9.10 º brix), TA (1.29% and 1.27%), (0.77% and 0.675%) than other treatments at maturity and after storage in both seasons, respectively. Calcium chloride at 2.0% level of application led to a superior peel color appearance contrary to calcium nitrate and Easygro™ also applied at 2.0%, which led to an inferior peel color appearance and an inferior taste of fruits. Therefore, calcium nitrate and easy gro should be sprayed at concentration of 1.5% for good taste and peel colour appearance.

Key words: Mango, total soluble sugars, total titratable acidity, organoleptic, shelf-life ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 3 March 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

INTRODUCTION

Mango is an important fruit crop though faced with short shelf life challenges in ambient conditions, which may lead to high post harvest losses. Various physiological processes occur in the mango fruit during ripening that lead to disintegration and softening of the fruit cell wall and eventual senescence. Calcium is a primary component of the pectin that strengthens the cell wall, hence plays a key role in fruit firmness [1, 2] and influences other physiological processes [3].

Calcium compounds have been shown to enhance post harvest shelf life of mango [4, 5, 6] peach [7], guava [8], and avocado [9] fruits. However, excessive application of calcium may lead to inferior eating quality [10]. Calcium in the form of calcium chloride has been reported to delay fruit ripening rate thus increasing the shelf life of guava [11], apple [12], mango [2] and pear [13]. Calcium nitrate on the other hand has been reported to be more effective than calcium chloride in quality preservation of mango fruits [14]. The effectiveness of any calcium formulation depends on the time, frequency and concentration of applications [2, 4, 5]. Therefore, the purpose of this study was to compare the effectiveness of varied formulations of calcium applied at different times and rates in delaying the ripening rate of mango fruits while maintaining fruit quality.

MATERIALS AND METHODS

The experiment was set up in Embu County, Kenya, with an elevation of 1174m ASL and coordinates of 0° 32́ S 37° 41E in seasons 2017/2018 and 2018/2019. “Van Dyke” mango cultivar trees aged approximately 10 years were used. Calcium chloride, calcium nitrate and easy gro were applied at 0%, 1.0%, 1.5% and 2.0 % at three varied stages of fruit development (fruit set, 30 days after fruit set and 30 days to physiological maturity). Randomized complete block design was used with a split-split plot arrangement, three trees per replication, replicated three times. The calcium sources formed the main plots, the timing of application formed the subplots while the rates of application formed the sub-sub plots. Easygro is a foliar based fertilizer with a composition of: 14% nitrogen, 2.5% magnesium, 2% potassium, and 13% calcium. Fruits were harvested at physiological maturity and transported to the post harvest laboratory at Jomo Kenyatta University of Agriculture and Technology in plastic crates which were lined with dampened newspapers to prevent injury and minimize heat load during transit.

https://doi.org/10.18697/ajfand.118.22485

Data collection and analysis

The fruits' total soluble solids (TSS) and titratable acidity (TTA) were assessed at harvest and after 12 days of storage under ambient conditions (25±2ºC, 70±5%, relative humidity). Selected fruit sensory attributes were also determined after 12 days of storage at ambient conditions. Analysis of data was done using the 14th Edition of the Genstat software [15]. The differences among the means of the treatments were compared using Fisher's Protected LSD test at 5% probability level.

Total soluble solids and titratable acidity determination

Three fruits, from each treatment, were selected and a fruit juice obtained from each batch. Three ml of the extracted juice was placed on a hand refractometer (Model 500, Atago, Tokyo, Japan). Total soluble solids level was recorded in ˚Brix. Five ml of the extracted juice was diluted with 25 ml of distilled water. Ten ml of the diluted solution was then titrated with 0.1 N NaOH using phenolphthalein indicator [16]. The TTA was then expressed as a percentage of citric acid using the equation below:

$$\text{Citric acid equivalent (\%)} = \left(\text{Sample reading (ml)} \times \frac{\text{Dilution factor}}{\text{Sample weight}} \times 0.0064(\text{citric acid factor})\right)100$$

Organoleptic attributes determination

Fifteen fruits were taken from each replication and sliced into approximately equal sized slices, which were then anonymously coded and placed on a white paper. A panel of 15 untrained, college researchers was guided on how to score selected sensory attributes (peel color, pulp taste and general acceptability) using a 7-point hedonic scale [17]: 1-Dislike extremely, 2-Dislike very much, 3-Dislike moderately, 4-Neither like nor dislike, 5-Like moderately, 6-like very much and 7-like extremely. The general acceptability of the fruits was determined by adding the scores of the evaluated attributes. The average of each of the panelists was then analysed and presented in graphs.

RESULTS AND DISCUSSION

Main and interactive effects of source, time and rate of calcium application on fruit TSS at harvest and after storage in ambient conditions

Source, rate and time of calcium application significantly (p≤0.05) affected the fruit TSS at harvest and after 12 days of storage under ambient conditions in both seasons (Table 1). Interactions between source and time of calcium application

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ISSN 1684 5374

significantly (P≤0.05) affected the fruit TSS at harvest and after 12 days of storage at ambient conditions in both seasons (Table 2).

Application of calcium significantly (P≤0.05) reduced the accumulation of soluble solids at harvest and after storage in both seasons. The low TSS among fruits sprayed with calcium implies that they could be stored longer than those with higher TSS because they had not ripened fully hence have an enhanced shelf life. The lower levels of TSS at the end of the storage period in calcium sprayed fruits could be because of the role of calcium in delaying metabolic activities of fruits [6,18]. There was an increase in fruit TSS as the storage period advanced irrespective of the treatment. The increase in TSS with storage is because of the conversion of carbohydrates to sugars through enzymatic activities [2, 19]. Fruits sprayed at fruit set had significantly lower TSS than those sprayed after 30 days, which were in turn significantly lower than those sprayed 30 days to physiological maturity at harvest and after storage in both seasons. This indicates that calcium is more effective when applied in the early periods of fruit development [2].

The interaction between rate and time of calcium application had significant (P≤0.05) effects on the fruit TSS at harvest and after 12 days of storage in both seasons (Table 3). Fruits sprayed with 2.0% calcium had significantly lower TSS than those sprayed with 1.5%, which in turn had significantly lower values than those sprayed with 1.0% at harvest and after storage during both seasons and in most cases irrespective of the time of application.

The interactions between source, rate and time of calcium application significantly (P≤0.05) affected the TSS of the fruits at harvest in both seasons (Table 4).

Main and interactive effects of source, time and rate of calcium application on fruit TTA at harvest and after storage in ambient conditions

Source, rate and time of calcium application had significant (P≤0.05) effects on fruit TTA at harvest and after 12 days of storage in both seasons (Table 5). Interactions between source and time (Table 6) and between rate and time (Table 7) of calcium application significantly (P≤0.05) affected the fruit TTA at harvest and after storage in both seasons. Fruits sprayed with calcium chloride at fruit set and 30 days later had significantly higher TTA than those sprayed with calcium nitrate, which were in turn not significantly different from those sprayed with easy gro. Most of the fruits sprayed at 30 days to maturity did not have significantly different TTA from each other and were not significantly different from unsprayed ones. Calcium treated fruits had significantly higher TTA content than untreated fruits due to delayed fruit ripening associated with calcium [20, 21]. The high acidity in calcium treated fruits has been previously reported [6, 22]. Fruits sprayed with calcium chloride had significantly higher TTA than those sprayed with easy gro at harvest and after storage in both seasons. Fruits sprayed at fruit set outperformed those sprayed 30 days after fruit set, which in turn outperformed those sprayed 30 days to physiological maturity at harvest and after storage regardless of the source of calcium. This is because calcium is more available at the early stages of fruit development as alluded in other studies [2,9]. Fruits sprayed at 2.0% had significantly higher TTA than those sprayed with calcium at 1.0% at harvest and after storage in both seasons.

Interactions between source, rate and time of calcium application significantly ($P \leq 0.05$) affected the fruit TTA at harvest in both seasons (Table 8) and in season 1 only after strorage.

There was a general decrease in fruit acidity after storage. During storage under ambient conditions, fruits start to ripen as they approach climacteric period, which triggers an increase in malic enzyme and pyruvate decarboxylation reaction [23] hence a decrease in acidity with storage. Ripening leads to the accumulation of TSS that is a result of breakdown of starch to sugars. The ripening process was probably slower in calcium-treated fruits than control, thus a high acidity comparatively even after storage. Similar results showing decline in TTA after storage has been reported [2,15, 24].

Effect of source, rate and time of calcium application on sensory quality of fruits after storage in ambient conditions

All the calcium sources invariably affected fruit peel color in both seasons (Fig 1). Application of calcium chloride led to higher peel color scores than untreated fruits. Peel color was ranked with superior scores as the rate of calcium chloride increased. Calcium nitrate on the other hand led to high scores as evaluated by the panelists for concentration 1.0% and 1.5%. However, as the concentration of calcium increased from 1.5% to 2.0%, peel color was given inferior scores irrespective of the time of application. Similarly, application of easygro at higher rates (1.5% and 2.0%) registered lower scores than the control in both seasons. The enhanced peel color appearance due to calcium chloride application has been reported previously [4]. The same authors reported a deteriorated skin colour due to application of calcium ammonium nitrate. The deterioration in color could be due to nitrogen in easy gro and calcium nitrate that affected color formation. Fruit color decreases as nitrogen content increases [25,26] because nitrogen inhibits anthocyanin synthesis and accumulation [27].

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ISSN 1684 5374

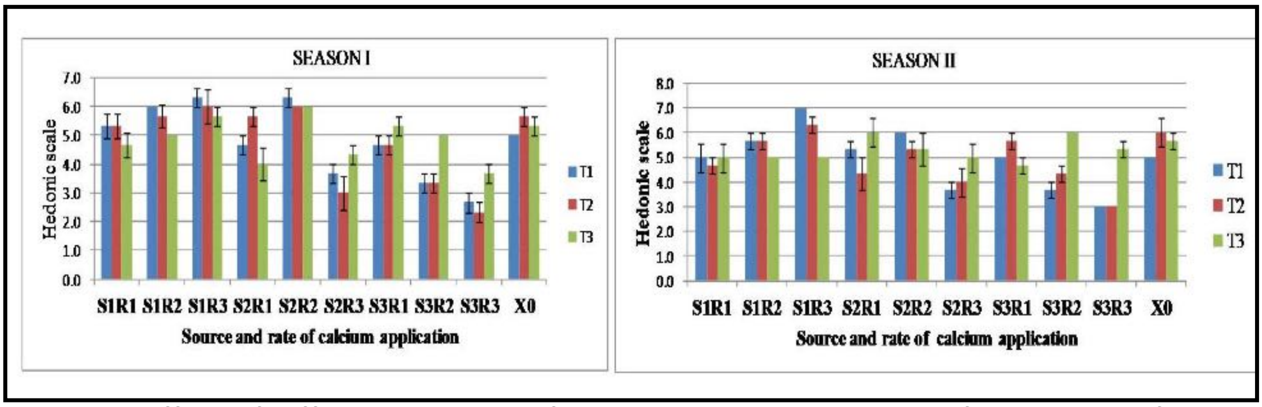

Figure 1: Effect of different sources of calcium on the peel color of ripe mango fruits

Bars represent standard errors of the means at $p \leq 0.05$

S_I-Calcium chloride, S_2-Calcium nitrate, S_3-Easygro, X_O-Control, R_1-1.0%, R_2-1.5%, R_3-2.0%, T_1-Fruit set, T_2-30 days after fruit set, T_3-30 days to physiological maturity

All the calcium sources affected the taste of fruits negatively in both seasons (Fig. 2). As the rate of calcium concentration increased the taste of the fruits deteriorated regardless of the source and time of application. Application of calcium at 30 days to maturity had superior taste scores than application at fruit set and 30 days later. This could be because earlier application led to more availability of calcium than later application [2, 9]. Calcium application led to deteriorated mango taste probably due to reduced accumulation of soluble solids with the application of calcium as previously reported [1, 14, 20], which led to a poor taste comparatively. This has also been reported in peach [28], apricot [29] and jujube [30]. Additionally, calcium may have imparted bitterness and saltiness, which results from residual calcium on the fruit mesocarp hence the unfavorable taste scores [31, 32, 33].

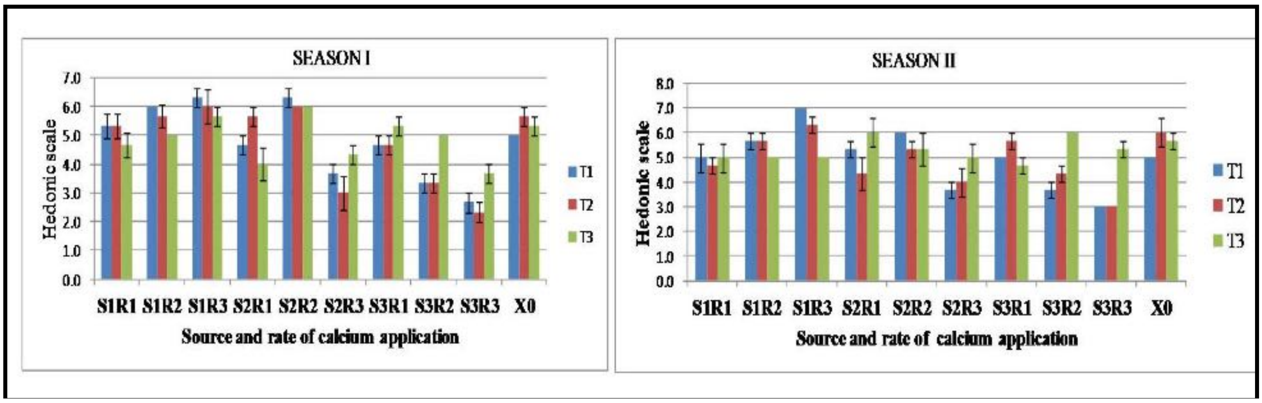

Figure 2: Effect of different sources of calcium on the taste of ripe mango fruits

Bars represent standard errors of the means at $p \leq 0.05$

S_I-Calcium chloride, S_2-Calcium nitrate, S_3-Easygro, X_O-Control, R_1-1.0%, R_2-1.5%, R_3-2.0%, T_1-Fruit set, T_2-30 days after fruit set, T_3-30 days to physiological maturity

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The general acceptability of the fruits was significantly ($p \leq 0.05$) affected by the source, rate and timing of application in both seasons (Fig.3). Fruits sprayed with calcium nitrate (1.5%) at 30 days to fruit maturity had significantly the highest scores. Application of calcium nitrate (2.0%) had the lowest acceptability rating irrespective of the timing of application in both seasons.

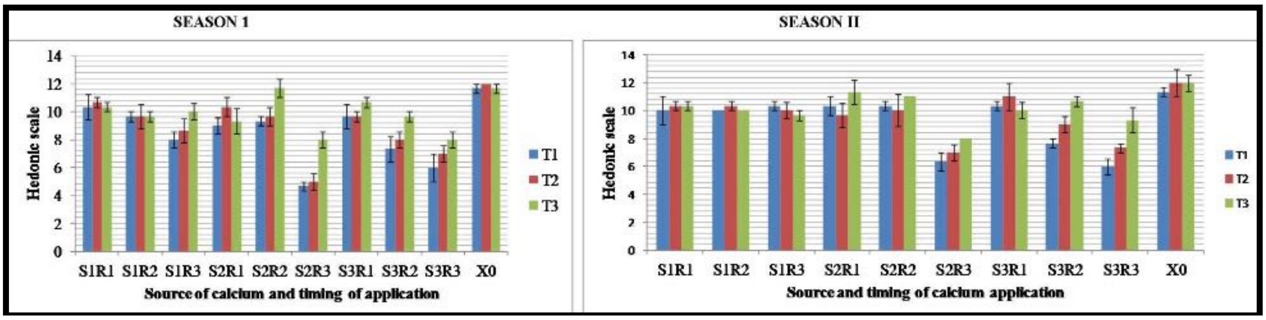

Figure 3: Effect of different sources of calcium on the general acceptability of ripe mango fruits

Bars represent standard errors of the means at $p \leq 0.05$

S_I-Calcium chloride, S_2-Calcium nitrate, S_3-Easygro, X_O-Control, R_1-1.0%, R_2-1.5%, R_3-2.0%, T_1-Fruit set, T_2-30 days after fruit set, T_3-30 days to physiological maturity

CONCLUSION

Calcium chloride (2.0%), applied at fruit set was more effective in maintenance of post harvest quality than other treatments. The taste of fruits was, however, negatively affected when calcium concentration increased to 2.0%, irrespective of the calcium source. Therefore, availability of calcium to the fruit should be optimised by either lowering the concentration to below 2% or spraying at 30 days after fruit set to achieve optimum levels. Similarly, calcium nitrate and easygro led to inferior peel colour when sprayed at 2.0%. Therefore, calcium nitrate and easy gro should only be sprayed at concentration of below 1.5% to achieve good peel colour.

ACKNOWLEDGEMENTS

This Research was supported by the Rockefeller Foundation (Yield Wise Initiative), Grant Number 2016 YWS 328.

Conflict of interest

Authors have declared that no competing interests exist.

https://doi.org/10.18697/ajfand.118.22485

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ISSN 1684 5374

Table 1: Main effects of source, time and rate of calcium application on fruit total soluble solids (°Brix) at harvest and after storage in ambient conditions

	Season 1		Season 2	
	At harvest	After storage	At harvest	After storage
Source				
Easy gro	11.73^{b}	15.43^{b}	10.43^{b}	14.37^{b}
Calcium nitrate	11.32^{bc}	15.10^{b}	10.26^{b}	14.16^{b}
Calcium chloride	10.19^{c}	14.50^{b}	9.81^{b}	13.27^{b}
Control	16.44^{a}	18.28^{a}	16.19^{a}	18.21^{a}
p-value	<.001	<.001	<.001	<.001
Lsd $_{(P\leq0.05)}$	1.13	2.08	1.91	2.12
Cv%	18	14.5	18.9	15.7
Time				
T_1	9.20^{c}	12.67^{c}	9.10^{c}	11.78^{c}
T_2	12.24^{b}	16.12^{b}	10.52^{b}	15.09^{b}
T_3	13.41^{a}	17.22^{a}	12.69^{a}	16.21^{a}
p-value	<.001	<.001	<.001	<.001
Lsd$_{(P\leq0.05)}$	1.04	0.73	1.18	0.93
Cv%	17.50	9.30	21.40	12.60
Rate				
1.0%	11.82^{b}	15.59^{b}	11.6^{b}	14.84^{b}

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1.5%	11.16[bc]	15.07[bc]	10.05[c]	13.87[bc]
2.0%	10.26[c]	14.37[c]	8.86[d]	13.09[c]
0%	16.44[a]	18.28[a]	16.19[a]	18.21[a]
p-value	<.001	<.001	<.001	<.001
Lsd(P≤0.05)	1.13	1.19	0.94	1.68
Cv%	18.00	14.30	16.10	15.3

T_1=Fruit set; T_2=30 days after fruit set; T_3=30 days to physiological maturity; LSD=Least significant difference; CV=Coefficient of variation. Treatments with different letters in the same column are significantly different according to LSD at p ≤0.05

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Table 2: Interactive effects of source and time of calcium application on fruit total soluble solids (°Brix) at harvest and after storage in ambient conditions

	Season 1		Season 2	
	At harvest	After storage	At harvest	After storage
Ctrl T_1	16.67[a]	18.20[a]	16.17[a]	18.30[a]
Ctrl T_3	16.50[a]	18.17[a]	16.13[a]	18.03[a]
Ctrl T_2	16.17[a]	18.22[a]	16.27[a]	18.30[a]
S_3 T_3	13.96[b]	17.58[ab]	12.89[b]	16.13[bc]
S_2 T_3	13.19[c]	17.01[bc]	12.31[b]	16.36[b]
S_3 T_2	12.30[d]	16.06[d]	9.87[cd]	15.37[cd]
S_2 T_2	12.17[d]	16.02[d]	9.79[cd]	14.91[d]
S_1 T_3	12.06[d]	16.77[c]	11.72[b]	15.53[bcd]
S_1 T_2	10.96[e]	15.50[d]	9.99[c]	13.92[e]
S_3 T_1	8.94[f]	12.66[e]	8.54[e]	11.60[fg]
S_2 T_1	8.61[f]	12.28[e]	8.68[de]	11.21[fg]
S_1 T_1	7.57[g]	11.23[f]	7.72[e]	10.34[g]
p-value	<.001	<.001	<.001	<.001
Lsd $_{(P\leq0.05)}$S*T	0.74	0.64	1.20	0.90
Cv%	6.80	4.40	11.80	6.70

S_l=Calcium chloride; S_2=Calcium nitrate; S_3=Easygro; R_1=1.0%; R_2=1.5%; R_3=2.0%; Ctrl=Control; T_1=Fruit set; T_2=30 days after fruit set; T3=30 days to physiological maturity; S=Source; T=Time; R=Rate; LSD=Least significant difference; CV=Coefficient of variation. Treatments with different letters in the same column are significantly different according to LSD at p ≤0.05

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Table 3: Interactive effects of rate and time of calcium application on fruit total soluble solids (°Brix) at harvest and after storage in ambient conditions

	Season 1		Season 2	
	At harvest	**After storage**	**At harvest**	**After storage**
Ctrl T_I	16.67[a]	18.20[a]	16.17[a]	18.30[a]
CtrlT_3	16.50[a]	18.17[a]	16.13[a]	18.03[a]
Ctrl T_2	16.17a	18.47[a]	16.27[a]	18.30[a]
R_1 T_3	13.90[b]	17.57[bc]	13.62[b]	16.98[b]
R_2 T_3	13.08[c]	17.09[cd]	12.36[c]	15.87[c]
R_1 T_2	12.32[d]	16.30[ef]	11.31[d]	15.52[c]
R_3 T_3	12.22[d]	16.70[de]	10.94[d]	15.18[cd]
R_2 T_2	11.88[de]	15.83[fg]	9.73[e]	14.67[de]
R_3 T_2	11.22[e]	15.44[g]	8.60[f]	14.01[e]
R_1 T_1	9.24[f]	12.90[h]	9.86[e]	12.02[f]
R_2 T_1	8.53[f]	12.29[i]	8.07[f]	11.07[g]
R_3 T_1	7.34[g]	10.98[j]	7.02[g]	10.07[h]
P-value	<.001	<.001	<.001	<.001
Lsd $_{(P\leq0.05)}$ R*T	0.75	0.54	0.61	0.75
Cv%	6.8	3.8	6.0	5.5

R_1=1.0%; R_2=1.5%; R_3=2.0%; Ctrl=Control; T_1=Fruit set; T_2=30 days after fruit set; T_3=30 days to physiological maturity; T=Time; R=Rate; LSD=Least significant difference; CV=Coefficient of variation. Treatments with different letters in the same column are significantly different according to LSD at p ≤0.05

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Table 4: Interactive effects of source, rate and time of calcium application on fruit total soluble solids (°Brix) at harvest

		Season 1			Season 2		
Source	**Rate**	**T_1**	**T_2**	**T_3**	**T_1**	**T_2**	**T_3**
Calcium chloride	1.0%	8.30^{pq}	11.53^{ij}	13.40^{cd}	9.17^{jkl}	11.43^{efg}	12.93^{cd}
	1.5%	7.60^{r}	11.00^{jk}	12.10^{ghi}	7.67^{no}	9.83^{ij}	11.77^{ef}
	2.0%	6.80^{s}	10.33^{lm}	10.67^{kl}	6.33^{p}	8.70^{klm}	10.47^{hi}
Calcium nitrate	1.0%	9.47^{no}	12.60^{efg}	13.80^{c}	10.80^{gh}	11.03^{fgh}	13.47^{c}
	1.5%	8.67^{p}	12.20^{gh}	13.17^{de}	8.17^{mn}	9.87^{ij}	12.30^{de}
	2.0%	7.70^{qr}	11.70^{hi}	12.60^{efg}	7.07^{op}	8.47^{lmn}	11.17^{fgh}
Easy gro	1.0%	9.97^{mn}	12.83^{def}	14.50^{b}	9.60^{ij}	11.47^{efg}	14.47^{b}
	1.5%	9.33o	12.43fg	13.97^{bc}	8.37^{lmn}	9.50^{jk}	13.00^{cd}
	2.0%	7.53r	11.63hi	13.40^{cd}	7.67^{no}	8.63^{klm}	11.20^{fgh}
Control	0%	16.67^{a}	16.17^{a}	16.50^{a}	16.17^{a}	16.27^{a}	16.13^{a}
P-value		0.008				0.038	
Lsd ($P \leq 0.05$)	SxTxR	0.63				0.87	
Cv (%)		3.30				4.90	

T1=Fruit set; T2=30 days after fruit set; T3=30 days to physiological maturity; S=Source; T=Time; R=Rate; LSD=Least significant difference; CV=Coefficient of variation. Treatments with different letters are significantly different according to LSD at $p \leq 0.05$

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Table 5: Main effects of source, time and rate of calcium application on fruit total titratable acidity (%) at harvest and after storage in ambient conditions

	Season 1		Season 2	
	At harvest	After storage	At harvest	After storage
Source				
Easy gro	0.41[b]	0.23[b]	0.49[b]	0.26[b]
Calcium nitrate	0.42[b]	0.26[ab]	0.54[ab]	0.30[ab]
Calcium chloride	0.59[a]	0.33[a]	0.67[a]	0.35[a]
Control	0.13[c]	0.05[c]	0.18[c]	0.15[c]
p-value	<.001	<.001	<.001	<.001
$Lsd_{(P\leq0.05)}$	0.14	0.09	0.13	0.07
Cv %	39.1	26.5	34.5	23.5
Time				
T_1	0.72[a]	0.41[a]	0.74[a]	0.41[a]
T_2	0.37[b]	0.24[b]	0.55[b]	0.27[b]
T_3	0.24[c]	0.10[c]	0.28[c]	0.19[c]
p-value	<.001	<.001	<.001	<.001
$Lsd_{(P\leq0.05)}$	0.10	0.07	0.10	0.05
Cv %	40	34.8	26.5	26.4

https://doi.org/10.18697/ajfand.118.22485

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 3
March 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Rate				
1.0%	0.35[b]	0.19[b]	0.45[b]	0.23[bc]
1.5%	0.46[b]	0.25[b]	0.56[ab]	0.29[b]
2.0%	0.62[a]	0.38[a]	0.68[a]	0.40[a]
0%	0.13[c]	0.05[c]	0.18[c]	0.15[c]
p-value	<.001	<.001	<.001	<.001
Lsd$_{(P\leq0.05)}$	0.14	0.09	0.13	0.06
Cv%	37.5	63.7	43.8	39.1

T1=Fruit set; T2=30 days after fruit set; T3=30 days to physiological maturity; LSD=Leastsignificant difference; CV=Coefficient of variation. Treatments with different letters in the same column are significantly different according to LSD at p ≤0.05

Table 6: Interactive effect of source and time of calcium application on fruit total titratable acidity (%) at harvest and after storage in ambient conditions

	Season 1		Season 2	
Treatment	At Harvest	After storage	At harvest	After storage
$S_1 T_1$	0.93[a]	0.50[a]	0.99[a]	0.52
S_2T_1	0.74[bc]	0.48[abc]	0.73[bc]	0.40
S_3T_1	0.69[bc]	0.39[abc]	0.69[bcd]	0.38
S_1T_2	0.57[c]	0.36[bc]	0.64[bcd]	0.30
$S_3 T_2$	0.32[d]	0.20[d]	0.55[d]	0.27
$S_2 T_2$	0.29[de]	0.22[d]	0.60[cd]	0.29
S_1T_3	0.29[de]	0.13[de]	0.36[e]	0.23
$S_3 T_3$	0.23[de]	0.09[e]	0.24[f]	0.15
$S_2 T_3$	0.23[de]	0.10[e]	0.29[ef]	0.21
S_4T_l	0.14[de]	0.04[e]	0.20[f]	0.18
$S_4 T_2$	0.14[de]	0.08[e]	0.19[f]	0.16
$S_4 T_3$	0.11[e]	0.02[e]	0.14[f]	0.09
P-value	<.001	<.001	<.001	0.09
$LSD_{(P\leq0.05)}$ S*T	0.18	0.14	0.16	ns
CV%	31.20	41.40	22.30	21.20

S_l=Calcium chloride; S_2=Calcium nitrate; S_3=Easygro; $T_{1=}$Fruit set; T_2=30 days after fruit set; T_3=30 days to physiological maturity; S=Source; T=Time; LSD=Least significant difference; CV= Coefficient of variation. Treatments with different letters in the same column are significantly different according to LSD at p ≤0.05

ajfand SCHOLARLY, PEER REVIEWED
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Volume 23 No. 3
March 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 7: Interactive effects of rate and time of calcium application on fruit total titratable acidity (%) at harvest and after 12 days of storage in ambient conditions

		Season 1		Season 2	
	Treatment	At harvest	After storage	At harvest	After storage
	R_3 T_1	0.99[a]	0.65[a]	0.96[a]	0.53[a]
	R_2 T_1	0.76[b]	0.41[b]	0.78[bc]	0.41[b]
	R_1 T_1	0.61[c]	0.31[c]	0.67[cd]	0.35[c]
	R_3 T_2	0.53[c]	0.34[c]	0.71[bcd]	0.42[b]
	R_2 T_2	0.36[de]	0.24[d]	0.59[de]	0.25[d]
	R_3 T_3	0.33[de]	0.17[e]	0.36[f]	0.24[de]
	R_1 T_2	0.28[de]	0.20[de]	0.48[e]	0.18[f]
	R_2 T_3	0.25[ef]	0.09[f]	0.31[fg]	0.19[ef]
	R_1 T_3	0.17[fg]	0.06[g]	0.22[gh]	0.16[f]
	Ctrl T_1	0.14[fg]	0.04[g]	0.20[gh]	0.18[f]
	Ctrl T_2	0.14[fg]	0.08[g]	0.19[gh]	0.16[f]
	CtrlT_3	0.11[g]	0.02[g]	0.14[h]	0.09[g]
P-value		<.001	<.001	<.001	<.001
Lsd $(P\leq 0.05)$	R*T	0.11	0.06	0.15	0.05
Cv%		27	27.1	20.7	19.3

S_l=Calcium chloride; S_2=Calcium nitrate; S_3=Easygro; T_{1}=Fruit set; T_2=30 days after fruit set; T_3=30 days to physiological maturity; S=Source; T=Time; LSD=Least significant difference; CV= Coefficient of variation; Ctrl=Control. Treatments with different letters in the same column are significantly different according to LSD at $p \leq 0.05$

ajfand SCHOLARLY, PEER REVIEWED
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Table 8: Interactive effects source, rate and time of calcium application on fruit total titrable acidity (%) at harvest

		Season 1			Season 2		
Source	Rate	T_1	T_2	T_3	T_1	T_2	T_3
Calcium chloride	1.0%	0.66^{cd}	0.46^{f}	0.21^{jklm}	0.80^{cd}	0.52^{jk}	0.24^{p}
	1.5%	0.83^{b}	0.55^{e}	0.30^{ghi}	0.91^{b}	0.64^{ghi}	0.37^{mn}
	2.0%	1.29^{a}	0.69^{c}	0.35^{g}	1.27^{a}	0.76^{cdef}	0.48^{kl}
Calcium nitrate	1.0%	0.59^{de}	0.20^{jklm}	0.15^{klmn}	0.64^{ghi}	0.50^{kl}	0.19^{pq}
	1.5%	0.78^{b}	0.30^{ghi}	0.23^{ijk}	0.71^{efg}	0.60^{hij}	0.33^{no}
	2.0%	0.85^{b}	0.37^{g}	0.32^{gh}	0.83^{bc}	0.70^{fg}	0.36^{mn}
Easy gro	1.0%	0.57^{e}	0.18^{jklmn}	0.15^{klmn}	0.56^{ijk}	0.42^{lm}	0.22^{pq}
	1.5%	0.67^{cd}	0.24^{hij}	0.22^{jkl}	0.72^{defg}	0.55^{jk}	0.24^{p}
	2.0%	0.82^{b}	0.54^{ef}	0.33^{g}	0.79^{cde}	0.67^{gh}	0.26o^{p}
Control	0%	0.14^{mn}	0.14^{mn}	0.11^{n}	0.20^{pq}	0.19^{pq}	0.14^{q}
p-value		<.001				<.001	
Lsd $_{(P\leq0.05)}$	SxTxR	0.08				0.09	
Cv (%)		11				10	

T_1=Fruit set; T_2=30 days after fruit set; T_3=30 days to physiological maturity; S=Source; T=Time; R=Rate; LSD=Least significant difference; CV=Coefficient of variation. Treatments with different letters are significantly different according to LSD at p ≤0.05

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