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EXOGENOUS APPLICATION OF $CACL_2$ ON PHYSICAL TRAITS OF INFECTED AND NON-INFECTED WHITE PULPED DRAGON FRUIT

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ABSTRACT

The study reported the effects of different concentrations of $CaCl_2$ (0, 1.0, 2.0, 3.0 and 4.0 g/L) applied as spray and soaked treatments on the physical traits for anthracnose-infected and non-infected dragon fruits. The findings unveiled that the spray treatment surpassed the soak treatments in enhancing the physical traits of both anthracnose-infected and non-infected dragon fruits, while also improving their storage longevity. Moreover, the application of a $CaCl_2$ concentration of 4% using both treatment methods significantly enhanced the physical parameters of the fruit. However, the spray treatment exhibited superior outcomes when compared to the soak treatments, resulting in an extended storage life for the fruit. Consequently, this study underscores the vital role of calcium application in prolonging the shelf life of fruit and emphasizes the potential for enhancing fruit quality.

Key words : Dragon fruit, Shelf life, Post-harvest, Anthracnose, $CaCl_2$.

Introduction

Postharvest loss is a significant concern in the agricultural industry, leading to a decrease in both the quantity and quality of food produce from the time of harvest to consumption (Guru and Mishra, 2017) serious concern with these fruit crops is that they are quickly perishable and can respire and transpire even after harvest, resulting in excessive ripeningassociated softening during post-harvest storage (Hegazy *et al*, 2016 and Shipman *et al*, 2021).

Dragon fruit, a non-climacteric fruit with low physiological activity is subject to serious physiological and parasitic disorders after harvest and during long-term storage (Ciccarese, 2013). The major constraints in dragon fruit during storage is short shelf life it is due to several factors such as high respiration, weight loss, loss of bract greenness, postharvest diseases and increased ripening process which causes shriveling of fruit after the few days of harvesting (Ali *et al*, 2013). In tropical regions, the main factor which reduces the shelf life of fruit is high temperature, Dragon fruit pericarp contains active stomata especially in the bracts of the fruit leading to rapid shrivelling and thus early and rapid deterioration of fruit quality (Mizrahi, 2014 and Nguyen *et al*, 2021).

Dragon fruits have natural skins that serve as a protective layer against water loss, pathogenic infections and other harmful effects (Thakur and Kumar, 2017). However, during postharvest handling processes, this protective waxy coating can be vulnerable to damage leading to physiological changes in the fruit. These changes include weight loss, firmness, color changes and visual appearance (Garcia and Barrett, 2002). However, these changes also can significantly be influenced by environmental conditions, handling practices and the presence of disease-causing pathogens which could be reinforced by applying calcium to the fruit surface. As Calcium is known for its ability to reduce or delay parasitic and physiological disorders in fruits and vegetables, has shown promising results in controlling storage rots when applied as organic and inorganic salts (Biggs, 1999; Conway *et al*, 1999; Punja and Grogan, 1982). Hence, the taking into consideration all the above-mentioned facts, the present study was carried out to determine the effect of sprayed and soaked treatments of $CaCl_2$ on physical parameters and disease incidence in white pulped dragon fruit besides, improving the shelf life of the produce.

Materials and Methods

Study site

The study was conducted at the ICAR-National Institute of Abiotic Stress Management (NIASM), situated in Baramati, Maharashtra, India located at 18° 09' 30.62"N latitude and 74° 30' 03.08"E longitude, with an altitude of 570 meters above mean sea level. Baramati experiences an average annual precipitation of 659 mm, which is distributed over the months of June to September. The region exhibits an average temperature ranging from minimum of 13.0°C to maximum of 33.7°C.

Experimental detail

The experiment was laid out with a three-factor randomized block design consisting of five different treatments of calcium chloride ($CaCl_2$) *viz*., 1.0, 2.0, 3.0 and 4.0 g/L applied as sprayed and soaked treatments on anthracnose-infected and non-infecteddragon fruits. During the study different physical parameters such as fruit weight, length, diameter, decay loss, firmness, cutting force, disease spread etc. were determined to evaluate the fruit's performance towards different concentrations of $CaCl_2$.

Physiological Loss in Weight (PLW %) was determined with help of initial and final weight obtained at the end of the storage life and was expressed in percentage. The values for PLW were quantified using the formula giver below:

$$\text{Physiological loss in weight (\%)} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}}$$

Further, the pulp to the peel ratio in the fruit was calculated using the formula:

$$\text{Pulp: peel ratio} = \frac{\text{Total weight of pulp}}{\text{Total weight of peel}}$$

However, decay loss percentage was determined using the percentage of fruits rotted at the end of the storage life and was expressed in percentage. Further, the values for decay loss percentage were quantified using the formula giver below

$$\text{Decay loss (\%)} = \frac{\text{Number of rotted fruits}}{\text{Total number of fruits}} \times 100$$

Fruit firmness (Kg/cm^2)

Fruit firmness was assessed using a texture analyzer (Stable Micro System, England) having a probe diameter of P 25-25 mm dia – cylinder (Aluminium) with a test speed of 1 mm s^{-1} and test distance of 15 cm. The data was analyzed using the Texture Expert Exceed TM software and the results were expressed in kg/cm^2 (Arumuganathan *et al.*, 2010).

Fruit cutting force (kg/cm^2)

Fruit cutting force was determined with help of a fruit texture analyser (Stable Micro System, England), having HDP/BSJ blade set with knife, with the test speed of 1 mm per sec and a total test distance of 15 cm. The force was applied with a cutter to rupture the fruit peel (Fidelibus *et al*, 2002) and the data obtained was expressed as kg/cm^2.

Disease spread and number of acervuli per fruit

Disease incidence in dragon fruit was meticulously assessed through visual observation. The manifestation of disease occurrence in the fruit was analyzed based on internal and external symptoms such as presence of pores formation of dark brown circular spots and appearance of sunken lesions. Daily monitoring of the fruit was carried out until the end of fruit shelf life.

Results and Discussion

Fruit length (cm)

The data presented in Table 1 depicts the observation recorded for spray and soaked treatments of $CaCl_2$ on infected and non-infected dragon fruit for fruit length. Non-infected fruits soaked with 3% concentration of $CaCl_2$ resulted maximum loss in length (11.98 per cent), followed by 2% (11.11 per cent) and 1% (10.73 per cent) concentrations. Similarly, the fruit sprayed 3% concentration of $CaCl_2$ resulted in maximum (8.80 per cent) loss in length, followed by the 2% treatment (8.12 per cent). However, the 4% $CaCl_2$ concentration resulted in the minimum loss in length (7.18% and 10.15%). In anthracnose- infected fruits, the maximum loss in length was observed in soak and spray treatment in 2% (11.99 per cent and 10.81 per cent) respectively, followed by 1% (10.70 per cent) and 3% (10.55 per cent) concentrations. However, all the spray and soak treatments for both infected and non-infected dragon fruits were significantly superior as compared to the control (water). This may be due to the effect of cell wall degrading enzymes like PG, PME and β-Gal affect weight loss in fruits and may indirectly affect fruit length Ranjbar *et al.* (2018). Further, $CaCl_2$ treatments increase fruit firmness and plant cell wall stability by binding to pectin homogalacturonan carboxyl groups, enhancing its backbone and protecting it from degradation Kohli *et al.* (2015). This aligns with Ranjbar *et al.* (2018) study on apple fruits.

Table 1 : Effect of spray and soaked application of $CaCl_2$ on infected and non-infected dragon fruits for fruit length.

$CaCl_2$	Initial Length (cm)				Final Length (cm)				Per cent loss in length			
	Non-Infected		Infected		Non-Infected		Infected		Non-Infected		Infected	
	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak
0	9.96	8.18	7.47	7.11	9.08	7.18	6.61	6.18	9.47	12.51	11.55	13.29
1	10.19	8.10	8.04	7.60	9.44	7.24	7.22	6.74	7.68	10.73	10.70	11.88
2	10.64	8.43	7.60	7.28	9.82	7.51	6.78	6.41	8.12	11.11	10.81	11.99
3	10.34	8.34	7.41	6.96	9.50	7.39	6.61	6.13	8.80	11.98	10.55	11.75
4	10.98	8.49	7.79	7.50	10.21	7.62	7.02	6.73	7.18	10.15	9.89	10.19
Mean	10.42	8.31	7.66	7.29	9.61	7.38	6.85	6.44	8.25	11.30	10.70	11.82
CD (0.05)												
Factor A	0.35				0.37				1.06			
Factor B	0.35				0.37				1.06			
Factor C	NS				0.14				0.10			
AXB	0.50				0.53				0.41			
BXC	NS				NS				NS			
AXC	NS				NS				NS			
AXBXC	NS				NS				NS			

Table 2 : Effect of spray and soaked application of $CaCl_2$ on infected and non-infected dragon fruits for fruit diameter.

$CaCl_2$	Initial Diameter (cm)				Final Diameter (cm)				Per cent loss in Diameter			
	Non-Infected		Infected		Non-Infected		Infected		Non-Infected		Infected	
	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak
0	8.65	5.83	6.28	6.32	7.88	5.04	5.42	5.39	9.47	14.11	13.72	14.98
1	9.06	6.11	6.95	6.88	8.38	5.41	6.17	6.03	7.68	11.69	12.01	13.01
2	9.17	6.02	6.51	6.40	8.47	5.18	5.68	5.54	8.12	13.06	12.99	13.67
3	8.89	6.18	6.31	6.30	8.17	5.49	5.57	5.47	8.80	13.08	11.78	12.99
4	9.77	6.24	6.75	6.56	9.09	5.45	6.00	5.80	7.18	11.20	11.39	11.69
Mean	9.11	6.77	6.56	6.49	8.40	5.31	5.77	5.64	8.25	12.60	12.38	13.82
CD (0.05)												
Factor A	0.326				0.345				1.228			
Factor B	0.326				0.345				1.228			
Factor C	NS				0.120				1.736			
AXB	0.461				0.488				NS			
BXC	NS				NS				NS			
AXC	NS				0.05				0.03			
AXBXC	NS				NS				NS			

Fruit diameter (cm)

The data presented in Table 2 depicts the observation recorded for spray and soaked treatments of $CaCl_2$ on infected and non-infected dragon fruit for fruit diameter, non-infected fruits soaked with 3% concentration of $CaCl_2$ resulted maximum loss in diameter (13.08 per cent), followed by 2% (13.06 per cent) and 1% (11.67 per cent) concentrations. Similarly, the fruit sprayed 3% concentration of $CaCl_2$ resulted in maximum (8.80 per cent) loss in diameter, followed by the 2% treatment (8.12 per cent). However, the 4% $CaCl_2$ concentration resulted in the minimum loss in diameter (7.18% and 11.20%). In anthracnose-infected fruits the maximum loss in diameter was observed in soak and spray treatment in 2% (13.67 per cent and 12.99 per cent) respectively, followed by 1% (12.01 per cent) and 4% (11.39 per cent) concentrations. However, all the spray and soak treatments for infected and non-infected dragon fruits were significantly superior as compared to the control. The reduction in fruit diameter was mainly due to fruit fly infestation in dragon fruit orchards, resulting in significant post-harvest fruit loss. However, the application of $CaCl_2$ is crucial in preserving and managing fruit quality after harvest. This was attributed to the reinforcement of cell wall and plant tissues by inhibiting the activity of cell wall degradation enzymes, which may direct or indirect impact on fruit length and diameter (Ranjbar *et al*., 2018).

Fruit weight (g)

The data presented in Table 3 depicts the observation recorded for spray and soaked treatments of $CaCl_2$ on infected and non-infected dragon fruit for fruit weight, non-infected fruits soaked with 3% concentration of $CaCl_2$ resulted maximum loss in weight (12.06 per cent) followed by 2% (12.03 per cent) and 1% (10.67 per cent) concentrations. Similarly, the fruit sprayed 3% concentration of $CaCl_2$ resulted in maximum (7.78 per cent) loss in weight, followed by the 2% treatment (7.10 per cent). However, the 4% $CaCl_2$ concentration resulted in the minimum loss in weight (6.16 per cent and 10.18 per cent). In anthracnose-infected fruits, the maximum loss in weight was observed in soak and spray treatment in 2% (12.65 per cent and 11.97 per cent) respectively, followed by 1% (10.99 per cent) and 4% (10.67 per cent) concentrations. However, all the spray and soak treatments for infected and non-infected dragon fruits were significantly superior as compared to the control. Calcium increases fruit weight by influencing carbohydrate formation and enzyme activity, while reducing abscission and maintaining middle lamella cell integrity. Calcium-treated fruits reported decreased weight loss due to its inhibitory effect on respiration rate, decay and cellular disintegration. Further, calcium aids in protein and nucleic acid synthesis, delaying senescence. Untreated fruits show higher respiratory rates and storage breakdown leading to increased weight loss. This effect is supported by previous studies conducted on various fruits such as sapota (Bhanja and Lenka, 1994; Bhalerao *et al*., 2009; Desai, 2016), papaya (Ramakrishna *et al*., 2001 and Rajkumar *et al*., 2006), ber (Saran *et al*., 2004 and Yadav *et al*., 2009), mango (Singh *et al*., 2012 and Bhusan *et al*., 2015) and custard apple (Bagul, 2016), which align with the findings of the present study. Additionally, pre-harvest spraying of $CaCl_2$ on kiwi fruits has been shown to reduce weight loss and fruit rot, improving overall fruit quality (Shiri *et al*., 2016).

Pulp weight

The data presented in Table 3 depicts the observation recorded for spray and soaked treatments of $CaCl_2$ on infected and non-infected dragon fruit for pulp weight, non-infected sprayed fruits, the maximum pulp weight was observed with 4% concentration of $CaCl_2$ (150.45 g), followed by the 2% (145.99 g). Similarly, for fruits soaked with 4% concentration reported the highest pulp weight (95.74 g), followed by the 1% (88.84 g) and 2% (87.25 g) concentrations. In anthracnose-infected fruits, soaked with 3% concentration resulted in the highest pulp weight (103.19 g), while the lowest pulp weight was reported for 2% (92.32 g). Additionally, in the spray treatment, the maximum pulp weight was observed with 4% concentration (99.70 g), followed by the 1% (99.57 g) and 2% (91.19 g) concentrations. However, all the spray and soak treatments for both infected and non-infected dragon fruits were significantly superior compared tocontrol. This may be due to fruit fly infestation in dragon fruit orchards leads to significant fruit loss, while fruits unaffected by flies show higher pulp weight (Schiffermuller, 2023). As the fruit ripens, the increase in sugar content in the pulp causes a change in osmotic pressure, resulting in moisture movement from the peel into the pulp. Additionally, the increased sugar content directly influences the weight of both the pulp and peel of the fruit (Adi *et al.*, 2019). Similar findings have been reported in other fruits, such as mango (Karemera *et al*., 2013), olive (Sillero *et al*., 2021) and fig (Souza *et al*., 2023).

Peel weight

The data presented in Table 4 depicts the observation recorded for spray and soaked treatments of $CaCl_2$ on infected and non-infected dragon fruit for peel weight, non-infected fruits sprayed with 4% concentration of $CaCl_2$ reported maximum peel weight (68.21 g), followed by 2% (66.26 g). Similarly, fruits soaked with 1% concentration reported highest peel weight (44.15 g), followed by 4% (43.98 g) and 3% (42.92 g) concentrations. In anthracnose-infected fruits, soaked with 4% concentration of $CaCl_2$ resulted in highest peel weight (70.06 g), while the lowest peel weight was reported for 3% concentration (62.82 g). Additionally, in the spray treatment maximum peel weight was observed with 4% concentration (66.49 g), followed by 1% (65.63 g) concentration. However, all the spray and soak treatments for infected and non-infected dragon fruits were significantly superior compared tocontrol. During the ripening process of mature fruits, osmotic pressure causes moisture movement from the peel into the pulp, resulting in the thinning of the peel. Additionally, transpiration contributes to the loss of moisture from the peel (Dadzie and Orchard, 1997). This continuous loss of moisture leads to gradual decrease in peel weight as ripening progresses (Adi *et al*., 2019). Firm fruits are

Table 3 : Effect of spray and soaked application of $CaCl_2$ on infected and non-infected dragon fruits for fruit weight.

$CaCl_2$	Initial weight (g)				Final weight (g)				Per cent weight loss			
	Non-Infected		Infected		Non-Infected		Infected		Non-Infected		Infected	
	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak
0	216.9	128.2	155.7	157.7	198.7	111.6	135.9	135.7	8.44	13.08	12.70	13.96
1	218.4	146.2	179.4	185.8	204.2	131.1	160.2	164.4	6.66	10.67	10.99	11.98
2	229.9	141.5	164.3	170.7	213.6	124.5	144.7	149.2	7.10	12.03	11.97	12.65
3	222.5	143.0	160.6	166.2	205.6	126.3	143.8	147.1	7.78	12.06	10.76	11.97
4	235.0	153.7	179.8	186.9	220.5	138.2	161.4	167.3	6.16	10.18	10.37	10.67
Mean	224.5	142.5	168.0	173.5	208.5	126.3	149.2	152.7	7.23	11.60	11.36	12.24
CD (0.05)												
Factor A	11.6				12.2				1.227			
Factor B	11.6				12.2				1.227			
Factor C	NS				2.36				1.73			
AXB	16.4				17.3				NS			
BXC	NS				NS				NS			
AXC	NS				NS				NS			
AXBXC	NS				NS				NS			

Table 4 : Effect of spray and soaked application of $CaCl_2$ on infected and non-infected dragon fruit for pulp weight, peel weight and pulp : peel ratio of fruit.

$CaCl_2$	Pulp weight (g)				Peel weight (g)				Pulp: Peel			
	Non-Infected		Infected		Non-Infected		Infected		Non-Infected		Infected	
	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak
0	134.88	77.03	82.57	86.81	62.91	36.69	60.27	56.36	2.13	2.09	1.37	1.57
1	137.51	88.84	99.57	102.73	64.63	44.15	65.63	68.67	2.12	1.99	1.54	1.45
2	145.99	87.25	91.19	92.32	66.26	39.75	60.16	63.82	2.20	2.20	1.52	1.47
3	138.82	85.88	85.56	89.68	65.62	42.92	61.83	62.82	2.11	1.99	1.38	1.49
4	150.45	95.74	99.70	103.19	68.21	43.98	66.49	70.06	2.20	2.19	1.53	1.57
Mean	141.53	86.95	91.72	94.95	65.52	41.50	62.88	64.35	2.15	2.09	1.47	1.50
CD (0.05)												
Factor A	7.618				5.067				0.102			
Factor B	7.618				5.067				NS			
Factor C	10.77				7.166				NS			
AXB	NS				NS				NS			
BXC	NS				NS				NS			
AXC	NS				NS				NS			
AXBXC	NS				NS				NS			

less susceptible to peel loss as their cells remain tightly held together, ultimately extending the shelf life of the fruits (Pessoa *et al*., 2022). Similar findings have been reported in other fruits likewise strawberry (Langer *et al*., 2019) and loquat (Akhtar *et al*., 2010).

Pulp: Peel ratio

The data presented in Table 4 depicts the observation recorded for spray and soaked treatments of $CaCl_2$ on infected and non-infected dragon fruit for pulp: peelratio, The data revealed that the maximum pulp: peel ratio for non-infected fruits was observed with 4% concentration of $CaCl_2$ in both spray and soak treatments (2.20 per cent and 2.19 per cent, respectively). Similarly, for fruits infected with anthracnose, the maximum pulp: peel ratio was reported with 4% concentration of $CaCl_2$ in both spray and soaked treatments (1.53 per cent and 1.57 per cent, respectively). However, the recorded data indicated that all the treatments were comparable, suggesting that different treatments did not have a significant impact on modifying the pulp: peel ratio in dragon fruit. Calcium chloride has been observed to positively influence fruit quality by reducing decay and enhancing firmness. However, there is limited evidence suggesting that it significantly alters the pulp: peel ratio of fruits (Ali *et al*., 2021). It can be concluded that the pulp: peel ratio is primarily determined by the inherent genetic characteristics of the fruit and the ripening process it undergoes (Tigchelaar *et al*., 1978). Similar trends in the pulp: peel ratio have been recorded in studies on Monthan banana by Palmer (1963) and Burdon *et al.* (1993) as well as in date plum by Khan *et al.* (2022).

Decay loss percentage

The data presented in Table 4 depicts the observation recorded for spray and soaked treatments of $CaCl_2$ on infected and non-infected dragon fruit for decay loss percentage, non-infected fruits, soaked with 1% concentration of $CaCl_2$ resulted in the highest decay loss percentage (32.30 per cent), followed by the 2% (29.80 per cent) concentration. Similarly, in the spray treatment the maximum decay loss percentage was observed with 1% (26.82 per cent), followed by the 2% (25.21 per cent) concentrations. However, the spray and soak treatments with 4% concentration resulted in minimum decay loss percentage (18.97 per cent and 25.05 per cent, respectively) compared to the control. In anthracnose-infected fruits, soaked with 1% concentration of $CaCl_2$ resulted in highest decay loss percentage (51.67 per cent), while the lowest decay loss percentage was reported for the 4% (42.30 per cent). Additionally, in sprayed treatment the maximum decay loss percentage was observed with 1% (44.07 per cent) and 2% (42.46 per cent) concentrations. However, all the spray and soaked treatments were significantly superior than control, indicating their effectiveness in reducing decay loss. The application of calcium in fruit treatment resulted in a notable reduction in decay loss percentage, which can be attributed to improved fruit firmness and higher calcium content in the peel. These factors contribute to enhanced intracellular organization and strengthened cell walls (Hocking *et al*., 2016). The findings of this study are consistent with previous research conducted on fruits and vegetables, as reviewed by Martin-Diana *et al*. (2007). Similar findings have also been reported in studies on tomato by Sati and Qubbaj (2021) and on apple by Lidster *et al*. (1978).

Fruit Firmness

The data presented in Table 5 reveals the effect of sprayed and soaked $CaCl_2$ treatments on fruit firmness of anthracnose infected and non-infected dragon fruit. non-infected dragon fruits soaked with 4% concentration of $CaCl_2$ exhibited the highest fruit firmness (0.53 kg/cm^2), closely followed by the 3% (0.52 kg/cm^2) and 2% (0.51 kg/cm^2) concentrations. Similarly, for non-infected fruits sprayed with 4% concentration reported maximum fruit firmness (0.47 kg/cm^2), followed by the 3% (0.47 kg/cm^2). However, both the spray and soaked treatments with 1% concentration resulted in minimum fruit firmness (0.44 kg/cm^2 and 0.50 kg/cm^2, respectively). In anthracnose-infected fruits, soaked with 4% concentration of $CaCl_2$ resulted in highest fruit firmness (0.45 kg/cm^2), while the minimum fruit firmness was reported for the 1% (0.36 kg/cm^2). Additionally, in sprayed treatments the maximum fruit firmness was observed with the 4% concentration of $CaCl_2$ (0.39 kg/cm^2), followed by 3% (0.38 kg/cm^2) and 2% (0.38 kg/cm^2) concentrations. However, all spray and soak treatments for infected and non-infected dragon fruits were significantly superior compared to the control, indicating their positive impact on fruit firmness. The application of calcium can improve the density of the intercellular layer within the cell wall, reducing hydrolase enzyme entry and enhancing the gelatinous layer's disintegration. Calcium also influences the pectin component, ensuring cell wall stability and fruit firmness. Gao *et al.* (2019) found that calcium applied through soak and spray method preserved cell wall integrity in fruits, forming calcium pectate complexes with pectin, increasing firmness was reported by Garcia *et al.* (1996) in straw berries. Similar findings have also been reported by Arumuganathan *et al.* (2010) in bananas and Ali *et al.* (2021) in peaches.

Fruit cutting force

The data presented in Table 5 reveals the effect of sprayed and soaked $CaCl_2$ treatments on fruit cutting force of anthracnose infected and non-infected dragon fruit. Non-infected dragon fruits soaked with 4% concentration of $CaCl_2$ exhibited the highest requirement of fruit cutting force (8.69 kg/cm^2), followed by the 3% (8.29 kg/cm^2) and 2% (7.92 kg/cm^2) concentrations. Similarly, for non-infected fruits sprayed with 4% concentration the maximum fruit cutting force was observed (7.41 kg/cm^2), followed by the 3% (7.13 kg/cm^2). However, both the spray and soak treatments with1% concentration reported minimum requirement of cutting force (6.56 kg/cm^2 and 7.57 kg/cm^2, respectively). However, anthracnoseinfected fruits sprayed with 4% concentration requires maximum cutting force for 4% concentration (6.07 kg/cm^2). Additionally, in the soak treatment the maximum fruit cutting force was reported with 4% concentration (5.74 kg/cm^2) followed by 3%

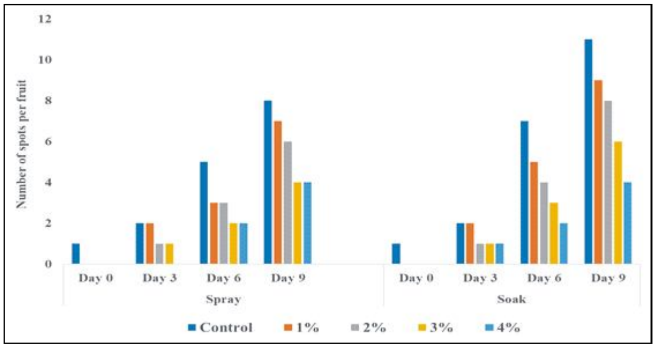

Fig. 1 : Effect of spray and soaked treatment of $CaCl_2$ on disease incidence and shelf life of dragon fruit.

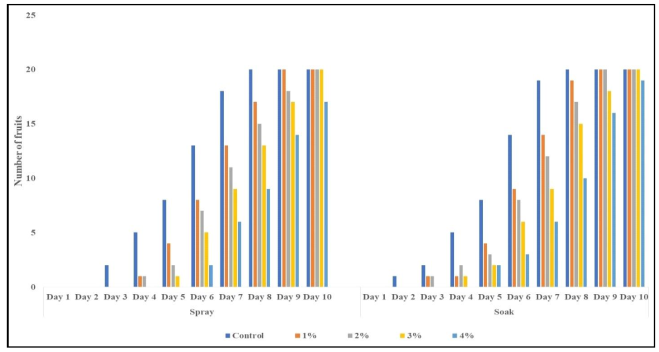

Fig. 2 : Effect of spray and soaked treatment of $CaCl_2$ on number of disease spots per fruit in dragon fruit.

Table 5 : Effect of spray and soaked application of $CaCl_2$ on infected and non-infected dragon fruit for fruit firmness, cutting force and decay loss percentage.

$CaCl_2$	Firmness (kg/cm^2)				Cutting force (kg/cm^2)				Decay loss%			
	Non-Infected		Infected		Non-Infected		Infected		Non-Infected		Infected	
	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak	Spray	Soak
0	0.43	0.45	0.33	0.36	6.24	6.64	4.81	5.16	30.83	34.34	48.68	51.67
1	0.44	0.50	0.35	0.36	6.56	7.57	5.11	5.41	26.82	32.30	44.07	49.55
2	0.46	0.51	0.38	0.40	6.72	7.92	5.53	5.54	25.21	29.80	42.46	47.08
3	0.47	0.52	0.38	0.41	7.13	8.29	5.55	5.74	22.78	28.04	40.03	45.29
4	0.47	0.58	0.39	0.45	7.41	8.69	6.07	5.74	18.97	25.05	36.22	42.30
Mean	0.45	0.51	0.37	0.40	6.81	7.82	5.41	5.51	24.92	24.91	42.17	47.16
CD (0.05)												
Factor A	0.029				0.394				4.549			
Factor B	0.029				0.394				4.549			
Factor C	NS				0.557				6.434			
AXB	0.046				0.623				NS			
BXC	NS				NS				NS			
AXC	NS				NS				NS			
AXBXC	NS				NS				NS			

(5.74 kg/cm^2) and 2% (5.54 kg/cm^2) concentrations. Fruits with higher firmness exhibit stronger cell walls, resulting in greater force required to cut through the fruit and vice versa. These findings are aligning with results reported by Argyropoulos *et al.* (2008) and Arumuganathan *et al.* (2010) in button mushrooms, Cano-Chauca *et al.* (2002) in banana reported that cutting force is a measure of hardness and influenced by the structure of fruit.

Disease incidence

The data presented in Fig. 1 reveals the effect of sprayed and soaked $CaCl_2$ treatments on disease incidence on dragon fruit, the results revealed that fruits sprayed with 4% concentration of $CaCl_2$ exhibited the highest resistance to disease incidence, followed by the 3% and 2% concentrations. However, the fruits soaked 4% concentration of $CaCl_2$ showed the highest resistance, while the fruit with 1% concentration were most susceptible to disease incidence, leading to shorter shelf life. This may be due the effect of the difference in moisture content between soaked and sprayed treatment could potentially explain the observed effect. The higher moisture content in soaked treatment may create a more favorable environment for the growth and spread of *Colletotrichum gloeosporioides*, the fungus responsible for anthracnose in dragon fruit. This finding aligns with the research conducted by Awang *et al.* (2011) on red-fleshed dragon fruit. Similar results have also been reported by Cruz *et al.* (2015) in guava.

Number of acervuliper fruit

The data presented in Fig. 2 reveals the effect of sprayed and soaked $CaCl_2$ treatments on disease incidence of anthracnose infected and non-infected dragon fruit, $CaCl_2$ sprayed fruits has delayed the occurrence of disease spots, leading to an improved shelf life compared to soaked treatment. Among the spray treatments, 4% concentration of $CaCl_2$ exhibited highest resistance to disease spots followed by 3% and 2% concentrations. Conversely, the fruit soaked with different concentrations of $CaCl_2$ experienced an earlier onset of disease spots, making them more susceptible to disease spread and resulting in shorter shelf life. While the fruit soaked with 4% concentration of $CaCl_2$ displayed highest resistance to disease spots and 1% concentration fruits were most susceptible in comparison to the control. These findings indicate that the spray treatment was more effective in providing disease resistance and extending shelf life of dragon fruit compared to the soaked treatment. The higher moisture content in soaked treatment may contribute to more favorable environment for the growth and spread of *Colletotrichum gloeosporioides* fungus responsible for anthracnose in dragon fruit Bordoh *et al.* (2020) and similar results have been observed by Børve *et al.* (2023) in European plum and Cruz *et al.* (2015) in guava. This suggests that moisture content plays a significant role in influencing the development and severity of anthracnose in fruits.

Conclusion

The utilization of Calcium chloride ($CaCl_2$) on dragon fruit has resulted in enhanced physical attributes of the fruit. The outcomes obtained from various treatments have demonstrated significant variations among the fruits. The treatment involving different concentrations of Calcium chloride exhibited superior results in terms of physical. Consequently, it can be inferred that the application of $CaCl_2$ can enhance the quality of dragon fruit while also extending its shelf life. Thus, based on the present study, it has been proven that all $CaCl_2$ treatments conducted through spray and soak methods have extended the shelf life of white-pulped dragon fruit beyond its natural storage period, while also imparting numerous desirable qualities. Additionally, all $CaCl_2$ treatments have contributed to a reduction in the occurrence of anthracnose in comparison to the control.

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