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Enhancing shelf life and freshness retention in jasmine flowers (*Jasminum multiflorum* L.) through Post-harvest chemical treatments

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Abstract
Jasmine flowers, known for their extreme perishability, were subjected to various chemical treatments and stored over a 5-day period under ambient conditions. The impact of these treatments on physiological factors such as weight loss, freshness, flower opening, browning, total phenol content, and microbial growth was assessed. Desirability studies were conducted using a multi-level categorical design with 100 runs in design expert software. The jasmine flowers treated with a mixture of sucrose (20%), GA_3 (100 ppm), and boric acid (2%) exhibited higher shelf life extension of up to 4.40 days, with minimal weight loss (31.31%), high freshness index (45.72), higher total phenol content (7.52 mg/g), reduced flower opening index (71.60), minimal browning index (64.11), and lower microbial population (13.75 cfu/g) at the end of storage.

Keywords: Jasmine flower-Shelf life-Pre-treatments

Introduction

With the global commerce in cut flowers increasing at a pace of 25% annually, floriculture is a prominent high-value agriculture sector. With a long history of floriculture, India has a meagre 0.65% market share in the $11 billion worldwide floriculture industry. Gladioli, jasmine, tuberoses, and roses are some of the most popular flowers grown in India. The aromatic jasmine blossom has been used for many years in religious ceremonies, as well as for crafting garlands, bouquets, and hair ornaments for ladies. Additionally, jasmine flowers contribute to the production of essential oils, such as ‘concrete’ and ‘absolute,’ which find applications in cosmetics and perfumery. India boasts over 80 jasmine species, but only three-*Jasminum sambac* (Arabian/Tuscan jasmine), J. *auriculatum*, and J. *grandiflorum* (Royal/Spanish jasmine)-are commercially cultivated. Jasmine, popularly known as ‘Kakada,’ holds a special place among ornamental and medicinal plants and is gaining prominence in the loose flower trade. Effective post-harvest management can significantly enhance jasmine’s shelf life and market value.”

Prices for cut flowers can increase by up to five to ten times the production when postharvest management and value addition are applied. As a result, increasing the vase life of flowers is both necessary and possible. The main issue with jasmine flower marketing is their short lifespan. Extending the shelf life of flowers is mostly dependent on treating them with appropriate chemicals. Numerous postharvest methods have been developed to enhance the quality, particularly the shelf life, of cut flowers in various ornamental plants. These methods mostly work by reducing the production or effect of ethylene (Ichimura *et al*., 2003; Ahmadi *et al*., 2009) [7, 1]. In light of this, an experiment was carried out at the Department of Agriculture Engineering to optimise the chemical treatment applied to jasmine flowers after harvest.

The jasmine flowers were harvested from the experimental plots in University of Agricultural Sciences, Bengaluru. Flower buds (25 g) are treated with chemical combination as given in Table 3 (Jawaharlal *et al.*, 2013; Majumder *et al.* 2014) [9, 15]. Treated flowers were allowed for surface drying in shade for 15 minutes. The initial weight (g) of flower buds was measured and stored in ambient condition.

The samples were evaluated for quality at room temperature after every 24 hours up to five days. (Jawaharlal *et al.* 2013) [9].

Materials and Methods

Chemical treatment of flowers

Chemical treatments were selected based on studies pertaining to post-harvest handling and management of loose flowers conducted by Jawaharlal *et al.* 2013; Majumder *et al.* 2014 [9, 15]. Twenty five grams of Jasmine flower buds sprayed with chemical treatments and kept for 15 minutes for surface drying and kept for shelf life studies. The weight of flower buds was measured (grams) and kept for observation in room temperature for every 24 hours up to five days (Jawaharlal *et al.* 2013) [9].

The entire study was divided into four replications which included four chemical pre-treatment combinations (Table 1) along with control.

Observations recorded

Physiological loss in weight (PLW)

The initial and final weights of the flowers were recorded and the physiological loss in weight (PLW) was calculated as given below (Lavanya *et al.* 2016) [13].

$$\text{Physiological loss in weight (\%)} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

Freshness index (FI)

The following score, represented as a percentage of fresh flowers or freshness index, will be used to visually observe how many flowers maintained their freshness without showing signs of petal drooping and browning (Nirmala *et al.* 1992) [19]. Table 1 shows the score that was utilised for the freshness index.

$$FI = \frac{(7\times X_1) + (6\times X_2) + (5\times X_3) + (4\times X_4) + (3\times X_5) + (2\times X_6) + (1\times X_7)}{(X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7)\times 7} \times 100$$

Flower opening index (FOI)

The flower opening index is the number of flowers opened which is measured by visual observation. If petals of the flowers open in a short period of duration, it decreases the shelf-life and market value of the flowers. Therefore, it needs a proper packaging technology to extend the shelf-life with minimum flower opening (Karuppaiah *et al.* 2006) [10]. The score used for flower opening index (Table 2) is given as:

$$FOI = \frac{(0\times X_1) + (1\times X_2) + (2\times X_3) + (3\times X_4)}{(X_1 + X_2 + X_3 + X_4)\times 4} \times 100$$

Browning Index (BI)

Browning index of jasmine flower was calculated by formula reported by Morteza *et al.* (2015) [4].

$$BI = \frac{100\,(X - 0.31)}{0.17}$$

$$\text{Where, } X = \frac{a* + 1.75\,L*}{5{,}645\,L* + a* - 3.012\,b*}$$

Total Phenol content

Phenols are organic aromatic compounds containing one or more hydroxyl groups on the benzene ring. They play a crucial role in plant resilience, and their oxidation can lead to the formation of quinones, which are highly reactive and detrimental to infections. To estimate the phenol content in jasmine flowers, the method outlined by Singh (1980) was followed. Using the Folin-Ciocalteau Reagent (FCR) as per AOAC (2005) guidelines, the total phenolic content (TPC) of the sample was determined. The process involved precisely weighing five grams of jasmine blossoms, pulverizing them with 80% alcohol, and filtering the extract. After mixing the filtrates, Whatman No. 41 filter paper was used to filter them, and alcohol was used to adjust the volume to a specified value. Then 30 ml of the prepared ethanol extract to 1.0 ml of freshly diluted Folin-Ciocalteau reagent was added. After thorough mixing with a solution of sodium carbonate, the test tubes were briefly heated in a boiling water bath. The resulting absorbance at 650 nm was measured using a spectrophotometer. Catechol served as the equivalent standard, and the concentration of phenols was expressed as µg equivalent of pyro-catechol per gram of the sample. All analyses were conducted in quadruplicate."

Total microbial count (cfu/g)

The total microbial count in flowers stored under various packaging materials and temperatures was determined using the Nutrient Agar (NA) method. For NA preparation, 7g of agar was added to a 500ml conical flask with 250ml distilled water. Cotton wool covered with aluminum foil sealed the flask, which was then homogenized by heating on a mantle. Subsequently, the medium was sterilized in an autoclave at 121 ºC for 15 minutes.

Microbial isolation was accomplished through the pour plate method. Serial dilution was initiated by adding 1g of each flower sample to test tubes containing 10ml sterile water, serving as stock solutions. A 10-1 dilution was created by transferring 1ml from the stock solutions to another set of test tubes containing 9ml sterile water. This procedure was reiterated to achieve a 10-4 dilution. Subsequently, 0.5ml of the 10-1 dilution was introduced into sterile petri dishes, followed by the pouring of sterile molten agar. The inoculated plates were allowed to solidify and were then placed in an inverted position during incubation at 37 ºC for 24 hours to prevent water vapor condensation on the plate covers.

Microbial load estimation for the flower samples was conducted on the 4th, 8th, 12th, 16th, and 21st days of the storage period, as outlined in studies. The number of colonies on each NA plate was quantified using a specific formula.

$$CFU/g = \frac{\text{Number of colonies X Dilution factor}}{\text{Weight of flower}}$$

Shelf-life: The number of days that at least 50% of the flowers remained fresh (i.e., 50% of the freshness index score) without showing signs of pink or brown deterioration was used to measure the shelf-life of flowers (Karuppaiah *et al.* 2006) [10].

Physiological loss in weight (PLW)

Data pertinent to the flower physiological loss in weight are pursued in the Table 4. Among the different post-harvest chemical treatments Jasmine flower (*Jasminum multiforum* L.) treated with T_4 (Sucrose 20% + GA_3 (100ppm) + Boric acid-2%) resulted in lowest physiological loss in weight (PLW) and followed by T_2 (Pre-treatment with Boric acid - 2% + 150 ppm Citric acid). The PLW (%) in T_4 was 0.89,16.18,23.19,29.92 and 31.31% respectively followed by T_2 was 0.7,20.22,26.81,33.09 and 42.58% respectively on first, second, third, fourth and fifth day after treatment. The maximum weight loss was observed in T_0 (Control) with 1.05, 24.75, 35.64, 46.78 and 51.09% respectively during first to fifth day of storage.

Freshness Index (FI)

Data on flower freshness index are presented in Table 4. Treating jasmine flower with T_4 (Sucrose 20% + GA_3 (100ppm) + Boric acid-2%) maintained higher value of freshness index followed by T_1 (Pre-treatment with Boric acid- 4%). The freshness index in T_4 was 87.1, 74.4, 69.8, 64.2 and 49.7 respectively followed by T_2 (83.4, 69.8, 66.4, 55.1, and 43.9) respectively on first, second, third, fourth and fifth day of storage. Lower percentage of freshness index was found in T_0 (Control) with the values as 80.7, 70.4, 55.5, 43.2 and 31.4 respectively.

Flower opening Index (FOI)

Data regarding flower freshness index parameters are presented in the Table 4. Flower opening index (FOI) was comparatively lower in both treatment combinations (Sucrose and boric acid). Superior results were obtained with T_2 (Pre-treatment with Boric acid - 2% + 150 ppm Citric acid) and this was followed by T_4 (Sucrose 20% + GA_3 (100ppm) + Boric acid-2%). The FOI in T_2 was 15.7, 35.4, 41.5, 46.1 and 58.9 respectively and for T_4 it was 21.9, 39.2, 47.5, 70.6 and 71.6 respectively. The higher percentage of flower opening index was found in T_0 (Control) with 30.1, 47.2, 62.6, 73.8 and 80.2 respectively on the consecutive first, second, third, fourth and fifth days.

Total phenol content

It is evident from the data shown in the Table 4 shows sharp decrease in Total phenol content with respect to storage period. Sucrose (20%) in combination with GA_3 (100ppm) and Boric acid-2%) (T_4) shows higher Total phenol content (7.91 mg/g) followed by T_2 (6.50 mg/g) at the end of storage period. Control shows lower Total phenol content (4.65 mg/g). These results are closer to the values reported by Manimaran *et al.* 2018 [16] where jasmine flowers var. *Jasminum nitidum* treated with boric acid stored at ambient condition recorded higher total phenol content (7.10mg/g). Similar findings of increased phenolic content using Boric acid have been recorded in Jasmine flowers (Lavanya *et al.* 2016; Manimaran *et al.* 2018) [13, 16].

Browning Index (BI)

The appearance is the major aspect related to storage of jasmine flower and consumers acceptability. The browning index during storage period increases gradually in jasmine flower as shown in Table 4. Superior results are obtained in T_4 (Sucrose 20% + GA_3 (100ppm) + Boric acid-2%) with 64.11 followed by T_1 (Pre-treatment with Boric acid - 4%) with 69.88 at the end of fifth day. T_0 (control) recorded higher browning index value with 74.23 at the end of fifth day.

Total microbial population (cfu)

The Table 4 demonstrates the changes in microbial population in jasmine flowers during ambient storage for different pre-treatments. The control sample (T_0) showed a consistent increase in microbial population over time. However, the other pre-treatments (T_1, T_2, T_3, T_4) exhibited lower microbial populations, indicating some level of inhibition of microbial growth. Among the pre treatments T_4 (Sucrose 20% + GA_3 (100ppm) + Boric acid-2%) showed the most effective reduction in microbial population, starting with a lower population on Day 1 (3.6) to Day 5 (13.6) and exhibiting slower growth throughout the storage period followed by T_2 (14.9).

Effect of treatment on shelf life of Jasmine flower

The overall acceptance of flower is most important and essential as it reflects market value as well as consumer acceptance. In other words, it indicates freshness of the flower and its shelf-life. The effect of treatment on shelf-life of jasmine flower is depicted in Table 5. Among all the treatments flowers treated with T_4 (Sucrose 20% + GA_3 (100ppm) + Boric acid-2%) was highly effective and registered maximum shelf-life of 4.4 days followed by T_2 ((Pre-treatment with Boric acid - 2% + 150 ppm Citric acid) which recorded 4.1 days. While the shelf-life of T_0 (control) was only 2.8 days. The results are in line with the findings of Nirmala and Reddy (1992) [19] Karuppaiah *et al.* (2006) [10] and Lavanya *et al.* (2016) [13].

Optimization of Chemical treatment

Factorial randomized design was used for the analysis of results. The data was subjected to Design Expert Software (Design Expert v. 13.0.10 software, United States). Multi-level categoric design was used in the software with eight responses (Dependent variables). The objective of the optimization was to obtain best desirability value in selecting best chemical pretreatment for extending shelf life of jasmine flower. The values of all the response during storage period was shown as desirability function as shown in Table 6. The maximum desirability value obtained for T_4 (Sucrose 20% + GA_3 (100ppm) + Boric acid-2%) was 0.357 on fifth day of storage. The desirability value of the minimum and maximum was configured between 0 to 1.Criteria for setting goal for each response was fixed based on type and importance of the parameter as Table 7.

Treatment combination T_4 was found to be the best treatment with desirability value 0.805 and T_0 (control) being the least with desirability value 0.088. It can be concluded that even though flower opening index found in T_4 (71.6) was quite higher compare with T_1 (65.9) and T_2 (58.9) but based on desirability value T_4 is selected for further experiment.

Discussion

Pre-treatment with a 20% sucrose solution increased the maximum weight of jasmine spikes and extended the duration during which they maintained their initial fresh weight (Majumder *et al.* 2016) [15]. However, this increased postharvest weight (PLW) eventually led to a decline in the overall fresh weight of the flowers. Visually, this decline manifested as senescence symptoms, including wilting, similar to observations in carnations (Nichols, 1966) [20] and Rosa damascena (Sharma, 1981) [25].

To enhance water balance and longevity in cut flowers, boric acid was employed as a mineral salt. It effectively increased the osmotic concentration and pressure potential of petal cells (Halevy, 1976) [6]. The higher freshness index observed could be attributed to the presence of sucrose in the solution, acting as a food source or respiratory substrate. This delay in protein degradation and reduction in transpiration allowed the flowers to remain fresh for an extended period (Singh *et al.* 2018) [24].

Furthermore, boric acid treatment positively impacted antioxidant enzyme activity, potentially preventing the accumulation of free radicals and thus preserving the freshness of jasmine flowers (Lavanya *et al.* 2016) [13]."

Previous research on the opening of flowers in cut roses has indicated a correlation with the amount of carbohydrates present in the petals (Marissen and Brijen, 1995) [18]. According to Kenis *et al.* (1985) [11], petal growth connected to flower bud opening is the consequence of cell expansion, allowing for the entry of water and carbohydrates into petal cells (Evans and Reid, 1988) [5]. Flowers with reduced water status have the lowest floral opening. 200 gauge PE bags showed a decreased flower opening index (Karuppaiah *et al.* 2006) [10].

Delay in senescence in Hemerocallis has been linked to a higher level of total phenols. According to Burzo *et al.* (1988) [2], the brown coloration in flower cell vacuoles is caused by the buildup of flavins and other phenolic compounds. According to Mohansundari *et al.* (2018) [17], the oxidation of phenolic substances by the polyphenol oxidase enzyme results in enzymatic discoloration that browns the petals.

The resultant browning in anthorium cut flower spathe affects its marketability causing economic losses. The brown colouration was due to the accumulation of complexes resulting from the polymerization of flavins and other phenolic substances in the cell vacuoles (Burzo *et al.* 1988) [2]. Nirmala and Reddy (1992) [19] reported that, in the presence of O2, the enzyme polyphenol oxidase might oxidise these compounds to quinones which simultaneously polymerised into brown pigment. The availability of moisture content and nutrients had tremendous impact on growth of microbial population. Boric acid acts as a weak acid, lowering the pH of the surrounding environment. Most microorganisms thrive in a neutral to slightly acidic pH range. By reducing the pH, boric acid creates a less favorable environment for microbial growth, inhibiting their proliferation. Sucrose increases the osmolarity of the preservative solution. This higher osmolarity creates a hypertonic environment that draws moisture out of microorganisms, causing plasmolysis and inhibiting their growth. Similar results were found where rose flowers treated with $AgNo_3$ and SNP (Silver Nano particle) packed in PP cover significantly suppressed bacteria number up to 5 days.

Table 1: Pre-treatment chemical details

T0- Control	**T_1- Boric acid - 4%**
T_2- Boric acid - 2% + 150 ppm Citric acid	T_3- Sucrose - 2% + STS (0.5 mM) + $KMnO_4$ (0.2%)
T_4- Sucrose 20% + GA3 (100ppm) + Boric acid - 2%	

Table 2: Score for freshness index

Condition of flower	Score	Number of flower buds under this score
Almost all buds turgid	7	X_1
Partial to half open flowers, turgid	6	X_2
Half to full open flowers, turgid	5	X_3
Partial to half open flowers, slightly wilted	4	X_4
Half to full open flowers, slightly wilted	3	X_5
Partial to half open flowers, fully wilted	2	X_6
Half to full open flowers fully wilted	1	X_7

Table 3: Score for Flower opening Index

Stage of flowers	Score	Number of flower buds under this score
Unopened buds	0	X1
Slightly opened	1	X2
Half opened	2	X3
Full opened	3	X4

Table 4: Effect of Pre-treatments on various parameters during storage in Jasmine flower

Treatment	Physiological Loss in Weight (PLW%)					Freshness Index (FI)					Flower opening Index (FOI)			
	Day1	Day2	Day3	Day4	Day5	Day1	Day2	Day3	Day4	Day5	Day1	Day2	Day3	Day4
T0	1.05	24.75	35.64	46.78	51.09	80.7	70.4	55.5	43.2	31.4	30.1	47.2	62.6	73.8
T1	0.76	20.08	25.38	32.34	42.58	77.0	71.7	63.4	52.6	40.0	26.5	45.3	59.2	62.3
T2	0.7	20.22	26.81	33.09	36.42	83.4	69.8	66.4	55.1	43.9	17.7	35.4	41.5	46.1
T3	0.87	22.99	28.81	34.12	38.90	80.4	69.1	61.1	47.2	37.2	28.1	46.7	61.1	70.7
T4	0.89	16.18	23.19	29.92	31.31	87.1	74.4	69.8	64.2	45.7	21.9	39.2	47.5	70.6
Mean	0.85	20.84	27.97	35.25	40.06	83.64	71.13	65.85	56.02	41.46	24.95	42.98	54.26	70.65
SE (m)	0.008	0.222	0.311	0.725	0.255	0.822	0.867	0.895	2.143	2.46	1.637	0.719	1.238	0.516
SE (d)	0.012	0.314	0.440	1.026	0.361	0.270	0.285	0.294	0.705	0.81	0.538	0.236	0.407	0.170
CD (5%)	0.026	0.676	0.946	2.206	0.776	0.382	0.403	0.416	0.996	1.15	0.761	0.334	0.576	0.240
CV	2.004	2.126	2.226	4.009	1.280	0.661	0.802	0.928	2.674	5.84	4.336	1.106	1.498	0.546
Significance	S	S	S	S	S	S	S	S	S	S	S	S	S	S

Whereas,

T0- Control	T1- Boric acid - 4%
T2- Boric acid - 2% + 150 ppm Citric acid	T3- Sucrose - 2% + STS (0.5 mM) + $KMnO_4$ (0.2%)
T4- Sucrose 20% + GA3 (100ppm) + Boric acid - 2%	

Contd..

Treatment	Total phenol content(mg/g)					Browning Index					Microbial population(cfu/g)			
	Day1	Day2	Day3	Day4	Day5	Day1	Day2	Day3	Day4	Day5	Day1	Day2	Day3	Day4
T0	11.19	8.57	7.59	6.05	4.81	39	47.23	51.58	63.28	74.23	5.50	8.00	12.75	15.25
T1	12.29	9.46	8.51	7.46	5.85	39.05	49.33	53.45	59.35	69.88	5.00	7.50	12.00	14.00
T2	13.05	10.59	8.63	7.60	6.77	35.31	44.51	52.16	56.66	70.54	4.50	6.50	9.50	11.25
T3	12.08	9.44	8.61	6.84	5.37	40.98	43.97	48.19	53.82	71.34	5.50	7.25	10.75	13.25
T4	13.49	11.75	10.36	8.36	7.52	38.6	41.38	45.25	49.16	64.11	3.75	5.50	7.50	10.50
Mean	12.42	9.96	8.74	7.26	6.06	38.58	45.28	50.12	56.45	70.02	4.85	6.95	10.50	12.85
SE (m)	0.585	0.273	0.225	0.243	0.310	0.53	0.66	0.66	1.30	0.83	0.31	0.51	1.04	0.36
SE (d)	0.822	0.391	0.314	0.340	0.451	0.75	0.94	0.94	1.84	1.17	0.43	0.72	1.47	0.51
CD (5%)	0.324	0.846	0.685	0.746	0.969	1.61	2.02	2.03	3.9	2.5	0.94	1.55	3.17	1.11
CV	9.42	5.58	5.15	6.75	10.51	2.72	7.22	8.58	4.54	2.36	10.05	4.67	8.58	5.76
Significance	S	S	S	S	S	S	S	S	S	S	S	S	S	S

Table 5: Effect of Pretreatment on Shelf life (Days) of Jasmine flower during ambient storage

Treatments	Days
T_0	2.8
T_1	3.9
T_2	4.1
T_3	3.7
T_4	4.4
Se(m)	0.11
Se(d)	0.16
CD	0.36
CV	6.25

Table 6: Process parameters and responses for optimization of Pre-treatments in jasmine flower

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A:A	is in range	T0	T4	1	1	3
Freshness Index	maximize	29.43	49	1	1	4
Flower Opening Index	minimize	58.6	80.8	1	1	4
Browning index	minimize	43.18	64.45	1	1	3
Physiological Loss in weight	minimize	31.05	51.03	1	1	3
Total phenol content	maximize	6.66	9.65	1	1	3
Colour value L*	maximize	49.43	63.1	1	1	2
Colour a*	minimize	6.49	13.55	1	1	2
Colour b*	maximize	6.49	13.55	1	1	2
Moisture content	maximize	35.18	50.1	1	1	3
Microbial load	minimize	13	19	1	1	2

Table 7: Desirability function of Pretreatment for shelf life extension of jasmine flower

No	Treatments	Fresh Ness Index	Flower Opening Index	Browning index	Physiological loss in weight	Total phenol content	Microbial load	Desir ability	
T_4	Day 5	59.50	31.308	71.575	7.018	71.445	13.475	0.805	Selected
T_1	Day 5	55.050	42.583	65.925	5.601	59.320	17.625	0.676	
T_2	Day 5	50.900	36.417	58.850	6.127	51.017	14.925	0.551	
T_3	Day 5	47.250	38.903	79.200	5.373	54.320	15.800	0.289	
T_0	Day 5	41.400	50.133	80.175	4.404	40.093	18.200	0.088	

Conclusion

Among all the pre-treatments jasmine flowers treated with T_4(Sucrose 20% + GA_3 (100ppm) + Boric acid-2%) recorded minimum physiological loss in weight, maximum freshness index, minimum browning index, maximum total phenol content, maximum moisture content and minimum microbial load at the end of storage period stored under ambient condition. Shelf-life of jasmine flower treated with T_4 (Sucrose 20% + GA_3 (100ppm) + Boric acid-2% recorded higher shelf life of 4.4 days followed by T_2 (Pre-treatment with Boric acid - 2% + 150 ppm Citric acid). The T_0 (Control) recorded 2.8 days.

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