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Optimization of Post Harvest Chemical Treatments in Extending Shelf Life and Freshness Retention in Jasmine Flower (*Jasminum multiforum* L.)

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Abstract

The present study aims at the extension of shelf life of Jasmine flowers (*Jasminum multiforum* L.) which are extremely perishable in nature. Flowers were treated with different chemical treatment combinations and observed at ambient condition for 5 days. The effect of chemical treatment and packaging material on the physiological loss in weight, freshness index, flower opening index, total phenol content and respiration rate was evaluated. The optimization was carried out in design expert software with multi-level categoric design having 100 runs. The flowers treated with (Sucrose 20 % + GA3 (100ppm) + Boric acid-2%) packed in polypropylene bags of 200 gauge without ventilation were effective in extending shelf life up-to 130 hours (5.40 days) with minimum physiological loss in weight of 31.3%, higher freshness index of 59.5, lower respiration rate of 5.49 ml-Co2/kg-h and lower total phenol content of 10.33 mg/g at the end of 5 days.

Keywords : *Jasminum multiforum* L., Pre-treatment, Shelf-life extension

Floriculture has become one of the important high value agricultural industries in many countries of theworld. International trade in cut flowers is growing at a rate of 25 per cent annually. India has a long tradition of floriculture. India's share in the US $ 11 billion global market is only 0.65 per cent. The major flowers grown in India are rose, tuberose, gladiolus and jasmine. Jasmine is the oldest of the fragrant flowers cultivated by man. The flowers are used for various purposes like, making garlands, bouquets, adoring hair of women and religious offering etc. Flowers are also used for the production of essential oils in the form of 'concrete' and 'absolute' which are used in cosmetic and perfumery industries. More than 80 jasmine species are found in India, of which only three species are used for commercial cultivation *viz., Jasminum sambac* (Arabian/Tuscan jasmine), *J. auriculatum* and *J. grandiflorum* (Royal/Spanish jasmine).

Jasmine flower occupies very special and selective place among the ornamental and medicinal plants. It is also gaining priority in the loose flower trade. Jasmine (*Jasminum multiforum* L.) popularly called as 'Kakada' is one of the commercial crop grown. Proper Post harvest management in Jasmine (*Jasminum multiforum* L.) flower can enhance prices up to 5-10 times of the produce. Therefore, there is a necessity and scope for extending flower shelf life for long time.

Postharvest management and value addition to cut flowers can enhance prices up to 5-10 times of the produce. Therefore, there is a necessity and scope for extending flower shelf life for long time. The major problem in jasmine flower marketing is short span of life. Pre-treatment of flowers with suitable chemicals plays major role in extending shelf life of flowers. Various post-harvest treatments have been evolved to improve the quality including shelf life of cut flower in many ornamental plants, mainly by controlling ethylene production or its action (Ichimura *et al.,* 2003 and Ahmadi *et al.,* 2009). Keeping this in view an experiment was conducted on optimization of post-harvest chemical treatment on jasmine flower in the department of agriculture engineering.

The jasmine flowers were harvested from the experimental plots in University of Agricultural Sciences, Bangalore. Flower buds (25 g) are treated with chemical combination as given in Table 3 (Jawaharlal *et al.,* 2013; Majumder *et al.,* 2014; Ravi, 2004 and Majumder *et al.,* 2014). Treated flowers were allowed for surface drying in shade for 15 minutes. The initial weight (g) of flower buds was measured and packed in polypropylene bags (PP) of size of 24 × 14 cm and 200-gauge thickness. The samples were evaluated for quality at room temperature after every 24 hours up to five days (Jawaharlal *et al.,* 2013).

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)

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

Freshness Index (FI)

The number of flowers which retained freshness without exhibiting petal wilting and browning will be measured by visual observation using the following score expressed as per cent of fresh flowers or freshness index (Nirmala *et al.,* 1992). The score used for freshness index is given in Table 1.

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

TABLE 1

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, lightly wilted	3	X_5
Partial to half open flowers, fully wilted	2	X_6
Half to full open flowers fully wilted	1	X_7

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). The score used for flower opening index (Table 2) is given as:

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

TABLE 2

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

Shelf-Life

Shelf-life of flowers was assessed by recording the number of days up to which 50 per cent or more flowers kept fresh (50 % of freshness index score), without exhibiting pink or brown discoloration (Karuppaiah *et al.,* 2006).

Respiration Rate

The respiration rate of the flowers was measured by the closed or static system at ambient condition (27°C). Jasmine flowers were kept in the closed system under air tight condition in the glass container. The container was fitted with a silicon septum (for sampling of gases) containing ambient air as the initial atmosphere. Gas samples were drawn from the container through silicon rubber septum using needle for first and fourth day and O_2 - CO_2 concentration inside the container was measured using CO_2 analyzer (PBI Dan sensor, Denmark). Rate of respiration was calculated on the basis of evolution of CO_2 from the sample per unit per unit time using the formula (Asrey *et al.,* 2012).

$$\text{Respiration rate (ml-}CO_2\text{/kg-h) m} = \frac{CO_2 \text{ x Headspace}}{100 \text{ x Weight (kg) x time}}$$

Optimization of the Chemical Treatments

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 six responses.The objective of the optimization was to obtain best chemical pretreatment and desirability value for extending shelf life of jasmine flower.

TABLE 3

Treatment combination for various chemicals

T_0	Control
T_1	Pre-treatment with Boric acid - 4%
T_2	Pre-treatment with Boric acid -2 % + 150 ppm Citric acid
T_3	Pre-treatment with Sucrose- 2 % + STS (0.5 mM) + $KMnO_4$ (0.2%)
T_4	Sucrose 20 % + GA3 (100ppm) + Boric acid - 2%

RESULTS AND DISCUSSION

Data pertinent to the flower physiological parameters are pursued in the Table 2. Among the different post-harvest chemical treatments Jasmine flower (*Jasminum multiforum* L.) treated with T4 (Sucrose 20 % + GA3 (100ppm) + Boric acid-2%) lowered the physiological loss in weight (PLW) (16.2, 23.2, 29.9 and 31.3%, respectively) and this was followed by T2 (Pre-treatment with Boric acid - 2 % + 150 ppm Citric acid) (20.2, 26.8, 31.1 and 36.4, respectively) on second, third, fourth and fifth day after treatment. The highest weight loss (24.8, 35.6, 47.4 and 61.6, respectively) was observed in T0 (Control). Increased PLW led to decline in fresh weight of flowers, which is expressed visually assenescing symptoms such as wilting of flowers as reported in carnation (Nichols, 1966) and in Rosa damascena (Sharma, 1981). Boric acid has been used as a mineral salt that could increase the osmotic concentration and pressure potential of the petal cells, thus improving their water balance and longevity in cut flowers (Halevy, 1976 and Vanmeeteren, 1982).

Flower opening index (FOI) was comparatively lower in both treatment combinations (Sucrose and boric acid). Superior results were obtained with T2 (Pre-treatment with Boric acid - 2 % + 150 ppm Citric acid) (35.4, 41.5, 46.1 and 58.9, respectively) and this was followed by T4 (Sucrose 20 % + GA3 (100ppm) + Boric acid-2%) (39.2,47.5, 49.5 and 65.9, respectively). The higher percentage of flower opening index was found T_0 (Control) (47.2, 62.6, 73.8 and 80.2, respectively) on the consecutive second, third, fourth and fifth days. Some of the earlier findings about flower opening in cut roses have been shown to be dependent on carbohydrate status in the petals (Vandoorn *et al.*, 1990 and Marissen & Brijen, 1995). Petal growth associated with flower bud opening results from cell expansion (Kenis *et al.*, 1985), which required the influx of water and carbohydrates into petal cells (Evans and Reid, 1988). Reduced water status of flowers is known to record the lowest flower opening under ambient conditions (Vandoorn and Witte 1991). Flower opening index were observed less with 200 gauge PE bag with no ventilation

(Karuppaiah *et al.*, 2006). The results were in agreement with Jyothi Majumder *et al.,* 2014 which shows treating Tuberose with Sucrose 20 % + GA3 (100ppm) + Boric acid - 2%) stored in PP bags kept at 4°C can results in minimum flower opening index (10.33).

Treating jasmine flower with T4 (Sucrose 20 % + GA3 (100ppm) + Boric acid - 2%) maintained higher amount of freshness index (74.4, 73.5,71.4 and 59.5, respectively) followed by T1 (Pre-treatment with Boric acid - 4%) (71.7, 69.5, 69.6 and 55.05, respectively) on second, third, fourth and fifth day of storage (Table 2). Lower percentage of freshness index was found in T_0 (Control) (70.4, 68.5, 54.2 and 41.4, respectively). Presence of sucrose in solution had acted as a food source or respiratory substrate and delayed the degradation of proteins, decrease transpiration and flower remains fresh for more days (Singh *et al.*, 2018). Boric acid treatment enhances the anti-oxidant enzyme activity that might have prevented the accumulation of free radicals thus preventing the wilting of jasmine flowers (Lavanya *et al.,* 2016).

The rate of respiration is inversely proportional to flower shelf life. Rate of respiration increased during first 12 hours of storage under ambient conditions for the treatments. Lower respiration rate was found in T4 (Sucrose 20 % + GA3 (100ppm) + Boric acid -2%) (5.49 (ml-Co2/kg-h) m) followed by T2 (Pre-treatment with Boric acid - 2 % + 150 ppm Citric acid) (6.76 (ml-Co2/kg-h) m). After this respiration rate reached to its minimum value (0.26(ml-Co2/kg-h) m) at the end of 48 hours. Higher respiration rate is observed in control at the beginning and end of 48 hours (8.13 (ml-Co2/kg-h) m) and 2.09 (ml-Co2/kg-h) m). Both the chemicals GA3 and boric acid are effective in reducing respiration rate significantly by inhibiting respiratory enzymes.(Mujumder *et al.*, 2014; Chalumuru *et al.*, 2015 and Ritu, 2018).

It is evident from the data that different chemicals and storage days was found significant. The trend line shows sharp increase in total phenol content with respect to storage period. Sucrose (20%) in combination with GA3 (100ppm) and Boric acid - 2%) (T4) shows lower Total phenol content (6.73 mg/g) at the end of 120 hours (5 days) followed by T2 (8.30 mg/g). Control shows higher total phenol content (9.16 mg/g). Burzo *et al.* (1988) reported that the brown colouration might be due to accumulation of flavins and other phenolic substances in flower cell vacuoles. Low phenol content in sucrose treatment designates delayed senescence which was further seen by higher shelf life (Mohanasundari *et al.,* 2018).

Moisture content in jasmine flower during storage period decreases gradually however in T4 treatment recorded lower reduction in moisture content (71.45%). Control shows higher moisture loss reduction with 40.09 per cent. Combination of treatment including boric acid and sucrose has maintained water balance in jasmine flower (Lavanya *et al.*, 2014). A rapid decline in moisture content of flowers four days after vase holding was identified as the main cause of flower senescence in Rosahybrida 'Samantha' (Xue and Lin, 2008). Similar reduction in moisture content due to rapid water loss in petals has also been reported in Rosa hybrida (Carpenter and Rasmussen, 1974) and in anthurium (Paull & Goo, 1985 and Paull *et al.*, 1985).

Among all pretreatments,jasmine flower treated with T4 (Sucrose 20 % + GA3 (100ppm) + Boric acid - 2%) was significant and registered maximum shelf-life of 130 hours (5.40 days) followed by T2 (Pre-treatment with Boric acid - 2 % + 150 ppm Citric acid) with 112 hours (4.67 days). The shelf-life of control sample was only 68 hours (2.85 days). Chemicals like Sucrose and Boric acid helps in decreasing microbial growth their by decreasing acidity by utilizing organic acids in the respiration process helps in increasing shelf life of the flower. (Murali *et al.,* 1990 and Gowda & Gowda, 1990). The results are in line with the findings of Mukopadhyay *et al.* (1980); Nirmala & Reddy (1992) and Karuppaiah *et al.* (2006).

TABLE 4

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

Treatment	Physiological Loss in Weight (PLW %)					Freshness Index (FI)					Moisture content (%)				
	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
T_0	1.05	24.75	35.64	46.78	51.09	80.7	70.4	68.5	54.2	41.4	86.30	74.17	59.32	46.75	40.09
T_1	0.76	20.08	25.38	32.34	42.58	77.0	71.7	69.5	65.9	55.1	88.05	79.52	68.75	62.63	59.32
T_2	0.7	20.22	26.81	33.09	36.42	83.4	73.4	69.8	68.5	50.9	87.33	66.72	60.41	53.64	50.67
T_3	0.87	22.99	28.81	34.12	38.90	80.4	71.1	67.5	60.4	47.3	85.54	69.67	64.76	57.69	54.33
T_4	0.89	16.18	23.19	29.92	31.31	87.1	74.4	73.5	71.4	59.5	84.30	86.27	81.85	76.59	71.45
Mean	0.85	20.84	27.97	35.25	40.06	83.64	72.98	70.25	66.76	52.55	85.72	74.22	69.01	62.64	58.82
S.Em	0.06	1.46	2.13	2.96	3.31	1.186	0.569	0.478	2.837	2.589	0.66	3.50	4.07	5.01	5.15
CD (5 %)	0.39	4.45	6.49	9.69	15.83	3.62	1.73	1.46	8.65	7.90	2.01	10.67	12.41	15.28	15.71
CV	15.77	15.65	17.00	18.80	18.48	4.51	2.28	3.25	10.24	13.28	1.72	10.54	13.18	17.88	19.58

TABLE 4.1.

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

Treatment	Flower opening Index(FOI)					Total Phenol content (mg/g)					Respiration rate (ml-Co2/kg-h)m			
	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	12 hrs	24 hrs	36 hrs	48 hrs
T0	30.1	47.2	62.6	73.8	80.2	2.87	3.60	6.33	9.16	14.78	8.13	2.91	2.34	2.09
T1	26.5	45.3	59.2	62.3	65.9	2.16	3.01	5.65	8.79	13.09	7.63	2.33	1.90	0.21
T2	17.7	35.4	41.5	46.1	58.9	2.58	2.75	5.82	8.30	12.61	6.76	3.09	2.48	1.06
T3	28.1	46.7	61.1	70.7	79.2	2.11	2.46	5.85	8.80	14.50	8.36	2.94	2.44	1.55
T4	21.9	39.2	47.5	70.6	71.6	2.05	2.50	5.02	6.73	10.33	5.49	2.66	2.04	0.26
Mean	24.95	42.98	54.26	70.65	75.39	2.25	2.57	5.56	7.94	12.48	6.87	2.90	2.32	0.96
S.Em	2.45	2.50	4.39	5.55	4.65	0.16	0.21	0.21	0.43	0.80	0.52	0.13	0.11	0.36
CD (5 %)	7.47	7.63	13.39	16.91	14.19	0.48	0.63	0.65	1.31	2.43	1.59	0.40	0.35	1.11
CV	20.13	12.17	17.20	15.90	11.96	15.78	18.06	8.51	12.10	14.27	17.01	10.24	10.97	85.24

Assessment of Quality of Jasmine Flower and Optimization of Chemical Treatments

The adequacy of the model of jasmine flower for shelf life extension and quality parameters were tested using coefficient of determination (R^2) and F-test to interpret the effect of treatments and storage period and both the variables were also optimized for getting best results of freshness index, flower opening index, respiration rate, total phenol content and colour values. The analysis of variance was used to analyze models of jasmine flower.

Statistical Analysis of Physiological Loss in Weight (PLW)

The ANOVA table where descriptive statistical tests are presented in Table 5 showsthe p-value for the model was found highly significant ($p<0.001$). The effect of treatments and storage period on PLW at linear level was found significant at 5 per cent level of significance. As the level of storage period increases irrespective of treatments there was increase in PLW. Interactive term was also found significant. The model F-value 2463.80 implies the model is significant. There is only 0.01 per cent chance that an F-value this large could occur due to noise. The statistical analysis indicates that proposed model was adequate, possessing significant fit and very satisfactory values of R^2 for PLW.

Regression analysis was performed to fit the data of PLW. The coefficient of determination (R^2) for PLW was obtained as 0.9987 which was closer to value R^2 to unity. The predicted R^2 of 0.9977 is in reasonable agreement with adjusted R^2 of 0.9983 *i.e.,* the difference of both is less than 0.2.

The Fig. 1 revealed that the interaction effect of storage period on PLW. It shows PLW increases with

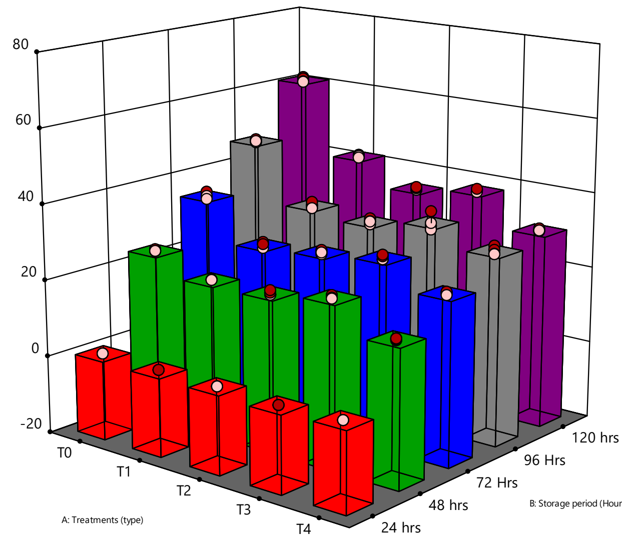

Fig 1. Interaction effect of storage period on Physiological loss in weight (PLW) of Jasmine flower

TABLE 5

ANOVA for Physiological loss in weight (PLW)

Source	Sum of Squares	df	Mean Square	F-value
Model	23595.74	24	983.16	2463.80
A-Treatments	2131.03	4	532.76	1335.10
B-Storage period	20106.54	4	5026.63	12596.79
AB	1358.17	16	84.89	212.72
R^2 (0.9987)	Adjusted R^2 (0.9983)		Predicted R^2 (0.9977)	

TABLE 6

ANOVA Table for Freshness Index

Source	Sum of Squares	df	Mean Square	F-value
Model	12262.12	24	510.92	1298.95
A-Treatments	1191.61	4	297.90	757.38
B-Storage period	10380.41	4	2595.10	6597.73
AB	690.10	16	43.13	109.66
R^2 (0.9976)	Adjusted R^2 (0.9968)		Predicted R^2 (0.9957)	

increase in storage period from 0.7 to 51.09 per cent irrespective of treatment. T_0 shows maximum reduction in PLW with 51.09 per cent.

Statistical Analysis of Freshness Index (FI)

The ANOVA table where descriptive statistical tests are presented in Table 6 shows the p-value for the model was found highly significant (p<0.001). The effect of treatments and storage period on FI at linear level was found significant at 5 per cent level of significance. As the level of storage period increases irrespective of treatments there was decrease in FI. Interactive term was also found significant. The model F-value 1298.95 implies the model is significant. There is only 0.01 per cent chance that an F-value this large could occur due to noise. The statistical analysis indicates that proposed model was adequate, possessing significant fit and very satisfactory values of R^2 for FI.

Regression analysis was performed to fit the data of PLW. The coefficient of determination (R^2) for FI was obtained as 0.9976 which was closer to value R^2 to unity. The predicted R^2 of 0.9957 is in reasonable agreement with adjusted R^2 of 0.9968 *i.e.,* the difference is less than 0.2.

The Fig. 2 revealed that the interaction effect of storage period on FI. It shows FI decreases with increase in storage period from 77 to 41.4 irrespective of treatment. T_0 shows maximum reduction in PLW with 41.4.

Statistical Analysis of Flower Opening Index (FOI)

The ANOVA table where descriptive statistical tests are presented in Table 7 shows the p-value for the

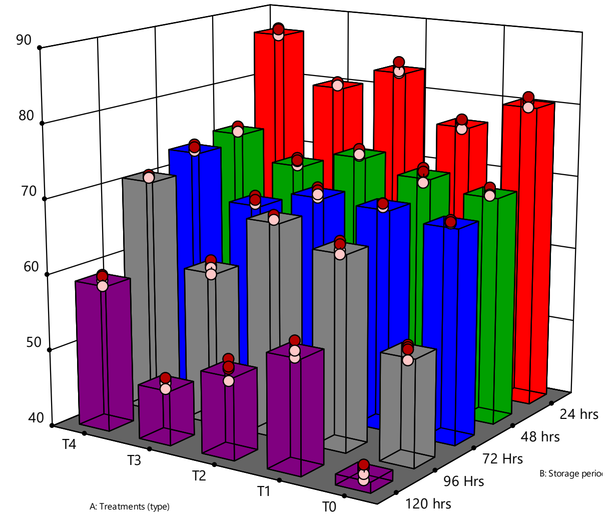

Fig 2. Interaction effect of storage period on Freshness index of Jasmine flower

model was found highly significant (p<0.001). The effect of treatments and storage period on Flower opening index (FOI) at linear level was found significant at 5 per cent level of significance. As the level of storage period increases irrespective of treatments there was increase in FOI. Interactive term was also found significant. The model F-value 2884.94 implies the model is significant. There is only 0.01 per cent chance that an F-value this large could occur due to noise. The statistical analysis indicates that proposed model was adequate, possessing significant fit and very satisfactory values of R^2 for FOI.

Regression analysis was performed to fit the data of PLW. The coefficient of determination (R^2) for FI was obtained as 0.9989 which was closer to value R^2 to unity. The predicted R^2 of 0.9981 is in reasonable agreement with adjusted R^2 of 0.9986 *i.e.,* the difference is less than 0.2.

TABLE 7

ANOVA Table for Flower opening index (FOI)

Source	Sum of Squares	df	Mean Square	F-value
Model	32214.35	24	1342.26	2884.94
A-Treatments	4502.02	4	1125.51	2419.05
B-Storage period	26642.18	4	6660.54	14315.54
AB	1070.15	16	66.88	143.76
R^2 (0.9989)	Adjusted R^2 (0.9986)		Predicted R^2 (0.9981)	

The Fig. 3 revealed that the interaction effect of storage period on FOI. It shows FOI increases with increase in storage period from 17.7 to 80.2 irrespective of treatment. T_0 shows maximum reduction in PLW with 80.2.

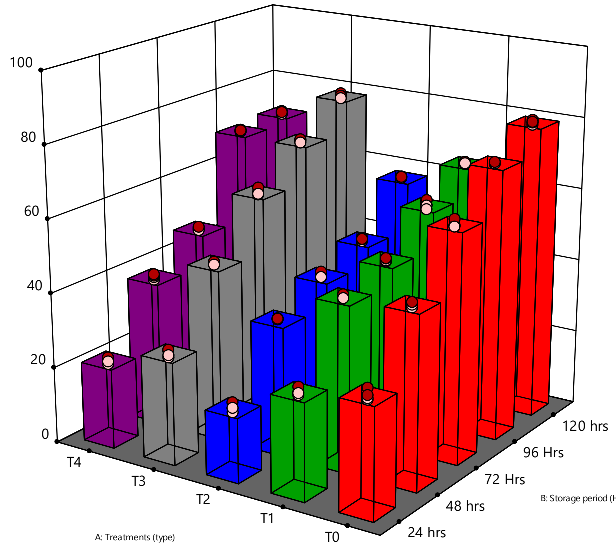

Fig 3. Interaction effect of storage period on Flower opening Index (FOI) of Jasmine flower

Statistical Analysis of Total Phenol Content

The ANOVA table where descriptive statistical tests are presented in Table 8 shows the p-value for the model was found highly significant ($p<0.001$). The effect of treatments and storage period on total phenol content at linear level was found significant at 5 per cent level of significance. As the level of storage period increases irrespective of treatments there was increase in total phenol content. Interactive term was also found significant. The model F-value 716.36 implies the model is significant. There is only 0.01 per cent chance that an F-value this large could occur due to noise. The statistical analysis indicates that proposed model was adequate, possessing significant fit and very satisfactory values of R^2 for total phenol content.

Regression analysis was performed to fit the data of total phenol content. The coefficient of determination (R^2) for total phenol content was obtained as 0.9957 which was closer to value R^2 to unity. The predicted R^2 of 0.9923 is in reasonable agreement with adjusted R^2 of 0.9943 *i.e.,* the difference is less than 0.2.

The Fig. 4 revealed that the interaction effect of storage period on total phenol content. It shows total phenol content increases with increase in storage period from 2.05 to 14.78 irrespective of treatment. T0 shows maximum increase in total phenol content with 14.78.

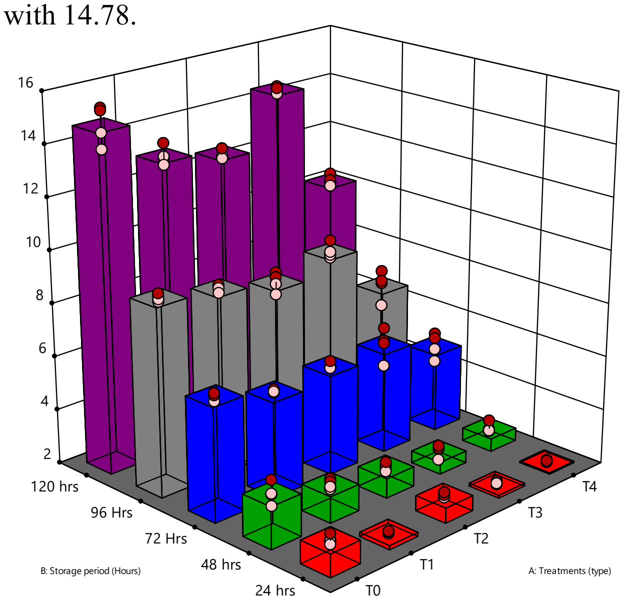

Fig 4. Interaction effect of storage period on Total phenol content of Jasmine flower

TABLE 8

ANOVA Table for Total phenol content

Source	Sum of Squares	df	Mean Square	F-value
Model	1625.39	24	67.72	716.36
A-Treatments	43.33	4	10.83	114.59
B-Storage period	1550.58	4	387.65	4100.35
AB	31.47	16	1.97	20.81
R^2 (0.9957)	Adjusted R^2 (0.9943)		Predicted R^2 (0.9923)	

Statistical Analysis of Moisture Content

The ANOVA table where descriptive statistical tests are presented in Table 9 shows the p-value for the model was found highly significant ($p<0.001$). The effect of treatments and storage period on moisture content at linear level was found significant at 5 per cent level of significance. As the level of storage period increases irrespective of treatments there was decrease in moisture content. Interactive term was also found significant. The model F-value 930.80 implies the model is significant. There is only 0.01 per cent chance that an F-value this large could occur due to noise. The statistical analysis indicates that proposed model was adequate, possessing significant fit and very satisfactory values of R^2 for moisture content.

Regression analysis was performed to fit the data of moisture content. The coefficient of determination (R^2) for total phenol content was obtained as 0.9967 which was closer to value R^2 to unity. The predicted R^2 of 0.9941 is in reasonable agreement with adjusted R^2 of 0.9956 i.e., the difference is less than 0.2.

The Fig. 5 revealed that the interaction effect of storage period on moisture content. It shows moisture content decreases with increase in storage period from 85.54 to 40.09 irrespective of treatment. T_0 shows maximum decrease in moisture content with 40.09.

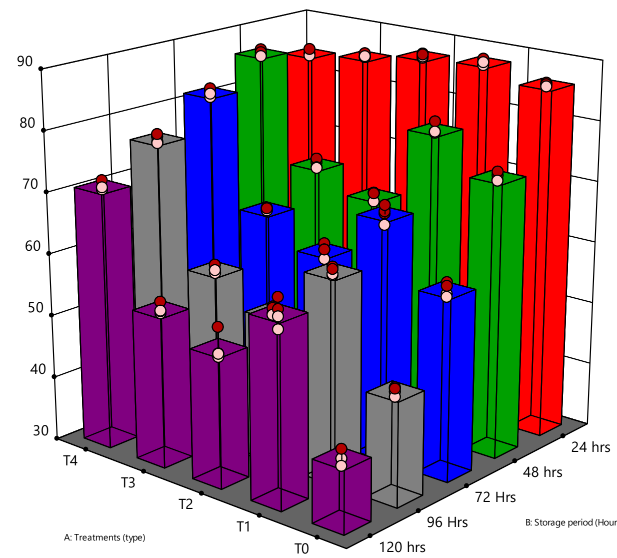

Fig 5. Interaction effect of storage period on Moisture content of Jasmine flower

TABLE 9

ANOVA Table for Moisture content

Source	Sum of Squares	df	Mean Square	F-value
Model	18904.48	24	787.69	930.80
A-Treatments	4438.33	4	1109.58	1311.18
B-Storage period	12448.57	4	3112.14	3677.59
AB	2017.58	16	126.10	149.01
R^2 (0.9967)	Adjusted R^2 (0.9956)		Predicted R^2 (0.9941)	

TABLE 10

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

Name	Goal	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Importance
A:Treatments	is in range	T0	T4	1	1	3
B:No of Hours	is equal to 120 hrs	24 hrs	120 hrs	1	1	3
Freshness Index	maximize	40.3	87.5	1	1	4
Physiological Loss in weight	minimize	0.32	62.32	1	1	3
Flower opening index	minimize	16.4	80.8	1	1	3
Total phenol content	minimize	2.01	15.4	1	1	2
Moisture content	maximize	38.86	88.56	1	1	3

TABLE 11
Desirability of Optimized pre-treatment for shelf life extension of Jasmine flower

Treatments	No of Hours	Freshness Index	PLW	Flower opening index	Total phenol content	Moisture content	Desirability	
T4	120 hrs	59.500	31.308	71.575	10.320	71.445	0.413	Selected
T1	120 hrs	55.050	42.583	65.925	13.095	59.320	0.295	
T2	120 hrs	50.900	36.417	58.850	12.615	51.017	0.268	
T3	120 hrs	47.250	38.903	79.200	14.510	54.320	0.113	
T0	120 hrs	41.400	61.580	80.175	14.775	40.093	0.026	

Optimization was done using Design Expert Software version 13.0.0. Multilevel categorical design was selected. Dependent variables *viz.,* treatments were of set within range and number of hours upto 120 hours in the criteria for optimization. Independent variables (Responses) were chosen either maximized or minimized to get the best treatment solution. The limits for different parameters to optimize the experiment is presented in Table10. There are five solutions found after analyzing variables.The best solution was obtained for T4 (Sucrose 20 % + GA3 (100ppm) + Boric acid - 2%) with best results for physiological loss in weight (31.31), freshness index (59.5), flower opening index (71.6), PLW (31.31), total phenol content (10.32), respiration rate (0.24), and moisture content (71.45) with desirability value of 0.413 (Table 11 and Fig. 6)

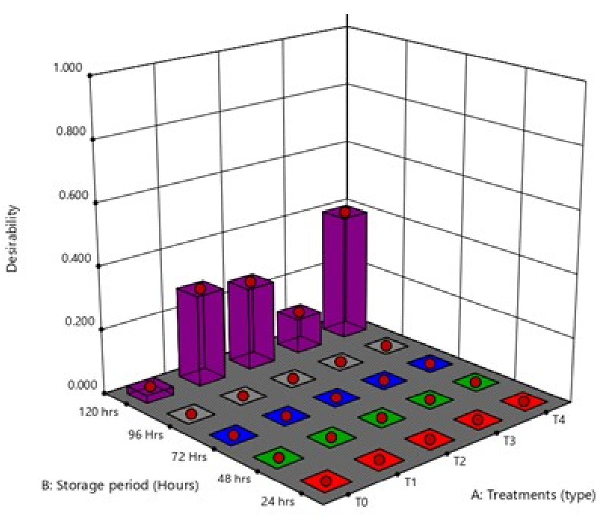

Fig.6 Desirability value obtained for optimization of experiment for jasmine flower

The study on optimization of pretreatments in extending shelf life and freshness of jasmine flower showed that flowers treated with T4 (Sucrose 20 % + GA3 (100ppm) + Boric acid - 2%) packed in polypropylene bags of 200 gauge without ventilation is effective in extending shelf life up to 130 hours (5.40 days) with minimum physiological loss in weight of 31.3 per cent, higher freshness index of 59.5, lower respiration rate of 5.49 ml-Co2/kg-h and lower total phenol content of 10.33 mg/g and higher moisture content of 71.45 per cent at the end of 5 days.

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