**Evaluation of Techniques for the Enhancement of Shelf Life in Custard Apple**

**ABSTRACT**

Custard apple is a climacteric fruit and starts ripening soon after detachment from the tree. It is a highly perishable fruit with a short shelf life of 1 to 2 days after ripening. The steady increase in area under custard apple has enhanced the fruit flow into the markets, which most of the time leads to a glut in the markets. There is a lack of information on the physiological studies to enhance the shelf life of the custard apple fruit after harvest. Therefore, it is necessary to investigate the effect of emulsions and chemicals to enhance the shelf life of custard apple and conserve the quality of the produce. The experiment was laid out in a Randomised Block Design with two replications. The experiments were framed with sixteen treatments. The varieties APK (Ca)1, Rayadurg, Balanagar and Mammoth were used as experimental materials with all normal cultural practices followed for aonla cultivation during 2022-2023. The post-harvest physiological parameters such as., Specific gravity, physiological loss in weight (%), TSS (°Brix) and acidity (pH) and percentage in decay loss were recorded after treatments. Among the treatments the fruits stored at room temperature without any treatment registered higher PLW (2.04, 3.01 and 4.07%) on 2nd, 4th and 6th day of storage and least physiological loss in weight was observed in wax emulsion 10% (0.39, 0.78, 1.26 and 1.60% at on 2nd, 4th, 6th day and 8th day of storage). Among the treatments, the fruits stored at room temperature without any treatment (control) registered the highest decay loss (14.86%) on the 6th day of storage, and the least was observed in wax emulsion treatments. Among the different pretreatments on the 4th day of storage, fruits without any treatment (control) recorded higher TSS (21.73%), but on the 6th day, total sugar decreased to 20.72%. Wax-treated fruits did not ripen even after on 8th days of storage. On the 6th day of storage, fruits treated with Calcium chloride (1.5 %) recorded higher TSS (21.68%). On the 4th day of storage, fruits without any treatment (control) recorded lower acidity (0.27%). On the 6th day of storage, fruits without any treatment (control) recorded lower acidity (0.28%), but fruits started to decay and fruits treated with Calcium chloride (1.5 %) recorded lower acidity (0.25%). Fruits treated with Calcium chloride (1.5 %) showed a longer shelf life of 5.98 days, while a shorter shelf life of 4.65 days was noticed in the control. Fruits treated with Wax emulsion (10%) showed a longer shelf life of 9.35 days, while a shorter shelf life of 5.72 days was noticed in the control.

***Key words*:** *Post-harvest Physiology, Shelf life, Custard apple varieties, Wax-treated fruits*

**Introduction**

“Vegetables are perishable; therefore, as soon as harvest maturity has occurred, speedy harvesting and handling become crucial. After harvesting, vegetables are typically handled and stored in a manner that can lead to further damage and spoilage, and every change in food that causes the food to lose its desired quality and eventually become inedible is called food spoilage or rotting” (Ibironke et al., 2025). “Detailed knowledge underpinning physiological interactions, as well as tools for precision quantification and imposition of “transient” plant physiological stress, is required before growers can implement pre-harvest management practices effectively. Another key challenge in postharvest technology is to minimise energy usage whilst not compromising produce quality, which is a more engineering issue than a biological one” (Xu, 2022). “Custard apple (*Annona squamosa* L.) is a climacteric, semi-deciduous, exotic, subtropical fruit, highly perishable in nature and consumed in many countries throughout the world. Hence, it is mostly utilised or preferred for the fresh market. Due to its climacteric nature, it ripens fast and spoils easily” (Manica, 1994). “It belongs to the family Annonaceae, is believed to be introduced in India from tropical South America” (Beerh, 1972), “and is widely distributed throughout the tropical and sub-tropical regions. It has several synonymous such as Sithaphal, Sharifa, Sugar apple, Sweet sop, etc., and more than 70 species come under the genus Annona, of which only six produce edible fruits. Custard apple is a rich source of nutrients, but it has a short storage life and has a great demand in the market. In India, custard apple is grown on marginal lands and hilly rocks with minimum inputs” (Rajput, 1985). “It is grown in Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal states. Besides India, it is common in China, the Philippines and Cuba and has commercial importance in Egypt and Central Africa. The plants are hardy and drought-resistant and can thrive well on marginal and neglected soils” (Rajput, 1985). “Custard apple is a climacteric fruit and starts ripening soon after detachment from the tree” (Wills *et al.,* 2001). “It is a highly perishable fruit with a short shelf life of 1 to 2 days after ripening. The steady increase in area under custard apple has enhanced the fruit flow into the markets, which most of the time leads to a glut in the markets” (Jalikop, 2006).

“An edible coating is a covering sheet composed of biological or chemical ingredients and utilised as a monolayer film or multilayer film on the surface of a product. Initially, edible coatings were developed to replace and decrease the usage of other kinds of chemicals and synthetic compounds that may be harmful to customers’ health” (Pham et al., 2023). “In recent years, edible waxes such as carnauba, shellac, and beeswax-based coatings have gained considerable attention as an alternative to synthetic wax coatings. Coatings developed from carnauba wax and shellac, either alone or combined with active agents, have potential for application on various fruits and vegetables, such as tomato, papaya, and mango, delaying ripening, reducing weight loss, decreasing the occurrence of diseases, and enhancing the visual appeal of the coated fruits” (Devi et al., 2025). There is a lack of information on the physiological studies to enhance the shelf life of the custard apple fruit after harvest. Therefore, it is necessary to investigate the effect of emulsions and chemicals to enhance the shelf life of custard apple and conserve the quality of the produce.

**Materials and Methods**

The experiment was laid out in a Randomised Block Design with two replications. The experiments framed with sixteen treatments viz., T1- Calcium chloride (0.5%), T2- Calcium chloride (1%), T3- Calcium chloride (1.5 %), T4- Calcium nitrate (4%), T5- Calcium nitrate (6%), T6- Calcium nitrate (8%), T7- Wax emulsion (6%), T8- Wax emulsion (8%), T9- Wax emulsion (10%), T10- GA3 Emulsion – 100 ppm, T11- GA3 Emulsion – 200 ppm, T12- GA3 Emulsion – 300 ppm, T13- Sago emulsion – 10 %, T14- Sago emulsion – 20 %, T15- Sago emulsion – 30 % and T16- Control. The APK 1 variety was chosen for this experiment. All normal cultural practices were followed for custard apple cultivation during 2023-2024. The post-harvest physiological studies, physiological loss in weight (PLW %), TSS (°Brix), Specific gravity, total sugar (%), acidity (pH) and Shelf life (Days)were measured during this experiment.

**Results and Discussion**

The result of the physiological loss in weight was recorded after pretreatments in custard apple fruits. Among the sixteen treatments, the fruits stored at room temperature without any treatment (Control) had higher PLW (10.44, 11.48, 13.47 and 14.71%) on the 2nd, 4th, 6th and 8th day of storage. However, the least physiological loss in weight was observed in wax emulsion 10% (3.11, 2.33, 2.70 and 2.58% on the 2nd, 4th, 6th day and 8th day of storage). This may have resulted from restricted availability of oxygen and CO2 accumulation and consequently reduction in respiration, leading to less moisture loss (Heining, 1975). Wax Coatings make a good oxygen and lipid barrier at low to intermediate RH because the polymers can effectively make hydrogen bonds (Sihag *et al*., 2005).

The effects of pretreatments on TSS of custard apple during storage were recorded on the 4th, 6th and 8th day of storage. Among the different pretreatments on the 8th day of storage, fruits treated with Wax emulsion (6%) recorded higher TSS (25.13, 26.64, 27.89 and 26.59% on the 2nd, 4th, 6th day and 8th day of storage). However, the fruits treated with GA3 Emulsion – 100 ppm recorded the lowest TSS of about 18.55, 19.64, 20.90 and 21.81%on the 2nd, 4th, 6th day and 8th day of storage. The lowest values with respect to PLW and TSS might be due to a low rate of respiration and transpiration caused by the wax coating. The findings are supported by Bojappa and Venkatesh Reddy (1990) in sapota; Jakhar and Singh (2008) in aonla.

The data on the specific gravity of custard apple during storage were recorded in different pretreatments. Among the treatments, the lowest specific gravity was recorded in fruits treated with wax emulsion at the concentration of 10% (1.07) on the 4th day of storage, which was followed by fruits treated with Wax emulsion at the concentration of 8% (1.07), whereas the highest specific gravity was recorded in control fruits (1.12). According to Asnath Prerna Minz et al., (2023) who stated that, the application of Paraffin wax emulsion (10%) + polythene wrap + KMnO4 (0.1%) recorded the total sugar per cent of custard apple fruit had an increasing trend up to 6 days of storage and thereafter declined on 8th days of the storage period. An increase in total sugar might be due to partial hydrolysis of complex carbohydrates.

The data on total sugar content gradually increased from the 2nd day of storage to the 8th day of storage period. Comparing the sixteen treatments, the fruits treated with Calcium chloride (0.5%) registered higher sugar content (19.33%) than the other treatments. However, the treatment GA3 Emulsion – 100 ppm had the least sugar content of about 15.26 % on the 8th day of the storage period.

On the 4th and 8th day of storage, fruits without any treatment (control) recorded lower acidity values of 0.29 % and 0.24% but fruits and the fruits treated with Wax emulsion (10%) recorded higher acidity 0.42 and 0.38 % on the 4th and 8th day of storage. Fruits treated with Wax emulsion (10%) showed a longer shelf life of 9.35 days, while a shorter shelf life of 5.72 days was noticed in the control. The lowest rotted fruits in the above treatment might be due to the inhibition of sporulation and spore germination of the rot-causing fungus by wax coating treatment (Jakhar and Singh, 2008). The presence of a thin coating of wax emulsion over the surface of the fruit leads to a reduction in oxygen concentration. As a result, the respiration of fruits may be minimised due to which reduces the degeneration of colour and softening of fruit tissues. These results are in conformity with the findings of Haribabu *et al.* (1990) and Singh *et al.* (2006) in custard apple and Sharma *et al* (2006) in kinnow mandarin fruits.

**Table 1. Effect of different treatments on PLW (%), TSS (B0) and specific gravity in fruits of
 custard apple.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Storage period (Days)** | **Storage period (Days)** | **Specific****Gravity** |
| **PLW (%)** | **TSS (%)** |
| 2 | 4 | 6 | 8 | 2 | 4 | 6 | 8 | **4th day** |
| Calcium chloride (0.5%) | 8.19 | 9.30 | 10.53 | 12.68 | 20.51 | 21.79 | 22.57 | 23.53 | 1.10 |
| Calcium chloride (1%) | 8.30 | 10.46 | 11.30 | 11.50 | 18.56 | 21.68 | 21.74 | 22.72 | 1.09 |
| Calcium chloride (1.5 %) | 8.25 | 9.41 | 11.32 | 12.59 | 21.50 | 22.57 | 23.53 | 24.83 | 1.08 |
| Calcium nitrate (4%) | 9.16 | 9.56 | 10.63 | 11.43 | 22.67 | 22.55 | 24.65 | 25.62 | 1.10 |
| Calcium nitrate (6%) | 7.47 | 9.54 | 9.58 | 11.60 | 23.77 | 24.73 | 25.55 | 26.84 | 1.09 |
| Calcium nitrate (8%) | 9.38 | 10.34 | 11.57 | 12.46 | 20.52 | 21.79 | 22.72 | 23.96 | 1.08 |
| Wax emulsion (6%) | 3.37 | 3.38 | 3.86 | 3.31 | 24.05 | 24.55 | 25.89 | 26.52 | 1.08 |
| Wax emulsion (8%) | 3.17 | 2.74 | 2.58 | 3.09 | 25.13 | 26.64 | 27.90 | 26.60 | 1.07 |
| Wax emulsion (10%) | 3.11 | 2.33 | 2.70 | 2.58 | 20.49 | 22.55 | 23.98 | 25.91 | 1.07 |
| GA3 Emulsion – 100 ppm | 8.39 | 9.26 | 10.31 | 10.75 | 18.55 | 19.64 | 20.90 | 21.81 | 1.09 |
| GA3 Emulsion – 200 ppm | 9.52 | 10.53 | 12.77 | 13.59 | 21.75 | 23.56 | 24.77 | 25.60 | 1.09 |
| GA3 Emulsion – 300 ppm | 7.55 | 8.54 | 9.79 | 9.95 | 22.81 | 23.96 | 24.73 | 26.59 | 1.09 |
| Sago emulsion – 10 % | 6.66 | 7.55 | 8.83 | 9.05 | 23.81 | 25.11 | 25.61 | 26.88 | 1.08 |
| Sago emulsion – 20 % | 5.19 | 6.43 | 7.96 | 8.61 | 20.72 | 22.70 | 25.86 | 24.58 | 1.08 |
| Sago emulsion – 30 % | 4.76 | 5.22 | 6.57 | 6.49 | 20.51 | 21.79 | 23.00 | 23.59 | 1.08 |
| Control | 10.44 | 11.48 | 13.47 | 14.71 | 21.68 | 23.53 | 24.73 | 25.93 | 1.12 |
| **SEd** | **0.131** | **0.183** | **0.196** | **0.250** | **0.484** | **0.438** | **0.503** | **0.557** | **0.025** |
| **CD (P=0.05)** | **0.267** | **0.375** | **0.400** | **0.510** | **0.989** | **0.895** | **1.028** | **1.137** | **0.051** |

**Table 2. Effect of different treatments on total sugar (%), acidity (%) and shelf life in fruits of custard apple**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Storage period (Days)** | **Storage period (Days)** | **Shelf life (Days)** |
| **Total sugar (%)** | **Acidity (%)** |
| 2 | 4 | 6 | 8 | 2 | 4 | 6 | 8 |
| Calcium chloride (0.5%) | 14.25 | 15.26 | 17.30 | 19.33 | 0.33 | 0.31 | 0.28 | 0.27 | 7.43 |
| Calcium chloride (1%) | 16.28 | 17.30 | 18.32 | 18.32 | 0.27 | 0.25 | 0.25 | 0.24 | 6.66 |
| Calcium chloride (1.5 %) | 14.25 | 15.26 | 16.28 | 18.32 | 0.31 | 0.29 | 0.28 | 0.27 | 6.99 |
| Calcium nitrate (4%) | 14.25 | 15.26 | 16.28 | 17.30 | 0.35 | 0.31 | 0.29 | 0.28 | 7.65 |
| Calcium nitrate (6%) | 14.25 | 15.26 | 17.30 | 18.32 | 0.32 | 0.30 | 0.29 | 0.29 | 7.61 |
| Calcium nitrate (8%) | 16.28 | 17.30 | 18.32 | 19.29 | 0.33 | 0.31 | 0.29 | 0.28 | 7.58 |
| Wax emulsion (6%) | 14.25 | 15.26 | 16.28 | 17.30 | 0.38 | 0.37 | 0.35 | 0.32 | 9.00 |
| Wax emulsion (8%) | 13.23 | 14.25 | 15.26 | 16.28 | 0.40 | 0.38 | 0.36 | 0.34 | 9.10 |
| Wax emulsion (10%) | 14.25 | 15.26 | 16.28 | 17.30 | 0.44 | 0.42 | 0.40 | 0.38 | 9.35 |
| GA3 Emulsion – 100 ppm | 13.23 | 14.25 | 14.25 | 15.26 | 0.31 | 0.31 | 0.29 | 0.27 | 6.47 |
| GA3 Emulsion – 200 ppm | 15.26 | 15.26 | 16.28 | 16.28 | 0.29 | 0.28 | 0.27 | 0.25 | 6.92 |
| GA3 Emulsion – 300 ppm | 12.21 | 13.23 | 14.25 | 16.32 | 0.27 | 0.27 | 0.24 | 0.23 | 7.43 |
| Sago emulsion – 10 % | 16.28 | 17.30 | 17.30 | 18.32 | 0.31 | 0.29 | 0.25 | 0.23 | 6.92 |
| Sago emulsion – 20 % | 13.23 | 17.30 | 18.32 | 18.32 | 0.38 | 0.37 | 0.35 | 0.32 | 6.68 |
| Sago emulsion – 30 % | 15.26 | 16.28 | 16.28 | 17.30 | 0.37 | 0.35 | 0.33 | 0.31 | 7.23 |
| Control | 10.18 | 12.21 | 13.23 | 14.25 | 0.30 | 0.29 | 0.27 | 0.24 | 5.72 |
| **SEd** | **0.282** | **0.269** | **0.280** | **0.315** | **0.007** | **0.006** | **0.007** | **0.006** | **0.176** |
| **CD(P=0.05)** | **0.576** | **0.549** | **0.572** | **0.644** | **0.014** | **0.013** | **0.014** | **0.012** | **0.360** |

**Conclusion:**

The result of the physiological loss in weight was recorded after pretreatments in custard apple fruits. Among the sixteen treatments, the fruits stored at room temperature without any treatment (Control) had higher PLW (10.44, 11.48, 13.47 and 14.71%) on the 2nd, 4th, 6th and 8th day of storage. However, the least physiological loss in weight was observed in wax emulsion 10% (3.11, 2.33, 2.70 and 2.58% on the 2nd, 4th, 6th day and 8th day of storage). The effect of pretreatments on TSS of custard apple during storage was recorded on the 4th, 6th and 8th day of storage. Among the different pretreatments on the 8th day of storage, fruits treated with Wax emulsion (6%) recorded higher TSS (25.13, 26.64, 27.89 and 26.59% on the 2nd, 4th, 6th day and 8th day of storage). However, the fruits treated with GA3 Emulsion – 100 ppm recorded the lowest TSS of about 18.55, 19.64, 20.90 and 21.81% on the 2nd, 4th, 6th day and 8th day of storage. The data on the specific gravity of custard apple during storage were recorded in different pretreatments. Among the treatments, the lowest specific gravity was recorded in fruits treated with wax emulsion at the concentration of 10% (1.065) on the 4th day of storage, which was followed by fruits treated with Wax emulsion at the concentration of 8% (1.073), whereas the highest specific gravity was recorded in control fruits (1.115). The data on total sugar content gradually increased from the 2nd day of storage to the 8th day of storage period. Comparing the sixteen treatments, the fruits treated with Calcium chloride (0.5%) registered higher sugar content (19.33%) than the other treatments. However, the treatment GA3 Emulsion – 100 ppm had the least sugar content of about 15.26 % on the 8th day of the storage period. On the 4th and 8th day of storage, fruits without any treatment (control) recorded lower acidity values of 0.29 % and 0.24% but fruits and the fruits treated with Wax emulsion (10%) recorded higher acidity 0.42 and 0.38 % on the 4th and 8th day of storage. Fruits treated with Wax emulsion (10%) showed a longer shelf life of 9.35 days, while a shorter shelf life of 5.72 days was noticed in the control.

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