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# Effect of 6-benzylaminopurine Treatments on Post-harvest Quality and Storage Life of Jamun (*Syzygium cumini* Skeels) Fruit

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

*Syzygium cumini* (Skeels.), commonly known as Jamun, Java plum, or black plum, is a bioactive-rich fruit recognized for its high concentrations of antioxidants, vitamins, and phytochemicals, including hydrolysable tannins, flavonoids, anthocyanins, gallic acid, and quercetin. Despite its

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nutritional and pharmacological significance, the fruit exhibits a notably short post-harvest shelf life of approximately 3–4 days under ambient conditions. This rapid perishability hinders effective storage, transportation, and commercialization, often resulting in considerable post-harvest losses. This study evaluated the impact of 6-benzylaminopurine (BAP) on extending shelf life and preserving the quality of fully ripe fruit under cold storage. Fruits were dipped in 6-benzylaminopurine (BAP) solutions (0.5, 1.0, and 1.5 mM), air-dried, and stored at 7 ± 1°C in low-density polyethylene (LDPE) bags. Two control groupsdistilled water-treated fruits in open LDPE bags and untreated fruits in sealed LDPE bagswere also included. The result demonstrated that the 1.5 mM 6-benzylaminopurine (BAP) treatment was most effective, significantly reducing spoilage and maintaining key physicochemical attributes. These findings demonstrate the potential of 6-benzylaminopurine (BAP), particularly at 1.5 mM, as a post-harvest treatment to enhance storability, reduce losses, and improve the commercial viability of jamun upto the 30 days after storage. By extending shelf life and minimizing losses, this approach can improve the availability of jamun to consumers and support its commercial viability. The results underscore the potential of 6-benzylaminopurine (BAP) as a post-harvest treatment to address storage challenges for perishable tropical fruits like jamun, contributing to reduced food waste and enhanced marketability.

*Keywords: Jamun; Bio-active compounds; 6-benzylaminopurine; low-density polyethylene.*

## 1. INTRODUCTION

The Indian blackberry (*Syzygium cumini* Skeels), commonly referred to as black plum or jamun, is a subtropical, underutilized fruit species native to the Indian subcontinent and belongs to the family Myrtaceae. The fruit is characterized by a deep purple exocarp and a purplish-pink to white mesocarp, enclosing a single, hard seed (endocarp). Jamun is a rich reservoir of essential nutrients and bioactive phytochemicals, including vitamins (ascorbic acid, retinol, niacin), minerals (calcium, iron, magnesium, phosphorus, potassium, sodium), sugars, amino acids, and a wide range of secondary metabolites (de Carvalho Tavares et al., 2016). Among the key bioactive constituents in jamun are anthocyanins, tannins, carotenoids, phenolic acids, flavonols, and flavanonols, which contribute to its recognized nutraceutical and therapeutic properties. The predominant anthocyanin pigments include malvidin and the 3,5-O-diglucosides of delphinidin, petunidin, and cyanidin (Raza et al., 2015). Additionally, compounds such as gallic acid, ellagic acid, and tannins—mainly present in the seeds—have been reported to exhibit antidiuretic activity. Other phytochemicals including lupeol, stigmasterol, and β-sitosterol are known for their significant anti-inflammatory and antinociceptive properties, suggesting the fruit's potential for pharmacological applications (Arya et al., 2017). Previous studies have also indicated the beneficial effects of jamun in regulating blood pressure (Bhargava et al., 1968), and mitigating heart, liver, and pulmonary disorders (Raza et al., 2015). Importantly, its hypoglycemic activity has been well documented, making it particularly valuable in the dietary management of diabetes mellitus (Koley et al., 2011; Ayyanar et al., 2013).

Despite its high nutritional and therapeutic value, *S. cumini* suffers from severe post-harvest losses. In India, it is estimated that approximately 0.5 million tonnes (MT) of jamun fruit are lost annually due to its extreme perishability and limited shelf life of only 2–3 days under ambient conditions (Patil et al., 2012). The fruit is harvested predominantly during the monsoonal season (mid-June to mid-August), resulting in a short harvesting window of about one month. This temporal concentration of harvest leads to market glut, forcing producers to sell their produce at reduced prices (Rai et al., 2011). The fruit's rapid post-harvest deterioration, primarily due to microbial and physiological spoilage, further complicates long-distance transportation and limits market accessibility, ultimately aggravating economic losses.

To reduce post-harvest spoilage and enhance shelf life, numerous approaches have been investigated, particularly those involving plant growth regulators. Some of the recent strategies include treatments with calcium chloride and gibberellic acid (Ayar et al., 2011), the use of antioxidant-rich edible coatings (Baraiya et al., 2015), modified atmosphere packaging techniques (Rai et al., 2011), and the application of salicylic acid in combination with chitosan coatings to slow down senescence (Saurabh et al., 2019).

One such compound, 6-benzylaminopurine (BAP), is a synthetic cytokinin known for its

capacity to delay senescence and improve post-harvest quality. 6-benzylaminopurine (BAP) has been demonstrated to reduce weight loss, spoilage, and undesirable changes in color, texture, and biochemical composition in a range of horticultural produce (Siddiqui et al., 2015; Zhang et al., 2018). Its effectiveness in preserving physicochemical and functional quality attributes during storage has been substantiated in several fruit and vegetable crops (Palma et al., 2019). Therefore, this study investigates the effectiveness of 6-benzylaminopurine (BAP) in delaying senescence and maintaining the post-harvest quality of jamun under low-temperature storage, focusing on its impact on physicochemical and functional attributes.

## 2. MATERIALS AND METHODS

Jamun fruits at the ripe stage were harvested from approximately 20-year-old trees in July 2019 and promptly transferred to the Post-harvest Laboratory, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University. The selection criteria for the fruits included uniformity in size, shape, color, and maturity, as well as the absence of blots, pests, diseases, and mechanical damage, to ensure that only healthy fruits were used for research. The fruits were disinfected with a 2% sodium hypochlorite solution for 2 minutes, air-dried, and then treated with 6-benzylaminopurine at concentrations of 0.5 mM, 1.0 mM, and 1.5 mM for 5 minutes. Control fruits were treated with distilled water under the same conditions as the treated fruits. The fruits were air-dried at room temperature, packaged in LDPE bags, and stored at 7±1°C. Quality attributes were assessed every 5 days during storage.

### 2.1 Weight Loss (WL)

The weight loss of jamun was quantified using a gravimetric approach, where the percentage weight loss was calculated using the formula: WL (%) = [(IW - FW) / IW] × 100, with IW representing the initial fruit weight and FW representing the fruit weight on the sampling day.

### 2.2 Decay Loss

This approach enabled an accurate assessment of post-harvest decay loss. The incidence of decay was evaluated by quantifying the number of fruits exhibiting symptoms of decay, and the result was expressed as a percentage of the total fruit sample observed, calculated using the formula: Decay Loss (%) = (Spoiled Fruits / Total Fruits) × 100, allowing for a precise determination of decay loss.

### 2.3 Malondialdehyde Content

MDA content in jamun fruit was determined following the protocol described by Zheng and Tian (2006). Fruit tissue (0.5 g) was homogenized in 5 mL of 5% TCA and centrifuged at 10,000 rpm for 15 min at 4°C. The supernatant (2 mL) was mixed with 2 mL of 5% TCA containing 0.6% TBA, heated at 90°C for 30 min, then rapidly cooled. Absorbance was measured at 450 and 532 nm, and MDA content was expressed as nmol/g FW.

### 2.4 Total Soluble Solids

Total soluble solids (TSS) in fruits during storage were measured using a digital refractometer (Atago, Tokyo, Japan), and the results were expressed in degrees Brix (°Brix). Titratable acidity was determined via titration method, following the standard protocol outlined by the Association of Official Analytical Chemists (AOAC, 2000).

### 2.5 Total Anthocyanins Content

The extraction of anthocyanins from 0.05 g of peel and 0.5 g of pulp was performed using 10 mL of ethanolic HCl, according to the standardized procedure described by Lees and Francis (1972). After overnight storage at a low temperature, the sample was centrifuged at 10,000 rpm for 10 minutes, and the absorbance was recorded at 535 nm. The total anthocyanin content was expressed as mg/100 g FW.

### 2.6 Ascorbic Acid Content

Jones and Hughes (1983) developed a procedure for determining ascorbic acid content in fruits. In this method, 0.2 g of fruit sample was mixed with a 3% w/v metaphosphoric acid solution, and the volume was adjusted to 20 mL. A 10 mL aliquot was taken from the solution and titrated with 2,6-dichlorophenol indophenol dye until a pink endpoint was reached. The ascorbic acid content of the fruit was expressed as milligrams per 100 grams of fresh weight (mg/100 g FW).

### 2.7 Total Phenolics Content

Total phenolic content was quantified following the method of Singleton *et al*. (1999). A 0.5 g fruit

sample was mixed with 10 mL of 80% ethanol. An aliquot of 100 µL of the extract was mixed with 2.9 mL distilled water and 0.5 mL of 1 N Folin–Ciocalteu reagent. After 3 minutes, 2 mL of 20% sodium carbonate solution was added, and the mixture was incubated for 90 minutes at room temperature. Absorbance was measured at 760 nm, and results were expressed as mg gallic acid equivalents per 100 g fresh weight (mg GAE/100 g FW).

## 2.8 Total Flavonoids Content

Zhishen *et al.* (1999) outlined a procedure for assessing the total flavonoid content in jamun fruit, where 0.5 g of fruit sample was mixed with 10 mL of methanol and then centrifuged at 10,000 rpm for 10 minutes. A precise combination of 1 mL of the supernatant, 4 mL of distilled water, and 0.3 mL of 5% sodium nitrite solution was prepared in a test tube, allowing for further analysis. After 5 minutes, 0.3 mL of 10% aluminum chloride hexahydrate ($AlCl_3 \cdot 6H_2O$) solution was added to the test tube. The solution was then incubated at room temperature for 6 minutes, followed by the addition of 1 N sodium hydroxide (NaOH) solution. The final volume was adjusted to 10 mL with distilled water. The analytical procedure involved measuring the absorbance at 510 nm, enabling the calculation of the total flavonoid content of jamun fruit as mg RE/100 g FW, providing a precise measurement of flavonoid compounds.

## 2.9 Total Antioxidant Capacity

Total antioxidant capacity was assessed using the CUPRAC (Cupric Ion Reducing Antioxidant Capacity) assay, following the protocol described by Apak *et al.* (2008), which enables reliable quantification of the fruit's antioxidant potential. The reaction mixture consisted of 100 µL of 80% ethanolic extract of fruit sample, 1 mL each of 10 mM copper(II) chloride, 7.5 mM neocuproine, ammonium acetate buffer (pH 7.0), and distilled water. After incubation at room temperature for 30 minutes, absorbance was measured at 450 nm. Results were expressed as micromoles of Trolox equivalents per gram of fresh weight (µmol TE/g FW).

## 2.10 Analysis of Data

The study was designed as a completely randomized factorial experiment comprising five treatment groups, each replicated three times. Data for all measured parameters are presented as mean values. Statistical differences among treatment means were assessed using Tukey's Honest Significant Difference (HSD) test. A significance level of $p \leq 0.05$ was established to determine statistically significant differences. All statistical analyses were performed using SAS software version 9.2 (SAS Institute Inc., Cary, NC, USA) for data interpretation.

# 3. RESULTS AND DISCUSSION

## 3.1 Weight Loss

In the present study, a progressive increase in fruit weight loss was observed across all treatments throughout the storage duration.Table 1. shows the effect of different treatments on physiological loss in weight (PLW%) of Jamun fruits during 30 days of cold storage. Fruit stored under open conditions (Control Open) exhibited the highest weight loss, reaching 27.32% at 30 days after storage (DAS). In contrast, sealing (Control Sealed) significantly reduced physiological loss in weight (PLW) to 9.10% at 30 DAS. Among the BAP (6-benzylaminopurine) treatments, 1.5 mM 6-benzylaminopurine (BAP) was most effective, resulting in the lowest weight loss of 4.67% at 30 DAS, followed by 1.0 mM (5.61%) and 0.5 mM (7.30%). These results indicate that 6-benzylaminopurine (BAP), particularly at 1.5 mM, effectively reduces PLW by delaying senescence and maintaining fruit integrity during storage. Fruits and vegetables often experience weight loss after harvest during storage, which can significantly reduce their consumer appeal and marketability. The primary cause of weight loss in jamun is the rapid loss of water due to its thin skin, resulting in fruit shrinkage during post-harvest storage. Additionally, weight loss leads to a loss of texture, compromising visual appeal and ultimately reducing consumer acceptance. The role of 6-benzylaminopurine (BAP) in reducing weight loss of fruit can be related to a strengthening of cell wall (Massolo et al., 2014) and reduction in respiration rate (An et al., 2006). The effectiveness of 6-benzylaminopurine (BAP) in reducing weight loss during post-harvest storage has also been reported in other crops such as Mangosteen (Efendi and Hermawati, 2010), cherimoya (Franco-Mora et al., 2015), apricot (Canli et al., 2014) and pointed gourd (Yadav et al., 2022).

## 3.2 Decay Loss

Jamun fruits deteriorate rapidly after harvesting due to spoilage-causing microorganisms that

enter through the thin skin and stem-end. Their delicate nature also makes them prone to mechanical damage, increasing susceptibility to infection. Table 1. shows that 6-benzylaminopurine (BAP) treatments effectively reduced disease incidence during low-temperature storage. The data reveals a progressive increase in decay loss in Jamun fruits during storage, particularly after 15 days. The Control Open samples exhibited the highest decay loss, reaching 34.30% at 30 days after storage (DAS), whereas the Control Sealed samples demonstrated a lower yet significant decay of 20.30%. BAP treatments were effective in reducing decay, with 1.5 mM BAP yielding the most favorable results, showing only 9.87% decay at 30 DAS. This was followed by 1.0 mM (14.48%) and 0.5 mM (19.35%). Notably, all treatments exhibited zero decay up to 15 DAS. These findings suggest that BAP, particularly at 1.5 mM, significantly delays the onset of decay and extends shelf life. This study showed that post-harvest 6-benzylaminopurine (BAP) application significantly reduced spoilage in jamun fruit. BAP may limit pathogen attack by delaying cell wall degradation and softening (Massolo et al., 2014) and enhancing the expression of defense-related proteins and genes (Ge et al., 2011; Kachroo and Robin, 2013). Similar effects were observed in litchi fruit (Zhang et al., 2018).

### 3.3 Malondialdehyde Content

Malondialdehyde, produced during lipid peroxidation by reactive oxygen species, serves as a common marker of fruit senescence, ripening, and tissue damage. In this study, malondialdehyde content increased progressively with storage duration. Table 1. presents the effects of 6-benzylaminopurine (BAP) treatments on malondialdehyde (MDA) content, a marker of lipid peroxidation and membrane damage, in Jamun fruits during storage. The Control Open samples exhibited the highest MDA accumulation, reaching 9.73 nmol/g at 30 DAS, indicative of increased oxidative stress. In contrast, Control Sealed fruits demonstrated slightly lower MDA levels (9.20 nmol/g). BAP-treated fruits exhibited a significant reduction in MDA content, with 1.5 mM 6-benzylaminopurine (BAP) proving most effective, limiting MDA to 7.63 nmol/g at 30 DAS. BAP concentrations of 1.0 mM and 0.5 mM also reduced MDA levels to 8.51 and 8.69 nmol/g, respectively. These findings underscore the protective role of BAP, particularly at 1.5 mM, in mitigating oxidative stress and preserving membrane stability during storage.This indicated that the treatment was highly effective in delaying senescence and maintaining better membrane integrity of the jamun fruit during storage.The results of this study demonstrate that 6-benzylaminopurine (BAP) treatments significantly reduce malondialdehyde accumulation in fruits by enhancing reactive oxygen species (ROS) scavenging capacity, thereby maintaining membrane integrity during storage.

### 3.4 Total Anthocyanins Content in Fruit Peel and Pulp

The results of this study showed that the total anthocyanin content of jamun fruit decreased gradually across all treatments during storage, likely due to enzymatic and non-enzymatic degradation reactions. Treatment with BAP may have stimulated phenylalanine ammonia lyase (PAL) activity, leading to increased anthocyanin synthesis and retention in jamun fruit. Anthocyanin content, responsible for the characteristic deep purple colour and antioxidant properties of Jamun, gradually decreased in both peel and pulp during cold storage (Table 2). However, fruits treated with BAP particularly at 1.5 mM showed significantly better retention of anthocyanins throughout the storage period. At 30 days after storage (DAS), the 1.5 mM BAP treatment preserved the highest levels of both peel (336.10 mg/100g FW) and pulp anthocyanins (6.28 mg/100g FW), whereas the untreated fruits stored under open conditions (Control Open) showed a marked decline, retaining only 273.13 mg/100g FW in peel and 4.87 mg/100g FW in pulp. This suggests that BAP effectively slows down anthocyanin degradation, possibly by reducing oxidative stress and delaying senescence, thereby helping maintain the fruit's visual appeal and nutritional quality during extended storage. Several studies have linked increased anthocyanin accumulation with enhanced PAL activity. Post-harvest 6-benzylaminopurine (BAP) treatment in jamun may have stimulated PAL activity, boosting anthocyanin synthesis and retention. Additionally, 6-benzylaminopurine (BAP) likely suppressed polyphenol oxidase (PPO) activity, further supporting the preservation of anthocyanin pigments (Zhang et al., 2018).

### 3.5 Total Soluble Solids

TSS (Total Soluble Solids) is a key quality indicator in the food industry, reflecting the

concentration of soluble compounds in fruits and vegetables. It helps assess ripeness, flavor, and processing suitability. In jamun, TSS includes sugars, acids, and vitamins, with major sugars being sucrose, fructose, maltose, glucose, galactose, and mannose (Noomrio & Dahot, 1996).In this experiment, Table 3, presentdata pertaining to the effect of different 6-benzylaminopurine treatments on total soluble solids content in *jamun* fruit. Total soluble solids (TSS), an important indicator of fruit sweetness and ripeness, initially increased in all treatments during early storage, and then gradually declined as storage progressed. The untreated control fruits stored in open conditions showed the highest early spike in TSS (17.63% at 15 DAS) but experienced a sharp decline, thereafter, dropping to 12.86% by 30 DAS. In contrast, fruits treated with BAP, especially at 1.5 mM, maintained more stable TSS levels over time. At 30 DAS, BAP (1.5 mM) retained the highest TSS (14.2%), significantly outperforming the open control, which reflects BAP's effectiveness in preserving fruit quality and delaying metabolic deterioration during storage. BAP treatment probably decreased respiration rate in fruit thereby reducing utilization of the respiratory materials, as a consequence delayed loss of soluble solids (Siddiqui et al., 2015).

## 3.6 Ascorbic Acid Content

Ascorbic acid content is an important quality attribute in fruit, offering nutritional benefits and antioxidant properties (Yahia et al., 2001). The ascorbic acid content, a crucial antioxidant and quality indicator in fruits, generally decreased during storage across all treatments. Nevertheless, fruits treated with BAP, particularly those subjected to 1.5 mM BAP, exhibited significantly better retention of ascorbic acid over time (Table 3). At 30 DAS, fruits treated with 1.5 mM BAP maintained the highest ascorbic acid level (29.31 mg/100 g), which was markedly higher than both the open (21.99 mg/100 g) and sealed control fruits (22.42 mg/100 g). This indicates that 6-benzylaminopurine (BAP) at 1.5 mM effectively delays vitamin C degradation, thereby enhancing the nutritional and antioxidant profile of jamun during extended cold storage.BAP treatment in jamun may help slow the breakdown of ascorbic acid by reducing the respiration rate and modulating senescence-related processes (Siddiqui et al., 2015). Similarly, post-harvest application of BAP has been shown to preserve ascorbic acid levels in cherimoya fruit (Franco-Mora et al., 2015).

## 3.7 Total Phenolics Content

In plants, phenolic compounds are synthesized as secondary metabolites. No significant differences in phenolic content were observed between treated and untreated jamun after 5 days of storage. A similar trend was also observed after 20 days of storage (Table.3). At the commencement of storage, phenolic levels were comparable across treatments. However, by 30 days after storage (DAS), the fruits treated with 1.5 mM BAP retained 274.33 mg gallic acid equivalent (GAE)/100g FW, whereas the control fruits stored in open bags decreased to 225.33 mg GAE/100g FW, and the sealed control fruits to 229.66 mg GAE/100g FW. A higher retention of phenolic compounds was observed in fruit treated with 1.5 mM BAP, with the maximum effect noted at the highest concentration. This suggests that BAP treatment helped in maintaining higher antioxidant levels during cold storage, possibly by reducing oxidative stress and delaying senescence. Jamun fruit is rich in phenolic compounds, including flavonoids, anthocyanins, and tannins, which contribute to its antioxidant and nutraceutical properties (Baraiya et al., 2015). Major phenolics include gallic, ferulic, ellagic, and chlorogenic acids, catechin, and caffeic acid. BAP application has been reported to maintain phenol content, possibly by inhibiting polyphenol oxidase activity and reducing phenolic oxidation (Zhang et al., 2018).

## 3.8 Total Flavonoids Content

Flavonoids, a group of polyphenolic secondary metabolites with strong antioxidant properties, are present in Jamun fruit in forms such as dihydroquercetindiglucoside, myricetin glucoside, rhamnoside, acetyl-rhamnoside, and pentoside (Jagetia, 2017). In this study, the total flavonoid content in Jamun fruits exhibited a gradual decline during cold storage across all treatments. However, the rate of decline was significantly slower in BAP-treated fruits, particularly at the 1.5 mM concentration (Table 4). Fruits treated with 1.5 mM BAP consistently retained higher flavonoid levels at 5-day intervals compared to controls. Notably, flavonoid content in BAP-treated fruits remained relatively stable up to 20 days of storage, while the control fruits, especially those stored in open packets, showed a more rapid decline. By 30 days after storage (DAS), the highest flavonoid content was recorded in the 1.5 mM BAP-treated fruits (33.33 mg rutin equivalent (RE)/g), in contrast to 25.2 mg rutin equivalent (RE)/g in the open control

**Table 1. Effect of 6-benzylaminopurine on malondialdehyde content (nmol/g FW) of *jamun* fruit during storage at low temperature. Vertical bars represent standard error of means (n= 3). Bars with different letters on each sampling day indicate significant difference (p ≤ 0.05) among treatments**

| | Treatments | Days after storage (DAS) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5 DAS | 10 DAS | 15 DAS | 20 DAS | 25 DAS | 30 DAS |
| Physiological loss in weight (%) | Control Open | 2.53 ± 0.12 a | 5.07 ± 0.25 a | 11.4 ± 0.4 a | 17.2 ± 0.52 a | 23.3 ± 0.41 a | 27.32 ± 0.80 a |
| | Control Sealed | 0.59 ± 0.08 bc | 1.35 ± 0.18 b | 2.6 ± 0.10 b | 5.4 ± 0.33 b | 6.64 ± 0.18 b | 9.10 ± 0.26 b |
| | BAP(0.5 mM) | 0.52 ± 0.06 bc | 0.92 ± 0.01 b | 1.23 ± 0.02 c | 4.32 ± 0.11 bc | 4.88 ± 0.19 c | 7.30 ± 0.19 bc |
| | BAP(1.0 mM) | 0.83 ± 0.02 b | 1.13 ± 0.09 b | 1.63 ± 0.03 bc | 3.08 ± 0.29 cd | 3.59 ± 0.10 d | 5.61 ± 0.03 cd |
| | BAP(1.5 mM) | 0.36 ± 0.00 c | 0.94 ± 0.04 b | 1.36 ± 0.17 c | 2.78 ± 0.11 d | 3.49 ± 0.14 d | 4.67 ± 0.12 d |
| Decay loss (%) | Control Open | 0 | 0 | 0 | 11.18 ± 0.68 a | 17.29 ± 0.44 a | 34.30 ± 2.12 a |
| | Control Sealed | 0 | 0 | 0 | 7.76 ± 0.20 b | 9.9 ± 0.37 c | 20.30 ± 1.12 b |
| | BAP(0.5 mM) | 0 | 0 | 0 | 5.45 ± 0.45 c | 13.84 ± 0.63 b | 19.35 ± 0.68 b |
| | BAP(1.0 mM) | 0 | 0 | 0 | 5.31 ± 0.26 c | 9.77 ± 0.25 c | 14.48 ± 0.75 c |
| | BAP(1.5 mM) | 0 | 0 | 0 | 2.12 ± 0.32 d | 5.91 ± 0.48 d | 9.87 ± 0.35 d |
| Malondialdehyde content (nmol/ g) | Control Open | 2.82 ± 0.14 a | 3.93 ± 0.20 a | 5.00 ± 0.09 a | 6.21 ± 0.20 a | 7.44 ± 0.23 a | 9.73 ± 0.08 a |
| | Control Sealed | 2.53 ± 0.07a | 3.61 ± 0.18a | 3.95 ± 0.14 b | 5.29 ± 0.15 b | 6.69 ± 0.14 ab | 9.20 ± 0.28 ab |
| | BAP(0.5 mM) | 2.62 ± 0.18 a | 3.37 ± 0.19 a | 4.03 ± 0.69 b | 5.17 ± 0.29 b | 6.61 ± 0.24 ab | 8.69 ± 0.12 b |
| | BAP(1.0 mM) | 2.54 ± 0.15 a | 2.93 ± 0.08 a | 3.79 ± 0.25 b | 5.11 ± 0.07 b | 5.87 ± 0.22 bc | 8.51 ± 0.22 bc |
| | BAP(1.5 mM) | 2.58 ± 0.11 a | 3.16 ± 0.03 a | 3.55 ± 0.22 b | 4.59 ± 0.15 b | 5.30 ± 0.14 c | 7.63 ± 0.16 c |

**Table 2. Effect of 6-benzylaminopurine on total peel and pulp anthocyanin content (mg/100g FW) of *jamun* fruit during storage at low temperature. Vertical bars represent standard error of means (n= 3). Bars with different letters on each sampling day indicate significant difference (p ≤ 0.05) among treatments**

| Parameters | Treatments | Days after storage (DAS) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5 DAS | 10 DAS | 15 DAS | 20 DAS | 25 DAS | 30 DAS |
| Total peel anthocyanin content (mg/100g FW) | Control Open | 489.11 ± 8.77 a | 489.01 ± 8.28 a | 446.46 ± 15.15 a | 403.49 ± 8.81 a | 339.96 ± 7.91 a | 273.13 ±14.59 b |
| | Control Sealed | 493.44 ± 16.59 a | 498.92 ± 12.17 a | 450.13 ± 9.05 a | 416.18 ± 5.99 a | 353.31 ± 11.58 a | 289.53 ± 8.78 ab |
| | BAP(0.5 mM) | 497.78 ± 11.13 a | 502.71 ± 14.58 a | 472.57 ± 12.92 a | 444.52 ± 18.99 a | 349.37 ± 14.48 a | 302.28 ± 9.03 ab |
| | BAP(1.0 mM) | 488.47 ± 17.69 a | 488.23 ± 9.63 a | 467.82 ± 16.34 a | 443.55 ± 16.24 a | 376.62 ± 4.81 a | 319.08 ± 19.15 ab |
| | BAP(1.5 mM) | 530.70 ± 11.27 a | 514.07 ± 11.71 a | 490.18 ± 8.07 a | 460.57 ± 7.75 a | 392.09 ± 14.4 a | 336.10 ± 10.91 a |
| Total pulp anthocyanin content (mg/100g FW) | Control Open | 12.25 ± 0.41 a | 9.99 ± 0.33 a | 8.45 ± 0.29 a | 7.66 ± 0.33 a | 6.56 ± 0.27 a | 4.87 ± 0.08 b |
| | Control Sealed | 11.91 ± 0.48 a | 10.02 ± 0.24 a | 9.04 ± 0.28 a | 8.07 ± 0.32 a | 6.98 ± 0.06 a | 4.94 ± 0.43 b |
| | BAP(0.5 mM) | 12.34 ± 0.25 a | 10.39 ± 0.19 a | 9.09 ± 0.25 a | 7.92 ± 0.40 a | 7.00 ± 0.41 a | 5.02 ± 0.09 b |
| | BAP(1.0 mM) | 12.65 ± 0.30 a | 11.00 ± 0.34 a | 9.58 ± 0.29 a | 8.32 ± 0.32 a | 6.84 ± 0.45 a | 5.71 ± 0.10 ab |
| | BAP(1.5 mM) | 12.95 ± 0.25 a | 10.97 ± 0.32 a | 9.68 ± 0.29 a | 8.83 ± 0.12 a | 7.75 ± 0.19 a | 6.28 ± 0.28 a |

**Table 3. Effect of 6-benzylaminopurine on total soluble solids (%), ascorbic acid (mg/ 100g) and phenolics content (mg GAE/100g FW)of *jamun* fruit during storage at low temperature. Vertical bars represent standard error of means (n= 3). Bars with different letters on each sampling day indicate significant difference (p ≤ 0.05) among treatments**

| Parameters | Treatments | Days after storage (DAS) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5 DAS | 10 DAS | 15 DAS | 20 DAS | 25 DAS | 30 DAS |
| Total soluble solids (%) | Control Open | 14.5 ± 0.11 ab | 16.26 ± 0.17 a | 17.63 ± 0.17 a | 16.93 ± 0.18 a | 13.93 ± 0.52 a | 12.86 ± 0.18 b |
| | Control Sealed | 14.36 ± 0.08 ab | 15.6 ± 0.41ab | 16.03 ± 0.23 b | 15.7 ± 0.32 ab | 14.2 ± 0.20 a | 13.33 ± 0.24 ab |
| | BAP(0.5 mM) | 13.86 ± 0.16 b | 14.8 ± 0.11 b | 15.5 ± 0.17 bc | 14.53 ± 0.38 b | 14.36 ± 0.20 a | 13.46 ± 0.23 ab |
| | BAP(1.0 mM) | 14.76 ± 0.18 a | 15.23 ± 0.35 ab | 14.93 ± 0.08 c | 14.76 ± 0.36 b | 14.73 ± 0.32 a | 13.53 ± 0.12 ab |
| | BAP(1.5 mM) | 14.33 ± 0.18 ab | 15.06 ± 0.29 ab | 15.16 ± 0.23 bc | 14.86 ± 0.29 b | 14.6 ± 0.20 a | 14.2 ± 0.23 a |
| Ascorbic acid content (mg/ 100 g) | Control Open | 58.80 ± 2.15 a | 48.10 ± 1.00 c | 41.50 ± 1.12 a | 34.63 ± 1.21 a | 27.08 ± 1.12 a | 21.99 ± 1.19 b |
| | Control Sealed | 60.62 ± 0.83 a | 54.63 ± 0.88 a | 44.44 ± 1.05 a | 35.42 ± 2.54 a | 31.20 ± 2.22 a | 22.42 ± 1.50 b |
| | BAP(0.5 mM) | 60.46 ± 1.78 a | 48.60 ± 0.93 bc | 45.78 ± 1.90 a | 37.16 ± 1.64 a | 33.26 ± 1.71 a | 23.68 ± 0.73 ab |
| | BAP(1.0 mM) | 63.19 ± 1.04 a | 53.31 ± 1.16 ab | 41.13 ± 1.87 a | 38.29 ± 1.87 a | 34.25 ± 1.31a | 25.40 ± 1.68 ab |
| | BAP(1.5 mM) | 62.38 ± 2.07 a | 55.42 ± 1.06 a | 44.28 ± 0.89 a | 40.15 ± 1.73 a | 35.96 ± 1.15a | 29.31 ± 1.75 a |
| Phenolics content (mg GAE/100g FW) | Control Open | 440.66 ± 7.21 a | 370.66 ± 11.05 a | 351.66 ± 6.71 a | 319.66 ± 11.46 a | 278.66 ± 5.48 a | 225.33 ± 4.09 a |
| | Control Sealed | 460.33 ± 12.91 a | 404.66 ± 22.39 a | 357.66 ± 14.11 a | 326 ± 5.19 a | 270.66 ± 11.21 a | 229.66 ± 11.97 a |
| | BAP(0.5 mM) | 456 ± 16.52 a | 399.66 ± 9.26 a | 368.33 ± 9.93 a | 343.66 ± 13.44 a | 283.00 ± 11.59a | 255.66 ± 9.33 a |
| | BAP(1.0 mM) | 468.33 ± 8.76 a | 406.33 ± 10.26 a | 350.66 ± 3.38 a | 330 ± 7.37 a | 301.66 ± 4.25 a | 257.66 ± 18.88 a |
| | BAP(1.5 mM) | 472.33 ± 8.00 a | 420 ± 6.08 a | 368.33 ± 13.13 a | 345.66 ± 9.83 a | 305 ± 11.71 a | 274.33 ± 7.62 a |

**Table 4. Effect of 6-benzylaminopurine treatments on total flavonoid content (mg RE/ g) and total antioxidant capacity (µmol TE/g FW) of *jamun* fruit during storage at low temperature. Vertical bars represent standard error of means (n= 3). Bars with different letters on each sampling day indicate significant difference (p ≤ 0.05) among treatments**

| Parameters | Treatments | Days after storage (DAS) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5 DAS | 10 DAS | 15 DAS | 20 DAS | 25 DAS | 30 DAS |
| Total flavonoid content (mg RE/ g) | Control Open | 62.06 ± 2.49 a | 54.46 ± 1.39 a | 48.26 ± 1.07 b | 42 ± 1.61 a | 33.93 ± 1.83 b | 25.2 ± 1.05 b |
| | Control Sealed | 62.6 ± 3.29 a | 58.93 ± 2.88 a | 51.2 ± 1.05 ab | 45.33 ± 2.09 a | 36.2 ± 1.03 ab | 26.73 ± 0.46 b |
| | BAP(0.5 mM) | 60.53 ± 2.35 a | 58.6 ± 1.81 a | 51 ± 0.70 ab | 45.06 ± 1.50 a | 39.06 ± 1.04 ab | 28.86 ± 0.63 ab |
| | BAP(1.0 mM) | 61.6 ± 2.80 a | 59.86 ± 1.27 a | 53.2 ± 1.22 a | 45.33 ± 0.93 a | 40.26 ± 1.57 a | 29.6 ± 1.55 ab |
| | BAP(1.5 mM) | 62.33 ± 1.33 a | 59.33 ± 2.18 a | 53.13 ± 1.15 ab | 46.73 ± 1.27 a | 40.93 ± 0.35 a | 33.33 ± 1.39 a |
| Total antioxidant capacity (mg CE/100g FW) | Control Open | 10.19 ± 0.08 a | 9.60 ± 0.06 a | 8.38 ± 0.26 b | 7.41 ± 0.14 a | 6.30 ± 0.18 c | 4.86 ± 0.11 c |
| | Control Sealed | 10.17 ± 0.08 a | 9.92 ± 0.12 a | 8.43 ± 0.12 b | 7.69 ± 0.17 a | 6.66 ± 0.12 bc | 5.51 ± 0.19 bc |
| | BAP(0.5 mM) | 10.49 ± 0.11 a | 9.77 ± 0.11 a | 9.15 ± 0.09 a | 7.85 ± 0.17 a | 7.18 ± 0.09 ab | 5.72 ± 0.12 ab |
| | BAP(1.0 mM) | 10.64 ± 0.06 a | 10.07 ± 0.13 a | 9.29 ± 0.08 a | 8.58 ± 0.13 a | 7.42 ± 0.04 a | 6.15 ± 0.13 ab |
| | BAP(1.5 mM) | 10.49 ± 0.25 a | 10.07 ± 0.11 a | 9.35 ± 0.11 a | 8.88 ± 0.24 a | 7.70 ± 0.09 a | 6.34 ± 0.20 a |


**Fig. 1. Appearance of 6-benzylaminopurine treated and untreated jamun fruit after 30 days of storage**

and 26.73 mg rutin equivalent (RE)/g in the sealed control. These findings suggest that BAP treatment, particularly at higher concentrations, effectively preserved flavonoid compounds by mitigating oxidative degradation and delaying senescence, thereby enhancing the nutritional and functional quality of jamun during extended cold storage.

## 3.9 Total Antioxidant Capacity (CUPRAC)

Jamun fruit's total antioxidant capacity is attributed to various bioactive compounds, including anthocyanins, phenols, flavonoids, and ascorbic acid. During the initial 10 days of storage, the total antioxidant capacity of both treated and untreated fruits remained relatively stable. However, by the 15th day of storage, fruits treated with BAP at concentrations of 0.5 mM, 1.0 mM, and 1.5 mM demonstrated significantly higher antioxidant capacity compared to the control fruits (Table 4). Among the treatments, BAP at 1.0 mM and 1.5 mM consistently maintained elevated antioxidant levels throughout the storage period. By the final day of storage (30 DAS), fruits treated with 1.5 mM BAP exhibited the highest total antioxidant capacity (6.34 mg CE/100g FW), whereas the lowest value was recorded in fruit stored in open LDPE packets without any treatment (4.86 mg CE/100g FW). Notably, there was no significant difference in antioxidant capacity between fruits treated with 0.5 mM BAP and the sealed control. These findings indicate that higher concentrations of BAP are more effective in preserving antioxidant potential by mitigating oxidative stress and delaying senescence during cold storage.BAP treatment has been shown to reduce ROS accumulation, contributing to enhance antioxidant capacity. Similarly, Zhang et al. (2018) reported that post-harvest BAP application preserves antioxidant capacity in litchi fruit.

## 4. CONCLUSION

This study investigated the effects of 6-Benzylaminopurine (BAP) on the post-harvest quality and shelf life of Jamun (*Syzygium cumini* Skeels) under controlled low-temperature storage conditions. After surface disinfection using 0.1% sodium hypochlorite, fruits were

treated with BAP at concentrations of 0.5, 1.0, and 1.5 mM, while distilled water served as the control. Among the tested concentrations, 1.5 mM BAP proved to be the most effective, significantly improving key quality attributes such as weight retention, total soluble solids, and biochemical composition. Overall, BAP at 1.5 mM emerged as the optimal treatment for preserving post-harvest quality and extending the shelf life of jamun fruit during cold storage upto 30 days after storage.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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