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Biochemical Characterization of Mixed Fruit Jam Under Storage Conditions

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Abstract

Research was conducted during January - June 2025 at the Post Harvest and Value Addition Laboratory, Mewar University Gangrar, Chittorgarh (Rajasthan) to evaluate the effect of different fruit pulp compositions on the quality attributes of mixed fruit jam during storage. The result revealed that among the treatments, T_1 (125 g each of apple, banana, papaya, and strawberry pulp + 500 ml wood apple juice + 1000 g sugar) recorded the highest total soluble solids (69.65, 70.50 and 70.98 °Brix), ascorbic acid content (51.65, 50.71 and 49.43 mg/100g), and titratable acidity (0.47, 0.45 and 0.42%) at 0, 30, and 60 days after storage, indicating a better retention of the biochemical parameters. The highest tannin content (1.95, 2.05, and 2.07%) was observed in T_9 (1000 ml wood apple juice + 1000 g sugar), highlighting the influence of wood apple juice on tannin levels. Overall, T_1 was found to be the most suitable formulation for producing high-quality mixed fruit jam with improved storage stability.

***Key words*:** Jam, Biochemical, Storage period, TSS, Ascorbic acid, titratable acidity, Tannin

Jam-making is an age-old method of fruit preservation that extends the shelf life of the seasonal and highly perishable fruits, enabling year-round consumption [1]. In recent years, mixed fruit jams have gained popularity due to their unique combination of flavors, enhanced nutritional profile and an appeal to health-conscious consumers [2]. In recent times, mixed fruit jams have emerged as a significant trend, driven by their capacity to deliver unique and intricate flavor combinations that single-fruit jams cannot achieve, alongside an enhanced nutritional profile derived from the diverse array of vitamins, minerals, and antioxidants contributed by multiple fruits. This confluence of complex flavors and improved nutritional content makes mixed fruit jams particularly appealing to the growing demographic of health-conscious consumers, offering a convenient and palatable means to incorporate a broader spectrum of fruit-derived benefits into their diet [3]. The thoughtful combination of diverse fruits like wood apple (*Limonia acidissima*), apple (*Malus domestica*), strawberry (*Fragaria* × *ananassa*), banana (*Musa spp.*), and papaya (*Carica papaya*) in a single product, such as a mixed fruit jam, offers a compelling synergy that transcends mere taste enhancement to deliver significant functional health benefits. This blend improves taste by creating complex and appealing flavor profiles, where the unique tang of wood apple can be balanced by the sweetness of banana and papaya, and the familiar crispness of apple complemented by the juicy tartness of strawberry. Beyond sensory pleasure, this combination provides a "consortium of vitamins, minerals, and antioxidants," leveraging the distinct nutritional strengths of each fruit. For instance, Wood Apple is rich in beta-carotene (a precursor to Vitamin A), B vitamins, and powerful phytochemicals with antioxidant, hepatoprotective, and anti-inflammatory properties, while Apples contribute various polyphenols and fiber, linked to reduced risk of chronic diseases like cancer and improved digestive and cardiovascular health [4]. Strawberries are a powerhouse of Vitamin C and polyphenols like anthocyanins, offering strong antioxidant and anti-inflammatory effects that support heart health, brain function, and immune system strength. Bananas provide essential potassium for blood pressure regulation and muscle function, as well as B vitamins and dietary fiber for digestive health and sustained energy. Papaya, with its high Vitamin C content, papain enzyme, and antioxidants like lycopene and beta-carotene, aids digestion, boosts immunity, supports skin health, and has anti-inflammatory properties. By combining these fruits, a mixed jam becomes a concentrated source of these varied nutrients, offering a holistic approach to wellness, and appealing to health-conscious consumers seeking both deliciousness and a broad spectrum of beneficial compounds in a convenient form [5].

Developing high-quality mixed fruit jams necessitates a meticulous scientific standardization of fruit pulp ratios, sugar levels, acidity, and pectin balance, as these interconnected factors are paramount for achieving the desired gel consistency, optimal flavor, and robust storage stability. Precise fruit pulp ratios are crucial to manage the varying natural pectin and acid

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content of different fruits, ensuring a harmonious flavor profile and foundational gelling properties. Sugar levels must be carefully controlled, typically targeting a soluble solids content of 65-69° Brix, as sugar not only provides sweetness but also acts as a primary preservative by reducing water activity and is essential for pectin's gelling action. Acidity (pH), ideally between 2.8 and 3.5, is critical for activating pectin's gelling ability and brightening fruit flavors, often requiring careful adjustment with external acids due to the varied natural acidity of mixed fruits. Finally, the overall pectin balance, whether inherent from the fruit blend or supplemented, must be precisely calibrated with sugar and acid to ensure the characteristic spreadable gel structure, transforming jam-making into a scientific process that guarantees consistent quality, appealing sensory attributes, and extended shelf life [6].

Utilizing underexploited fruits, such as the wood apple (*Limonia acidissima*), presents a compelling opportunity for value addition, waste reduction, and agricultural sustainability, aligning perfectly with the contemporary consumer demand for clean-labelled and nutrient-dense processed foods. Many underexploited fruits, despite their rich nutritional and often therapeutic properties, suffer from limited market demand and significant post-harvest losses due to their perishable nature, unusual flavors, or lack of established commercial processing. By transforming these fruits into value-added products like jams, we can effectively mitigate waste that would otherwise occur from seasonal gluts or unmarketable fresh produce [7]. This not only bolsters agricultural sustainability by creating new revenue streams for farmers and diversifying crop systems, but also contributes to food security by making these nutritious resources available year-round. Wood apple, for instance, is recognized for its abundance of vitamins (A and C), minerals (calcium, phosphorus, iron), dietary fiber, and a unique array of bioactive compounds, including antioxidants. Incorporating such a fruit into a mixed jam allows for the creation of a "nutrient-dense" product that goes beyond basic sustenance, offering significant health benefits. Furthermore, by focusing on minimal processing and avoiding artificial additives, these products can meet the growing consumer preference for "clean-labelled" foods—those with transparent, recognizable ingredients and a perception of naturalness. This strategic utilization of underexploited fruits, therefore, offers a holistic approach to sustainable food systems, marrying economic viability with environmental responsibility and consumer well-being [8]. Thus, mixed fruit jam production represents an important strategy for minimizing the post-harvest losses while delivering a convenient and nutritious product to diverse consumer segments.

MATERIALS AND METHODS

An experiment was conducted during January to June, 2025 at the Post Harvest and Value Addition Laboratory, Department of Agriculture (Horticulture) Fruit Science, Faculty of Agriculture and Veterinary Sciences, Mewar University Gangrar, Chittorgarh (Rajasthan). The experiment was laid out in CRD (Completely Randomized Design) with nine treatments and three replications. The method for the analysis of the biochemical parameters were followed using standard methods at 0, 30, and 60 days of storage. The parameters viz. TSS, ascorbic acid, titratable acidity and tannin were recorded. The data obtained from the set of observations for each character were subjected to “Analysis of variance” as advocated by Panse and Sukhatme [9].

RESULTS AND DISCUSSION

The mean data of TSS (°Brix) of mixed fruit jam is given in (Table 1). The results revealed that the highest TSS (69.65, 70.50 and 70.98 °Brix) at 0, 30, and 60 days after storage was recorded in treatment T_1 – 125g apple pulp + 125g banana pulp + 125g papaya pulp + 125g strawberry pulp + 500ml wood apple juice + 1000g sugar, and it was found to be the best treatment for maintaining higher soluble solids content in mixed fruit jam as compared to other treatments. Whereas the minimum TSS (64.52, 65.37 and 65.85 °Brix) at 0, 30, and 60 days after storage was recorded in treatment T_6 (250g banana pulp + 250g papaya pulp + 500ml wood apple juice + 1000g sugar) [10-11]. T_1 consistently maintained the highest TSS content in mixed fruit jam over 60 days of storage, making it the most effective formulation for this characteristic.

Table 1 Effect of different treatments on the TSS (°Brix) of mixed fruit jam at various storage intervals

Treatments	0 DAS	30 DAS	60 DAS
T_1: 125g Apple pulp + 125g Banana pulp + 125g Papaya pulp + 125g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	69.65	70.50	70.98
T_2: 166g Apple pulp + 166g Banana pulp + 166g Papaya pulp + 500ml Wood apple juice + 1000g Sugar	68.52	69.37	69.85
T_3: 166g Apple pulp + 166g Banana pulp + 166g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	64.85	65.70	66.18
T_4: 166g Apple pulp + 166g Papaya pulp + 166g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	67.25	68.10	68.58
T_5: 250g Apple pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	66.25	67.10	67.58
T_6: 250g Banana pulp + 250g Papaya + 500ml Wood apple juice + 1000g Sugar	64.52	65.37	65.85
T_7: 250g Papaya pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	64.85	65.70	66.18
T_8: 250g Apple pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	65.00	65.85	66.33
T_9: 1000 ml Wood apple juice + 1000g Sugar	69.65	70.50	70.98
S.Em.	0.75	0.74	0.73
CD (5%)	2.24	2.20	2.17

The mean data of ascorbic acid content (mg/100g) of mixed fruit jam is presented in (Table 2). Results revealed that the highest ascorbic acid content (51.65, 50.71 and 49.4 mg/100g) at 0, 30, and 60 days after storage was recorded in treatment T_1 (125g Apple pulp + 125g Banana pulp + 125g Papaya pulp + 125g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar). The minimum ascorbic acid content (44.40, 43.36 and 42.18 mg/100g) was observed in treatment T_6 (250g Banana pulp + 250g Papaya pulp + 500ml Wood apple juice + 1000g Sugar) [12-13].

The mean data of titratable acidity (%) of mixed fruit jam is presented in (Table 3). Result revealed that the highest

titratable acidity (0.47, 0.45 and 0.42%) at 0, 30 and 60 days storage was recorded in the treatment T_1 (125g apple pulp + 125g banana pulp + 125g papaya pulp + 125g strawberry pulp + 500ml wood apple juice + 1000g sugar). The lowest titratable acidity (0.39, 0.37 and 0.34%) was recorded in the treatment T_6 (250g banana pulp + 250g papaya pulp + 500ml wood apple juice + 1000g sugar) [14-16]. Treatment T_1 consistently exhibited the highest titratable acidity across all storage periods, indicating its superiority in maintaining a higher acid content compared to other mixed fruit jam formulations, particularly T_6.

Table 2 Effect of different treatments on the ascorbic acid (mg/100g) of mixed fruit jam at various storage intervals

Treatments	0 DAS	30 DAS	60 DAS
T_1: 125g Apple pulp + 125g Banana pulp + 125g Papaya pulp + 125g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	51.65	50.71	49.43
T_2: 166g Apple pulp + 166g Banana pulp + 166g Papaya pulp + 500ml Wood apple juice + 1000g Sugar	49.91	48.97	47.69
T_3: 166g Apple pulp + 166g Banana pulp + 166g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	49.50	48.56	47.28
T_4: 166g Apple pulp + 166g Papaya pulp + 166g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	48.07	47.13	45.85
T_5: 250g Apple pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	47.82	46.88	45.60
T_6: 250g Banana pulp + 250g Papaya + 500ml Wood apple juice + 1000g Sugar	44.40	43.46	42.18
T_7: 250g Papaya pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	44.41	43.47	42.19
T_8: 250g Apple pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	44.80	43.86	42.58
T_9: 1000 ml Wood apple juice + 1000g Sugar	46.51	45.57	44.29
S.Em.	0.93	0.95	0.95
CD (5%)	2.77	2.81	2.82

Table 3 Effect of different treatments on the titratable acidity (%) of mixed fruit jam at various storage intervals

Treatments	0 DAS	30 DAS	60 DAS
T_1: 125g Apple pulp + 125g Banana pulp + 125g Papaya pulp + 125g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	0.47	0.45	0.42
T_2: 166g Apple pulp + 166g Banana pulp + 166g Papaya pulp + 500ml Wood apple juice + 1000g Sugar	0.46	0.44	0.41
T_3: 166g Apple pulp + 166g Banana pulp + 166g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	0.45	0.43	0.40
T_4: 166g Apple pulp + 166g Papaya pulp + 166g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	0.44	0.42	0.39
T_5: 250g Apple pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	0.43	0.41	0.38
T_6: 250g Banana pulp + 250g Papaya + 500ml Wood apple juice + 1000g Sugar	0.39	0.37	0.34
T_7: 250g Papaya pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	0.40	0.38	0.35
T_8: 250g Apple pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	0.41	0.39	0.36
T_9: 1000 ml Wood apple juice + 1000g Sugar	0.42	0.40	0.37
S.Em.	0.01	0.01	0.01
CD (5%)	0.02	0.03	0.03

Table 4 Effect of different treatments on the tannin of mixed fruit jam at various storage intervals

Treatments	0 DAS	30 DAS	60 DAS
T_1: 125g Apple pulp + 125g Banana pulp + 125g Papaya pulp + 125g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	1.75	1.85	1.87
T_2: 166g Apple pulp + 166g Banana pulp + 166g Papaya pulp + 500ml Wood apple juice + 1000g Sugar	1.70	1.80	1.82
T_3: 166g Apple pulp + 166g Banana pulp + 166g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	1.62	1.72	1.74
T_4: 166g Apple pulp + 166g Papaya pulp + 166g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	1.57	1.67	1.69
T_5: 250g Apple pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	1.79	1.89	1.91
T_6: 250g Banana pulp + 250g Papaya + 500ml Wood apple juice + 1000g Sugar	1.83	1.93	1.95
T_7: 250g Papaya pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	1.88	1.98	2.00
T_8: 250g Apple pulp + 250g Strawberry pulp + 500ml Wood apple juice + 1000g Sugar	1.90	2.00	2.02
T_9: 1000 ml Wood apple juice + 1000g Sugar	1.95	2.05	2.07
S.Em.	0.03	0.07	0.03
CD (5%)	0.10	3.65	0.07

The mean tannin content (%) of mixed fruit jam is presented in (Table 4). Results revealed that the highest tannin content (1.95, 2.05, and 2.07%) at 0, 30, and 60 days after storage was recorded in treatment T_9 (1000 ml Wood apple juice + 1000g Sugar). It was followed by T_8 (1.90, 2.00, and 2.02%), T_7 (1.88, 1.98, and 2.00%), and T_6 (1.83, 1.93, and 1.95%) at respective storage intervals. The minimum tannin content (1.57, 1.67, and 1.69%) was observed in the treatment

T_4 (166g apple pulp + 166g papaya pulp + 166g strawberry pulp + 500ml wood apple juice + 1000g sugar) [17-20].

CONCLUSION

Based on the findings, it can be concluded that among the various treatments tested for mixed fruit jam, the treatment T_1 (125 g each of apple, banana, papaya, and strawberry pulp + 500 ml wood apple juice + 1000 g sugar) consistently performed best in maintaining higher total soluble solids (TSS) (°Brix), ascorbic acid content and titratable acidity throughout the storage period of 60 days, indicating superior quality retention. Meanwhile, the highest tannin content was recorded in treatment T_9 (1000 ml wood apple juice + 1000 g sugar), highlighting the significant contribution of wood apple juice to tannin level.

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