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Effect of natural preservatives of leaf extract and alternative sweetener to extend the shelf life of pineapple jam

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Abstract
This study aimed to evaluate the efficacy of natural preservatives—tulsi, mint, and lemongrass extracts—and alternative sweeteners—honey, stevia, and coconut sugar—in formulating a low-sugar pineapple jam that appeals to health-conscious consumers. Employing a 50% concentration of each sweetener, the research examined their impact on the jam's physicochemical properties, sensory attributes, and microbial stability. Physicochemical assessments revealed that the type of sweetener and preservative significantly influenced the jam's total soluble solids (TSS) (70.133±0.233) and titratable acidity (0.874±0.002), with honey-based jams exhibiting the highest values, and stevia-based jams the lowest. On the other side, Honey-based jam exhibits the lowest value in pH (2.934±0.010) and moisture content (17.595±0.079), whereas stevia-based jam shows the highest value. The study found that honey-tulsi infused pineapple jam has high organoleptic properties, indicating consumer preference. Stevia-sweetened jams were less popular due to textural issues and residual aftertaste. Microbiological assays revealed Gram-negative bacteria in all jams, questioning the long-term efficacy of natural preservatives. The research supports the use of tulsi and honey as natural additives in low-sugar pineapple jams, highlighting the need for healthier alternatives.

Keywords: Pineapple jam, shelf-life, physiochemical, sensory, natural preservative, alternative sugar

Introduction

Pineapple (*Ananas comosus*), known for its rich flavour and tropical sweetness, holds the esteemed title of the 'queen of fruits' and stands as the third most popular tropical fruit worldwide (Li *et al*., 2022) [7]. Pineapple, which traces its origins to the Amazon region in Brazil and Paraguay, has been cultivated since the 15th century and currently ranks as the fourth-largest pineapple producer globally (dos Santos *et al*., 2020) [3]. Pineapples flourish in hot and moist environments, and people enjoy them in a variety of ways, such as in the form of canned slices, diced pieces, jams, fruit salads, sweetened syrup, alcoholic beverages, citric acid, crispy chips, and smooth puree (Wu *et al*., 2021) [16].

India holds the position of the world's fourth most prodigious cultivator of pineapples, accounting for approximately 9% of the worldwide production of this fresh fruit. This significant contribution underscores India's pivotal role in the global pineapple agro-industry (dos Santos *et al*., 2020) [3]. The pineapple is characterized by its substantial content of water, sucrose, and ascorbic acid, yet it is deficient in coarse dietary fibre. Its composition makes it an ideal candidate for vinification, boasting a rich profile of minerals including calcium, chlorine, phosphorus, and sodium. Consumed in its natural state and through various processed or culinary forms, the pineapple is a nutritious source that promotes health and vitality (Frances *et al*., 2023) [4].

In India, the predominant consumption of fruits and vegetables is in their unprocessed form, with merely 1.6% undergoing processing post-harvest. To inhibit microbial spoilage of jams during storage, prevailing practices encompass the utilization of sanctioned preservatives and thermal treatment, specifically pasteurization. Nonetheless, such heat treatments are known to diminish fruit preserves' nutritional integrity and perceived freshness substantially (Celina *et al*., 2018) [2]. Additionally, buyers often criticise using artificial preservatives, which can negatively affect human health.

Edible commodities are constituted by an amalgamation of water, lipids, carbohydrates, proteins, and minute quantities of minerals and ancillary compounds, all of which foster microbial proliferation. Preservation stratagems are advocated for quartet categories of aliment, predicated on their intrinsic properties, to avert their spoilage. Certain preservation methodologies necessitate the incorporation of additional preservative agents, which bifurcate into categories of natural and synthetic origin (Sharif *et al*., 2017) [12].

Medicinal plants, rich in phytochemicals like flavonoids, polyphenols, tannins, and terpenoids, offer preservation properties and control microbial development through their chemical variety (Viji *et al.*, 2015) [17]. Basil (*Ocimum basilicum*, Lamiaceae), Mint (*Mentha arvensis*), lemongrass (*Cymbopogon citratus*), and other herbs and spices have been used for medicinal and decorative purposes, while low-calorie sweeteners like honey, stevia (*Stevia rebaudiana*), and coconut sugar can be used to make jams without sugar. Honey, rich in fructose, glucose, and monosaccharide, has shown health benefits (Timothy *et al.*, 2019) [14]. Stevia leaves, rich in steviol glycosides, are a potent sweetener in the natural food market, used as a substitute for sugar in meals, drinks, and medications (Schiatti-Sisó *et al*., 2023) [11]. Coconut sugar, produced from palm flower sap, is a natural, healthier alternative to other sugars, beneficial for human organisms and those seeking a healthier diet or diabetes (Salgado *et al*., 2022) [10].

Phytochemically endowed medicinal flora, harbouring an array of compounds such as flavonoids, polyphenols, tannins, and terpenoids, confer preservative efficacies and modulate microbial growth via their chemical heterogeneity, as documented by (Viji *et al.*, 2015) [17]. Notably, *Ocimum basilicum* (Lamiaceae), *Mentha arvensis*, and *Cymbopogon citratus*, among other botanicals, have been traditionally harnessed for both therapeutic and ornamental applications. Concurrently, low-caloric sweetening agents such as honey, *Stevia rebaudiana*, and coconut sugar present viable alternatives to conventional sucrose in jam production. Honey, with its abundance in fructose, glucose, and monosaccharides, has been associated with salutary effects (Timothy *et al.*, 2019) [14]. The leaves of stevia, laden with steviol glycosides, have emerged as a formidable natural sweetener within the alimentary domain, supplanting sugar in a spectrum of culinary, beverage, and pharmaceutical preparations (Schiatti-Sisó *et al.*, 2023) [11]. Furthermore, coconut sugar, derived from the sap of palm inflorescences, stands as a salubrious sweetener option, particularly advantageous for individuals pursuing a health-conscious regimen or managing diabetes (Salgado *et al*., 2022) [10].

The present investigation endeavours to evaluate the impact on the attributes of pineapple jam when alternative sweeteners—stevia, honey, and coconut sugar—supplant traditional sucrose. The objective is to appraise the jam's quality parameters and shelf-life efficacy through the analysis of its physicochemical attributes, microbial proliferation, and fundamental nutritional constituents. The incorporation of aqueous extracts from Tulsi, mint, and lemongrass leaves in the jam's production process serves as a botanical preservative measure. The aim is to calibrate the utilization of various liquid leaf extracts as natural preservative agents and as substitute sweetening agents in the formulation of pineapple jam and to study the different parameters of physiochemical properties, microbial growth and sensory evaluation of pineapple jam.

Materials and Methods

Materials and reagents

The research was conducted in the Laboratory of the Department of Horticulture (Fruit Science), School of Agriculture, Lovely Profession University, Phagwara, Punjab. Essential raw materials such as pineapples, tulsi, lemongrass, and mint leaves were acquired from local commerce. The laboratory furnished all requisite reagents, including citric acid, pectin, NaOH, DPPH, and the like, in addition to alternative sweeteners like honey, stevia, and coconut sugar, and the necessary instrumentation for the study.

Preparation of liquid leaf extract

The experimental protocol necessitated the thorough decontamination of several utensils, encompassing a mixing grinder, glassware, muslin fabric, a beaker, and a measuring cylinder, employing a liquid dishwashing agent. After the procurement and purification of Tulsi, mint, and lemongrass leaves, they were macerated in a mixing grinder. The macerate was then filtered using muslin fabric into a beaker. The resultant aqueous extract was quantitatively assessed with a measuring cylinder and subsequently stored in a glass container or flask for further use.

Preparation of pineapple jam

Utilizing a sterilised stainless-steel wok, the pineapple jam was crafted. The puree was gently heated, with consistent stirring, before the addition of alternative sweeteners (sucrose was utilized in T_{10}). The Total Soluble Solids (TSS) levels were monitored via a digital refractometer, stirring the mixture until a TSS of 68.5 was achieved. Following this, pectin and citric acid were amalgamated into the blend, subsequent to which the heat source was discontinued. A precise quantity of liquid leaf extract, measuring 4-5 drops, was integrated into each batch, with the exception of T_{10}. The final product was then securely deposited into a sterilised glass jar and preserved at ambient temperature, ensuring a well-integrated and consumable jam. All the treatment details are: Treatment 1 (Honey @ 50% + Tulsi liquid leaf extract @ 1%), Treatment 2 (Honey @ 50% + Mint liquid leaf extract @ 1%), Treatment 3 (Honey @ 50% + Lemongrass liquid leaf extract @ 1%), Treatment 4 (Stevia @ 50% + Tulsi liquid leaf extract @ 1%), Treatment 5 (Stevia @ 50% + Mint liquid leaf extract @ 1%), Treatment 6 (Stevia @ 50% + Lemongrass liquid leaf extract @ 1%), Treatment 7 (Coconut sugar @ 50% + Tulsi liquid leaf extract @ 1%), Treatment 8 (Coconut sugar @ 50% + Mint liquid leaf extract @ 1%), Treatment 9 (Coconut sugar @ 50% + Lemongrass liquid leaf extract @ 1%), Treatment 10 (Control).

Physiochemical properties

TSS: A refractometer is employed to ascertain the concentration of water-soluble solids in fruit jam, quantified in degrees Brix. Post-production, the benchmark for pineapple jam is established at approximately 68° Brix, as delineated by Li *et al.*, 2022 [7]. This standard serves as a critical indicator of the jam's quality and consistency.

Acidity: The acidity of pineapple fruit, which oscillates between 0.6 and 1.2% citric acid as reported by Kanchan *et al*. (2020) [18], is quantitatively evaluated through a titrimetric analysis. This method involves the titration of a fresh fruit jam specimen against a standard solution of 0.1 N NaOH, employing phenolphthalein as a colourimetric indicator. The endpoint of this titration is marked by the emergence of a faint pink tint, subsequent to which the acidity is computed and articulated as a percentage. This protocol is pivotal for ascertaining the citric acid content in pineapple jam, reflecting its tartness and preservation potential.

$$\text{Titrable acidity (\%)} = \frac{\text{Titre} \times \text{Normality of NaOH} \times \text{Eq.wt.of fruit acid} \times 100}{10 \times \text{wt.of sample}}$$

pH: In their research, Kanchan *et al*. (2020) [18] described a methodological approach for the determination of jam pH levels, utilizing an electronic digital pH meter. This precise technique is essential for quantifying the acidity of pineapple jam, which is a significant factor affecting its flavour, preservation efficacy, and microbial stability. The pH value, indicative of the jam's acid-base balance, is a crucial quality parameter in the food processing industry.

Total sugar: The methodology for estimating the total sugar content within jam, as influenced by Kanchan *et al.* (2020) [18], involves a dilution of the jam specimen in aqua pura, followed by its transfer into a 100 ml volumetric flask. The flask is then subjected to a thermal bath to facilitate the reaction, after which sodium carbonate is introduced to neutralise the hydrolysate. The flask's contents are then brought to volume with distilled water. The quantification of the total sugar present in the neutralised hydrolysate is executed using this identical procedure. The resultant data is expressed as a percentage, relative to the weight of the sample. This process ensures a standardized measurement of the sugar concentration in pineapple jam.

$$\text{Total sugars (\%)} = \frac{\text{Factor (0.05)} \times \text{Volume made up} \times \text{Dilution} \times 100}{\text{Titer value} \times \text{Weight of the sample taken}}$$

Reducing sugar: The protocol delineated by Kanchan *et al.* (2020) [18] for the quantification of reducing sugars in jam is a meticulous process that commences with the dilution of the jam sample in water, followed by its transfer into a 250-ml flask. To this mixture, a lead acetate solution is introduced, succeeded by the addition of potassium oxalate. The resultant solution is then filtered to eliminate any precipitates. The clear filtrate is subjected to a titration process using Fehling's solutions A and B. After a minor addition of water, the solution is heated until boiling is achieved, at which point a crimson colouration signifies the presence of reducing sugars.

$$\text{Reducing sugar (\%)} = \frac{\text{Factor (0.05)} \times \text{Volume made up} \times \text{Dilution} \times 100}{\text{Titre} \times \text{volume of sample}}$$

The titration is further refined with the introduction of a 1% methylene blue aqueous solution, which acts as an indicator until the endpoint of the titration is observed. This method is pivotal for the accurate determination of reducing sugar content in pineapple jam, which is essential for understanding the jam's sweetness profile and its implications on texture and shelf-life.

Moisture content: The methodology for determining the moisture content of pineapple jam, as influenced by Etebu *et al*. (2016) [19], involves a systematic approach where a sample of known weight is subjected to desiccation in an oven pre-set at 55 °C. Following the drying process, the sample is allowed to cool in desiccators for a duration of 10 minutes. The weight of the dehydrated sample is then accurately measured. The moisture content is deduced from the final recorded weight, employing the same procedural standards. This method is critical for assessing the water activity in the jam, which is a determinant of its shelf-life and textural properties.

$$\text{\% moisture content} = \frac{\text{Loss in weight} \times 100}{\text{Initial weight of the sample}}$$

Loss in weight = Weight of dish with samples – (Weight of the dish + sample after drying in the oven)
The initial weight of the sample = Weight of dish with samples - Tared weight of the dish

Sensory evaluation: A sensory assessment of pineapple jam at Lovely Professional University involved ten panellists grading it using a 9-point hedonic scale. Multiple comparison tests evaluated the jam's colour, taste, aroma, texture, spreadability, and overall acceptability. Hedonic scale scores are: Like extremely (9), Like very much (8), Like moderately (7), Like slightly (6), Neither like nor dislike (5), Dislike slightly (4), Dislike moderately (3), Dislike very much (2), Dislike extremely (1).

Total microbial count
Grammeme staining: Grammeme staining is a common technique used in research to differentiate between Grammeme-positive and Grammeme-negative bacteria. Samples are exposed to crystal violet for five minutes, then rinsed with tap water and iodine mordant. After decolourising with a Gramme decolouriser solution, the slides are cleaned. Gramme Safranin is then stained for one minute and forty seconds, followed by dehydration with alcohol. The slides are viewed under a microscope at 100X magnification to identify Grammeme-positive or Grammeme-negative bacteria. If the bacteria are blue, they are Grammeme-positive, and if not, a red stain is used. This method was influenced by Becerra *et al.* (2016) [1].

Results and Discussion
Physiochemical properties
TSS: Table- 1 shows information about the impact of TSS in pineapple jam. At the initial 10-day interval, the Honey @ 50% + Mint extract @ 3 ml variant exhibited the highest TSS value of 71.333±0.260, indicating a higher concentration of soluble constituents. Conversely, the Honey @ 50% + Tulsi extract @ 3 ml variant showed the lowest TSS value of 66.167±0.177. This suggests that the mint extract may contribute to a higher retention of soluble solids compared to the tulsi extract.

Acidity: Table- 1 presents information about the impact of titrable acidity in pineapple jam. At 10-day intervals, the titrable acidity of the pineapple jams was lowest (0.833±0.003) for coconut sugar at 50% + lemongrass extract at 3 ml (T_9) and highest (0.846±0.001) for honey at 50% + lemongrass extract at 3 ml (T_{10}). The lowest titrable acidity was observed at 20-day intervals in stevia at 50% +

tulsi extract at 3 ml (T_4) pineapple jam (0.853±0.001), while the highest was seen in honey at 50% + tulsi extract at 3 ml (T_1) pineapple jam (0.865±0.003). The titrable acidity of pineapple jam at 30-day intervals was greatest (0.874±0.002) for honey at 50% + tulsi extract at 3 ml (T_1) and lowest (0.864±0.001) for stevia at 50% + lemongrass extract at 3 ml (T_6).

pH: Table- 1 contains information about how pH affects pineapple jam. At 10-day intervals, the maximum pH was 3.235±0.018 for pineapple jam made with 50% Stevia and 3% mint extract (T_5), whereas the lowest pH was 3.152±0.017 for pineapple jam made with 50% Honey and 3% tulsi extract (T_1). The highest and lowest pH values were found at 20-day intervals in coconut sugar at 50% + tulsi extract at 3 ml (T_7) pineapple jam (3.163±0.021) and honey at 50% + lemongrass extract at 3 ml (T3) pineapple jam (3.033±0.015). Measurements were taken at 30-day intervals for the pineapple jams with the highest and lowest pHs: Stevia @ 50% + Tulsi extract @ 3 ml (T_4) (3.038±0.017) and honey @ 50% + mint extract @ 3 ml (T_2) (2.934±0.010).

Total sugar: Table- 2 presents data pertaining to the impact of total sugar content in pineapple jam. The sugar content at 50% (Control) (T_{10}) pineapple jam (43.750±0.012) had the greatest total sugar at 10-day intervals, whereas the lowest sugar content was seen in stevia at 50% + mint extract at 3 ml (T_5) pineapple jam (43.553±0.012). At 20-day intervals, the maximum total sugar was found in 3 ml (T_9) pineapple jam made with coconut sugar at 50% + lemongrass extract (43.951±0.006), whereas the lowest total sugar was found in 3 ml (T_4) pineapple jam made with stevia at 50% + tulsi extract (43.754±0.015). The results showed that at 30-day intervals, stevia at 50% + tulsi extract at 3 ml (T_4) pineapple jam (44.174±0.006) had the lowest total sugar and coconut sugar at 50% + tulsi extract at 3 ml (T_9) pineapple jam (43.955±0.025) had the greatest total sugar.

Reducing sugar: Table- 2 presents data about the impact of lowering the sugar content in pineapple jam. The sugar at 50% (control) (T_{10}) pineapple jam had the highest decreasing sugar at 10-day intervals (34.128±0.035), while the lowest was found in coconut sugar at 50% + tulsi extract at 3 ml (T_7) pineapple jam (33.918±0.009). At 20-day intervals, the pineapple jam with the largest decreasing sugar content was the T_8 pineapple jam (34.364±0.018) made with coconut sugar at 50% plus lemongrass extract, and the T_5 pineapple jam (34.128±0.017) made with stevia at 50% plus mint extract. At 30-day intervals, Sugar at 50% (Control) (T_{10}) pineapple jam had the greatest lowering sugar (34.742±0.017), whereas Honey at 50% + mint extract at 3 ml (T_2) pineapple jam (34.518±0.011) had the lowest.

Moisture content: Table- 2 presents data pertaining to the impact of moisture content in pineapple jam. Coconut sugar at 50% + mint extract at 3 ml (T_8) pineapple jam (24.893±0.236) had the maximum moisture at 10-day intervals, whereas coconut sugar at 50% + lemongrass extract at 3 ml (T_9) pineapple jam (24.484±0.031) had the lowest moisture. Coconut sugar at 50% + tulsi extract at 3 ml (T_7) pineapple jam (22.417±0.031) had the maximum moisture at 20-day intervals, whereas coconut sugar at 50% + mint extract at 3 ml (T_8) pineapple jam (21.706±0.170) had the lowest moisture. At 30-day intervals, the moisture content of the following products was measured: honey at 50% + tulsi extract at 3 ml (T_1) pineapple jam (17.595±0.079) and coconut sugar at 50% + mint extract at 3 ml (T_8) pineapple jam (18.77±0.123).

Sensory evaluation

Table- 3 presents data pertaining to the impact of sensory evaluation in pineapple jam. The sensory evaluation of pineapple jam, as part of the study, revealed distinct preferences among the assessors for various sweetener and natural preservative combinations. The formulation containing 50% honey and 3 ml of tulsi extract (T_1) was unanimously favoured for its golden-brown hue, aligning with the aesthetic expectations for pineapple jam. This variant also excelled in sensory attributes, receiving high marks for aroma, taste, texture, and spreadability.

Total Microbial Count

Gram staining: The microorganisms in the pineapple jam sample looked red when examined under a microscope. It is clear from this that the bacteria in the jam were of the gram-negative variety.

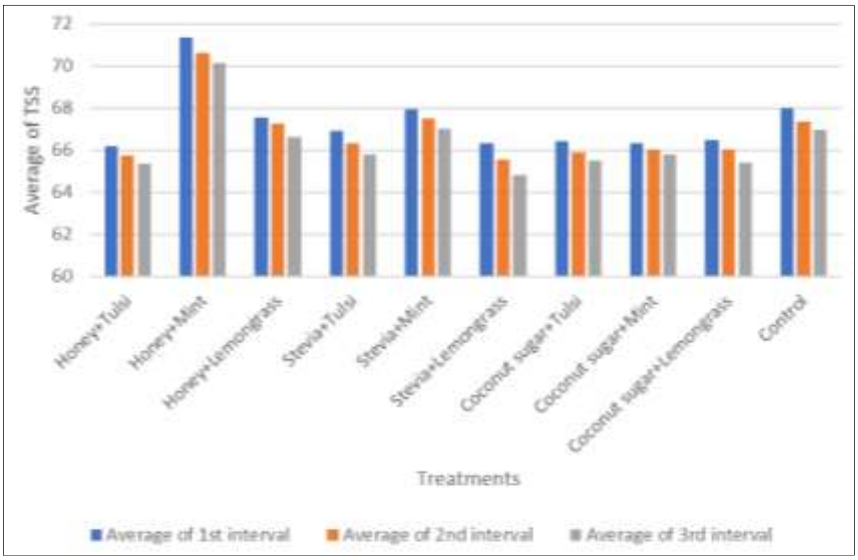

Fig-1: TSS of pineapple jams at 30-days storage condition

Table 1: Data related to TSS, Titrable acidity and pH of pineapple jam of 30-day interval

Sl No.	Treatments	TSS			Titrable acidity			pH		
		10 days interval	20 days interval	30 days interval	10 days interval	20 days interval	30 days interval	10 days interval	20 days interval	30 days interval
T_1	Honey @ 50% + Tulsi extract @ 3 ml	66.167±0.177	65.767±0.260	65.333±0.233	0.842±0.000	0.865±0.003	0.874±0.002	3.152±0.017	3.065±0.012	2.948±0.013
T_2	Honey @ 50% + Mint extract @ 3 ml	71.333±0.260	70.600±0.208	70.133±0.233	0.843±0.001	0.863±0.001	0.871±0.001	3.166±0.018	3.103±0.012	2.934±0.010
T_3	Honey @ 50% + Lemongrass extract @ 3 ml	67.567±0.536	67.233±0.546	66.633±0.736	0.846±0.001	0.864±0.003	0.873±0.002	3.167±0.012	3.033±0.015	2.955±0.003
T_4	Stevia @ 50% + Tulsi extract @ 3 ml	66.933±0.338	66.333±0.484	65.800±0.405	0.836±0.001	0.853±0.001	0.865±0.002	3.234±0.008	3.151±0.003	3.038±0.017
T_5	Stevia @ 50% + Mint extract @ 3 ml	67.933±0.088	67.500±0.152	67.033±0.176	0.837±0.002	0.855±0.001	0.866±0.001	3.235±0.018	3.158±0.022	2.991±0.005
T_6	Stevia @ 50% + Lemongrass extract @ 3 ml	66.333±0.260	65.533±0.384	64.833±0.348	0.835±0.002	0.854±0.002	0.864±0.001	3.231±0.027	3.154±0.029	3.006±0.012
T_7	Coconut sugar @ 50% + Tulsi extract @ 3 ml	66.433±0.261	65.867±0.348	65.500±0.436	0.837±0.002	0.854±0.001	0.864±0.002	3.222±0.045	3.163±0.021	3.001±0.010
T_8	Coconut sugar @ 50% + Mint extract @ 3 ml	66.333±0.202	66.033±0.234	65.800±0.306	0.834±0.001	0.853±0.002	0.865±0.002	3.218±0.028	3.145±0.027	3.026±0.009
T_9	Coconut sugar @ 50% + Lemongrass extract @ 3 ml	66.467±0.145	66.033±0.166	65.400±0.152	0.833±0.003	0.853±0.001	0.864±0.002	3.198±0.030	3.122±0.016	3.024±0.037
T_{10}	Sugar @ 50% (Control)	67.967±0.120	67.333±0.119	66.967±0.176	0.844±0.003	0.865±0.002	0.875±0.002	3.158±0.015	3.063±0.023	2.947 ±0.012
C.D.		0.798	0.954	1.073	0.005	0.006	0.005	N/A	0.058	0.047
SE (m)		0.269	0.321	0.361	0.002	0.002	0.002	0.024	0.019	0.016
SE (d)		0.380	0.454	0.511	0.003	0.003	0.002	0.034	0.028	0.022
C.V.		0.691	0.833	0.943	0.376	0.375	0.343	1.303	1.081	0.908

Table 2: Data related to Total sugar, Reducing sugar and Moisture of pineapple jam of 30-days interval

Sl No.	Treatments	Total sugar			Reducing sugar			Moisture content		
		10 days interval	20 days interval	10 days interval	20 days interval	10 days interval	20 days interval	10 days interval	20 days interval	30 days interval
T_1	Honey @ 50% + Tulsi extract @ 3 ml	43.653±0.000	43.838±0.020	44.070±0.012	33.953±0.000	34.266±0.017	34.668±0.013	24.831±0.235	22.127±0.009	17.595±0.079
T_2	Honey @ 50% + Mint extract @ 3 ml	43.636±0.018	43.891±0.017	44.067±0.019	34.063±0.033	34.145±0.020	34.518±0.011	24.822±0.0202	22.122±0.102	17.875±0.071
T_3	Honey @ 50% + Lemongrass extract @ 3 ml	43.555±0.013	43.831±0.028	44.034±0.048	34.068±0.023	34.253±0.000	34.645±0.028	24.891±0.226	21.937±0.254	18.079±0.101
T_4	Stevia @ 50% + Tulsi extract @ 3 ml	43.569±0.030	43.754±0.015	43.955±0.025	34.014±0.045	34.243±0.023	34.637±0.025	24.830±0.237	21.848±0.181	18.112±0.291
T_5	Stevia @ 50% + Mint extract @ 3 ml	43.553±0.012	43.939±0.051	44.122±0.018	34.010±0.053	34.128±0.017	34.545±0.027	24.839±0.213	22.0.35±0.233	18.133±0.069
T_6	Stevia @ 50% + Lemongrass extract @ 3 ml	43.652±0.011	43.828±0.033	44.022±0.035	33.998±0.013	34.268±0.001	34.619±0.021	24.858±0.227	21.951±0.205	17.858±0.047
T_7	Coconut sugar @ 50% + Tulsi extract @ 3 ml	43.722±0.008	43.841±0.034	44.160±0.019	33.918±0.009	34.356±0.024	34.736±0.026	24.849±0.136	22.417±0.031	18.192±0.203
T_8	Coconut sugar @ 50% + Mint extract @ 3 ml	43.725±0.020	43.936±0.016	44.142±0.025	33.924±0.037	34.364±0.018	34.761±0.020	24.893±0.236	21.706±0.170	18.77±0.123
T_9	Coconut sugar @ 50% + Lemongrass extract @ 3 ml	43.712±0.007	43.951±0.006	44.174±0.006	34.008±0.034	34.256±0.029	34.556±0.021	24.484±0.031	21.940±0.240	18.019±0.265
T_{10}	Sugar @ 50% (Control)	43.750±0.012	43.973±0.015	44.149±0.017	34.128±0.035	34.363±0.000	34.742±0.017	24.709±0.163	22.087±0.196	18.065±0.264
C.D.		0.045	0.078	0.075	0.096	0.053	0.066	N/A	N/A	N/A
SE (m)		0.015	0.026	0.025	0.032	0.018	0.022	0.200	0.181	0.176
SE (d)		0.021	0.037	0.036	0.046	0.025	0.031	0.283	0.257	0.249
C.V.		0.060	0.104	0.099	0.165	0.091	0.111	1.400	1.428	1.691

Table 3: Data related to Sensory evaluation of pineapple jam of 30-days interval

Sl no.	Treatments	Colour	Aroma	Taste	Texture	Spreadability	Overall acceptability
T_1	Honey @ 50% + Tulsi extract @ 3 ml	9.000±0.000	8.938±0.056	9.000±0.000	9.000±0.003	9.000±0.003	9.000±0.002
T_2	Honey @ 50% + Mint extract @ 3 ml	8.920±0.055	8.856±0.040	8.581±0.098	8.744±0.060	8.744±0.062	8.513±0.004
T_3	Honey @ 50% + Lemongrass extract @ 3 ml	8.465±0.081	8.866±0.035	8.303±0.044	8.494±0.063	8.463±0.152	8.535±0.000
T_4	Stevia @ 50% + Tulsi extract @ 3 ml	6.596±0.024	6.831±0.038	4.937±0.065	4.899±0.062	4.812±0.077	6.576±0.026
T_5	Stevia @ 50% + Mint extract @ 3 ml	6.722±0.080	6.082±0.074	4.763±0.037	4.863±0.055	4.743±0.037	6.600±0.031
T_6	Stevia @ 50% + Lemongrass extract @ 3 ml	6.276±0.099	6.537±0.089	4.806±0.037	4.826±0.068	4.978±0.035	6.588±0.036
T_7	Coconut sugar @ 50% + Tulsi extract @ 3 ml	7.458±0.070	7.819±0.094	7.679±0.127	7.837±0.030	8.012±0.011	8.252±0.036
T_8	Coconut sugar @ 50% + Mint extract @ 3 ml	7.858±0.052	7.861±0.042	7.603±0.072	8.057±0.057	7.745±0.090	8.237±0.058
T_9	Coconut sugar @ 50% + Lemongrass extract @ 3 ml	7.900±0.040	8.728±0.060	7.869±0.114	8.029±0.053	7.635±0.051	8.071±0.079
T_{10}	Sugar @ 50% (Control)	8.528±0.101	8.937±0.018	8.400±0.093	8.404±0.047	8.453±0.077	8.014±0.005
C.D.		0.201	0.177	0.233	0.158	0.215	0.110
SE (m)		0.068	0.060	0.079	0.053	0.072	0.037
SE (d)		0.096	0.084	0.111	0.075	0.102	0.053
C.V.		1.509	1.297	1.891	1.259	1.725	0.820

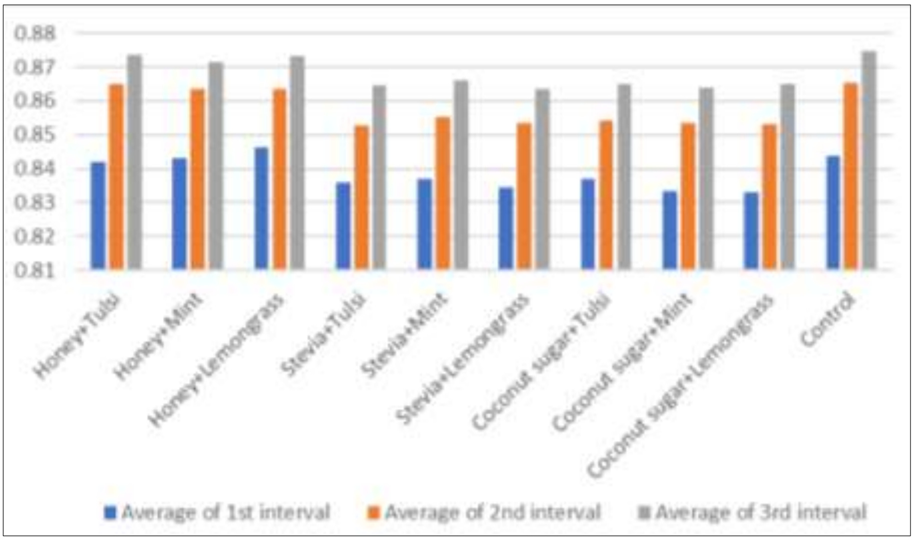

Fig 2: Titrable acidity of pineapple jams at 30 days storage condition.

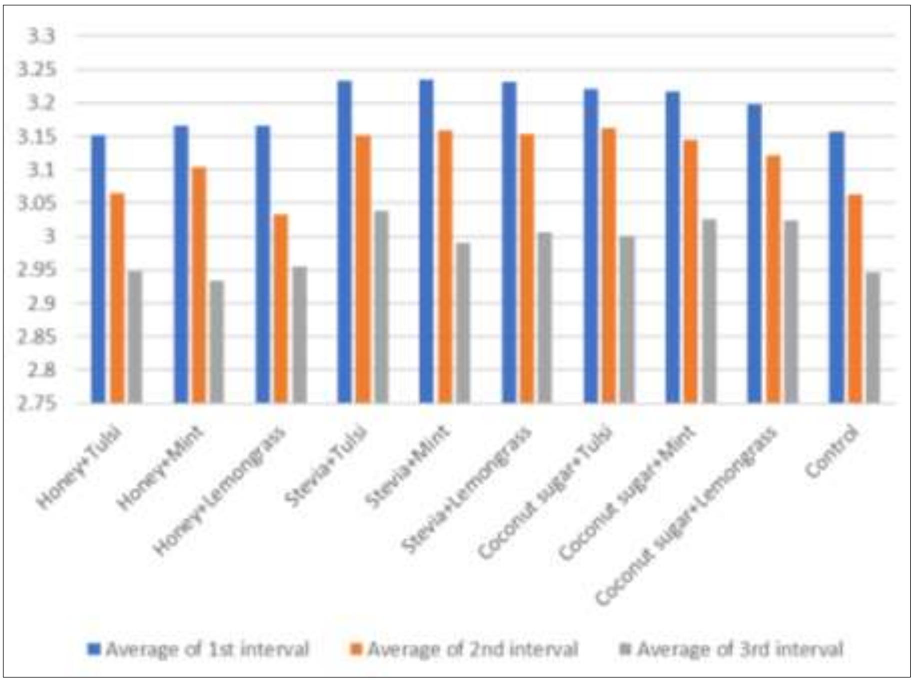

Fig 3: pH of pineapple jams during 30-days storage condition

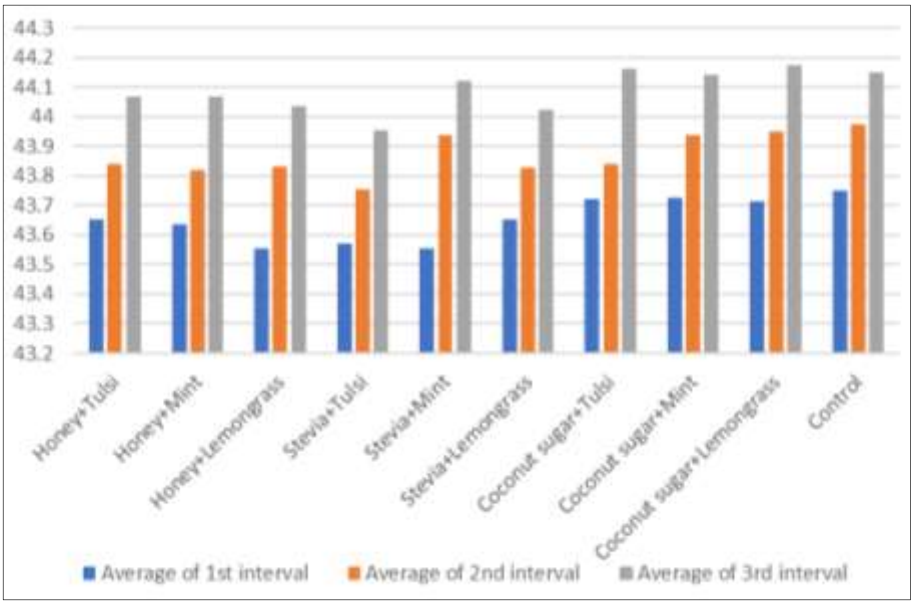

Fig 4: Total sugar of pineapple jams during 30-days storage condition

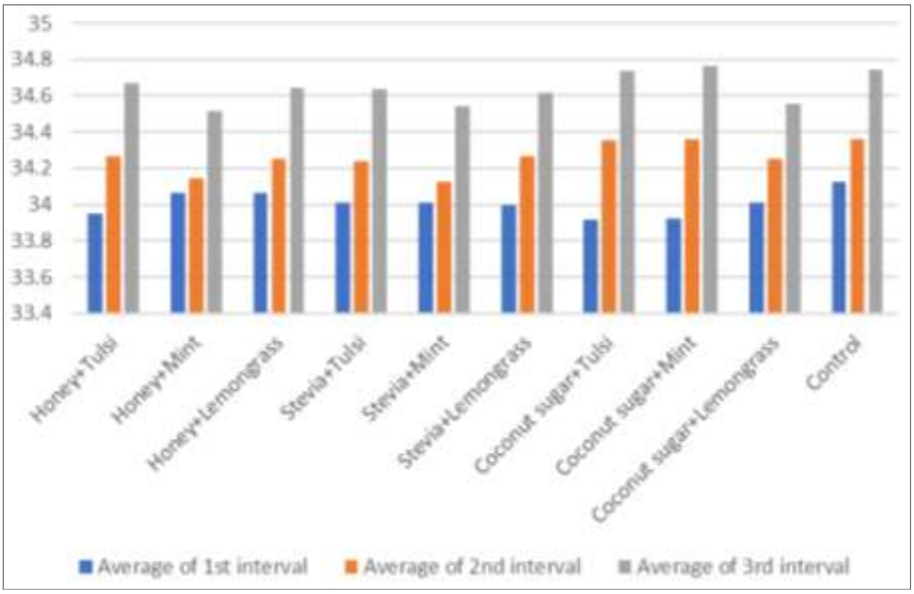

Fig 5: Reducing sugar of pineapple jams during 30-days storage condition

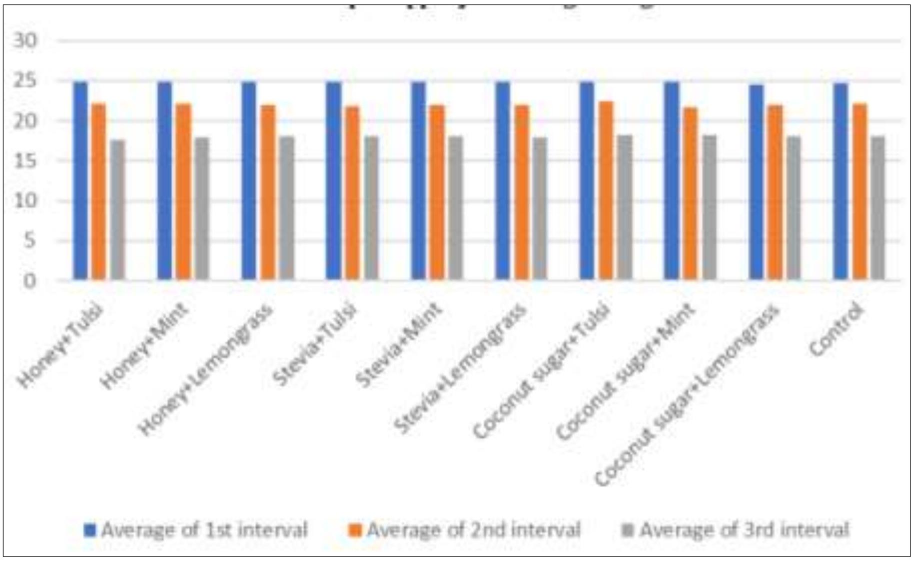

Fig 6: Moisture content of pineapple jam during 30-days storage conditions

Discussion

Data analysis revealed that TSS levels in pineapple jam decrease due to polysaccharide hydrolysis, turning complex carbs into simpler sugars. Mint extract preserves TSS better than tulsi, suggesting preservative choice is key for product stability, echoing Kanwal *et al*. (2017) [6] and Rahman *et al*. (2018) [9] findings on guava jam. This underscores the importance of selecting suitable preservatives for quality maintenance in fruit-based products.

Titratable acidity in pineapple jam rises due to pectin breakdown into pectenic acid and sugar oxidation, both increasing free acid content. This mirrors Kanwal *et al.* (2017)'s [6] findings for guava jam. Proper storage is crucial to control acidity, affecting both flavour and preservation quality.

The pH of pineapple jam decreases with storage time due to acids formed during boiling and from added sugars and puree. Stevia leads to a higher pH than honey, suggesting it's better for shelf life and safety. These findings, supporting Kanwal *et al*. (2017) [6], emphasize the importance of ingredient choice in fruit preserve quality.

Total sugar in pineapple jam increases over 30 days due to starch hydrolysis into simpler sugars, a trend also noted by Sutwal *et al*. (2019) [13] in guava jam. Sweetener and preservative types affect sugar content slightly, impacting taste and shelf life. This emphasizes the importance of ingredient selection for product quality and consumer appeal.

Reducing sugar levels in pineapple jam rise due to sucrose hydrolysis into glucose and fructose, a reaction enhanced by organic acids and storage conditions. This is in line with Ullah *et al*. (2020) [15] and Kanwal *et al*. (2017) [6], who found similar trends in carrot-kinnow and guava jams, respectively. Higher reducing sugars can affect jam's taste, texture, and microbial stability, underscoring the need for controlled storage to ensure quality and longevity.

Moisture content in pineapple jam decreases over time, likely due to water being absorbed by soluble solids and sugars, which is crucial for preventing microbial growth. Sweetener and extract types have minimal effect on moisture, but storage temperature is key, with higher temperatures causing more evaporation. These observations are consistent with Nafri *et al.* (2021) [8], emphasizing the importance of proper storage to ensure jam quality and longevity.

In contrast, the stevia-sweetened jams (T_6) were less favoured, primarily due to their creamy colour, which deviated from the traditional appearance of pineapple jam, and their gritty texture, which resulted in a crystalline consistency post-cooling. The stevia variant with mint extract (T_5), while slightly appreciated for its aroma, fell short in taste evaluations. The study's findings underscore the importance of colour in influencing consumer perception and acceptance, with the coconut sugar variants receiving moderate approval for their rich brown colouration. Texture emerged as a critical factor in overall product satisfaction, with the honey and tulsi extract combination (T_1) setting the benchmark for an ideal spreadable consistency. Overall, the study concludes that the hedonic score, which represents the cumulative average of sensory ratings, is a reliable indicator of overall acceptability. The honey and tulsi extract blend (T_1) not only met but exceeded the sensory expectations set by the traditional sucrose-sweetened control, suggesting its potential as a superior alternative in pineapple jam production. However, the presence of gram-negative bacteria across all samples indicates a need for further refinement in preservation techniques to ensure microbial safety alongside sensory quality.

Food properties, preservatives, pH, and moisture influence the resilience of gram-negative bacteria in processed foods like pineapple jam. Non-reducing sugars, which don't react in the Maillard process, may impact bacterial nutrient availability. Jam *et al.* (2022) [20] highlight the need for careful quality control and ingredient balance to prevent bacterial growth and ensure product safety.

Conclusion

In conclusion, the research elucidates that using alternative sweeteners and liquid leaf extracts of tulsi, mint, and lemongrass as natural preservatives markedly influences the physiochemical attributes of pineapple jam. The empirical evidence suggests that honey, particularly when synergised with tulsi extract, significantly enhances the jam's sensory appeal and shelf-life, outperforming the traditional sucrose-based control. Conversely, stevia is noted for its lower acceptability due to textural and aftertaste challenges. The study underscores the potential of these natural constituents to create a reduced-sugar, consumer-preferred pineapple jam variant, with honey and tulsi extract being the optimal combination.

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