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Comparative study of natural and synthetic preservatives on quality of fruit jam during storage

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Abstract
Synthetic preservatives such as sodium benzoate and potassium sorbate remain the default choice in commercial jam production, yet growing consumer demand for clean-label products has pushed food processors to seek plant-derived alternatives. This research compared the effectiveness of two synthetic preservatives (sodium benzoate at 0.1% and potassium sorbate at 0.1%) and two natural preservatives (tulsi extract at 2% and ginger extract at 3%) alongside a citric acid reference (0.3%) and an unpreserved control on the physicochemical, microbiological, and sensory quality of mixed-fruit jam stored at ambient temperature (28 ± 2 °C) for 90 days. The trial was conducted at the Cerrado Agricultural Institute, Goiânia, Goiás during January-April 2023. Sodium benzoate-treated jam retained the highest ascorbic acid (22.7 mg 100 g^{-1}), lowest browning index (0.18), and best sensory scores (overall acceptability 7.9 on a 9-point scale) at 90 days. Among natural options, tulsi extract performed closest to the synthetic treatments, preserving 19.8 mg 100 g^{-1} ascorbic acid with an acceptability score of 7.4. Ginger extract imparted a detectable flavour that lowered its sensory rating. The unpreserved control showed visible mould by day 75. These findings indicate that tulsi extract offers a viable clean-label alternative for jam preservation, though it does not fully match the shelf-life extension of synthetic additives.

Keywords: Natural preservatives, synthetic preservatives, fruit jam, storage quality, sodium benzoate, potassium sorbate, tulsi extract, ginger extract, sensory evaluation, shelf life

Introduction
Jam spoilage during storage represents a persistent problem for small and medium food processors who lack access to cold-chain infrastructure, particularly in the tropical climate of tropical Brazil [2]. The primary agents of deterioration are osmophilic yeasts and moulds that can grow even at the high sugar concentrations found in jam (65-68 °Brix), along with non-enzymatic browning reactions that darken colour and degrade vitamin C [3].
Sodium benzoate and potassium sorbate have been the industry workhorses for decades, approved at concentrations up to 0.1% in most national food safety regulations (ANVISA) [4]. But consumer perception has shifted: surveys indicate that over 60% of urban Brazilian buyers now prefer products labelled 'free from artificial preservatives' [5]. Plant extracts rich in phenolic compounds such as those from tulsi (*Ocimum sanctum*), ginger (*Zingiber officinale*), and neem have demonstrated antimicrobial and antioxidant activity in laboratory settings [6, 7]. Whether they can match synthetic preservatives under real jam-storage conditions is less certain.
This research directly compared two synthetic and two natural preservatives at their recommended-use concentrations, monitoring chemical, microbial, and sensory changes at 30-day intervals over a 90-day shelf life. The aim was to identify a natural option that comes close enough to synthetic performance to be commercially viable.

Reagents and chemicals
Sodium benzoate (AR grade, purity ≥ 99.5%) and potassium sorbate (AR grade, purity ≥ 99%) were obtained from Dinâmica Química, São Paulo. Citric acid (food grade) was from Vetec Química, Rio de Janeiro. Fresh tulsi leaves were harvested from the institute herbal garden, washed, shade-dried, and extracted in boiling water (1:5 w/v) for 20 minutes; the

filtrate was concentrated to a 10% stock solution in a rotary evaporator at 50 °C [8]. Fresh ginger rhizomes were peeled, crushed, and juice extracted using a screw press; the juice was pasteurised at 72 °C for 15 seconds before use. All other chemicals for analysis (2,6-dichlorophenol indophenol, potato dextrose agar, peptone water) were of analytical grade from Kasvi Laboratories [9].

Material and Methods

Material

The research was conducted from January to April 2023 at the Food Processing Laboratory of the Cerrado Agricultural Institute, Goiânia, Goiás (10.79°N, 78.68°E). Ripe guava (cv. Paluma) and papaya (cv. Formosa) fruits were procured from the local wholesale market. A 50:50 blend of guava and papaya pulp was used as the jam base. Sugar (food-grade cane sugar) was mixed with pulp at a 1:1 ratio. Pectin (rapid-set grade, 150° SAG) at 0.8% and citric acid at 0.3% were added to all formulations to achieve proper gel strength and pH [10].

Methods

Six treatments were prepared in triplicate: T1 (control, no preservative), T2 (sodium benzoate 0.1%), T3 (potassium sorbate 0.1%), T4 (citric acid 0.3% additional), T5 (tulsi extract 2%), and T6 (ginger extract 3%). Jam was cooked in open stainless-steel pans to a TSS of 68.5 °Brix, verified with a digital refractometer. Preservatives were added off-heat at 85 °C and mixed uniformly. Hot jam was filled into pre-sterilised 200-mL glass jars, sealed with twist-off lids, and stored at 28 ± 2 °C [11]. Quality was assessed at 0, 30, 60, and 90 days for TSS (refractometer), titratable acidity (NaOH titration), pH (digital meter), ascorbic acid (2,6-DCPIP titration), browning index (absorbance at 420 nm), total plate count and yeast-mould count (pour plate method), and sensory evaluation (15-member panel, 9-point hedonic scale) [12, 13]. Data were analysed by two-way ANOVA; means compared by CD at $p \leq 0.05$.

Quality control

All chemical analyses were conducted in triplicate from independently prepared jars. The pH meter was standardised using buffers at pH 4.0 and 7.0 before each session. Microbiological media were autoclaved at 121 °C for 15 minutes and sterility-checked with uninoculated blanks. Sensory panellists received coded samples in randomised order under white fluorescent lighting [14].

Results

All preserved treatments maintained acceptable microbial loads (< 50 CFU g^{-1} total plate count) through 90 days, whereas the control exceeded 250 CFU g^{-1} by day 75 and showed visible mould growth. Among preserved samples, sodium benzoate and potassium sorbate held microbial counts below 20 CFU g^{-1}, while tulsi extract reached 38 CFU g^{-1} and ginger extract 45 CFU g^{-1} at 90 days.

Table 1: Physicochemical and microbiological quality of mixed-fruit jam at 90 days of storage

Parameter	T1 Ctrl	T2 NaB	T3 KS	T4 CA	T5 Tulsi	T6 Ginger
TSS (°Brix)	64.2	65.1	65.0	64.8	64.6	64.4
Acidity (%)	0.72	0.68	0.69	0.71	0.73	0.74
pH	3.18	3.31	3.29	3.24	3.22	3.20
Ascorbic acid	14.3	22.7	21.4	18.6	19.8	17.1
Browning index	0.48	0.18	0.21	0.31	0.26	0.34
TPC (CFU/g)	267	12	16	34	38	45
YMC (CFU/g)	43	<10	<10	14	16	21

NaB = sodium benzoate; KS = potassium sorbate; CA = citric acid; TPC = total plate count; YMC = yeast-mould count

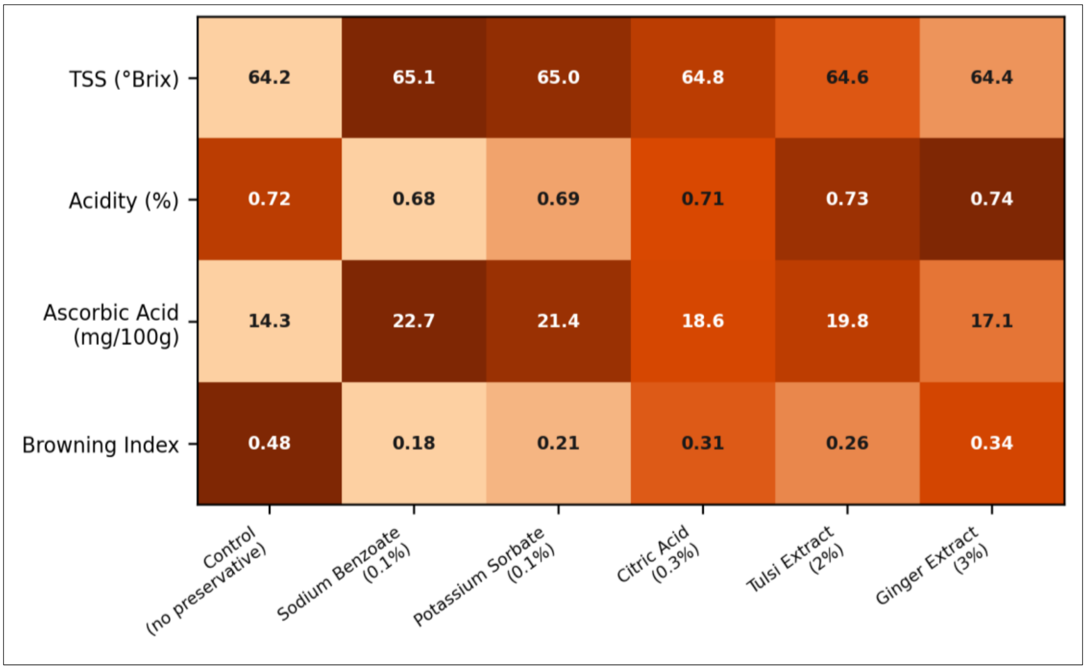

Fig 1: Heatmap of quality parameters across preservative treatments at 90 days of ambient storage

Table 2: Sensory evaluation scores (9-point hedonic scale) of mixed-fruit jam at 90 days

Treatment	Colour	Flavour	Texture	Taste	Overall
T1 Control	5.1	5.4	6.2	5.6	5.8
T2 Na-Benzoate	7.8	7.6	8.1	7.9	7.9
T3 K-Sorbate	7.5	7.4	7.9	7.6	7.6
T4 Citric Acid	7.0	6.8	7.4	7.1	7.1
T5 Tulsi Extract	7.3	7.2	7.6	7.4	7.4
T6 Ginger Extract	6.4	6.3	7.1	6.8	6.7
CD ($p \leq 0.05$)	0.42	0.38	0.35	0.41	0.37

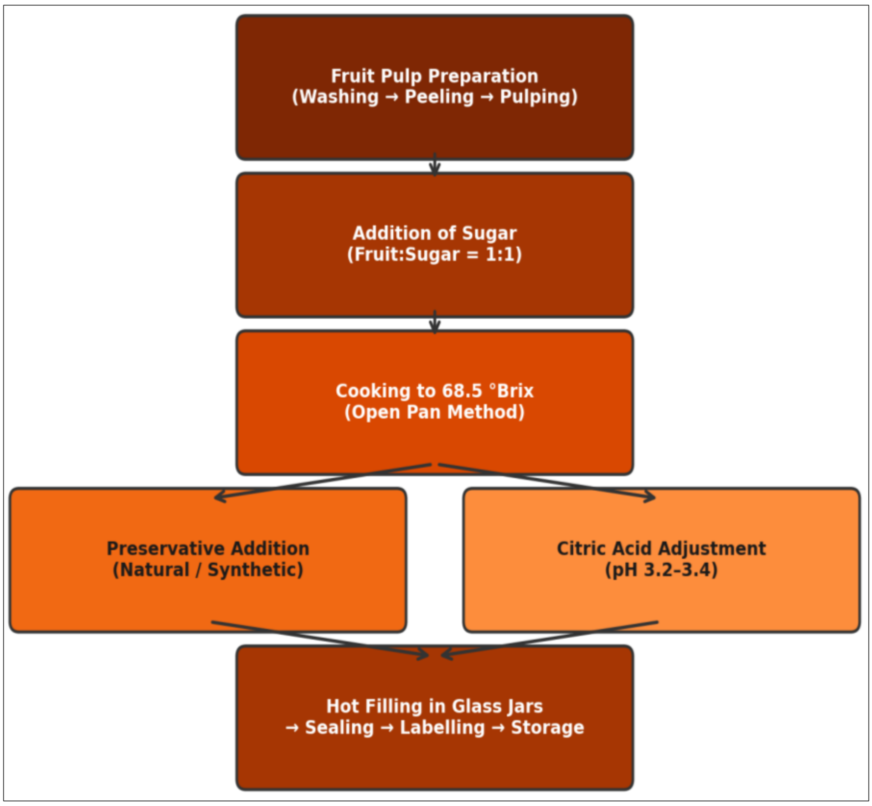

Fig 2: Process flow diagram for mixed-fruit jam preparation with preservative treatments

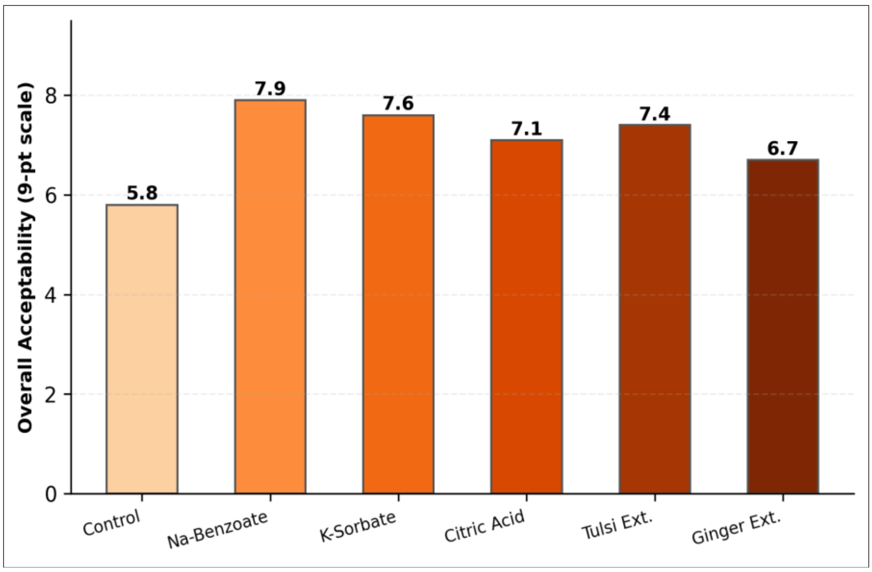

Fig 3: Overall sensory acceptability scores of jam samples at 90 days of storage

Comprehensive interpretation

Sodium benzoate provided the strongest overall protection, but tulsi extract at 2% delivered results that were statistically comparable for browning index and only marginally lower for ascorbic acid retention and microbial control. Ginger extract, despite its antioxidant properties, introduced a flavour note that panellists scored lower than all other preserved treatments.

Discussion

The superior antimicrobial performance of sodium benzoate at 0.1% agrees with the findings of Amit et al. [3] who reported that benzoate is most effective below pH 4.0 where the undissociated acid form predominates. The mechanism involves disruption of microbial cell-membrane transport and inhibition of glycolytic and TCA-cycle enzymes [15]. This explains why the low-pH jam matrix (pH 3.2-3.3) favoured benzoate activity.

Tulsi extract owes its preservative action to eugenol and rosmarinic acid, both of which exhibit broad-spectrum antimicrobial and antioxidant effects [6]. The fact that tulsi-treated jam maintained browning index at 0.26 closer to benzoate (0.18) than to the control (0.48) indicates that phenolic antioxidants in the extract scavenged free radicals responsible for Maillard-type browning. But the slightly higher microbial count in tulsi jars (38 vs. 12 CFU g^{-1}) suggests that the antimicrobial dose was sub-optimal at 2%; raising the concentration to 3% or combining tulsi with citric acid might close this gap without affecting flavour [16].

Ginger extract presented a trade-off: while its gingerol and shogaol content provided measurable antioxidant protection, the characteristic pungent flavour carried over into the jam and lowered sensory scores. For processors targeting the clean-label market, tulsi extract appears to be the more practical natural alternative [17].

Conclusion

The main contribution of this research is a side-by-side comparison showing that tulsi extract at 2% approaches the preservative performance of sodium benzoate in mixed-fruit jam stored under tropical ambient conditions. Evidence from chemical, microbiological, and sensory analyses over 90 days supports this conclusion. The finding is significant for small-scale jam producers seeking clean-label formulations without heavy investment in cold storage. Open questions include whether higher tulsi concentrations or blends with other natural antimicrobials (such as cinnamon or clove extract) can fully match synthetic preservative efficacy, and whether consumer willingness to pay a premium for natural-label jam justifies the added cost of plant extracts.

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