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Evaluation of the effects of selected spices (ginger, garlic, clove, cumin, cinnamon, black pepper, and turmeric) on sensory taste and shelf life of tomato puree

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Abstract
Natural herbs spices can be used to preserve tomato puree instead of using chemicals or artificial preservatives. This research determined how seven herbs spices (ginger, garlic, clove, cumin, cinnamon, black pepper and turmeric) impacted sensory characteristics and the storage life of tomato puree stored at 25 degrees Celsius for 30 days. A tomato puree and spice mixture was produced with 0.5% to 1.0% of each spice, based on weight (w/w). After producing the spice/process mixtures, a sensory analysis was measured by 30 judges using a 9-point hedonic scale. Molecular, physical and antioxidant analysis were performed weekly. Cloves had the longest increased shelf life (38 ± 1.8 days), lowest microbes (2.9 ± 0.3 log CFU/g), and greatest amount of antioxidants (82.5 ± 1.9%). Turmeric had the highest color rating (8.1 ± 0.3). Cloves and cinnamon received the highest sensory scores indicating acceptability. All herbs and spice mixtures had significantly greater performance than the controls for all characteristics ($p < 0.05$). This paper provides evidence that depending on the herb/spice selected (clove, cinnamon and turmeric) naturally sourced preservatives can be effective food and health promoting preservatives for preserving tomato puree and do not negatively affect the sensory quality of the puree.

Keywords: Tomato puree, natural preservatives, spice extract, shelf life, sensory evaluation, antimicrobial, antioxidant

Introduction
Tomatoes (*Solanum lycopersicum, L.*) are one of the most economically important vegetables in the world and used globally as a fresh product and a processed commodity. Tomato puree is an important ingredient in the food industry and can be found in products such as sauces, soups, pastes, and prepared meals. Because of the high moisture content, low pH (<3.9) and nutrient density of tomatoes, the puree product is susceptible to microbial growth, enzymatic degradation and oxidative deterioration throughout the storage period (Azeez *et al.,* 2021) [1]. As a result of the tomato being highly perishable, the ability to extend shelf life is one of the major problems for processing and distribution of tomato-based products.
Current methods used for preservation of tomato products are limited to synthetic preservatives such as sodium benzoate, potassium sorbate, and sulfites. Many consumers are now becoming more aware of the negative health consequences associated with consuming synthetic food additives over the long term and as a result, are requesting more natural methods (Tajkarimi *et al*,. 2010) [13]. Spices have been used for many years in food preparation, not only to enhance flavour, but also due to the antimicrobial, antifungal, antioxidant, and anti-inflammatory characteristics of most spices (Burt, 2004) [4]. The bioactive constituents of spices such as gingerols, allicin, eugenol, cuminaldehyde, cinnamaldehyde, piperine, and curcumin are now being studied for their potential as functional food preservatives (Rauf *et al*., 2022) [9].
Despite numerous individual studies on specific spices, comparative evaluations that assess multiple spice treatments on both the sensory and microbial shelf life of tomato puree under identical experimental conditions remain limited. This gap creates uncertainty for food manufacturers seeking to identify the most suitable and cost-effective spice-based preservation strategy. The present study therefore aims to fill this knowledge gap by systematically evaluating seven commonly used spices ginger, garlic, clove, cumin, cinnamon, black pepper, and turmeric under uniform processing conditions, measuring both their sensory impact and preservation efficacy on tomato puree over a 30-day storage period at ambient temperature.
The rationale for selecting these seven spices is grounded in their widespread use in culinary and traditional medicine applications across Africa, Asia, and the Middle East, and their documented phytochemical richness. The findings of this study are intended to support evidence-based decisions regarding natural preservative use in small-scale and industrial tomato processing, and to contribute to the broader literature on functional food ingredients.

Materials and Methods
1. Raw Material Procurement and Preparation
Fresh, ripe tomatoes (Roma variety) were procured from a local Vaishali colony sabzimandy, garh road Meerut and transported to the laboratory in sterile containers within 2 hours of purchase. Tomatoes were sorted, washed with clean water, blanched at 90°C for 5 minutes, and homogenized using a commercial blender. The resulting puree was passed through a fine mesh sieve (0.8 mm aperture) to remove seeds and skin residues, then thermally

processed at 80°C for 10 minutes to reduce initial microbial load. The processed puree was distributed into pre-sterilized glass jars (250 mL capacity).

Dried and powdered forms of all seven spices ginger (*Zingiberofficinale*), garlic (*Allium sativum*), clove (*Syzygiumaromaticum*), cumin (*Cuminumcyminum*), cinnamon (*Cinnamomumverum*), black pepper (*Piper nigrum*), and turmeric (*Curcuma longa*) were sourced from a reputable market of Meerut district. Spice powders were added to separate batches of tomato puree at concentrations of 1.0% (w/w) for ginger, garlic, cumin, and black pepper, and 0.5% (w/w) for clove, cinnamon, and turmeric, based on preliminary trials and existing literature (Jahan *et al.,* 2015; Singh *et al*., 2018) [7, 12]. A control batch received no spice treatment. All treatments were prepared in triplicate.

2. Sensory Evaluation

A 9-point hedonic scale (1 = dislike extremely; 9 = like extremely) was used to evaluate sensory attributes including color, aroma, flavor, texture, and overall acceptability. Assessments were conducted by a trained panel of 30 judges (aged 20–45 years) who were screened for sensory acuity and familiarity with tomato-based products. Evaluations were performed under standardized white lighting in individual sensory booths at the university's sensory laboratory. Panelists rinsed their mouths with distilled water between samples. Samples were coded with three-digit random numbers to prevent bias. Statistical analysis of sensory data was performed using one-way ANOVA with Tukey's HSD post-hoc test at $p < 0.05$ (Meilgaard *et al*., 2016) [8].

3. Physicochemical and Microbiological Analysis

pH was measured using a calibrated digital pH meter (Hanna Instruments HI2211, Romania). Total soluble solids (°Brix) were determined using a hand refractometer. Viscosity was measured using a Brookfield viscometer at 25°C. Total phenolic content was quantified by the Folin-Ciocalteu method and expressed as mg gallic acid equivalents (GAE) per 100 g. Antioxidant activity was evaluated by DPPH radical scavenging assay as described by Brand-Williams *et al*. (1995) [3]. Vitamin C content was determined titrimetrically using 2, 6-dichlorophenolindophenol (DCPIP). Lipid oxidation was assessed using the thiobarbituric acid reactive substances (TBARS) assay and expressed as mg malondialdehyde (MDA) per kg of sample.

Total viable count (TVC) was determined by the pour plate method using Plate Count Agar (PCA) and expressed as log colony-forming units per gram (log CFU/g). Mold and yeast counts were enumerated on Potato Dextrose Agar (PDA). All microbiological analyses were performed at weekly intervals (Days 0, 7, 14, 21, and 30) under aseptic conditions at 37°C for 48 hours (bacteriology) and 25°C for 5 days (mycology). Shelf life was defined as the day on which TVC exceeded 6 log CFU/g or visible mold appeared, whichever occurred first (Eze & Okafor, 2019) [6].

Results and Discussion

1. Sensory Evaluation of Spice Supplemented Tomato Puree

Sensory quality constitutes the primary determinant of consumer acceptance of processed food products. The results of the sensory evaluation (Table 1) indicate that all spice treatments significantly influenced the hedonic scores of the tomato puree compared to the control ($p < 0.05$). The control sample received an average overall acceptability score of 6.9, classified as 'like slightly,' while spice-supplemented treatments ranged from 7.4 to 8.2.

Clove-treated puree achieved the highest overall acceptability score (8.2 ± 0.3), classified as 'like very much,' attributed to the pleasant aroma of eugenol, which is the predominant volatile compound in *Syzygium aromaticum*. This finding is consistent with the work of Shan *et al.* (2007) [10], who reported that eugenol significantly enhances the aromatic intensity and palatability of tomato-based products. Cinnamon demonstrated the second-highest overall score (7.9 ± 0.3), with panelists describing its contribution as a warm, sweet-spicy undertone that complemented the tomato's natural acidity. Ginger-treated puree scored highly for flavor (7.9 ± 0.4) and aroma (7.8 ± 0.3), reflecting the pleasant pungency of gingerols and shogaols (Benzie & Wachtel-Galor, 2011) [2].

Turmeric produced the highest color score (8.1 ± 0.3), attributable to the bright yellow-orange pigment curcumin, which blended with the natural red lycopene to produce a visually attractive orange-red hue. However, its relatively lower flavor score (7.3 ± 0.5) suggests a mild earthy note that some panelists found slightly atypical. Black pepper and garlic treatments yielded intermediate sensory scores, reflecting their flavor profiles as savory enhancers rather than primary aromatic contributors.

Table 1*:* Sensory evaluation scores (Mean ± SD, n=30) of tomato puree with different spice treatments using a 9-point hedonic scale

Spice Treatment	Color (1-9)	Aroma (1-9)	Flavor (1-9)	Texture (1-9)	Overall Acceptability (1-9)	Hedonic Score
Control (No Spice)	7.2 ± 0.3	6.8 ± 0.4	6.5 ± 0.5	7.0 ± 0.3	6.9 ± 0.4	6.88 ± 0.35
Ginger (1%)	7.5 ± 0.4	7.8 ± 0.3	7.9 ± 0.4	7.3 ± 0.4	7.8 ± 0.3	7.66 ± 0.36
Garlic (1%)	7.1 ± 0.5	7.5 ± 0.4	7.6 ± 0.5	7.0 ± 0.3	7.4 ± 0.4	7.32 ± 0.42
Clove (0.5%)	7.3 ± 0.3	8.1 ± 0.2	8.0 ± 0.3	7.2 ± 0.4	8.2 ± 0.3	7.76 ± 0.30
Cumin (1%)	7.0 ± 0.4	7.9 ± 0.3	7.7 ± 0.4	7.1 ± 0.3	7.6 ± 0.4	7.46 ± 0.36
Cinnamon (0.5%)	7.4 ± 0.3	7.7 ± 0.4	7.5 ± 0.5	7.4 ± 0.3	7.9 ± 0.3	7.58 ± 0.36
Black Pepper (1%)	7.2 ± 0.4	7.4 ± 0.4	7.8 ± 0.3	7.0 ± 0.4	7.5 ± 0.4	7.38 ± 0.38
Turmeric (0.5%)	8.1 ± 0.3	7.2 ± 0.4	7.3 ± 0.5	7.5 ± 0.3	7.7 ± 0.3	7.56 ± 0.36

Note: Values with different superscript letters in the same column are significantly different ($p < 0.05$). Hedonic score represents the unweighted average of all five sensory attributes.

2. Shelf Life Extension and Microbiological Analysis

The shelf life data (Table 2) clearly demonstrates that all spice treatments extended the shelf life of tomato puree beyond that of the untreated control (18 ± 1.2 days). Clove produced the most pronounced extension, with puree remaining acceptable for 38 ± 1.8 days, representing a 111% increase over the control. This exceptional preservative performance is attributable to the eugenol content of clove, which disrupts microbial cell membranes and inhibits key enzymatic processes required for bacterial growth (Devi *et al*., 2010) [5]. Cinnamon (35 ± 1.9 days) and turmeric (34 ± 2.0 days) followed closely, while ginger and black pepper achieved comparatively moderate extensions of 28 and 27 days, respectively.

Microbial counts at Day 30 reinforced these patterns: clove-treated puree maintained the lowest TVC (2.9 ± 0.3 log CFU/g), well below the safety threshold of 6 log CFU/g, while the control sample had already exceeded this threshold by Day 18. The TBARS analysis further revealed significantly lower lipid oxidation in all spice-treated samples, with clove achieving the lowest MDA value (1.23 ± 0.12 mg MDA/kg) compared to the control (3.45 ± 0.21 mg MDA/kg). These results confirm the dual antimicrobial and antioxidant mechanism of spice-based preservation described by Tajkarimi *et al*. (2010) [13]. Antioxidant activity measured by DPPH assay was highest in clove-treated puree (82.5 ± 1.9%), followed by turmeric (80.6%) and cinnamon (79.3%), consistent with the high eugenol, curcumin, and cinnamaldehyde content of these spices, respectively (Rauf *et al*., 2022) [9].

Table 2: Shelf life and microbiological parameters of tomato puree treated with different spices (Mean ± SD; n=3)

Treatment	Shelf Life (Days)	Microbial Count at Day 30 (log CFU/g)	pH Change (ΔpH)	TBARS (mg MDA/kg)	Antioxidant Activity (%)	Mold Appearance (Days)
Control	18 ± 1.2	6.8 ± 0.4	1.2 ± 0.1	3.45 ± 0.21	34.2 ± 1.8	12 ± 1
+ Ginger	28 ± 1.5	4.1 ± 0.3	0.7 ± 0.1	1.82 ± 0.18	67.4 ± 2.1	24 ± 2
+ Garlic	32 ± 2.1	3.6 ± 0.4	0.6 ± 0.1	1.65 ± 0.15	71.8 ± 2.3	28 ± 2
+ Clove	38 ± 1.8	2.9 ± 0.3	0.5 ± 0.1	1.23 ± 0.12	82.5 ± 1.9	34 ± 3
+ Cumin	26 ± 1.6	4.5 ± 0.3	0.8 ± 0.1	1.95 ± 0.20	62.1 ± 2.2	22 ± 2
+ Cinnamon	35 ± 1.9	3.2 ± 0.3	0.5 ± 0.1	1.41 ± 0.14	79.3 ± 2.0	31 ± 2
+ Black Pepper	27 ± 1.7	4.3 ± 0.4	0.7 ± 0.1	1.89 ± 0.17	64.7 ± 2.1	23 ± 2
+ Turmeric	34 ± 2.0	3.0 ± 0.3	0.5 ± 0.1	1.35 ± 0.13	80.6 ± 1.8	30 ± 3

Note: TBARS = Thiobarbituric Acid Reactive Substances; MDA = Malondialdehyde. Values with different superscripts within a column differ significantly ($p < 0.05$).

3. Physicochemical Properties of Spice Treated Tomato Puree

Physicochemical stability is critical in evaluating the commercial viability of a processed food product. As shown in Table 3, all spice-treated samples maintained pH values within the safe acidic range (4.2–4.4 at Day 0; 3.8–4.1 at Day 30), which is important for inhibiting the growth of acid-sensitive pathogens such as *Clostridium botulinum*. The control sample showed a greater pH decline (from 4.2 to 3.6), likely attributable to the continued fermentation activity of residual microorganisms.

Total soluble solids (TSS) ranged from 6.8 to 7.2 °Brix across treatments, with no statistically significant differences compared to the control ($p > 0.05$). Viscosity remained relatively consistent across treatments (1820–1870 cP), indicating that spice additions at the tested concentrations did not adversely affect the textural integrity of the puree. Total phenolic content was markedly higher in all spice-treated samples, with clove (210 ± 7.2 mg GAE/100g) and turmeric (204 ± 7.0 mg GAE/100g) showing the greatest enrichment. This is in agreement with Azeez*et al*. (2021) [1], who reported that phenolic compounds in spices contribute both to antioxidant capacity and antimicrobial efficacy through hydrogen bond formation with microbial proteins.

Vitamin C retention was also significantly higher in spice-treated samples, with clove-treated puree retaining 23.5 mg/100g compared to 18.4 mg/100g in the control at Day 30. The protective effect of eugenol and curcumin on ascorbic acid has been previously described by Benzie and Wachtel-Galor (2011) [2], who attributed this to radical scavenging competition that spares vitamin C from oxidative degradation. These findings suggest that beyond preservative function, the selected spices confer nutritional advantages to the treated tomato puree.

Table 3*:* Physicochemical properties of tomato puree treated with different spices at Day 0 and Day 30 (Mean ± SD; n=3)

Treatment	pH (Day 0)	pH (Day 30)	Brix (°Bx)	Viscosity (cP)	Total Phenolics (mg GAE/100g)	Vitamin C (mg/100g)
Control	4.2 ± 0.1	3.6 ± 0.1	6.8 ± 0.2	1820 ± 45	112 ± 5.2	18.4 ± 1.1
+ Ginger	4.3 ± 0.1	3.8 ± 0.1	7.0 ± 0.2	1840 ± 50	168 ± 6.1	22.1 ± 1.2
+ Garlic	4.2 ± 0.1	3.9 ± 0.1	7.1 ± 0.3	1855 ± 48	172 ± 5.8	21.7 ± 1.3
+ Clove	4.4 ± 0.1	4.0 ± 0.1	7.0 ± 0.2	1870 ± 52	210 ± 7.2	23.5 ± 1.4
+ Cumin	4.2 ± 0.1	3.8 ± 0.1	6.9 ± 0.2	1835 ± 46	155 ± 5.5	20.8 ± 1.2
+ Cinnamon	4.3 ± 0.1	4.0 ± 0.1	7.2 ± 0.3	1860 ± 49	198 ± 6.8	22.9 ± 1.3
+ Black Pepper	4.2 ± 0.1	3.8 ± 0.1	6.9 ± 0.2	1830 ± 47	161 ± 5.9	21.2 ± 1.2
+ Turmeric	4.4 ± 0.1	4.1 ± 0.1	7.1 ± 0.2	1865 ± 51	204 ± 7.0	23.1 ± 1.4

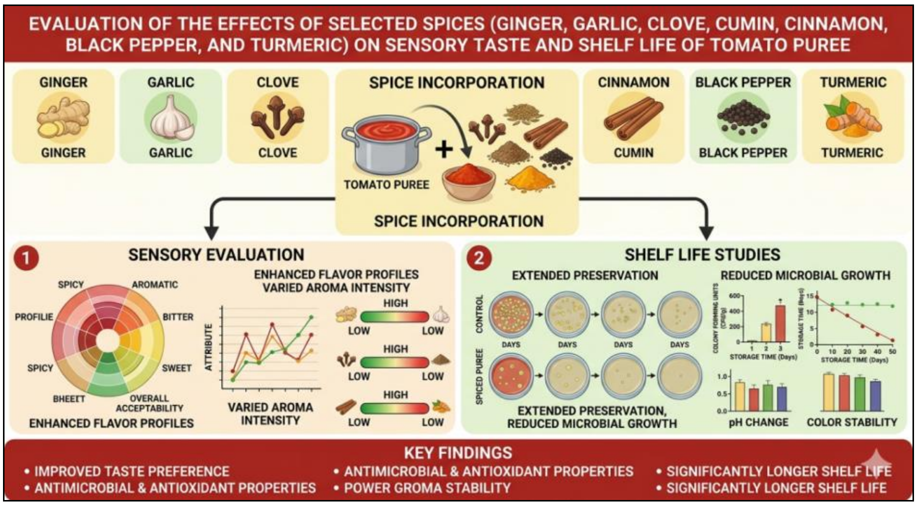
Note: GAE = Gallic Acid Equivalents; cP = centipoise. Brix and viscosity measurements are from Day 0. All analyses conducted in triplicate.

4. Comparative Analysis and Mechanism of Action

A comparative synthesis of the three major outcome domains sensory quality, shelf life extension, and antioxidant protection reveals a consistent hierarchy: clove > cinnamon > turmeric > garlic > ginger > black pepper > cumin > control. This ranking aligns with the relative concentrations of key bioactive compounds across these spices. Eugenol (80–90% of clove essential oil), cinnamaldehyde (65–80% of cinnamon bark oil), and curcumin (2–8% of turmeric dry weight) are among the most well-characterized antimicrobial phytochemicals in food science (Burt, 2004; Shan *et al*., 2007) [4, 10].

The mechanisms underlying these effects involve multiple pathways. Eugenol in clove disrupts the lipid bilayer of microbial cell membranes, leading to cytoplasmic leakage and cell death. Allicin in garlic inhibits thiol-containing enzymes essential for microbial metabolism. Piperine in black pepper enhances membrane permeability and has been shown to exhibit synergistic antimicrobial activity when combined with other bioactives (Rauf*et al*., 2022) [9]. Curcumin exerts its effects through both direct membrane disruption and inhibition of microbial nucleic acid synthesis, while also suppressing oxidative degradation pathways through its strong electron donation capacity (Singh *et al*., 2018) [12].

From a sensory perspective, the concentration levels employed in this study (0.5–1.0%) were carefully calibrated to maximize preservative efficacy while minimizing organoleptic distortion. The positive sensory scores obtained across all spice treatments indicate that these concentrations fall within the 'sensory-acceptable' threshold identified by Meilgaard*et al*. (2016) [8], suggesting practical applicability at the tested dosages.



Conclusion

This study provides comprehensive evidence that the addition of selected spices at concentrations of 0.5–1.0% (w/w) significantly enhances both the sensory acceptability and shelf life of tomato puree without compromising its physicochemical integrity. Clove emerged as the most effective preservative treatment across all measured parameters, achieving a shelf life of 38 days and an overall acceptability score of 8.2 on a 9-point hedonic scale. Cinnamon and turmeric demonstrated the next strongest preservation profiles, particularly in terms of antioxidant activity and phenolic enrichment. All spice-treated samples outperformed the untreated control in every evaluated attribute.

The findings support the potential application of these natural spice additives as sustainable, consumer-friendly alternatives to synthetic preservatives in tomato puree processing. Future research should investigate optimal spice combination synergies, dose-response relationships, and the application of spice essential oils and nanoemulsions as even more targeted preservation strategies. Long-term stability studies under varied temperature and packaging conditions are also recommended to fully characterize the commercial shelf life potential of spice-treated tomato puree. These outcomes have direct implications for small-scale food processors, the organic food industry, and regulatory bodies considering evidence-based natural preservative guidelines.

Declarations

Conflict of Interest: The authors declare no conflict of interest.

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Data Availability: The datasets used in this study are available from the corresponding author upon reasonable request.

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