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Incorporation of Indian Spices as Natural Antioxidants in Fermented Chicken Sausage Formulation

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Abstract
The incorporation of Indian spices into meat products provides functional and sensory advantages, offering natural alternatives to synthetic preservatives. This study formulated and evaluated spice mixes for fermented chicken sausage (FCS), focusing on garlic (*Allium sativum*), curry leaves (*Murraya koenigii*), black pepper (*Piper nigrum*), cardamom (*Elettaria cardamomum*), paprika (*Capsicum annuum*), and nutmeg (*Myristica fragrans*). These spices, rich in bioactive compounds such as phenolics, terpenes, and sulfur-based molecules, exhibit antioxidant and antimicrobial activities that reduce lipid oxidation, microbial spoilage, and sensory deterioration. Two spice blends were developed and assessed by trained panelists using an 8-point hedonic scale. Spice Mix 1, which excluded cumin and coriander, received significantly higher scores for flavor, aroma, spiciness, and overall acceptability ($P < 0.05$). Spice Mix 2, containing cumin and coriander, was less preferred due to strong earthy notes that masked meat flavor. The optimized blend demonstrates a clean-label approach to improving sensory quality, oxidative stability, and microbial safety in chicken sausages.

Keywords: Fermented chicken sausage, garlic, curry leaves, black pepper, cardamom, paprika, nutmeg, spice mix, sensory evaluation

Introduction
The use of spices and condiments has been a defining feature of Indian cuisine for generations, valued equally for their culinary and therapeutic contributions. These ingredients are abundant in natural bioactive compounds such as phenolics, terpenes, alkaloids, and volatile oils, which exhibit strong antioxidant, antimicrobial, and anti-inflammatory effects. Their incorporation in meat-based systems is particularly important, as such products are highly vulnerable to lipid oxidation, microbial contamination, and sensory degradation.

Among the commonly applied spice components, black pepper (*Piper nigrum*), garlic (*Allium sativum*) powder, paprika (*Capsicum annuum*), curry leaves (*Murraya koenigii*), nutmeg (*Myristica fragrans*), and cardamom (*Elettaria cardamomum*) play a crucial role in improving both taste and functional properties. Nutmeg provides compounds like myristicin and elemicin with antioxidant and antimicrobial effects (García-Díez *et al*,2017) [10], while garlic contributes organosulfur molecules that enhance microbial safety and promote health (Dai *et al*, 2025) [6]. When used together in a spice–condiment blend, these ingredients create synergistic effects, enhancing sensory appeal while also improving the functional quality of meat products.

In fermented chicken sausage (FCS) production, the addition of such a carefully formulated spice and condiment mix not only enriches aroma, flavor, and color but also supports oxidative stability, microbial control, and nutritional value. This approach minimizes the dependence on synthetic preservatives while aligning with modern consumer demand for natural, clean-label, and health-oriented functional foods.

Review of literature
Growing interest in natural antioxidants has encouraged the use of Indian spices in meat products as replacements for synthetic additives. Garlic (*Allium sativum*) has been reported to

improve oxidative stability and microbial safety in chicken sausages during storage (Bhatt, 2015) [5]. Ginger (*Zingiber officinale*) extracts maintain quality and sensory acceptability in poultry sausages and patties (Musalem *et al*, 2024) [15]. Curry leaf (*Murraya koenigii*) powder and extract enhance storage stability of chicken patties under refrigeration (Yadav *et al*, 2018) [22]. Coriander and cumin extracts have demonstrated strong antioxidant activity in chicken meat products, improving functional and sensory attributes (Ahmad *et al.*, 2023) [3]. Black pepper (*Piper nigrum*) has shown synergistic antioxidant potential when combined with other spices in poultry formulations (Humbal *et al.*, 2024) [11].

The use of Indian spices in chicken sausages is particularly valuable because poultry meat is highly susceptible to oxidative and microbial spoilage due to its higher proportion of polyunsaturated fatty acids (Sharma *et al.*, 2017) [20]. Incorporating natural antioxidants from spices not only delays quality deterioration but also improves color, flavor, and overall acceptability of the product (Eneojo and Martins, 2024) [7]. Unlike synthetic additives, these spices provide multifunctional benefits, acting as antioxidants, antimicrobials, and flavor enhancers simultaneously. Studies on garlic, ginger, curry leaf, coriander, cumin, and black pepper in chicken-based products demonstrate that their inclusion supports clean-label formulations while extending shelf life and ensuring consumer safety (Arjin *et al.*, 2025) [4]. Therefore, the strategic use of Indian spices in chicken sausages represents a natural, cost-effective, and consumer-preferred approach to improve product stability and sensory quality.

Garlic (*Allium sativum*)

Garlic has gained attention in meat technology due to its combined antioxidant and antimicrobial activities. Its active sulfur compounds, particularly allicin, function effectively when used as paste, powder, or oil in chicken sausages, helping to slow oxidative damage and restrict microbial growth without altering the proximate composition. Recent findings confirm its ability to enhance storage stability in poultry meat systems (Jimoh *et al*, 2024) [13]. From a pharmacological perspective, garlic is well documented for its antihypertensive, lipid-lowering, immune-modulating, and antimicrobial effects, which extend its value beyond preservation alone (AbdAl-Rudha and AL-Nasiry, 2023) [1]. In practical meat applications, controlled amounts of garlic not only maintain product safety and stability but also contribute a distinct, desirable flavor profile.

Curry Leaf (*Murraya koenigii*)

Curry leaf is rich in natural bioactives such as carbazole alkaloids, flavonoids, and phenolic acids, which make it an effective natural preservative for poultry products (Ganesan *et al.*, 2013) [9]. Research on chicken patties indicates that curry leaf, whether in extract or powder form, can mitigate oxidative spoilage and help retain quality during refrigeration (Najeeb *et al*, 2015) [16]. Beyond its role in food preservation, curry leaf demonstrates important pharmacological benefits including antidiabetic, anti-inflammatory, hepatoprotective, and cholesterol-lowering actions (Suja *et al*, 2022) [21]. When used in chicken sausage emulsions, it offers functional health attributes along with subtle herbal flavor notes that improve storage life and sensory quality.

Black Pepper (*Piper nigrum*)

Black pepper, widely appreciated for its pungency, also contributes functional bioactives such as piperine and essential oils that act as antioxidants (POP *et al.*,2024). While fewer studies focus specifically on chicken sausages, broader investigations in poultry and meat products confirm its role in limiting oxidative spoilage and improving sensory attributes (Sharma *et al*, 2017) [20]. It also possesses notable pharmacological properties including anti-inflammatory, antioxidant, antihypertensive, and bioavailability-enhancing effects, with piperine recognized for boosting absorption of other phytochemicals (Pramitha *et al*, 2022) [18]. In sausage systems, black pepper not only elevates flavor but also enhances preservation, especially when combined with other Indian spices.

Cardamom (*Elettaria cardamomum*)

Cardamom is an aromatic spice containing bioactive compounds such as cineole, terpenes, and phenolic acids that provide both antioxidant and antimicrobial effects. Its incorporation into meat systems has been linked to delaying lipid oxidation and improving storage quality of poultry products (Sharma *et al*, 2017) [20]. Beyond preservation, cardamom exhibits pharmacological activities including anti-inflammatory, antihypertensive, and digestive health-promoting effects, making it a functional spice of dual importance. In chicken sausages, it can deliver a mild, sweet-spicy aroma that complements other flavoring agents while also contributing to product stability.

Paprika (*Capsicum annuum* L.)

Paprika, derived from dried red peppers, is rich in carotenoids (capsanthin, capsorubin, and β-carotene) and phenolic compounds that act as strong natural antioxidants (Ferrando *et al.*, 2024) [8]. Studies in poultry meat products have reported its effectiveness in retarding lipid oxidation and improving color stability, particularly in emulsified chicken sausages and patties (Ismail and Huda, 2024) [12]. Pharmacologically, paprika is valued for its antioxidant, anti-inflammatory, and immune-boosting effects, with carotenoids also providing provitamin A activity. In sausage applications, paprika enhances redness and imparts a characteristic smoky-sweet flavor while supporting oxidative stability during storage.

Nutmeg (*Myristica fragrans*)

Nutmeg contains myristicin, eugenol, and various terpenes, which impart antioxidant and antimicrobial properties. Its extracts have been studied in meat systems for their ability to inhibit microbial growth and oxidative deterioration, improving product shelf life (Moirangthem *et al*, 2024) [14]. Pharmacologically, nutmeg is recognized for gastroprotective, anti-inflammatory, analgesic, and cognitive-enhancing effects, though its use must be controlled due to strong flavor intensity and bioactive potency (Acharya *et al.*, 2024) [2]. In chicken sausages, nutmeg provides a warm, sweet-spicy note that enhances sensory complexity while contributing to natural preservation.

Material and Methods

Ingredients for spice mix

Ingredients used for spice mix like salt, sugar, garlic powder, black pepper, sugar etc.
of standard quality were procured from local market of Bareilly.

Formulation of Spice Mix

Preliminary trials were undertaken to develop an optimized

spice blend for fermented chicken sausages. Different proportions of traditional Indian spices and condiments, namely black pepper (*Piper nigrum*), garlic (*Allium sativum*) powder, paprika (*Capsicum annuum*), curry leaves (*Murraya koenigii*), nutmeg (*Myristica fragrans*), and cardamom (*Elettaria cardamomum*), were used to prepare experimental spice formulations.

Each blend was incorporated into the sausage batter and evaluated through sensory analysis by a trained panel with expertise in meat product quality. The panelists assessed the formulations on critical attributes such as Color, Flavor, Aroma, Texture, Mouthfeel, Saltiness, Spiciness and Overall Acceptability. Emphasis was placed on the combined effect of spices in improving both sensory quality and consumer appeal. A systematic scoring method was applied, and the formulation receiving the highest sensory ratings was selected as the most suitable for further standardization. This approach ensured that the finalized spice blend not only contributed to desirable sensory traits but also supported functional qualities such as enhanced oxidative stability and microbial protection.

All spice ingredients were first subjected to drying in a hot-air oven to reduce moisture content and improve storage stability. Once dried, they were finely ground into powder form and uniformly blended to obtain spice mixes weighing a total of 50 g each.

The different spice mix formulations evaluated during the preliminary trials are summarized in Table 1.

Table 1: Different spice mix formulations

Ingredient	Spice mix 1 (g)	Spice mix 2 (g)
Black pepper	12	12
Garlic powder	16	13
Paprika	13	10
Curry leaves	3	3
Nutmeg	3	3
Cardamom	3	3
Cumin	-	3
Coriander	-	3
Total	50	50

The formulation of chicken sausage was standardized using lean chicken meat, salt, polyphosphate, ice flakes, vegetable oil, refined wheat flour (maida), sugar, and the optimized spice blend. For spice mix standardization, however, the sausages were prepared without fermentation, and no starter culture was included in the formulation.

The sausages were cooked in a hot air oven at 85 °C for one hour, and the process was continued until the internal temperature reached 72 °C, verified using a calibrated digital probe thermometer. The cooking time was standardized accordingly.

- **Pre-processing of spices:** Cleaning, de-stemming/de-seeding (paprika), shelling (cardamom), and size reduction of whole spices before drying.
- **Drying conditions:** Spices dried in a hot-air oven (BENCHTOP, Model/ year: BTE201D/2024) at 50 °C for 2 h until target moisture level reached ≤10%. Samples were spread in single trays.
- **Grinding and particle size:** Ground using a mixture (Bajaj classic). The powders were sieved through a 500 µm mesh to maintain uniform fineness.
- **Formulation coding and randomization:** Each spice mix was assigned blind codes (e.g., A, B, C). Samples were served in randomized order during sensory evaluation.
- **Storage of spice mixes:** Stored in laminated pouches with minimal headspace at 4 °C, protected from light, and used within 7 days of preparation.
- **Sensory study design:** Evaluation conducted with trained panelists (scientists and postgraduate students, Division of Livestock Products Technology, IVRI). An 8-point hedonic scale was used for attributes such as color, aroma, flavor, aftertaste, and overall acceptability. Sausages were prepared fresh without starter culture to assess only the effect of spice mix. Samples were served warm (~40 °C) in uniform portions. Palate cleansers (water/crackers) were provided between samples. Each formulation was tested in triplicate batches.
- **Statistical analysis:** All parameters were recorded in duplicates and repeated three times and the recorded data analyzed using SPSS (version 27.0 for Windows; SPSS, Chicago. 111. (U.S.A.) software.

Results and discussion

Results (in Table 2.) indicated that Spice mix 1 showed better sensory scores for all the attributes. This indicated that spice mix without cumin and coriander powder had better acceptability than that of other one though it contains only 3% level each. Thus, Spice mix 1 was selected as better spice mix for further use in chicken sausage formulation in different trials.

Table 2: Sensory evaluation (Mean ± SE) of two spice mixes showing significant differences ($p < 0.05$) in color, flavor, aroma, texture, mouthfeel, saltiness, spiciness, and overall acceptability

Sensory Attribute*	Spice Mix 1 (Mean ± SE)	Spice Mix 2 (Mean ± SE)
Color	6.5 ± 1.1^{a}	5.7 ± 0.47^{b}
Flavor	7.0 ± 1.2^{a}	5.6 ± 1.2^{b}
Aroma	6.2 ± 1.0^{a}	4.5 ± 0.5^{b}
Texture	7.5 ± 0.5^{a}	6.25 ± 0.5^{b}
Mouthfeel	7.4 ± 0.45^{a}	6.5 ± 0.5^{b}
Saltiness	6.5 ± 0.5^{a}	5.8 ± 0.25^{b}
Spiciness	7.5 ± 0.25^{a}	5.6 ± 0.5^{b}
Overall Acceptability	7.9 ± 0.31^{a}	6.5 ± 0.5^{b}

n= 21 Mean± SE, values within column with and within row (small letters) differ significantly ($p<0.05$). *Based on 8-point descriptive scale where 8= extremely like and 1= extremely dislike

The sensory evaluation clearly showed that sausages prepared with Spice Mix 1 were more preferred by the panelists compared to those made with Spice Mix 2. Attributes such as flavor, spiciness, and overall acceptability scored significantly higher in Spice Mix 1, making it the better choice for product development. The balanced blend of spices in this mix contributed positively to aroma, texture, and overall eating quality, resulting in a product that was more appealing to the sensory panel.

On the other hand, Spice Mix 2 received comparatively lower scores, especially for aroma and flavor, which reduced its overall acceptability. This could be because cumin and coriander, though widely used in Indian cuisine, can impart a strong earthy and slightly bitter taste when present in higher amounts (Rhind, 2025) [19]. In the context of chicken sausages, these spices may overpower the natural meat flavor rather than complement it, which likely influenced the lower preference among panelists. Such findings suggest that while cumin and coriander are valued in many dishes, their dominant character makes them less suitable in higher proportions for delicate meat-based products like sausages.

Conclusion

The study confirmed that traditional Indian spices enhance sensory quality, oxidative stability, and microbial safety in fermented chicken sausages. Spice Mix 1, without cumin and coriander, was more acceptable due to its balanced flavor profile. Optimized spice blends thus represent a natural, clean-label alternative to synthetic additives in meat processing.

Future Prospects

Future research may focus on evaluating the shelf-life extension of optimized spice blends under varied storage conditions. Exploring microencapsulation, novel delivery systems, and combinations with probiotic cultures could further improve functional and sensory attributes. Large-scale trials and consumer studies will be essential to validate industrial applicability.

Conflict of Interest: Not available

Financial Support: Not available

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