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Development and Standardization of a Traditional Biryani Masala Powder: A Study on Ingredient Synergy and Processing Parameters

Mallinedi Venkata Naga Lakshmi
Department of Food Technology, Vignan's Foundation for Science, Technology and Research (Deemed to be University), Vadlamudi, Guntur-522213, Andhra Pradesh, INDIA

***Abstract*—The increasing demand for natural, flavor-rich, and minimally processed culinary ingredients has accelerated the development of traditional spice blends with standardized processing protocols. In this study, a traditional Biryani Masala Powder was developed using sixteen whole spices including bay leaf, cinnamon, cloves, green cardamom, black cardamom, star anise, cumin, fennel, black pepper, mace, nutmeg, red chilli, Kashmir chilli, and coriander seeds. The spices were cleaned, sequentially dry-roasted on low flame to preserve volatile essential oils, and cooled completely before grinding. The roasted spices were milled to a fine powder and sieved to achieve uniform particle size, followed by storage in airtight glass containers. The prepared masala powder combines the sensory and functional benefits of multiple spices, including volatile compounds (cinnamaldehyde, eugenol, 1,8-cineole), alkaloids, and flavonoids. The use of sequential roasting without synthetic preservatives or artificial colorants enhances the safety, authenticity, and consumer acceptability of the formulation. The developed masala powder exhibited desirable aroma, uniform consistency, free-flowing texture, and potential health benefits such as improved digestion, anti-inflammatory activity, and antioxidant properties. This study demonstrates a simple, cost-effective, and reproducible approach for developing traditional spice blends with potential applications in culinary, packaged food, and ready-to-cook meal industries.**

***Index Terms*—Biryani Masala, spice blend, dry roasting, volatile oils, traditional food, functional spice mix.**

I. INTRODUCTION

In recent years, there has been a growing interest in traditional spice blends and minimally processed culinary ingredients due to increasing awareness regarding authentic flavors, health benefits, and the avoidance of synthetic additives. Traditional spice blends not only enhance the sensory attributes of food but also offer additional physiological benefits, including improved digestion, anti-inflammatory effects, antioxidant activity, and metabolic support. Among these, Biryani Masala occupies a unique position in South Asian cuisine, valued for its complex layering of warm, sweet, pungent, and floral notes derived from a combination of whole spices.

Biryani Masala is traditionally composed of sixteen or more whole spices, each contributing distinct bioactive compounds and organoleptic properties. Cinnamon (Cinnamomum verum) provides cinnamaldehyde, known for its antimicrobial and glucose-lowering effects. Cloves (Syzygium aromaticum) are rich in eugenol, a potent antioxidant and analgesic compound. Green cardamom (Elettaria cardamomum) contains 1,8-cineole, which supports respiratory health and digestion. Black cardamom (Amomum subulatum) imparts a smoky camphoraceous note while contributing phenolic compounds. Cumin (Cuminum cyminum) and fennel (Foeniculum vulgare) are traditionally recognized for their carminative properties, reducing bloating and improving gastrointestinal motility. Nutmeg (Myristica fragrans) and mace provide myristicin, a compound with sedative and neuroprotective potential. The inclusion of both red chilli and Kashmir chilli balances pungency with color, while coriander seeds add citrusy, terpenoid-rich notes [1].

Despite its widespread culinary use, the preparation of Biryani Masala lacks standardization, leading to significant batch-to-batch variability in flavor, aroma intensity, and bioactive retention. Improper dry

roasting—particularly excessive heat or duration—can degrade volatile essential oils and generate bitter pyrazines. Furthermore, grinding spices while still warm causes moisture condensation, promoting clumping, hydrolytic rancidity, and reduced shelf life. The absence of sequential roasting protocols based on spice morphology and thermal sensitivity further compromises quality [2].
This study aims to develop a standardized, reproducible method for preparing traditional Biryani Masala Powder using sixteen whole spices, with emphasis on sequential low-temperature dry roasting, mandatory post-roast cooling, and optimized milling parameters. The developed formulation combines the sensory and functional benefits of multiple spices without synthetic additives, enhancing both consumer acceptability and potential health-promoting properties. This work demonstrates a simple, cost-effective, and traditional yet standardized approach for producing high-quality Biryani Masala suitable for culinary, packaged food, and ready-to-cook meal applications.

II. MATERIALS AND METHODS

2.1 Materials
Fresh whole spices and other ingredients used for the preparation of the traditional Biryani Masala Powder included bay leaf (Laurus nobilis), cinnamon (Cinnamomum verum), cloves (Syzygium aromaticum), green cardamom (Elettaria cardamomum), black cardamom (Amomum subulatum), star anise (Illicium verum), cumin (Cuminum cyminum), fennel (Foeniculum vulgare), black pepper (Piper nigrum), mace (Myristica fragrans aril), nutmeg (Myristica fragrans seed), red chilli (Capsicum annuum), Kashmir chilli (Capsicum annuum, mild variety), and coriander seeds (Coriandrum sativum). All spices were procured from local markets in fresh, whole form and used without further purification or pretreatment except as described in the cleaning procedure. Distilled water was used for cleaning purposes where required.

2.2 Cleaning and Preparation of Spices
All whole spices were manually inspected and sorted to remove foreign matter including stones, dust, stems, and any visibly damaged or insect-infested specimens. Spices that appeared excessively moist or damp were spread in a single layer on a clean, dry stainless-steel tray and exposed to ambient air circulation for 15–20 minutes to reduce surface moisture content. No artificial drying or heat treatment was applied during this cleaning and preparation stage to preserve volatile components [3].

2.3 Sequential Dry Roasting
A heavy-bottomed stainless-steel pan (tawa) was preheated over low flame, achieving a surface temperature range of approximately 80–100°C. No oil or additional medium was used during roasting. The spices were roasted in three sequential batches based on their morphological characteristics and thermal sensitivity to prevent burning and ensure uniform release of volatile compounds.

Batch 1: (Aromatic Barks and Large Spices): Bay leaf (5 pieces), cinnamon (10 g), cloves (1.5 tsp), green cardamom (5 g), black cardamom (10 g), star anise (5 pieces), mace (3 pieces), and nutmeg (3 pieces) were added to the preheated pan. The mixture was roasted for 1–2 minutes with continuous, gentle stirring using a wooden spatula. Roasting was continued until a characteristic warm, sweet, and pungent aroma became distinctly perceptible. The spices were not allowed to darken or char.

Batch 2 (Seeds): Following the removal of Batch 1 spices, cumin (50 g), fennel (30 g), coriander seeds (2 tbsp), and black pepper (3 tsp) were added to the same pan. These were roasted on low flame for approximately 1–2 minutes with continuous stirring until fragrant. Special care was taken to prevent the seeds from turning dark brown, as over-roasting would result in bitterness and loss of volatile oils.

Batch 3 (Chillies): Red chilli (1 tsp) and Kashmir chilli (1 tsp) were added last and roasted for only 10–20 seconds. This brief roasting duration was selected to prevent the development of bitter off-flavors known to result from excessive thermal degradation of capsaicinoids and carotenoids [4].

2.4 Post-Roast Cooling
Immediately after the completion of roasting for each batch, all roasted spices were transferred to a wide, dry, stainless-steel plate. The spices were spread evenly in a thin layer (approximately 1–2 cm depth) to

facilitate rapid and uniform heat dissipation. The spices were then allowed to cool naturally to ambient temperature (25–30°C) for a period of 15–20 minutes. No artificial cooling methods such as refrigeration or forced air were applied, as rapid temperature changes could induce moisture condensation on the spice surfaces.

2.5 Grinding and Particle Size Reduction

After complete cooling to ambient temperature, the entire roasted spice mixture was transferred to a high-speed electric mixer grinder (capacity 500 W, approximately 20,000 rpm). The spices were ground in two cycles of 30 seconds each, with a 10-second between cycles to prevent excessive heat buildup. Intermediate shaking of the grinder contents ensured uniform particle size reduction. The grinding process was continued until a visually fine, free-flowing powder was obtained [5].

2.6 Sieving and Re-grinding

The ground spice powder was passed through a stainless-steel sieve with a mesh size of 0.5 mm (500 µm). The fraction passing through the sieve was collected as the final Biryani Masala Powder. Any coarse particles retained on the sieve (typically less than 5–10% of the total mass) were returned to the grinder for an additional 15–20 second grinding cycle, followed by re-sieving through the same mesh.

2.7 Storage

The final sieved Biryani Masala Powder was immediately transferred into a dry, airtight, amber-colored glass jar to protect against moisture, light, and oxygen exposure. The container was sealed tightly and stored in a cool, dark place away from direct sunlight and heat sources. For stability evaluation, samples were stored under refrigerated conditions (4°C) as well as ambient conditions (25±2°C) for comparative analysis.

III. RESULTS AND DISCUSSION

3.1 Physical and Sensory Characteristics of the Developed Masala Powder

The developed Biryani Masala Powder exhibited a uniform reddish-brown color, primarily attributed to the presence of Kashmir chilli, which contributed natural carotenoid pigments (capsanthin and capsorubin) without excessive pungency. The powder demonstrated a free-flowing texture with no visible clumping, agglomeration, or phase separation, indicating successful drying, roasting, and cooling protocols. The particle size analysis via sieving confirmed that more than 90% of the powder mass passed through the 500 µm mesh, achieving a particle size distribution suitable for uniform flavor dispersion in rice-based dishes.

The sensory evaluation of the powder revealed a complex, layered aroma profile. Initial olfactory notes were warm and sweet, contributed by cinnamaldehyde from cinnamon and anethole from fennel. Mid-notes included the camphoraceous, eucalyptus-like scent of 1,8-cineole from cardamom, followed by the pungent, peppery finish from black pepper and cloves. The extended cooling period (15–20 minutes) prior to grinding was found to preserve these volatile fractions significantly better than grinding without cooling, which resulted in a noticeable loss of top notes and the emergence of cooked or burnt undertones.

The taste profile of the masala powder was balanced, with initial sweetness from fennel and cinnamon, followed by warmth from cloves and black pepper, and a mild, non-bitter pungency from the controlled roasting of chillies. The brief roasting duration for chillies (10–20 seconds) proved critical, as trial batches roasted for 60 seconds or longer developed a perceptibly bitter aftertaste, consistent with published reports on thermal degradation of capsaicinoids and the formation of bitter pyrazine derivatives at elevated temperatures [6].

3.2 Effect of Sequential Roasting on Volatile Oil Retention

The sequential roasting approach (barks and aromatics first, followed by seeds, then chillies) was found to be essential for maximizing volatile oil retention while achieving adequate thermal exposure for each spice type. Larger, denser materials such as cinnamon sticks, star anise, and nutmeg required longer heating durations (1–2 minutes) to release their bound volatile compounds through thermal expansion of the plant matrix. In contrast, delicate seeds such as cumin and fennel required only brief heating (approximately 1 minute) to become fragrant, as their smaller particle size and higher surface area-to-volume ratio allowed rapid heat penetration.

The chillies, which contain both volatile flavor compounds and non-volatile capsaicinoids, required the shortest roasting duration (10–20 seconds). Extended roasting beyond 30 seconds resulted in the development of acrid, burnt notes and a significant reduction in the characteristic fruity aroma of Kashmir chilli. This observation aligns with the known thermal instability of carotenoids, which begin to degrade rapidly above 80°C, leading to both color loss and the formation of volatile degradation products with undesirable sensory properties.

Furthermore, roasting the chillies separately from the seeds and barks prevented cross-contamination of the entire batch with burnt chilli compounds. In traditional single-batch roasting methods, the lighter, smaller chilli pieces tend to scorch while denser spices are still under-roasted. The sequential method described here eliminated this problem entirely [7].

3.3 Critical Role of Post-Roast Cooling on Powder Quality

The cooling step (ambient temperature, 15–20 minutes) emerged as one of the most critical parameters in the entire protocol. Spices that were ground immediately after roasting (without the mandatory cooling period) produced a powder that was visibly clumpy, semi-moist, and prone to caking within 24–48 hours of storage. This phenomenon is attributed to residual heat within the spice matrix, which, upon grinding, causes moisture migration from the interior of spice particles to the newly exposed surfaces. This surface moisture acts as a binding agent, promoting agglomeration and creating a microenvironment conducive to hydrolytic enzymatic activity and microbial growth [8].

Conversely, spices that were cooled completely to ambient temperature (25–30°C) before grinding produced a free-flowing, dry powder that remained stable for extended periods without clumping. The 15–20-minute cooling period allowed internal and external temperatures to equilibrate, and any residual surface moisture from the roasting process (primarily from steam released during heating) evaporated completely.

Additionally, cooling prevented the thermal degradation of heat-labile volatile compounds during the grinding process itself. Grinding generates significant frictional heat, and starting with warm spices results in cumulative thermal exposure that can exceed 60–70°C within the grinder chamber, accelerating the loss of low-boiling-point volatiles such as limonene (boiling point 176°C but highly volatile at room temperature) and other monoterpenes [9].

3.4 Nutritional and Functional Contributions of Individual Spices

The selected spices significantly contributed to the functional and potential health-promoting properties of the developed Biryani Masala Powder.

Cinnamon (Cinnamomum verum) contains cinnamaldehyde (65–80% of its essential oil), which has been extensively studied for its antimicrobial activity against foodborne pathogens, its glucose-lowering effects through insulin-mimetic mechanisms, and its anti-inflammatory properties via inhibition of NF-κB pathway activation.

Cloves (Syzygium aromaticum) are one of the richest natural sources of eugenol, a phenolic compound with potent antioxidant activity (comparable to synthetic antioxidants such as BHT), as well as analgesic and local anesthetic properties. Eugenol constitutes 70–90% of clove essential oil and has demonstrated significant free radical scavenging activity in DPPH assays.

Green cardamom (Elettaria cardamomum) provides 1,8-cineole (also known as eucalyptol), a monoterpene ether with documented bronchodilator, anti-inflammatory, and carminative properties. Black cardamom (Amomum subulatum) contains higher concentrations of phenolic compounds and imparts a distinctive smoky, camphoraceous note while contributing additional antioxidant capacity.

Cumin (Cuminum cyminum) and fennel (Foeniculum vulgare) are traditionally recognized for their carminative properties, reducing intestinal gas, bloating, and improving gastrointestinal motility. The essential oils of both spices contain cuminaldehyde (cumin) and anethole (fennel), which have demonstrated antispasmodic effects on smooth muscle tissue.

Nutmeg (Myristica fragrans) and mace contain myristicin, elemicin, and safrole, compounds with documented neuroprotective, sedative, and monoamine oxidase inhibitory (MAOI) activity. While these compounds are beneficial in culinary quantities, they also require responsible usage, as excessive consumption (well beyond typical culinary doses) can produce psychoactive and adverse effects.

Black pepper (Piper nigrum) contains piperine, an alkaloid that not only contributes pungency but also functions as a bioavailability enhancer, increasing the absorption of various nutrients and phytochemicals including curcumin, beta-carotene, and certain B vitamins [10].

The combination of these spices in the developed masala powder creates a synergistic effect, wherein the bioactive compounds from different spices may enhance each other's absorption, stability, and physiological activity. The inclusion of black pepper, in particular, is expected to improve the bioavailability of polyphenols from cinnamon, cloves, and other spices.

3.5 Comparison with Commercial and Traditional Preparations

Commercially available Biryani Masala powders often contain anti-caking agents (such as silicon dioxide), synthetic preservatives (such as sodium benzoate or potassium sorbate), artificial colorants (such as tartrazine or sunset yellow), and flavor enhancers (such as monosodium glutamate). In contrast, the developed formulation uses no synthetic additives of any kind, relying entirely on the natural properties of whole spices and the controlled thermal processing described above.

Consumer acceptability of natural, clean-label products has increased significantly in recent years, driven by concerns regarding synthetic food additives and a preference for traditional, minimally processed ingredients. The developed masala powder aligns with this trend, offering an authentic, additive-free alternative to commercial spice blends without compromising on shelf stability or sensory quality.

The sequential roasting and cooling protocol described here is derived from traditional culinary practices but standardized for reproducibility. While traditional methods rely on the visual judgment and experience of the cook, the present study provides quantifiable parameters (roasting duration in seconds, cooling time in minutes, particle size in micrometers) that enable consistent results across different operators and settings [11].

3.6 Storage Stability and Shelf-Life Considerations

The developed Biryani Masala Powder was stored under two conditions: refrigerated (4°C, 50–60% relative humidity) and ambient (25±2°C, 65±5% relative humidity), both in airtight amber glass jars. Observations were recorded at weekly intervals for 8 weeks.

Under both storage conditions, the powder showed no visible signs of caking, clumping, or moisture absorption for the first 4 weeks. Between weeks 5 and 6, ambient-stored samples exhibited a slight but perceptible reduction in aroma intensity, particularly the volatile top notes from cardamom and fennel. Refrigerated samples retained their full aroma profile throughout the 8-week observation period.

No visible mold growth, insect infestation, or color degradation was observed in either storage condition during the study period, confirming that the low moisture content achieved through roasting and cooling, combined with the natural antimicrobial properties of the spices (particularly cloves, cinnamon, and black pepper), provides adequate preservation without synthetic additives.

The use of amber glass containers (as opposed to clear glass or plastic) provided protection against UV-induced photodegradation of heat-labile pigments (capsanthin from chilli) and volatile compounds. Airtight sealing prevented moisture ingress and oxygen exposure, which would otherwise accelerate lipid oxidation (rancidity) of the volatile oils present in nutmeg, cumin, and other oil-rich spices.

For extended storage beyond 8 weeks, refrigerated conditions (4°C) are recommended, as ambient storage may result in gradual aroma loss over 3–4 months. The powder is not recommended for frozen storage, as condensation upon thawing may introduce moisture and promote clumping.

3.7 Practical Applications and Usage Guidelines

Based on iterative sensory evaluation in test batches of biryani, the optimized usage rate was established at 2–3 tablespoons (approximately 15–20 g) of the developed masala powder per 1 kilogram of raw basmati rice, or 1–2 teaspoons (approximately 3–5 g) per cup (150 g) of cooked rice. This dosage produced a well-balanced flavor profile with no bitterness or excessive pungency.

The masala powder can be incorporated at two stages in biryani preparation: (1) added to the marinade for raw protein (chicken, mutton, or vegetables) to allow flavor absorption during marination, and (2) added to the partially cooked rice layer during dum cooking for aromatic infusion. The powder is heat-stable under typical cooking conditions (simmering, 85–95°C) but should not be subjected to high-temperature frying (above 150°C) for extended periods, as this may degrade volatile compounds and produce bitter notes.

Beyond biryani, the developed masala powder has potential applications in other rice-based dishes (pulao, jeera rice, fried rice), meat and vegetable curries, marinades and rubs for grilled or roasted meats, spice-infused oils and ghee, and as a seasoning for roasted vegetables or legumes [12].

3.8 Functional and Nutraceutical Potential

The developed Biryani Masala Powder demonstrates potential as both a culinary spice blend and a functional ingredient due to the presence of bioactive compounds, including volatile essential oils, phenolic acids, flavonoids, alkaloids, and carotenoids. The formulation offers several potential health benefits, including:

- Digestive support: Carminative properties from cumin, fennel, cardamom, and black pepper reduce flatulence, bloating, and improve gastrointestinal motility.
- Antioxidant activity: Phenolic compounds including eugenol (cloves), cinnamaldehyde (cinnamon), and various flavonoids (present in most spices) provide free radical scavenging capacity and reduce oxidative stress.
- Anti-inflammatory effects: Multiple spice constituents inhibit pro-inflammatory mediators including NF-κB, COX-2, and various cytokines.
- Antimicrobial properties: Volatile oils from cloves, cinnamon, black pepper, and cardamom exhibit broad-spectrum activity against foodborne bacteria including Bacillus cereus, Staphylococcus aureus, Escherichia coli, and Salmonella species.
- Bioavailability enhancement: Piperine from black pepper increases the absorption of various dietary phytochemicals and nutrients.
- Metabolic support: Cinnamon has demonstrated glucose-lowering effects, while several spices (cumin, fennel, black pepper) may modestly improve lipid profiles and metabolic parameters.

The use of whole, natural spices without synthetic preservatives, anti-caking agents, or artificial colorants further enhances the safety, authenticity, and consumer acceptability of the developed formulation, making it suitable for clean-label product development and health-conscious consumers.

3.9 Limitations and Future Directions

While the present study successfully standardized the processing parameters for Biryani Masala Powder, certain limitations should be acknowledged. Quantitative analysis of volatile compound retention (via gas chromatography-mass spectrometry, GC-MS) and antioxidant capacity (via DPPH, FRAP, or ABTS assays) was not performed in this formulation study. Future work should include analytical quantification of key bioactive markers including cinnamaldehyde, eugenol, 1,8-cineole, anethole, cuminaldehyde, piperine, and myristicin before and after roasting to establish optimal thermal exposure thresholds.

Additionally, accelerated shelf-life studies under varying temperature and humidity conditions would provide data for predicting long-term stability and establishing expiration dating. Sensory evaluation with larger consumer panels ($n > 100$) would enable statistical validation of acceptability scores and identification of optimal flavor profiles for different regional preferences [13].

The potential synergistic antimicrobial effects of the complete spice blend against foodborne pathogens also warrant investigation, as this could support applications in natural food preservation. Finally, clinical studies (even small-scale, short-duration) examining the digestive and metabolic effects of regular consumption of the masala powder in real-world culinary contexts would provide valuable evidence for functional food claims.

IV. CONCLUSION

In the present study, a traditional Biryani Masala Powder was successfully developed using sixteen whole spices, including bay leaf, cinnamon, cloves, green cardamom, black cardamom, star anise, cumin, fennel, black pepper, mace, nutmeg, red chilli, Kashmir chilli, and coriander seeds. The formulation was prepared using sequential low-temperature dry roasting, complete ambient cooling, and controlled milling to obtain a fine, uniform powder. The developed masala powder exhibited desirable physical and sensory characteristics, including a fragrant aroma, uniform reddish-brown color, free-flowing texture, and good structural stability without clumping.

The incorporation of diverse spices enhanced the functional profile of the masala powder by providing volatile essential oils (cinnamaldehyde, eugenol, 1,8-cineole, anethole, myristicin), phenolic compounds, flavonoids, and carotenoids. Cinnamon contributed antimicrobial cinnamaldehyde, cloves provided antioxidant eugenol, cardamom offered digestive 1,8-cineole, cumin and fennel supplied carminative properties, nutmeg and mace delivered neuroprotective myristicin, and chillies contributed capsaicinoids and natural color. The sequential roasting approach barks and aromatics first (1–2 minutes), followed by seeds (until fragrant), and finally chillies (10–20 seconds only) prevented burning and bitterness while preserving volatile fractions.

The mandatory cooling step (ambient temperature, 15–20 minutes) prior to grinding proved critical for preventing moisture-induced clumping and reducing the risk of hydrolytic rancidity of lipids present in nutmeg, cumin, and other oil-rich seeds. The sieving step (≤500 µm) ensured uniform particle size, enabling consistent flavor distribution in culinary applications. Storage in airtight glass containers protected the powder from moisture, light, and oxygen, extending shelf stability without the need for synthetic preservatives.

The developed Biryani Masala Powder demonstrated good stability under ambient storage conditions when properly sealed, without visible caking or loss of aroma. The formulation offers several potential health benefits, including improved digestion (from carminative spices), anti-inflammatory activity (from eugenol and cinnamaldehyde), antioxidant protection (from phenolic compounds), and antimicrobial effects (from volatile oils). Additionally, the use of whole, natural spices without synthetic colorants, preservatives, or artificial flavor enhancers enhances consumer safety and acceptability.

The formulation also offers advantages such as ease of preparation, cost-effectiveness (using widely available whole spices), reproducibility through standardized protocols, and suitability for various applications including home cooking, restaurant kitchens, packaged spice mixes, and ready-to-cook meal kits. This study provides a scientific basis for the standardization of traditional Biryani Masala and opens avenues for further research into the quantification of volatile compounds, antioxidant capacity, and shelf-life modeling of the optimized blend.

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