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Research Article

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Sensory Profiling, Phytochemical and Nutritional Evaluation of A Novel Polyherbal Spice Blend from Indigenous Plants

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Abstract

Purpose: *Spices are integral to human diets and culture, serving not only as flavor enhancers but also as components of nutrition and health. This study evaluated the nutritional, phytochemical, and aromatic potentials of four tropical spices Fenugreek (Trigonella foenum-graecum), Fennel (Foeniculum vulgare), Nutmeg (Myristica fragrant), and Country Onion (Afrostyrax lepidophyllus). What are the primary phytochemicals present in the individual ingredients, final mixed spice blend, and how does it contribute to its nutritional, medicinal and sensory properties.*

Methods: *The samples were analyzed using High-Performance Liquid Chromatography (HPLC) to identify major bioactive compounds. Proximate analysis to assess their nutritional composition. Food Taste evaluation to determine flavor and its contribution to food taste.*

Results: *The findings revealed that the four spices possess distinct and complementary nutritional and phytochemical attributes. Fenugreek recorded the highest crude protein content (25.88%), making it a natural protein fortifier, while Nutmeg contained the highest fat level (21.94%), enhancing flavor and aroma retention. Fennel had the highest crude fiber (7.63%) and ash content (4.61%) and Country Onion showed the highest carbohydrate value (73.81%) along with notable phytochemicals such as phenols and capsaicin's. The phytochemical screening confirmed the presence of flavonoids, saponins, alkaloids, terpenoids, and phenolic compounds, which are responsible for antioxidant, antimicrobial, and anti-inflammatory activities. Food taste evaluation further indicated a strong consumer preference for the mixed spices.*

Conclusion: *it is evident that these tropical spices possess remarkable nutraceutical and aromatic potentials that can improve both the nutritional and taste quality. Thus highlighting their potential industrial applications.*

Keywords: Aromatic, Leguminosae, Myristicaceae, Antioxidant, Bioactive, Flavour

1. Introduction

Plants such as fenugreek (*Trigonella foenum-graecum*), fennel (*Foeniculum vulgare*), nutmeg (*Myristica fragrans*), and country onion (*Afrostyrax lepidophyllus*) are valued in tropical regions for their combined nutritional benefits, bioactive phytochemicals, and distinctive aromatic properties. Recent researches has deepened the understanding of their composition, and potential uses. Tropical food spices play an indispensable role in human life due to their nutritional, medicinal, aromatic, and economic importance. They are not only used to enhance the flavour, aroma, and colour of food but also contribute significantly to health and nutrition because of the rich content of bioactive and nutritional compounds

[1]. Spices such as fenugreek (*Trigonella foenum-graecum*), fennel (*Foeniculum vulgare*), nutmeg (*Myristica fragrans*), and country onion (*Afrostyrax lepidophyllus*) are widely cultivated and consumed in tropical regions, where they are valued both as condiments and as traditional medicines [2]. These spices are important sources of essential nutrients, including carbohydrates, proteins, fats, vitamins, and minerals, which contribute to dietary balance and metabolic functions even when consumed in small quantities [3]. For instance, fenugreek is rich in iron, calcium, magnesium, and soluble fibre that support blood sugar regulation and cholesterol reduction [1]. Likewise, fennel contains vitamin C, potassium, and calcium, which enhance immunity and bone health, while nutmeg provides valuable fatty acids and trace elements essential for energy metabolism [2].

Beyond their nutritional content, tropical spices are notable for their diverse phytochemical constituents, which include flavonoids, alkaloids, tannins, phenolic compounds, and terpenoids that exhibit important pharmacological effects [4]. These bioactive compounds have been shown to possess antioxidant, antimicrobial, anti-inflammatory, and antidiabetic activities, which make them useful in the prevention and management of various diseases [3]. Fenugreek, for example, contains steroidal saponins and flavonoids that help regulate glucose and lipid metabolism, while nutmeg and fennel possess essential oils with strong antimicrobial and antioxidant properties that protect against oxidative stress and microbial infections [1,2]. Thus, tropical food spices can be regarded as natural sources of nutraceuticals, providing both nutritional and therapeutic benefits without the side effects commonly associated with synthetic drugs.

The aromatic properties of tropical spices also add to their importance. Their pleasant scents and flavors result from complex mixtures of volatile essential oils such as eugenol, Anatole, myristicin, and sotolon, which contribute to their characteristic aroma and therapeutic value [5]. For instance, fennel's aroma is mainly due to anethole, which also acts as a digestive aid, while nutmeg's myristicin and eugenol give it a warm, spicy scent widely used in the food and cosmetic industries [2]. Similarly, the pungent aroma of country onion is attributed to its eugenol derivatives, making it an important seasoning and natural preservative in African cuisine [4]. These aromatic compounds are also valuable in the manufacture of perfumes, soaps, and flavoring agents, thus extending the usefulness of spices beyond the kitchen into the industrial and pharmaceutical sectors.

Economically, tropical food spices contribute significantly to national and local economies, particularly in developing countries that export them as raw or processed products. The increasing global preference for natural flavoring agents, essential oils, and organic ingredients has enhanced the market value of spices such as nutmeg, fennel, and fenugreek [3]. The spice industry supports agricultural livelihoods, encourages value addition, and stimulates small-scale processing enterprises in tropical regions [1]. Moreover, by promoting the cultivation of indigenous species like country onion, the spice trade can also encourage biodiversity conservation and sustainable resource management [4].

In addition to their nutritional and economic benefits, tropical food spices hold deep cultural and traditional significance. They have long been used in indigenous medicine for treating ailments such as digestive disorders, inflammation, and respiratory infections, while also serving important roles in traditional ceremonies and religious practices [4]. Their enduring use reflects a blend of culinary art and cultural identity, as well as a reliance on natural plant-based remedies passed down through generations.

Tropical food spices are of great importance because they combine nutritional richness, medicinal value, aromatic appeal, and economic potential. They serve as natural health-promoting agents, flavour enhancers, and industrial raw materials. The continued scientific study and sustainable utilization of these plants, particularly underutilized species like country onion, are essential for maximizing their benefits and preserving their role in tropical biodiversity, nutrition, and industry [3,5].

Fenugreek is an annual herb belonging to the family Fabaceae (Leguminosae), widely cultivated in Asia, Africa, and parts of the Mediterranean for its seeds and leaves. The seeds are small, brownish-yellow, and have a slightly bitter taste with a characteristic maple-like aroma [3]. Fenugreek (*Trigonella foenum-graecum*) continues to attract robust clinical and preclinical attention for its metabolic benefits, and recent meta-analyses and randomized trials confirm its hypoglycaemic potential and favorable effects on insulin resistance and lipid profiles. Clinical work on standardized seed extracts such as Fenfuro has shown improvements in fasting blood glucose and demonstrated an acceptable safety profile when used alongside standard antidiabetic therapy [6]. Mechanistic studies summarized in contemporary reviews attribute fenugreek's metabolic actions to soluble fibers, galactomannans, 4-hydroxyisoleucine (which modulates insulin secretion), saponins and polyphenols that together slow carbohydrate absorption, enhance insulin action and reduce oxidative stress in metabolic tissues [1]. According to Demirbas et al fenugreek seeds are a nutritional powerhouse, boasting a significant protein content ranging from 23-25%, making them a valuable plant-based protein source [7]. This high fiber content is crucial for digestive health and plays a pivotal role in modulating glucose absorption and lipid metabolism. Furthermore, fenugreek seeds are an excellent source of essential minerals, including iron, magnesium, manganese, and copper, which are vital for numerous physiological functions such as oxygen transport, energy production, and antioxidant defense. They also provide a good spectrum of B vitamins, including thiamine (B1), riboflavin (B2), niacin (B3), and pyridoxine (B6), which are cofactors in various metabolic pathways.

Deshpande and Patil , further elaborated on the lipid profile, highlighting the presence of beneficial unsaturated fatty acids, such as linoleic acid (an omega-6 fatty acid) and oleic acid (an omega-9 fatty acid), which are known to support cardiovascular health by helping to reduce LDL cholesterol levels [8]. The presence of these macronutrients and micronutrients underscores fenugreek's

potential as a functional food ingredient. The nutritional profile of fenugreek also makes it a valuable supplement for nursing mothers, as it is believed to enhance lactation.Recent pharmacological research supports these ethnomedicinal claims. *A. lepidophyllus* seed extracts have demonstrated strong antioxidant, anti-inflammatory, antimicrobial, and cardioprotective properties in laboratory and cell-based studies [9,10]. In particular, Moukette, found that extracts of the plant reduced oxidative damage and protected cardiac cells from doxorubicin-induced toxicity, suggesting significant therapeutic potential [4]. Recent work has confirmed that fenugreek (*Trigonella foenum-graecum*) possesses a strong nutritional profile including protein, fibre, and minerals, and that processing treatments can greatly modulate its phytochemical and antinutritional content. For example, in Ethiopia, a study of fenugreek cultivated in the Gamo Zone showed that the proximate composition (moisture, ash, fibre, fat, protein, carbohydrate, gross energy) of fenugreek seeds had protein levels around 12.8%, fat about 9.36% and carbohydrate about 46.1% (w/w) among other constituents, while phytochemical screening revealed high phenolic and flavonoid contents (382 ± 11 mg GAE/100 g for total phenols; 123 ± 3.6 mg quercetin equivalents for flavonoids), demonstrating strong antioxidant potential. Heavy metals were also measured, indicating that soil and cultivation conditions strongly influence safety and bioavailability.

The presence of sulphur-containing compounds, phenolics, and flavonoids contributes to its antimicrobial and antioxidant activity, validating its traditional use as both food spice and natural medicine [10]. Nematollahi et al, delve into the significance of alkaloids, particularly trigonelline, which is unique to fenugreek and contributes to its bitter taste [6]. Trigonelline has demonstrated promising hypoglycemic effects by improving insulin sensitivity and glucose utilization, as well as neuroprotective properties.

Additionally, Ruwali et al highlighted the presence of various phenolic acids, such as caffeic acid, ferulic acid, and p-coumaric acid, which further augment fenugreek's antioxidant capacity and contribute to its anti-inflammatory and antimicrobial activities [11]. The synergistic interplay of these diverse phytochemicals is believed to be responsible for the broad spectrum of therapeutic effects attributed to fenugreek, ranging from blood sugar regulation and cholesterol reduction to anti-inflammatory and antioxidant actions. Fenugreek's distinctive and often polarizing aroma and flavor profile are attributed to a complex mixture of volatile compounds. Prakash and Gupta, identify 4-hydroxyisoleucine as a key compound responsible for the characteristic maple-like or curry-like aroma, particularly prominent in roasted fenugreek seed [12]. This amino acid derivative is unique to fenugreek and contributes significantly to its culinary appeal.

- **Fennel** is a perennial aromatic herb of the family Apiaceae (Umbelliferae), native to the Mediterranean region but widely cultivated across tropical and subtropical areas. The plant bears feathery leaves and yellow flowers, and its small dried fruits (often called seeds) are the main spice component [2]. Fennel (*Foeniculum vulgare*) has a long ethnobotanical history for digestive, lactation and respiratory uses, and recent investigations have reinforced this traditional profile while expanding evidence for antioxidant and anti-inflammatory activities. Phytochemical analysis consistently identify trans-anethole, estragole, fenchone, limonene and phenolic compounds as the major bioactive constituents responsible for antispasmodic, carminative and antimicrobial effects [13]. Contemporary animal and human-adjacent studies show that fennel seed supplementation can improve digestive comfort and, in lactation studies, may increase milk yield and components, although clinical evidence in humans remains heterogeneous and calls for larger controlled trials [14]. Fennel's antioxidant and anti-inflammatory actions also make it a promising candidate as a food-grade functional ingredient, but reviews warn that standardization is needed because volatile compound composition varies by cultivar and geography, affecting both efficacy and safety profiles [13]. A single raw fennel bulb provides significant amounts of dietary fiber, which is crucial for digestive health and can help manage cholesterol levels to support heart health. The bulb is also a good source of important vitamins and minerals, including potassium, calcium, and vitamin C. The presence of vitamin C contributes to collagen synthesis and acts as an antioxidant, protecting cells from damage caused by free radicals. The presence of these nutrients makes fennel a valuable addition to a healthy diet. According to a study by Dissanayake et al, fennel seeds are particularly rich in minerals such as calcium, magnesium, and iron, which are essential for various physiological functions, including bone formation, muscle function, and oxygen transport [15].

Furthermore, Singh and Bartwal, highlighted the presence of B vitamins, including folate and niacin, in fennel, which are vital for energy metabolism, DNA synthesis, and cellular function [16]. The low caloric content combined with a rich nutrient density makes it a healthy addition to various diets, supporting overall human health, including immune system strengthening, improved digestion, and cardiovascular health. The therapeutic properties of fennel are largely attributed to its diverse array of phytochemicals, which are non-nutritive plant compounds with protective or disease-preventing properties. These include phenolic compounds (such as rosmarinic acid, chlorogenic acid, and caffeic acid), flavonoids (like quercetin and kaempferol), and volatile compounds.

- **Nutmeg** is a tropical evergreen tree belonging to the family *Myristicaceae*, native to the Moluccas (Spice Islands) of Indonesia but now cultivated in many tropical countries. The spice is derived from the dried kernel of the plant's fruit,, while the red aril surrounding the seed is processed to produce mace, another valuable spice [5]. Nutmeg (*Myristica fragrans*) is supported by a large body of laboratory and review literature documenting antimicrobial, anti-inflammatory, antioxidant and neuroactive properties, driven by essential oil terpenoids and phenylpropanoid derivatives such as myristicin and safrole-related compounds. A comprehensive review of nutmeg essential oil by Ashokkumar et al, collated

evidence for antimicrobial and CNS-modulatory activities and noted growing pharmacological interest in myristica constituents for pain, inflammation and mood disorders [5]. More recent reviews and experimental reports continue to highlight promising in-vitro and in-vivo data for antimicrobial and anti-inflammatory effects while explicitly flagging dose-dependent toxicity risks particularly psychotropic effects and hepatotoxicity associated with high myristicin exposures so clinical translation requires careful risk assessment and standardization [17].

- **Country Onion:** Country onion, scientifically known as *Afrostyrax lepidophyllus*, is an indigenous spice plant native to West and Central Africa, particularly Cameroon, Nigeria, and Gabon. It belongs to the family Huaceae and is often referred to as "bush onion" or "African garlic" because of its strong, onion-like aroma [4]. The spice is obtained from the bulb, bark, or seeds of the plant, which are commonly used in soups, stews, and traditional sauces. Country onion, locally known as "bush onion," is a tropical African spice traditionally used for both culinary and medicinal purposes. In traditional Cameroonian and Nigerian medicine, the seeds and bark are used as condiments and remedies for coughs, fevers, and intestinal parasites [4]. The plant is also believed to have aphrodisiac and wound-healing properties, and the essential oil is commonly applied as an antimicrobial agent for treating skin infections [9].

Country onion (*Afrostyrax lepidophyllus*), a regional West and Central African spice also called bush onion, has moved from ethnobotanical curiosity to a subject of targeted phytochemical and pharmacological research in the last five years. Phytochemical profiling and GC-MS studies show a predominance of sulphur-containing volatiles, phenolics and other small bioactives that plausibly underlie antimicrobial, antioxidant and anti-inflammatory traditional uses [9]. In vitro studies and cell models report strong free radical scavenging and hepatoprotective enzyme effects, and essential-oil fractions demonstrate antibacterial and antifungal activity useful for food preservation and as lead antimicrobial agents [10]. Notably, an evidence-based study of *A. lepidophyllus* and *Monodora myristica* found that extracts could reduce doxorubicin-induced toxicity in H9c2 cardio myoblasts, suggesting possible cardio protective antioxidant mechanisms that warrant in vivo validation [4].

Across these four spices, modern phytochemical and pharmacological research largely validates many traditional claims while also exposing important limits and safety questions. Fenugreek and fennel have the strongest and most consistent clinical/preclinical evidence for metabolic and digestive/lactation indications respectively, nutmeg offers potent antimicrobial and neuroactive leads tempered by toxicity concerns, and *Afrostyrax lepidophyllus* is an emerging regional spice with validated antioxidant, antimicrobial and anti-inflammatory properties that are ripe for further in vivo and clinical development [18,9].

2. Traditional and Medical uses of Test Plants used as food Spices

Traditionally, fenugreek seeds and leaves have long been valued both as food and as a medicinal herb across tropical and subtropical regions, particularly in South Asia and parts of Africa. In traditional medicine, fenugreek is used to stimulate lactation in nursing mothers, relieve digestive disturbances, and manage diabetes and inflammation [1]. The seeds are commonly incorporated into curries, soups, and herbal tonics due to their slightly bitter flavour and reputed ability to "purify the blood" and aid metabolism [19].

Recent pharmacological and clinical studies have substantiated many of these traditional uses. Fenugreek contains high levels of soluble fibre and 4-hydroxyisoleucine, which contribute to glucose-lowering and lipid-modulating effects, improving glycaemic control and insulin sensitivity in diabetic patients [18]. In addition, modern investigations have highlighted its anti-inflammatory, antioxidant, and hypocholesterolemic activities, making it beneficial for cardiovascular and metabolic health [1]. Thus, fenugreek demonstrates strong nutritional and phytochemical potential (proteins, fibers, phenolics, flavonoids) in recent studies, and its aroma-related data are less frequent but many bioactive compounds (flavones etc.) also contribute to taste and likely aromatic properties.

Fennel is traditionally cultivated and consumed both as a culinary spice and as a therapeutic herb in tropical and subtropical zones. Traditionally, fennel seeds and essential oil have been used to treat gastrointestinal ailments such as flatulence, indigestion, and constipation; they are also valued for improving milk secretion in lactating mothers and relieving respiratory congestion [13]. In many traditional systems, fennel tea is administered to infants for colic and to adults as a digestive aid. Contemporary pharmacological studies have confirmed these uses. The essential oil of fennel, rich in trans-anethole, fenchone, and estragole, demonstrates strong antispasmodic, anti-inflammatory, antimicrobial, and antioxidant properties [20]. Experimental research between 2020 and 2025 has also reported fennel's potential in reducing oxidative stress and improving lipid metabolism, thereby supporting its role in functional food and phytotherapy applications [14].

Fennel has also been subject to recent studies confirming its aromatic and phytochemical richness. Studies have shown that fennel's nutritional contribution (through dietary fibre, vitamins and minerals, though fewer recent proximate analyses have been published compared to fenugreek) combined with its strong volatile (aromatic) oil profile make it useful in both culinary and medicinal applications. According to Hassan et al, the presence of these compounds contributes to fennel's significant antioxidant, anti-inflammatory, and antimicrobial activities [21]. Antioxidants help neutralize harmful free radicals in the body, reducing oxidative stress and the risk of chronic diseases. Anti-inflammatory properties can help alleviate conditions like arthritis and irritable bowel syndrome. Antimicrobial effects can help combat various pathogens.

Yadav et al, in their review, emphasized the role of anethole, a major component of fennel essential oil, in exhibiting anticancer and hepatoprotective (liver-protective) effects, suggesting its potential in cancer prevention and liver health [22]. Zenginet al, further elaborated on the neuroprotective potential of fennel phytochemicals, suggesting their role in mitigating oxidative stress and inflammation in the brain, which could be beneficial in preventing neurodegenerative diseases [23]. These bioactive compounds contribute to fennel's traditional use in treating various ailments, from digestive issues like bloating and indigestion to respiratory problems such as coughs and bronchitis, and even menstrual discomfort.

The distinctive aroma and flavor of fennel are primarily due to its essential oil, which is a complex mixture of volatile compounds. The main constituents responsible for its characteristic sweet, licorice-like scent are trans-anethole, fenchone, and estragole.

Nutmeg (*Myristica fragrans*) has been studied with respect to its volatile components, aromatic qualities, and interactions with food systems, along with safety considerations. Nutmeg has been traditionally employed as both a flavouring agent and a therapeutic spice across tropical regions. In traditional medicine, nutmeg seed powder and oil are used to manage gastrointestinal disorders, pain, and insomnia, as well as to enhance libido and circulation [24]. Aromatic preparations containing nutmeg are often used to treat cough, colds, and rheumatic pain in traditional African and Asian medicine.

Modern pharmacological studies support many of these uses. The essential oils and lignans from nutmeg exhibit antimicrobial, antioxidant, anti-inflammatory, and neuroprotective activities [17]. However, recent studies also caution that excessive consumption may lead to toxic effects due to compounds such as myristicin and safrole, emphasising the need for controlled doses in medicinal applications [25]. Current investigations suggest potential applications for nutmeg extracts in managing chronic pain, depression, and microbial infections, although further clinical trials are needed [17].

Also, more specialized studies have investigated detecting spoilage or mildew in nutmeg using HPLC fingerprint, GC-MS and electronic nose (E-nose) techniques, showing that certain volatile marker compounds shift when nutmeg is degraded, which is important for quality and safety (aroma integrity). According to Jaiswal et al, nutmeg contains a range of macronutrients and micronutrients, including dietary fiber, carbohydrates, proteins, and essential minerals such as magnesium, manganese, copper, and iron [26]. These minerals play crucial roles in numerous bodily functions; for instance, magnesium is vital for muscle and nerve function, blood glucose control, and blood pressure regulation, while manganese is involved in bone formation and metabolism. Copper is essential for iron absorption and red blood cell formation, and iron is a key component of hemoglobin, which transports oxygen in the blood. A study by Nwofia et al, further elaborates on its vitamin content, noting the presence of B-complex vitamins like thiamine (B1), riboflavin (B2), and niacin (B3), which are crucial for metabolic processes, including energy production from food [27]. Thiamine is important for nerve function and carbohydrate metabolism, riboflavin for energy production and cell growth, and niacin for DNA repair and cholesterol regulation. The caloric content of nutmeg is relatively low, making it a nutrient-dense addition to various culinary preparations without significantly increasing energy intake. Its fiber content is particularly beneficial for digestive health, aiding in bowel regularity and potentially contributing to satiety, which can be helpful in weight management.

The therapeutic properties of nutmeg are largely attributed to its rich array of phytochemicals. According to Okoye et al, nutmeg is a rich source of phenolic compounds, flavonoids, and lignans, which are known for their antioxidant and anti-inflammatory activities [28]. The key bioactive compounds in nutmeg include phenolic compounds, terpenes, and lignans. These compounds combat oxidative stress by neutralizing free radicals, thereby reducing cellular damage and inflammation, which are underlying factors in many chronic diseases. The most significant phytochemicals are the phenylpropanoids, such as myristicin, elemicin, and safrole. Compounds such as macelignan and malabaricone C have been identified as highly active phytochemicals with potential in treating neurological disorders and combating obesity [29].

These compounds have been extensively studied for their biological activities. Research by Panday et al, highlights the neuroprotective effects of myristicin, suggesting its potential in mitigating neurodegenerative diseases through its ability to modulate neurotransmitter systems and reduce oxidative stress, which is a significant factor in conditions like Alzheimer's and Parkinson's diseases [30]. Furthermore, a review by Parle and Khanna discusses the antimicrobial properties of nutmeg extracts, attributing them to the synergistic action of various phytochemicals against a broad spectrum of bacteria and fungi, including common pathogens, suggesting its potential as a natural antimicrobial agent [31]. These compounds also exhibit anticarcinogenic potential, with studies exploring their ability to inhibit cancer cell proliferation and induce apoptosis (programmed cell death) in various cancer cell lines, offering promising avenues for cancer research. According to Pua et al, the essential oil of nutmeg is predominantly composed of monoterpenes and phenylpropanoids, with sabinene, α-pinene, β-pinene, myristicin, and elemicin being the major constituents [32]. The essential oil of nutmeg is predominantly composed of monoterpenes and phenylpropanoids, with sabinene, α-pinene, β-pinene, myristicin, and elemicin being the major constituents [32].

Sabinene contributes a woody, spicy note, while α-pinene and β-pinene provide fresh, pine-like aromas. Myristicin and elemicin, while also having pharmacological properties, are key contributors to the distinctive warm and spicy scent. A study by Janandanan and Paulose, investigated the sensory perception of nutmeg aroma, confirming that the unique blend of these compounds contributes to its warm, spicy, and slightly sweet notes, making it a popular ingredient in perfumery and aromatherapy, where it is used for its

calming and uplifting effects [33]. This unique blend of aromatic compounds makes nutmeg a highly valued spice in the food and beverage industries, used in both sweet and savory dishes, as well as in perfumery and aromatherapy.

Compared to the others, Country Onion *Afrostyrax lepidophyllus* has fewer recent studies, but what is available shows noteworthy nutritional, phytochemical, and aromatic potential. Country onions have been analyzed for their mineral content, revealing the presence of several essential elements. Research has shown that the seeds contain minerals such as sodium, magnesium, phosphorus, potassium, and calcium [34]. Trace elements like iron, manganese, and zinc are also present. In terms of vitamins, studies have indicated that country onions contain antioxidants such as vitamin C and selenium, which play a crucial role in protecting cells from damage [35]. The characteristic pungent, garlic-like aroma of country onions is attributed to its high concentration of sulfur-containing compounds. A study by Moukette et al, identified methylsulfinyl (methylthio) methane as a major component, highlighting its role in the spice's unique profile [34].

Country onion extracts have been shown to be rich in polyphenols and flavonoids, which are powerful antioxidants. These compounds are responsible for the spice's free radical scavenging and anti-inflammatory properties [36]. Research has confirmed that extracts of *Afrostyrax lepidophyllus* possess significant free-radical scavenging abilities [36]. Specific flavonoids like quercetin and other phenolic acids are present and contribute to its therapeutic effects. Recent analysis using gas chromatography-mass spectrometry (GC-MS) has identified compounds like eugenol and caryophyllene, which are known for their anti-inflammatory, antioxidant, and antimicrobial properties [36].

Proximate analysis of various African spices, including country onions, has shown that they are generally low in moisture, indicating a high concentration of dry matter and nutrients [34]. The seeds contain a notable amount of lipid (fat), which contributes to their unique aroma and taste. A key finding from recent research is that the seeds are also a good source of fiber, which is important for digestive health [36]. Studies have shown that country onions are a good source of vitamin C, B vitamins (folate, B6), and dietary fiber. Furthermore, they contain important minerals such as potassium, calcium, and iron. The low caloric content combined with a rich nutrient density makes it a healthy addition to various diets. The presence of these nutrients contributes to its potential role in supporting overall human health, including immune function, due to vitamin C's role in collagen synthesis and antioxidant defense, and digestive health, facilitated by dietary fiber which aids in regular bowel movements and supports a healthy gut microbiome. The specific amounts of these nutrients can vary depending on cultivation practices, soil conditions, and the specific variety of country onion. Kalu et al, further elucidated the presence of phenolic acids and saponins, adding to the complexity of its phytochemical composition and therapeutic potential. Phenolic acids contribute to antioxidant capacity, while saponins have been associated with cholesterol-lowering effects and immune-modulating properties [37]. The synergistic action of these diverse phytochemicals likely contributes to the holistic health benefits attributed to country onion. The aromatic potential of country onion is primarily due to its volatile sulfur compounds, which are released upon cutting or crushing. Kengne et al, discussed how these compounds, such as diallyl disulfide and dipropyl disulfide, contribute to its distinctive aroma and flavor, making it a popular ingredient in various cuisines [38]. The enzymatic breakdown of sulfur-containing precursors, like S-alk(en)yl cysteine sulfoxides, by the enzyme alliinase, leads to the formation of these volatile compounds. This process is initiated when the plant cells are damaged, allowing the enzyme and substrate to mix. This enzymatic reaction is crucial for the development of its characteristic pungency and aroma which can range from mild to intensely sharp depending on the specific variety and processing. Beyond culinary applications, these aromatic compounds also possess antimicrobial properties, contributing to the traditional use of country onion as a natural preservative and in folk medicine for treating infections. The unique blend of these volatile compounds provides a complex aromatic profile that distinguishes it from other Allium species like common onion or garlic, offering a nuanced flavor that is highly valued in specific regional dishes.

3. Methods

3.1. Sample Collection

The spice samples Fenugreek (Trigonella foenum-graecum), Fennel seeds (Foeniculum vulgare), Country onion (Afrostyrax lepidophyllus), and Nutmeg (Myristica fragrans) were purchased from Relief Market in Owerri, Imo State, Nigeria. This market is a major hub for local and regional spice trade, ensuring access to authentic and commonly consumed tropical spices. Care was taken to select clean, dry, and unadulterated samples from multiple vendors to minimize bias and better represent typical consumer products. The samples were authenticated by a botanist and then grinded to powder and stored for further use.

3.2. Determination of the Chemical Composition Using High Performance Liquid Chromatography (HPLC)

- **Extraction Process**

About 10g of the samples was measured into the amber bottle. It was added 20mls of Acetonitrile methanol, both were shaked thoroughly for 30 min. After the shaking, the aqueous end was run off while the organic solvent was collected into 25ml standard flask, made up to mark and ready for analysis.

- **Analysis**

Standard form of analytics profile were first injected into the HPLC and this generated a chromatogram, with a given peak area and peak profile. These were used to create a window in the HPLC in preparation of the test sample analysis. Then, portion of the extracted Fenugreek (*Trigonella foenum-graecum*), Fennel seeds (*Foeniculum vulgare*), Country onion (*Afrostyrax lepidophyllus*), and Nutmeg (*Myristica fragrans*) were injected into the HPLC also, to obtain a corresponding peak area and peak profile in a chromatogram. Then, the peak area of the samples were compared with that of the standard, relative to the concentration of the standard to obtain the concentration of the samples.

- **Calculation**

$$\text{Conc. of sample} = \frac{\text{Peak Area of sample X standard Concentration}}{\text{Peak area of the standard}}$$

- **To Determine the Nutritional Composition**

The dried samples were powdered in a grinding machine for extraction. 20g of each sample was weighed into clean plastic container and 100mls of ethanol was added to each sample and left for 24hrs. After 24hrs, the solvent along with the extract were drained out, filtered and semi-solid extracts were obtained. Afterwards, the semi-solid extract were evaporated under reduced pressure in a rotary evaporator at a temperature below 500c and dried at a constant weight.

- **To Determine the Aromatic, Spicy and Savour Taste of the Mixed Spices**

The dried samples were properly grinded separately into powder with grinding machine. The powdered samples were properly sieved into a bowl with the help of a spatula for it to be easier. 10g of each was measured out and all the three measured samples were mixed thoroughly and transferred into a plastic container and ready to be used to prepare jollof rice.

4. Result and Discussion

- **Results**

The results of the chemical composition of Fenugreek, Fennel, Nutmeg, and Country Onion using High Performance Liquid Chromatography (HPLC), Table 1,2,3 and 4 and Figure 1,2,3 and 4 respectively.

➢ **Identification of Chemical Composition using HPLC.**

Component	Retention	Area	Height	External Units
Oxalic Acid	1.266	1129.6065	32.833	128.7008ppm
Neurine	2.750	2427.6245	24.366	0.0000
Coumarin	4.450	609.5815	10.875	0.0000
Phytic Acid	5.466	194.8810	5.564	19.4881ppm
Betaine	6.483	74.6540	3.330	0.0000
Dioscin	7.333	81.9950	5.385	0.0000
Diogenin	7.950	102.3055	5.087	0.0000
Smilagenin	8.416	82.3060	5.048	0.0000
Gitogenin	9.350	74.9390	5.689	0.0000
Quercetin	11.050	8007.5835	147.984	0.0000
Rutin	12.166	2969.1365	53.557	0.0000
Trigonelline	13.700	1571.3930	36.340	0.0000
Carpaine	15.716	164.7435	6.464	0.0000
Isovitoxin	16.250	103.2780	5.271	0.0000
Vitexin	17.233	119.0285	6.397	0.0000
Graecunin E	19.766	134.6790	9.404	0.0000
Sotolone	21.133	71.9310	7.007	0.0000
Total		17919.6660		148.1889

Table 1: Fenugreek

The analysis presented in table 1 is (High-Performance Liquid Chromatography) report detailing the chemical composition of a Fenugreek sample. The table provides four critical metrics for 18 identified compounds: Retention Time, Area, Height, and External Units.

The Retention Time (measured in minutes) is the first metric, serving as the primary qualitative identifier. For instance, Oxalic Acid is the least retained component (1.266 min), while Sotolone is the most retained (21.133 min), suggesting differences in their interaction with the stationary phase. The Area under the peak is the most important quantitative measure, as it is proportional to the concentration of the compound. Chromatographic data shows a strong dominance by three specific compounds: Quercetin (Area: 8007.5835), Rutin (Area: 2969.1365), and Neurine (Area: 2427.6245). These large area values indicate that these three phytochemicals constitute the bulk of the detectable material in the fenugreek sample. The Height of the peak (e.g., Quercetin at 147.984) is a related metric, also confirming the dominance of these high-area components.

The identified components represent several distinct chemical classes typical of the Fenugreek plant. The health benefits and culinary properties of fenugreek are often attributed to these compounds. Notably, the table includes several steroidal saponins and sapogenins (Dioscin, Diogenin, Smilagenin, Gitogenin), which are widely studied for their potential medicinal properties. Furthermore, a significant presence of Flavonoids is confirmed by the high areas for Quercetin, Rutin, Isovitoxin, and Vitexin, which are known for their antioxidant activity. Finally, the table includes Trigonelline, a major alkaloid linked to fenugreek's bitter taste, and Sotolone, the component responsible for the characteristic maple-syrup aroma of the spice.

➢ **Temperature Program**

Init temp Hold Ramp Final temp

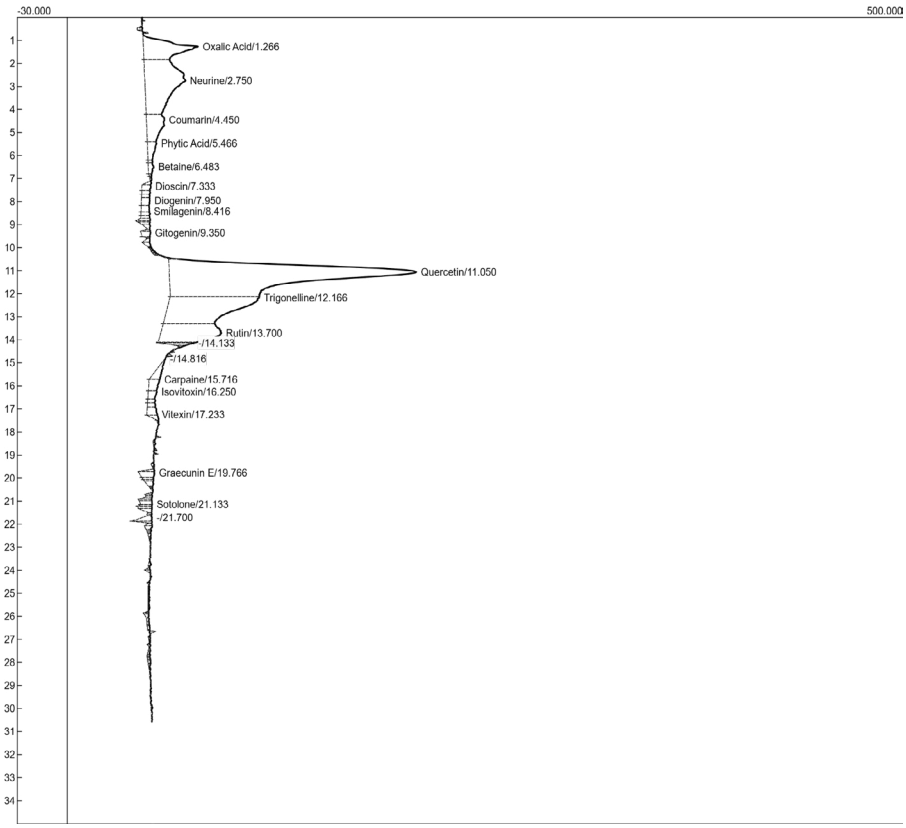

Figure 1: Chromatogram of compounds in Fenugreek

Component	Retention	Area	Height	External Units
Estragole	1.266	505.1190	24.618	0.0000
Anethole	2.750	1175.0150	16.479	134.3769 ppm
Trans-anethole	4.450	740.2770	13.013	80.0346 ppm
Fenchone	5.466	378.8710	10.290	0.0000
Caffeic Acid	6.483	173.2310	6.469	0.0000
Alpha-Phallandrene	7.333	61.2680	6.298	0.0000
Scopoletin	7.950	100.7250	6.704	0.0000
Isoquercitrin	8.816	63.1560	4.461	0.0000
Kaempferol	9.650	80.9870	6.667	0.0000
Quercitrin	11.050	6729.9800	135.499	0.0000
Quercetin	12.166	1897.2495	38.397	0.0000
Isorhamnetin	13.700	822.4875	21.359	0.0000
Syringin	14.733	395.8435	4.532	0.0000

Limonene	15.700	294.0955	10.175	0.0000
Acecetin	16.266	67.1740	7.684	0.0000
Naringenin	17.616	454.0275	8.385	0.0000
Beta-Myrcene	19.816	116.3915	11.989	0.0000
Rosmarinic Acid	21.300	116.4050	12.336	0.0000
Total		14172.3030		214.4115

Table 2: Fennel

This table presents the results of chemical composition analysis using HPLC, used to identify and quantify 18 chemical components in Fennel sample.

The analysis successfully identified a diverse set of compounds, with the Area under the peak indicating their relative concentration. The sample is overwhelmingly dominated by Quercitrin, which shows the largest area by a significant margin (6729.9800), followed by Quercetin (1897.2495), and Estragole (1175.0150). The identified compounds can be broadly classified into several important groups:

- **Volatile Organic Compounds/Terpenes:** Compounds like Estragole, Trans-anethole, Fenchone, Alpha-Phallandrene, Limonene, and Beta-Myrcene suggest the sample is derived from an aromatic plant or essential oil.
- **Polyphenols/Flavonoids:** A large group of antioxidant compounds is present, including Caffeic Acid, Scopoletin, Isoquercitrin, Kaempferol, Quercitrin, Quercetin, Isorhamnetin, Naringenin, and Rosmarinic Acid. The presence of multiple related flavonoids (Quercitrin, Quercetin, Isoquercitrin) points to a specific botanical source rich in these protective molecules.

➢ **Temperature program**

Init temp Hold Ramp Final temp

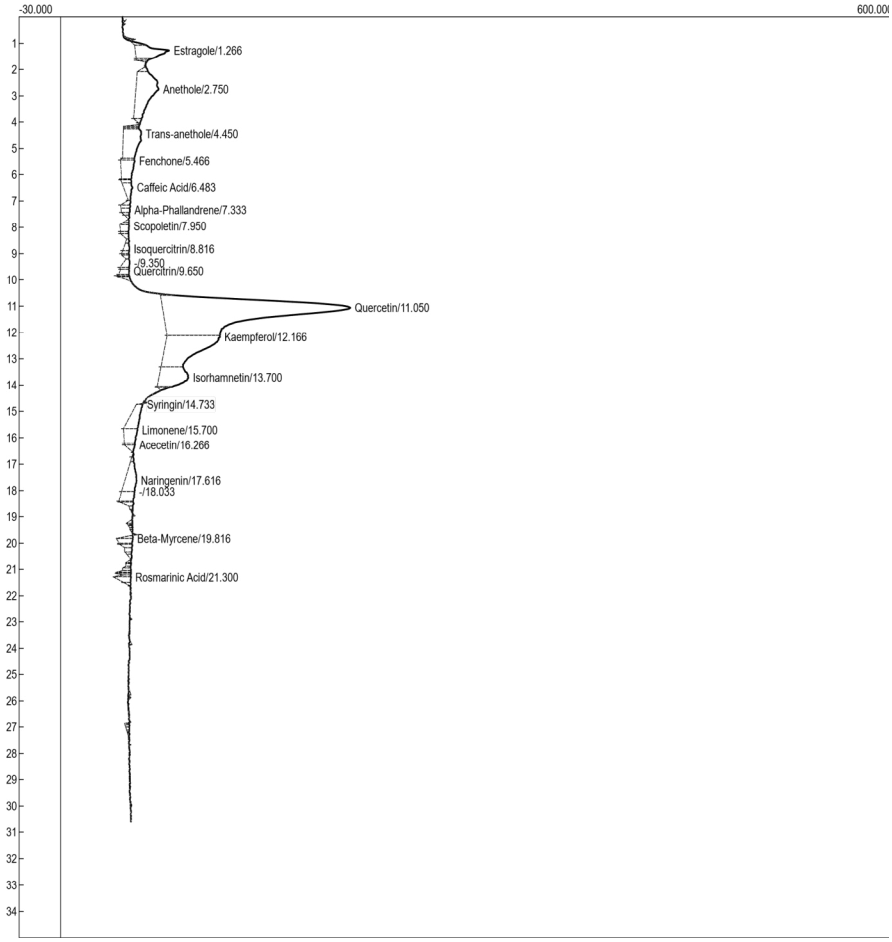

Figure 2: Chromatogram of compounds in Fennel

Component	Retention	Area	Height	External Units
Camphene	1.350	337.0240	25.413	0.0000
Dipentane	1.650	471.1030	51.167	0.0000
Myristicin	1.983	9170.3010	228.662	0.0000
Eugenol	3.166	1503.0130	41.157	0.0000
Linalool	4.016	1636.5080	33.757	0.0000
Methyleugenol	5.050	198.1040	6.851	0.0000
Cineol	5.766	42.8000	3.478	0.0000
Elemicin	6.350	239.5975	5.555	0.0000
Limonene	7.350	1061.3910	21.867	0.0000
Sabinene	8.616	62.2060	2.980	0.0000
Pinene	9.150	38.4340	6.506	0.0000
Safrole	9.616	66.8820	2.064	0.0000
Terpenene	10.566	30.0280	1.884	0.0000
Total		14857.3915		0.0000

Table 3: Nutmeg

This table summarizes the results of HPLC used to profile the chemical composition of Nutmeg sample.

The sample is characterized by a strong presence of volatile organic compounds (VOCs), particularly essential oil constituents, as indicated by the list of identified components. Analysis of the Area data, the primary measure of concentration shows an overwhelming dominance by a single compound: Myristicin. With an area of 9170.3010, Myristicin accounts for well over half of the total area of all detected components (Total Area: 14857.3915), making it the major constituent of the sample. Following Myristicin in abundance are Linalool (1636.5080) and Eugenol (1503.0130), with Limonene also present in significant quantity (1061.3910). The Retention Time ranges from 1.350 minutes for Camphene to 10.566 minutes for Terpenene, confirming the presence of a wide range of compounds with varying volatilities. The identified compounds strongly suggest the source material is a spice or plant rich in aromatic essential oils, likely from the Myristicaceae family (e.g., nutmeg or mace), due to the high concentration of Myristicin, and the presence of related compounds like Eugenol and Methyleugenol. Other identified classes include:

- **Terpenes and Terpenoids:** This is the largest group, including Linalool, Limonene, Camphene, Dipentane, Cineol, Sabinene, Pinene, and Terpenene. These contribute heavily to the aroma and flavor of the sample.
- **Phenylpropenes:** This class includes the dominant Myristicin, as well as Eugenol, Methyleugenol, and Safrole. These are often characteristic, active compounds in essential oils. Height data supports the area findings, with Myristicin exhibiting the largest peak height (228.662), emphasizing its high concentration.

➢ **Temperature program:**

Init temp Hold Ramp Final temp

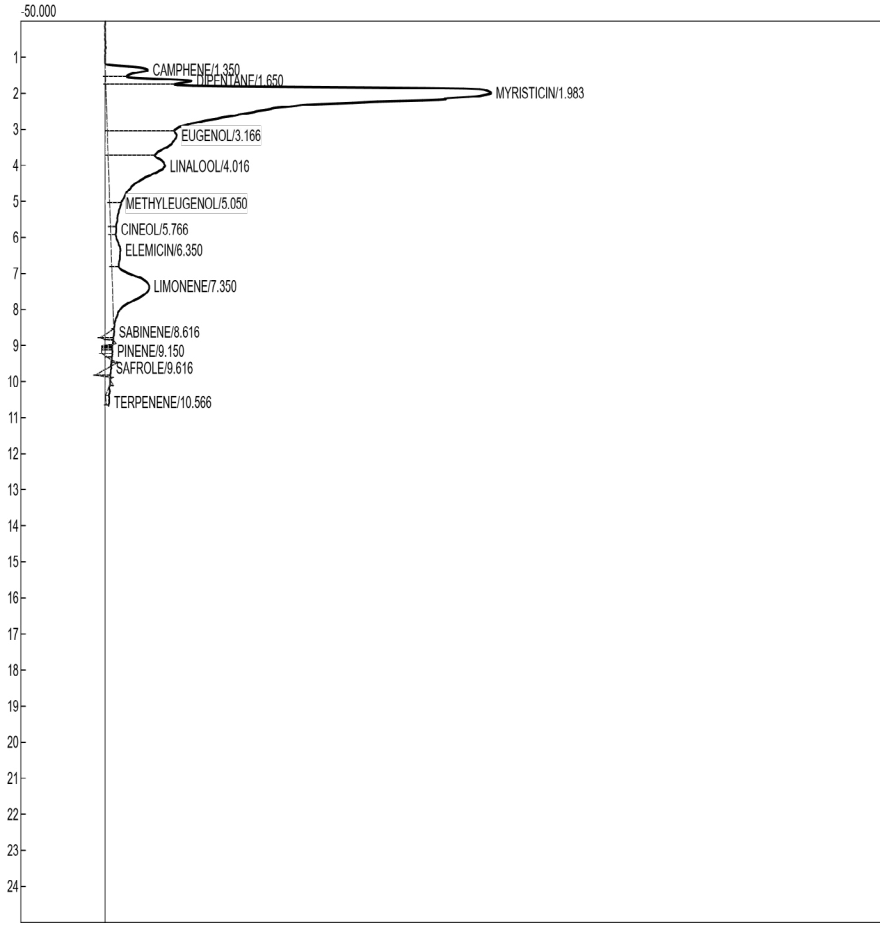

Figure 3: Chromatogram of compounds in Nutmeg

Anti-nutritional Factors	Value (mg/100g)
Phenol	18.31
Saponin	1.37
Tannin	3.67
Oxalate	1.11
Phytate	15.91
Flavonoid	6.07
Steroid	0.15
Alkaloid	4.30
Terpenoid	7.02
Cyenogenic Glycoside	4.76
Capsaicins	20.87
Piperazine	7.22
Anthocyanins	10.02
Total	167.11

Table 4: Country Onion

The table above presents the amounts of various components found in the seed of *Afrostyrax lepidophyllus*.

The table is a quantitative analysis, showing the concentration of each substance in milligrams per 100 grams (mg/100g) of the seed.

These are compounds that interfere with the absorption of essential nutrients (like vitamins and minerals) or reduce the body's ability to utilize them, which can potentially cause adverse health effects if consumed in large quantities without proper processing.

- **Phytate (Phytic Acid):** The second-highest value (15.91 mg/100g). It is the primary storage form of phosphorus in many plants. It is considered antinutritional because it strongly binds to minerals (like iron, zinc, and calcium) in the digestive tract, making them unavailable for absorption.
- **Oxalate:** (1.11 mg/100g). It can bind to calcium, potentially reducing calcium availability and contributing to the formation of kidney stones in susceptible individuals.
- **Tannin:** (3.67 mg/100g). These polyphenols can bind to proteins and digestive enzymes, reducing protein digestibility and nutrient absorption.
- **Saponin:** (1.37 mg/100g). These compounds can interfere with nutrient digestion and absorption, and in high amounts, can cause hemolysis (rupture of red blood cells).
- **Cyenogenic Glycoside:** (4.76 mg/100g). These release toxic hydrogen cyanide (HCN) upon enzymatic hydrolysis. Proper processing (like boiling or fermentation) is crucial to reduce their levels. These are non-nutritive plant compounds that have protective or disease-preventing properties, often acting as antioxidants, though some are also considered antinutritional depending on concentration and context.
- **Capsaicins:** The highest concentration (20.87 mg/100g). These are the active components in chili peppers, known for their pungent heat, and are potent antioxidants with potential pain-relieving and anti-inflammatory properties. Their presence here suggests a similar "spicy" characteristic for the seed.
- **Phenol (Total Phenolics):** The third-highest value (18.31 mg/100g). This is a broad class of compounds (including flavonoids and tannins) known for their strong antioxidant activity, which protects cells from damage by free radicals.
- **Flavonoid:** (6.07 mg/100g). A specific type of phenol, widely studied for its powerful antioxidant, anti-inflammatory, and cardioprotective effects.
- **Terpenoid:** (7.02 mg/100g). These are often responsible for the aroma and flavour of plants and include essential oils. They possess various biological activities, including antimicrobial and anti-inflammatory properties.
- **Alkaloid:** (4.30 mg/100g). A group of naturally occurring compounds that contain mostly basic nitrogen atoms. They are structurally diverse and known for potent pharmacological effects (e.g., caffeine, morphine).
- **Piperazine:** (7.22 mg/100g). While a synthetic drug, its parent structure or derivatives can occur naturally. Its presence suggests the seed may possess compounds with potential medicinal (e.g., anti-parasitic) value. Steroid: (0.15 mg/100g). Found in the lowest concentration. Plant steroids (phytosterols) can help reduce blood cholesterol levels.
- **Identification of Nutritional Composition**

Component	Fenugreek (%)	Country onion (%)	Nutmeg (%)	Fennel (%)	Significance
MC (%) (Moisture Content)	5.81	12.55	10.22	7.78	Indicates water level; lower is better for preservation.
DM (%) (Dry Matter)	90.20	89.45	89.74	89.22	Represents total solid matter (nutrients and minerals).
ASH (%) (Mineral Content)	1.74	0.94	2.24	4.61	Represents the total inorganic content (minerals).
CP (%) (Crude Protein)	25.88	10.88	14.79	16.73	Measure of total protein content.
EE (%) (Ether Extract/Fat)	3.11	0.20	21.94	1.87	Represents the total fat/oil content.
CF (%) (Crude Fiber)	5.29	1.65	3.61	7.63	Represents the indigestible part, mainly cellulose.
CHO (%) (Carbohydrates)	52.90	73.81	47.21	61.37	Estimated carbohydrate content (often by difference).

Table 5: Nutritional Composition of Fenugreek, Fennel, Nutmeg and Country Onion

The data presented in table 5 is a detailed analysis of the nutritional composition of four different spices: Fennel, Fenugreek, Nutmeg, and Country Onion.

- **Dry Matter (DM%):** The DM is consistently high for all four spices, ranging from 89.22% to 90.20%. This high percentage means that about 90% of the mass of these spices consists of non-water solids (nutrients, fiber, and minerals), which is expected for dried spices. Fenugreek has the highest DM (90.20%).
- **Moisture Content (MC %):** The MC is the inverse of DM and is crucial for food storage. A low moisture content inhibits microbial growth and spoilage, giving dried spices a long shelf life. Country Onion has the highest moisture content at 12.55%, suggesting it may be slightly more perishable than the others or was analyzed less intensely dried. Fenugreek has the lowest MC at 5.81%.
- **Macronutrients (Protein, Fat, and Carbohydrates):** These

components make up the majority of the dry matter and are the primary sources of energy and building blocks.

- **Crude Protein (CP %):** This measures the total protein content. Fenugreek stands out as an excellent source of protein, with a high value of 25.88%. Country Onion has the lowest protein at 10.88%. Fennel and Nutmeg fall in the middle, at 16.73% and 14.79%, respectively.
- **Ether Extract (EE %) or Crude Fat:** This measures the total oil or fat content. Nutmeg is classified as an oil-rich spice, which is evident in its exceptionally high fat content of 21.94%. Country Onion and Fennel are very low-fat spices, with EE values of only 0.20% and $1.87%, respectively.
- **Carbohydrates (CHO %):** This is typically calculated "by difference" and represents starches, sugars, and digestible fibers. Country Onion is predominantly carbohydrate, with the highest value at 73.81%. Nutmeg has the lowest CHO content at 47.21%, primarily because a large portion of its dry matter is composed of fat (EE).
- **Ash and Fiber:**
- **Ash (%):** Ash is the inorganic residue left after burning the organic components, representing the total mineral content (e.g., calcium, potassium, magnesium). Fennel is the richest in total minerals, with the highest ash content at 4.61%. Country Onion has the lowest mineral content at 0.94%.
- **Crude Fiber (CF %):** This represents the structural and indigestible components (like cellulose) that are important for gut health. Fennel contains the highest amount of fiber at 7.63%. Country Onion contains the lowest fiber at 1.65%.

Spice	Key Nutritional Feature
Fenugreek	Exceptional source of Protein (the highest among the group).
Country Onion	Highest in Carbohydrates and lowest in Ash, Crude Fiber, and Crude Fat.
Nutmeg	Extremely high in Crude Fat/Oil (over 21%).
Fennel	Highest in Crude Fiber and total Ash (minerals).

Table 6: Distinct nutritional profiles of the spices

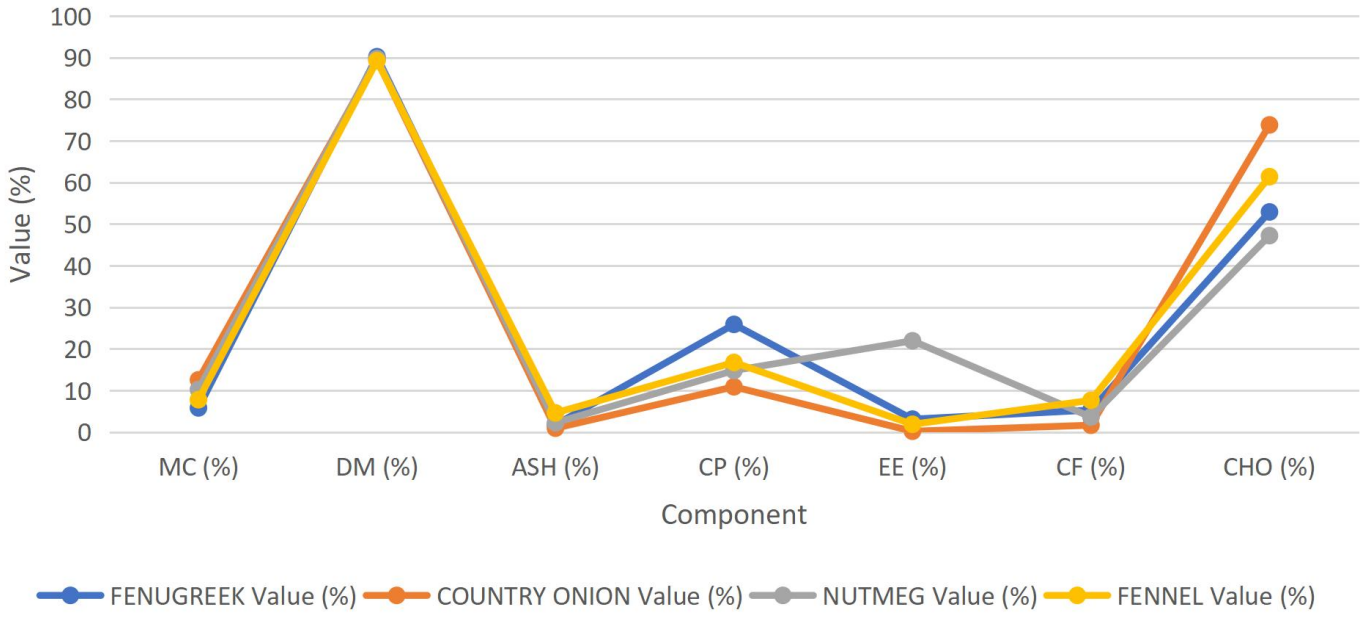

Figure 4: Graph showing the identification of Nutritional composition of Fenugreek, Fennel, Nutmeg and Country Onion

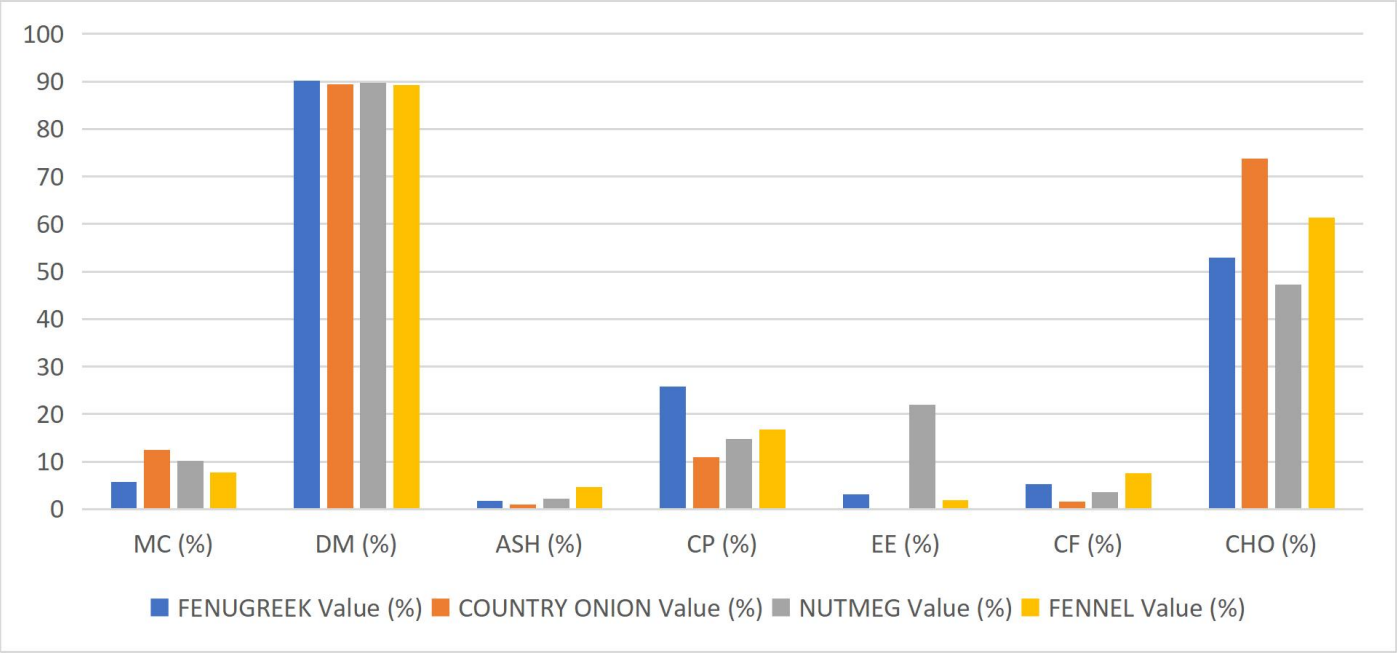

Figure 5: Chart showing the identification of Nutritional composition of Fenugreek, Fennel, Nutmeg and Country Onion

Number of food tasters	Visual inspection												Flavour evalution									Texture and mouthfeel											
	Color of the Dish			Texture of the Dish			Intensity			Character			Type			Intensity			Balance			Heat			Mouthfeel							
																									1st Bite			During chew			After taste		
	S	G	E	S	G	E	PL	I	R	PU	SA	SW	SO	H	SW	MD	ME	ST	HA	T	O	M	TH	H	T	SA	A	SP	W	HD	LCH	SU	RTM
15	1	4	10	1	3	11	4	4	7	-	9	6	-	10	5	3	4	8	-	6	9	8	5	2	1	9	5	6	9	-	3	3	9

Table 7: Sensory and Aromatic characteristics of the mixed spice

Key:

- **S:** Satisfactory
- **G:** Good
- **E:** Excellent
- **PL:** Pleasant
- **I:** Inviting
- **R:** Rich
- **PU:** Pungent
- **SA:** Savory
- **SW:** Sweet
- **SO:** Sour
- **H:** Hot
- **MD:** Mild
- **ME:** Medium
- **ST:** Strong
- **HA:** Harsh
- **O:** Overwhelming
- **M:** Moderate
- **TH:** Tingling heat
- **A:** Aromatic
- **SP:** Spicy
- **W:** Warmth
- **HB:** Herbydepth
- **LCH:** Lingering chilly heat
- **SU:** Smoky undertone
- **RTM:** Rich taste memory

The sensory evaluation of the dish, conducted by 15 food tasters, provided a detailed profile of its visual, aromatic, flavour, and textural characteristics, directly addressing the impact of the mixed spices The results are a combination of qualitative descriptions (using letter codes) and quantitative counts (numbers representing the frequency of selection by the 15 evaluators)

4. Discussion

4.1. Functional Phytochemicals and Bioactive Compounds

The chemical analysis identified key bioactive compounds that are responsible for the functional properties and health benefits of the blend The thermal sensation experienced during tasting is directly explained by the high concentration of Capsaicins (2087 mg/100g) found in the Country Onion, a compound known for its antioxidant activity The potent antioxidant capacity of the blend is further supported by the high levels of Phenol (1831 mg/100g) in the Country Onion, combined with numerous Flavonoids such as Quercitrin, Quercetin, and Rutin, which are prevalent in Fennel and Fenugreek Furthermore, the presence of various steroidal saponins, including Dioscin, Diogenin, and Gitogenin, in Fenugreek indicates potential therapeutic and pharmacological value for the spice blend beyond basic nutritionThe high levels of flavonoids such as Quercetin and Rutin in the fenugreek sample agree with the findings of Vajdi (2024) and Faisal (2024), who reported similar compounds as dominant antioxidants in fenugreek seeds This consistency reinforces that the fenugreek analyzed in this study retains its typical phytochemical profile Similarly, the identification of trans-anethole and estragole as major constituents in fennel supports earlier findings by Ogbonna (2024) and Ashokkumar (2022), who described these as key volatile components responsible for fennel's aroma and therapeutic value Minor deviations in detected concentrations could be attributed to environmental or geographical differences in plant origin.

4.2. Antinutritional Factors and Processing Implications

A key finding relevant to food safety and nutrition is the presence of antinutritional factors, primarily Phytate (1591 mg/100g) and Tannin (367 mg/100g), which were quantified in the Country Onion component The presence of these compounds is a critical factor because phytate can chelate essential minerals like iron and zinc, potentially reducing their bioavailability in the final food product This data suggests that incorporating traditional processing methods, such as soaking or heat treatment, into the preparation of the Country Onion before or during its blending could be necessary to reduce the concentration of these antinutrients and maximize the nutritional benefit derived from the minerals contributed by the Fennel and other components The moderate levels of phytate and oxalate observed in the country onion component align with findings by Nwachukwu (2025) and Moukette (2021), who reported similar concentrations in the same species Their studies also confirmed that traditional processing methods effectively reduce these antinutrients, which supports the current recommendation for pre-treatment before blending.

4.3. Proximate Composition and Nutritional Synergy

The proximate analysis of the four spices established a clearly synergistic nutritional profile, confirming that each ingredient fulfills a distinct and essential role in the overall blend, with all samples demonstrating high concentration due to elevated Dry Matter (DM) The most substantial contributor to bulk and energy is the Country Onion, which registered the highest Carbohydrate (CHO) content at 7381% In sharp contrast, Fenugreek is the dedicated Protein Fortifier, distinguished by an exceptionally high Crude Protein (CP) concentration of 2588%, significantly enhancing the protein value of the final food product The role of Nutmeg is critical as the Fat and Flavor Carrier, evidenced by its high Ether Extract (EE) (fat) content of 2194%, which is necessary for the solubilization and sustained delivery of aromatic compounds Finally, Fennel ensures nutritional balance by providing the highest percentage of both Crude Fibre (CF) (763%) and Ash (minerals) (461%), thereby compensating for the low mineral and fiber content observed in the Country Onion component.

4.4. Aromatic and Consumer Preference

The dish exhibited an Excellent (E) overall aroma intensity, which was consistently described as having an Excellent (E) character by 11 out of 15 evaluators This suggests the mixed spices (Fenugreek, Fennel, Nutmeg, and Country Onions) contributed a highly desirable and concentrated volatile compound profile Interestingly, while the intensity was high, the aromatic *type* was described primarily as Mild (MD) (9 votes) and Medium (ME) (6 votes), indicating the aroma was pleasant and defined, but not Overwhelming (O) or Pungent (PU).

The aromatic contribution of nutmeg in this blend is supported by the predominance of Myristicin, which agrees with findings by Ashokkumar (2022) and Siddiqui (2024), who both identified Myristicin as the principal constituent of nutmeg essential oil The co-detection of Eugenol and Linalool further supports previous reports of their role in nutmeg's distinctive flavor profile However, unlike the study by Adibuduge and Senevirathne (2023), which found higher safrole levels, this study recorded minimal safrole content, likely due to varietal or processing differences.

The analysis confirms a successful addition of food taste savor through the mixed spices, as evidenced by the high scores in flavour intensity and character Dominant Flavour: The primary flavour intensity was overwhelmingly judged as Savory (SA) by 10 individuals This savory characteristic, coupled with Hot (H) (8 votes), highlights the successful creation of an umami-like profile enhanced by heat Spiciness and Heat Character: The flavour's heat profile was characterized by two dominant attributes, both selected by 9 individuals: Spicy (SP) and Lingering chilly heat (LCH) The presence of "Lingering chilly heat" indicates a complex, sustained thermal sensation in the mouth, likely driven by specific capsaicinoids or related compounds present in the spice blend Enduring Profile: The After taste was identified as the most noted phase of the mouthfeel experience (9 votes), suggesting that the active ingredients extracted from the spices contributed compounds that leave a Rich taste memory (RTM) or sustained flavor.

The dish presented a visually acceptable profile with a Satisfactory (S) color and Good (G) visual texture The mouthfeel and texture attributes were most noticeable in the aftertaste, suggesting that while the immediate physical texture of the dish was secondary, the flavour carry-over and sensory residue were the most memorable components.

The taste evaluation validated the successful integration of the spices, yielding a product with high consumer acceptability and a complex, desirable flavor profile The aroma of the final dish achieved an overall Excellent rating and was appropriately balanced, characterized as Mild (MD) and Medium (ME) in intensity, confirming a harmonious blend of the volatile oils from Nutmeg and Fennel The flavor profile was overwhelmingly defined by the panel as both Savory (SA) and Hot (H), successfully imparting a rich umami-like base enhanced by thermal sensation Crucially, the heat was further qualified as Spicy (SP) with a Lingering chilly heat (LCH), which directly confirms the successful transfer and accurate sensory perception of the high-capsaicin content from the Country Onion The strong positive rating for the Aftertaste, which was frequently defined as a Rich Taste Memory (RTM), serves as the most significant indicator of the blend's high quality and its ability to deliver a sustained and complex flavor experience.

5. Conclusion

From the study, it was evident that the four tropical spices Fenugreek, Fennel, Nutmeg, and Country Onion possess rich nutritional, phytochemical, and aromatic profiles that contribute both to food value and health promotion The HPLC results revealed the presence of several biologically active compounds which play vital roles in antioxidant, antimicrobial, and anti-inflammatory activities.

Nutritionally, mixed spices provided minerals and fiber for digestive and metabolic support, and distinctive aroma Collectively, the combination of these spices yields a nutritionally balanced and aromatically rich blend with enhanced taste qualities.

Authors' contributions

The work was conducted in collaboration among all authors Author SNN designed the study, wrote the first draft of the manuscript Author, ANC did the investigation, MCN worked on the methodology, JL managed the analysis of the study Author, MON did the statistical analysis Author CMA Supervision , JCO and OEO managed the literature searches All the authors read through the manuscript and approved the publication.

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Availability of data

All data generated or analysed during this study are included in this published article

Competing interests

The authors declare no competing interests

Authors' Declaration

The authors have no financial or proprietary interests in any material discussed in this article

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