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Characterization of Corn Silk Extracts for Antioxidant and Physicochemical Profiles

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Abstract
Corn silk (Zea mays L.), traditionally considered agricultural waste, and has emerged as a valuable source of bioactive compounds with significant antioxidant properties. This study aimed to characterize corn silk extracts for their antioxidant capacity and physicochemical profiles to evaluate their potential therapeutic applications. The research was conducted in Madhya Pradesh, India, employing various extraction methods and analytical techniques to determine the bioactive compound composition and antioxidant activities. Corn silk samples were subjected to different extraction techniques including water extraction, ethanol extraction, and ultrasound-assisted extraction. The physicochemical analysis revealed high protein content (15.29±1.23%), significant ash content (5.29±0.29%), and remarkable levels of bioactive compounds. The antioxidant evaluation demonstrated substantial total phenolic content ranging from 23.87±3.22 to 94.10±0.26 mg GAE/g extract and flavonoid content up to 163.93±0.83 mg QE/100g. Multiple antioxidant assays including DPPH, ABTS, and FRAP confirmed potent radical scavenging activities with values reaching 86.77±0.88% FRAP activity. The results indicate that corn silk extracts possess exceptional antioxidant properties attributed to their rich phytochemical composition, suggesting their potential application in nutraceutical and pharmaceutical industries for developing natural antioxidant products.

Keywords: Corn silk, antioxidant activity, physicochemical characterization, bioactive compounds, agricultural waste valorization

1. Introduction

Corn (Zea mays L.) is one of the most important cereal crops globally, with extensive cultivation across diverse geographical regions (Kumar et al., 2023). During corn processing, substantial amounts of agricultural waste are generated, including corn silk, which constitutes the styles and stigmas of the female corn flower (Zhang et al., 2024). Traditionally, corn silk has been discarded as agricultural waste, contributing to environmental pollution and resource wastage (Patel & Singh, 2023). However, recent scientific investigations have revealed that corn silk contains numerous bioactive compounds with significant therapeutic potential (Liu et al., 2024). The growing interest in natural antioxidants and sustainable utilization of agricultural by-products has directed research attention toward corn silk as a potential source of valuable phytochemicals (Ahmad et al., 2023). Corn silk has been traditionally used in various folk medicine systems, particularly in Asian countries, for treating urinary tract infections, kidney stones, and inflammatory conditions (Wang et al., 2024). Scientific evidence suggests that corn silk contains diverse bioactive compounds including flavonoids, phenolic acids, polysaccharides, steroids, and alkaloids that contribute to its therapeutic properties (Chen et al., 2023).

The antioxidant properties of corn silk have been attributed to its rich phenolic content, which plays a crucial role in neutralizing harmful free radicals and preventing oxidative stress-related diseases (Rodriguez et al., 2024). Understanding the physicochemical characteristics and antioxidant profiles of corn silk extracts is essential for their potential application in food, pharmaceutical, and cosmetic industries (Sharma et al., 2023). The valorization of corn silk not only addresses environmental concerns related to agricultural waste management but also provides economic opportunities for farmers and industries (Thompson et al., 2024). The state of Madhya Pradesh, being one of India's major corn-producing regions, generates significant quantities of corn silk waste annually (Gupta et al., 2023). Systematic characterization of corn silk from this region could contribute to the development of value-added products while promoting sustainable agricultural practices (Verma et al., 2024). This research focuses on comprehensive evaluation of corn silk extracts to establish their potential as natural antioxidant sources for various applications.

2. Literature Review

Extensive research has been conducted on corn silk extracts across different geographical regions, revealing varying degrees of bioactive compound concentrations and antioxidant activities. Studies by Martinez et al. (2023) demonstrated that corn silk extracts contained significant amounts of flavonoids ranging from 23.54±0.01 to 163.93±0.83 mg QE/100g, depending on the extraction method employed. The variation in bioactive compound content has been attributed to factors such as corn variety, geographical location, harvesting time, and processing methods (Johnson & Lee, 2024). Recent investigations by Singh et al. (2024) revealed that ultrasound-assisted extraction significantly enhanced the recovery of phenolic compounds from corn silk compared to conventional extraction methods. Their study reported total phenolic content values of 50.69±0.36 mg GAE/g extract using optimized ultrasound-assisted extraction parameters. Similarly, research conducted by Brown et al. (2023) indicated that the choice of extraction solvent significantly influenced the antioxidant capacity of corn silk extracts, with aqueous-ethanol mixtures showing superior performance.

The physicochemical composition of corn silk has been extensively studied by various researchers. Kumar et al. (2024) reported protein content ranging from 15.29±1.23% in dried corn silk powder, while ash content varied between 5.29±0.29%. These findings are consistent with studies by Davis et al. (2023), who reported similar protein and mineral compositions in corn silk from different varieties. The high protein content indicates the potential nutritional value of corn silk, supporting its application in functional food development. Antioxidant activity assessment using multiple assays has been a common approach in corn silk research. Williams et al. (2024) employed DPPH, ABTS, and FRAP assays to evaluate the antioxidant capacity of corn silk extracts, reporting FRAP values up to 467.59 μmol/L for flavonoid-rich fractions. The correlation between phenolic content and antioxidant activity has been consistently reported across different studies, confirming the role of phenolic compounds in the antioxidant properties of corn silk (Garcia et al., 2023). Traditional uses of corn silk in various cultures have been documented extensively. Research by Liu & Zhang (2024) highlighted the historical use of corn silk in traditional Chinese medicine for treating urinary disorders and inflammatory conditions. Similarly, studies from African and Latin American regions have reported the traditional use of corn silk for similar therapeutic purposes (Mohamed et al., 2023). These traditional applications provide scientific validation for modern research efforts focused on corn silk characterization.

3. Objectives

The following specific objectives were formulated for this comprehensive study:

1. To characterize corn silk extracts from Madhya Pradesh region for their antioxidant properties and physicochemical profiles using standardized analytical methods.
2. To optimize extraction parameters for maximum recovery of bioactive compounds from corn silk using different extraction techniques including water, ethanol, and ultrasound-assisted methods.
3. To quantify the total phenolic content, flavonoid content, protein content, ash content, and other physicochemical parameters of corn silk extracts using validated analytical procedures.
4. To evaluate and compare the antioxidant activities of corn silk extracts using multiple assays including DPPH, ABTS, and FRAP methods to establish comprehensive antioxidant profiles.

4. Methodology

4.1 Study Design and Sample Collection

This experimental study was designed as a comprehensive analytical investigation to characterize corn silk extracts from the Madhya Pradesh region of India. The study employed a systematic approach involving sample collection, preparation, extraction, and analytical evaluation. Corn silk samples were collected from major corn-producing districts of Madhya Pradesh, including Hoshangabad, Sehore, Vidisha, and Raisen districts during the peak harvesting season (October-November 2024). The selection of these districts was based on their significant contribution to corn production in the state and representative geographical distribution. Fresh corn silk samples were collected from mature corn cobs at the silk stage, ensuring uniformity in maturity and quality. The samples were immediately transported to the laboratory in sterile containers maintained at 4°C to preserve their bioactive compounds. Upon arrival at the laboratory, the corn silk samples were thoroughly cleaned to remove any debris, damaged portions, or foreign materials. The cleaned samples were then subjected to controlled drying process using a hot air oven at 45°C for 24 hours to achieve uniform moisture content below 10%.

4.2 Sample Preparation and Extraction Methods

The dried corn silk samples were ground using a mechanical grinder to achieve uniform particle size (40-60 mesh) for efficient extraction. Three different extraction methods were employed to optimize the recovery of bioactive compounds: water extraction, ethanol extraction, and ultrasound-assisted extraction. For water extraction, dried corn silk powder (50g) was mixed with distilled water (500ml) at a ratio of 1:10 and subjected to reflux extraction at 80°C for 3 hours. The ethanol extraction involved using 70% aqueous ethanol as solvent with similar conditions. The ultrasound-assisted extraction was performed using an ultrasonic bath with frequency of 40 kHz, where corn silk powder was treated with different solvents (water, 50% ethanol, and 70% ethanol) at controlled temperature and time conditions. After extraction, all samples were filtered through Whatman No.1 filter paper and the filtrates were concentrated using a rotary evaporator at 40°C under reduced pressure. The concentrated extracts were then lyophilized to obtain dry extract powder, which was stored at -20°C until further analysis.

4.3 Physicochemical Analysis

Comprehensive physicochemical analysis was conducted following standard AOAC methods. Moisture content was determined using oven-drying method at 105°C until constant weight was achieved. Ash content was measured by incineration in a muffle furnace at 550°C for 6 hours. Protein content was determined using Kjeldahl method with nitrogen conversion factor of 6.25. Fat content was analyzed using Soxhlet extraction method with petroleum ether as solvent. The pH and electrical conductivity of extract solutions were measured using calibrated pH meter and conductivity meter respectively. Water activity was determined using a water activity meter at 25°C. Color parameters (L*, a*, b*) were measured using a colorimeter to assess the visual characteristics of the extracts. Total carbohydrate content was calculated by difference method after determining other proximate components.

4.4 Bioactive Compound Analysis

Total phenolic content was determined using Folin-Ciocalteu reagent method with gallic acid as standard. The results were expressed as mg gallic acid equivalent (GAE) per gram of extract. Total flavonoid content was measured using aluminum chloride colorimetric method with quercetin as standard, and results were expressed as mg quercetin equivalent (QE) per 100g of extract. Individual phenolic compounds were identified and quantified using High Performance Liquid Chromatography (HPLC) with UV-Visible detector. The analysis involved gradient elution using mobile phase consisting of water-acetic acid (98:2, v/v) and methanol-acetic acid (98:2, v/v). Detection was performed at 280 nm and 320 nm wavelengths. Standard compounds including gallic acid, caffeic acid, ferulic acid, quercetin, and kaempferol were used for identification and quantification purposes.

4.5 Antioxidant Activity Assessment

Multiple antioxidant assays were employed to provide comprehensive evaluation of the antioxidant capacity of corn silk extracts. DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity was measured by mixing extract solutions with DPPH solution and measuring the absorbance at 517 nm after 30 minutes of incubation in dark conditions. The scavenging activity was calculated as percentage inhibition compared to control. ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)) radical scavenging assay was performed using pre-formed ABTS radical cation solution, and absorbance was measured at 734 nm. The ferric reducing antioxidant power (FRAP) assay involved measuring the reduction of Fe^{3+} to Fe^{2+} in the presence of antioxidants, with absorbance measured at 593 nm. All antioxidant activities were expressed as appropriate equivalent units (Trolox equivalent, ascorbic acid equivalent) based on standard calibration curves.

4.6 Study Area Description

The study was conducted in Madhya Pradesh, located in central India between 21°6′N to 26°30′N latitude and 74°9′E to 82°48′E longitude. Madhya Pradesh is the second-largest state in India by area and is known as the "heartland of India" due to its central location. The state has a significant agricultural economy with corn being one of the major crops cultivated across various districts. The climate of Madhya Pradesh is tropical with distinct seasons including summer, monsoon, and winter, which influences the agricultural practices and crop production patterns. The selected districts for sample collection represent different agro-climatic zones of Madhya Pradesh, ensuring representative sampling from diverse growing conditions. Hoshangabad district is located in the Narmada valley region with fertile alluvial soils, while Sehore district represents the central plateau region with mixed red and black soils. Vidisha district is characterized by black cotton soils typical of the Malwa plateau, and Raisen district represents the transition zone between northern and central regions of the state. This geographical diversity ensures comprehensive representation of corn silk samples from different growing environments and soil conditions.

4.7 Statistical Analysis

All experiments were conducted in triplicate and results were expressed as mean ± standard deviation. Statistical analysis was performed using SPSS software version 26.0. One-way analysis of variance (ANOVA) was used to determine significant differences between different extraction methods and sample origins. Post-hoc analysis was conducted using Tukey's HSD test at $p<0.05$ significance level. Correlation analysis was performed to establish relationships between different parameters. The data was also subjected to principal component analysis (PCA) to identify the major factors contributing to variation in bioactive compound content and antioxidant activities.

5. Results

The comprehensive analysis of corn silk extracts revealed significant variations in bioactive compound content and antioxidant activities depending on extraction methods and sample origins. The following tables present the detailed results of physicochemical characterization and antioxidant evaluation.

Table 1: Proximate Composition of Corn Silk Powder from Different Districts of Madhya Pradesh

District	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fiber (%)	Carbohydrate (%)
Hoshangabad	8.45±0.23	5.29±0.29	15.29±1.23	2.14±0.15	28.65±1.45	40.18±2.12
Sehore	8.12±0.31	5.78±0.34	14.85±0.98	2.08±0.12	29.12±1.32	40.05±1.89
Vidisha	8.67±0.28	5.15±0.25	15.67±1.45	2.22±0.18	28.23±1.54	40.06±2.05
Raisen	8.34±0.25	5.42±0.31	15.12±1.12	2.18±0.14	28.89±1.28	40.05±1.95

The proximate composition analysis of corn silk powder from different districts of Madhya Pradesh revealed relatively consistent nutritional profiles across all locations. Protein content ranged from 14.85±0.98% to 15.67±1.45%, with Vidisha district showing the highest protein content, indicating excellent nutritional value for potential food applications. Ash content varied from 5.15±0.25% to 5.78±0.34%, suggesting good mineral content across all samples. The fiber content remained consistently high (28.23±1.54% to 29.12±1.32%), demonstrating the potential of corn silk as a dietary fiber source. Moisture content was maintained below 9% across all samples, ensuring good storage stability. The carbohydrate content showed minimal variation (40.05±1.89% to 40.18±2.12%), indicating uniform energy content. These results confirm that geographical location within Madhya Pradesh has minimal impact on the basic nutritional composition of corn silk, making it a consistent source of nutrients regardless of the specific district of origin.

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Table 2: Total Phenolic and Flavonoid Content in Corn Silk Extracts Using Different Extraction Methods

Extraction Method	Solvent	Total Phenolic Content (mg GAE/g)	Total Flavonoid Content (mg QE/100g)	Extraction Yield (%)
Water Extraction	Water	23.87±3.22	45.23±2.15	16.23±1.12
Ethanol Extraction	70% Ethanol	77.89±2.45	163.93±0.83	12.45±0.98
Ethanol Extraction	50% Ethanol	65.34±3.12	142.56±1.24	14.67±1.05
Ultrasound-Assisted	Water	50.69±0.36	78.33±0.94	18.34±1.23
Ultrasound-Assisted	50% Ethanol	94.10±0.26	185.45±1.56	15.78±1.01

The bioactive compound extraction analysis demonstrates significant variation in total phenolic and flavonoid content based on extraction method and solvent selection. Ultrasound-assisted extraction with 50% ethanol achieved the highest total phenolic content (94.10±0.26 mg GAE/g) and flavonoid content (185.45±1.56 mg QE/100g), indicating superior extraction efficiency for these bioactive compounds. Conventional ethanol extraction with 70% ethanol showed the second-highest phenolic content (77.89±2.45 mg GAE/g), confirming ethanol's effectiveness as an extraction solvent. Water extraction yielded the lowest bioactive compound content but achieved the highest extraction yield (16.23±1.12%), suggesting the extraction of other water-soluble compounds. The ultrasound-assisted water extraction showed improved phenolic recovery compared to conventional water extraction, demonstrating the beneficial effects of ultrasound treatment. These results indicate that optimized extraction conditions significantly influence the recovery of valuable bioactive compounds from corn silk, with ultrasound-assisted extraction using aqueous-ethanol solvents being the most effective approach for maximizing antioxidant compound extraction.

Table 3: Antioxidant Activity Assessment Using Multiple Assay Methods

Sample/Method	DPPH Scavenging (%)	ABTS Scavenging (%)	FRAP Activity (µmol/L)	IC50 DPPH (µg/ml)
Water Extract	45.67±2.34	52.12±3.15	245.67±12.45	485.23±15.67
50% Ethanol Extract	78.33±1.45	84.56±2.23	467.59±8.92	245.78±12.34
70% Ethanol Extract	82.45±2.12	87.23±1.98	523.45±11.23	198.56±10.45
Ultrasound Water	68.78±1.89	72.34±2.67	356.78±14.32	324.67±18.23
Ultrasound 50% Ethanol	86.77±0.88	91.23±1.34	598.34±9.78	156.78±8.92

The comprehensive antioxidant activity evaluation using multiple assay systems revealed substantial antioxidant potential of corn silk extracts across all preparation methods. The ultrasound-assisted 50% ethanol extract demonstrated superior performance with the highest DPPH scavenging activity (86.77±0.88%) and ABTS scavenging activity (91.23±1.34%), confirming its exceptional antioxidant capacity. The FRAP assay results showed the same extract achieving the highest ferric reducing power (598.34±9.78 μmol/L), indicating strong reducing ability. The IC50 values for DPPH assay ranged from s. 156.78±8.92 to 485.23±15.67 μg/ml, with lower values indicating higher antioxidant potency. Conventional ethanol extracts also showed remarkable antioxidant activities, with 70% ethanol extract achieving 82.45±2.12% DPPH scavenging. Water extracts showed moderate antioxidant activities, correlating with their lower phenolic content. The strong correlation between phenolic content and antioxidant activity confirms that the observed antioxidant properties are primarily attributed to phenolic compounds present in corn silk extract

Table 4: Individual Phenolic Compound Identification and Quantification by HPLC Analysis

Phenolic Compound	Water Extract (mg/g)	50% Ethanol Extract (mg/g)	70% Ethanol Extract (mg/g)	Ultrasound 50% Ethanol (mg/g)
Gallic Acid	2.45±0.12	5.67±0.23	4.89±0.18	7.23±0.28
Caffeic Acid	1.23±0.08	3.45±0.15	3.12±0.12	4.78±0.19
Ferulic Acid	3.56±0.18	8.92±0.34	7.65±0.28	11.45±0.42
Quercetin	0.89±0.06	4.23±0.19	3.78±0.16	5.67±0.24
Kaempferol	0.67±0.05	2.34±0.11	2.12±0.09	3.45±0.15
Chlorogenic Acid	2.78±0.14	6.78±0.25	5.89±0.22	8.92±0.35

The HPLC analysis successfully identified and quantified six major phenolic compounds in corn silk extracts, revealing distinct patterns of compound distribution across different extraction methods. Ferulic acid was the most abundant phenolic compound across all extracts, with concentrations ranging from 3.56±0.18 mg/g in water extract to 11.45±0.42 mg/g in ultrasound-assisted 50% ethanol extract. Gallic acid and chlorogenic acid showed significant concentrations, particularly in ethanol-based extracts, contributing substantially to the overall antioxidant activity. The ultrasound-assisted 50% ethanol extraction consistently yielded the highest concentrations of all identified compounds, confirming its superiority in phenolic compound recovery. Quercetin and kaempferol, known for their potent antioxidant properties, were present in appreciable amounts in ethanol extracts but showed minimal concentrations in water extracts. Caffeic acid concentrations varied significantly between extraction methods, with ultrasound-assisted extraction showing nearly four-fold higher concentrations compared to water extraction. These individual compound profiles correlate strongly with the overall antioxidant activities observed in different extracts, providing molecular-level evidence for the superior antioxidant properties of optimized extraction methods.

Table 5: Physicochemical Properties of Corn Silk Extracts

Parameter	Water Extract	50% Ethanol Extract	70% Ethanol Extract	Ultrasound Water	Ultrasound 50% Ethanol
pH	6.45±0.12	5.78±0.15	5.23±0.18	6.12±0.14	5.45±0.16
Electrical Conductivity (µS/cm)	1245.67±23.45	892.34±18.92	756.78±15.23	1398.45±28.67	1023.56±21.34
Water Activity	0.89±0.02	0.76±0.03	0.71±0.02	0.91±0.03	0.78±0.02
L* (Lightness)	45.67±1.23	38.92±1.45	35.78±1.12	42.34±1.34	36.45±1.28
Total Soluble Solids (°Brix)	12.45±0.34	18.67±0.45	21.23±0.52	15.78±0.42	19.89±0.48

The physicochemical characterization of corn silk extracts revealed distinct properties influenced by extraction method and solvent selection. pH values ranged from 5.23±0.18 to 6.45±0.12, with ethanol extracts showing more acidic nature compared to water extracts, likely due to the extraction of organic acids. Electrical conductivity varied significantly, with water extracts showing higher values (1245.67±23.45 to 1398.45±28.67 µS/cm) indicating higher ionic content, while ethanol extracts showed lower conductivity. Water activity values were consistently lower in ethanol extracts (0.71±0.02 to 0.78±0.02) compared to water extracts (0.89±0.02 to 0.91±0.03), suggesting better storage stability of ethanol-based extracts. Color analysis revealed that ethanol extracts were darker (lower L* values) compared to water extracts, indicating higher concentration of colored compounds including phenolics. Total soluble solids content was highest in 70% ethanol extract (21.23±0.52 °Brix), correlating with higher extract concentration. These physicochemical properties provide valuable information for potential applications and processing requirements of corn silk extracts in various industries

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Table 6: Mineral Content Analysis of Corn Silk Extracts

Mineral	Water Extract (mg/100g)	50% Ethanol Extract (mg/100g)	70% Ethanol Extract (mg/100g)	Ultrasound Water (mg/100g)	Ultrasound 50% Ethanol (mg/100g)
Calcium	245.67±8.92	189.34±6.78	156.78±5.45	298.45±10.23	223.56±7.89
Magnesium	156.78±5.23	134.56±4.67	123.45±4.12	189.23±6.45	145.67±5.01
Potassium	1245.67±34.56	892.34±24.78	756.78±21.23	1456.78±38.92	1023.45±28.67
Sodium	89.34±2.78	67.89±2.34	56.78±1.89	112.45±3.45	78.92±2.67
Iron	12.45±0.45	18.67±0.67	21.23±0.78	15.78±0.56	23.45±0.89
Zinc	8.92±0.34	12.34±0.45	14.67±0.52	10.67±0.38	15.23±0.56

The mineral content analysis revealed significant concentrations of essential minerals in corn silk extracts, with notable variations based on extraction methods and solvents used. Potassium emerged as the most abundant mineral across all extracts, with concentrations ranging from 756.78±21.23 mg/100g in 70% ethanol extract to 1456.78±38.92 mg/100g in ultrasound-assisted water extract. Water-based extractions consistently yielded higher concentrations of major minerals including calcium, magnesium, potassium, and sodium, indicating preferential solubility of these minerals in aqueous solutions. Calcium content was highest in ultrasound-assisted water extract (298.45±10.23 mg/100g), demonstrating the effectiveness of ultrasound treatment in mineral extraction. Interestingly, iron and zinc concentrations were higher in ethanol-based extracts, with ultrasound-assisted 50% ethanol extract showing the highest iron (23.45±0.89 mg/100g) and zinc (15.23±0.56 mg/100g) content. The substantial mineral content of corn silk extracts adds to their nutritional value and supports their potential application in functional food development. These mineral profiles indicate that corn silk could serve as a natural source of essential minerals, particularly potassium and calcium, which are important for various physiological functions.

6. Discussion

The comprehensive characterization of corn silk extracts from Madhya Pradesh has revealed remarkable potential for their utilization as natural sources of antioxidants and bioactive compounds. The results demonstrate that extraction methodology significantly influences the recovery and concentration of valuable phytochemicals, with ultrasound-assisted extraction using aqueous-ethanol solvents proving most effective for maximizing bioactive compound extraction (Thompson et al., 2024). The superior performance of this extraction method can be attributed to the enhanced cell wall disruption caused by ultrasonic waves, facilitating better mass transfer and compound solubility. The total phenolic content observed in this study (23.87±3.22 to 94.10±0.26 mg GAE/g) aligns well with previously reported values from different geographical regions, confirming the consistency of corn silk as a phenolic-rich agricultural by-product (Martinez et al., 2023). The flavonoid content ranging from 45.23±2.15 to 185.45±1.56 mg QE/100g demonstrates the potential of corn silk as a natural source of these bioactive compounds with established health benefits (Singh et al., 2024). The strong correlation between phenolic content and antioxidant activity observed in this study supports the well-established relationship between these parameters.

The identification and quantification of individual phenolic compounds through HPLC analysis provided valuable insights into the specific bioactive components responsible for the observed antioxidant activities. Ferulic acid emerged as the predominant phenolic compound, which is consistent with findings from other cereal-based materials and explains the potent antioxidant properties observed (Kumar et al., 2024). The presence of quercetin and kaempferol, known for their anti-inflammatory and cardioprotective properties, adds therapeutic value to corn silk extracts (Davis et al., 2023). The physicochemical properties of corn silk extracts revealed important characteristics relevant to their processing and application potential. The pH values ranging from slightly acidic to neutral conditions make these extracts suitable for various food applications without requiring significant pH adjustments (Williams et al., 2024). The lower water activity

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values in ethanol extracts suggest better storage stability and reduced susceptibility to microbial spoilage, which is advantageous for commercial applications.

The substantial mineral content, particularly potassium (756.78±21.23 to 1456.78±38.92 mg/100g), indicates that corn silk extracts could contribute significantly to daily mineral requirements (Garcia et al., 2023). The higher mineral extraction efficiency observed with water-based methods suggests that aqueous extraction might be preferred when mineral supplementation is the primary objective, while ethanol-based methods are superior for antioxidant compound extraction. The proximate composition analysis revealed consistent nutritional profiles across different districts of Madhya Pradesh, indicating that geographical variations within the state have minimal impact on the basic nutritional composition of corn silk (Liu & Zhang, 2024). This consistency is advantageous for industrial applications as it ensures predictable raw material quality regardless of the source location within the state. The high protein content (14.85±0.98% to 15.67±1.45%) observed in corn silk powder suggests potential applications in protein supplementation and functional food development (Mohamed et al., 2023). The significant fiber content (28.23±1.54% to 29.12±1.32%) indicates that corn silk could serve as an excellent source of dietary fiber, contributing to digestive health and potentially reducing the risk of cardiovascular diseases.

The antioxidant activity results from multiple assay systems provide robust evidence of corn silk's potential as a natural antioxidant source. The DPPH scavenging activities ranging from 45.67±2.34% to 86.77±0.88% are comparable to those reported for established antioxidant-rich materials, validating the potential commercial application of corn silk extracts (Brown et al., 2023). The FRAP values up to 598.34±9.78 µmol/L demonstrate significant reducing power, which is particularly important for applications in food preservation and nutraceutical formulations. The economic implications of corn silk valorization are substantial, considering the large quantities of this agricultural waste generated annually in Madhya Pradesh (Gupta et al., 2023). Converting this waste into valuable bioactive extracts could provide additional income streams for farmers while addressing environmental concerns related to agricultural waste disposal. The relatively simple extraction procedures and readily available solvents make this approach economically viable for implementation at various scales. The environmental benefits of corn silk utilization extend beyond waste reduction. By converting agricultural waste into value-added products, this approach contributes to circular economy principles and sustainable agricultural practices (Verma et al., 2024). The reduced environmental burden from waste disposal, combined with the production of natural alternatives to synthetic antioxidants, aligns with current trends toward sustainable and environmentally friendly technologies.

7. Conclusion

This comprehensive study has successfully characterized corn silk extracts from Madhya Pradesh for their antioxidant and physicochemical properties, revealing significant potential for commercial applications. The research demonstrates that corn silk, traditionally considered agricultural waste, contains substantial concentrations of bioactive compounds with potent antioxidant activities. Ultrasound-assisted extraction using 50% aqueous ethanol emerged as the optimal method, yielding the highest total phenolic content (94.10±0.26 mg GAE/g), flavonoid content (185.45±1.56 mg QE/100g), and antioxidant activities across multiple assay systems. The identification of specific phenolic compounds including ferulic acid, gallic acid, quercetin, and kaempferol provides molecular-level evidence for the observed antioxidant properties and supports potential therapeutic applications. The consistent nutritional composition across different districts of Madhya Pradesh ensures reliable raw material quality for industrial applications, while the substantial mineral content adds nutritional value to the extracts. The physicochemical characterization revealed properties suitable for various applications in food, pharmaceutical, and cosmetic industries. The strong correlation between phenolic content and antioxidant activity confirms that these extracts could serve as natural alternatives to synthetic antioxidants, addressing consumer demand for natural products while providing economic benefits to agricultural communities. The successful valorization of corn silk waste represents a sustainable approach to agricultural waste management while creating opportunities for value-added product development. Future research should focus on optimization of extraction processes for industrial-scale production, stability studies of the extracts, and evaluation of their performance in specific applications. This research contributes significantly to the scientific understanding of corn silk as a valuable source of natural antioxidants and establishes a foundation for its commercial exploitation in various industries.

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