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Phytochemical Analysis and Characterization of Corn Silk (*Zea mays*, G5417)

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Abstract: Corn silk has long been thought of as a waste product; however, due to its numerous therapeutic attributes, it has remarkably gained popularity in Asian and African countries. Therefore, this study aimed to assess the bioactivity of dried corn silk powder (*Zea mays*, G5417) in terms of its physicochemical and bio-functional characteristics. The protein (15.29 ± 1.23) and ash (5.29 ± 0.29) contents in the corn silk powder were found to be high. The high phenolic content (94.10 ± 0.26 mg GAE/g) and flavonoid content (163.93 ± 0.83 mg QE/100 g) are responsible for its high antioxidant activity. The corn silk powder showed 45.40 ± 0.92% FRSA, 75.25 ± 0.59 TEAC mg/gdw of ABTS, and 86.77 ± 0.88% of FRAP. FT-IR spectroscopy revealed stretching, bending, and vibrations of abundantly present polysaccharides and protein functional groups. Moreover, the DSC thermograph revealed the exothermic reactions at on-set temperature (T_{onset}) = 21.9 °C and end temperature (T_{endset}) = 102.80 °C, and exothermic reactions at on-set temperature (T_{onset}) = 252.02 °C, end temperature (T_{endset}) = 296.80 °C, and denaturation peak temperature (T_{peak}) = 277.48 °C, whereas XRD (2θ = 21.5°) confirmed the amorphous nature of the corn silk powder. Therefore, due to the potential bioactivity and thermal stability, dry corn silk powder can be scaled up at an industrial level.

Keywords: corn silk; characterization; antioxidant; functional; phenols; flavonoids

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1. Introduction

Corn silk is a yellow silky component that grows on top of the corn cob (corn fruit) and is a part of the female flower (stigma) of the corn plant (*Zea mays L.*). Additionally, corn silk is a major by-product of the corn processing industry that is traditionally discarded as eco-friendly agricultural waste or used as animal feed [1]. However, corn silk is a good source of vital nutrients, including carbohydrates, proteins, vitamins, and minerals, as well as resins, mucilage, and fibers [2]. In addition, it also contains a wide range of bioactive compounds in the form of volatile oils, steroids, and other natural antioxidants, such as polyphenols and flavonoids [3–5]. According to the traditional Chinese medicine system, these bioactive and fibrous compounds possess various health benefits and help to avoid numerous chronic diseases, including edema, cystitis, gout, rheumatism, and rheumatoid arthritis [6–8]. In addition, several in vivo and clinical studies reported corn silk safe for human consumption [9,10]. Given these benefits, corn silk is now being utilized in the development of value-added foods, such as beverages and patties. Furthermore, earlier studies of 10 different corn silk genotypes showed a significant number of bioactive components, including flavonoids and phenolics, and also revealed the antioxidant activities of corn silk polysaccharides; however, this characterization based on various techniques is not studied for corn silk powder. As corn silk nutrients and bioactives are mostly subject to large variations owing to soil conditions, environmental variations, and different cultivars, the current study aims to investigate the nutritional composition, bioactive composition,

and characterization of a selected variety of corn silk (G5417) that is most commonly grown in the northern region of India, owing to its high yield and acceptability.

2. Materials and Methods

2.1. Sample Collection and Sample Preparation

Corn silk samples from the G5417 variety of *Zea mays* were collected from the agriculture farm of Lovely Professional University, Phagwara, Punjab, India. The samples were harvested after the 10th day of emergence (silking stage) and washed under running tap water. The corn silks were blanched at 100 °C for 60 s to retain the color and to avoid any chemical changes. To obtain the dry powder, the blanched corn silk samples were subjected to tray drying at 50 °C for 4 h (Labfit India Pvt. Ltd., Mumbai, India) until a constant weight was achieved, as per the method proposed by reference [11]. The dried corn silk samples were then ground to powder using a commercial mechanical grinder (Rex 500, Bajaj Electrical and Electronics Pvt. Ltd., Punjab, India) and sieved through 22 mesh-sieve sizes by using an electric sieve shaker (8" Sieve Shaker SS-15, Gilson Company, Inc., Lewis Center, OH, USA). The corn silk powder was stored in sealed zip-lock pouches (Wellworth Packers Pvt. Ltd., Delhi, India) at refrigerated temperature 4–7 °C for further analysis. The flow chart of the process with the pictorial presentation of corn silk powder is shown in Figure 1.

Figure 1. Processing of corn silk powder using tray drying method. (**a**) Corn silk at silking stage, (**b**) harvested corn silk, (**c**) powdered corn silk.

2.2. Nutritional Composition of Corn Silk Powder

The chemical composition (moisture, carbohydrates, protein, fat, and ash) of the corn silk powder (2 g) was determined [12] and the values were mentioned in g/100 g. The moisture content of the sample was calculated using the oven-dry method. Protein content was estimated by using Kjeldahl's method and the values were obtained by multiplying the nitrogen content by a factor of 6.25. The fat content of the corn silk powder samples was determined by the Soxhlet method [13]. The digestion method was used to examine the crude fiber content of the corn silk powder samples [14]. The carbohydrate content of the sample was calculated by the difference method [15]. The water activity of the dried corn silk powder sample was determined by water-activity analyzer (Testo AG 400, Germany), as per the proposed method of Pant et al. [16]. The calculation of the result was done on the fresh weight basis of the dehydrated powder. The methods used for analysis were validated for reproducibility, accuracy, and precision indicated with relative standard deviation (%RSD) in Table 1. The correlation coefficient for the methods was found to be >0.98.

2.3. Mineral Analysis

The mineral content of the corn silk sample was determined using the Thermo iCAP 7000 Duo ICP OES (Thermo Fisher Scientific, Bremen, Germany) [5]. For plasma, pure argon gas was used (Himalayan Gases, Baddi, India). The microwave digestion process was carried out in PTFE vessels utilizing a Multiwave Pro microwave oven (Anton Par, Graz, Austria). Deionized water ASM Type I (18.2 mΩ, Aurium mini, Sartorius, Germany) was used to prepare all the solutions. In the digestion of the materials, nitric acid (HNO_3 69%, Loba Chemie Pvt Ltd., Mumbai, India) was used. Standard solution dilutions (1000 μg mL^{-1}) of Ag, Al, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, In, K, Li, Mg, Mn, Na, Ni, Pb,

Sr, Tl, and Zn were used to make the analytical solutions (Alfa Aesar, Specure, MA, USA). In the PTFE vessels, sample masses of 0.5 g were directly weighed, followed by the addition of 7 mL of HNO_3. The microwave-assisted digestion was carried out utilizing the following five-step heating program: (1) 10 min ramp to 150 °C; (2) 10 min hold at 150 °C; (3) 10 min ramp to 180 °C; (4) 10 min hold at 180 °C; and (5) 21 min ramp to 55 °C cooling temperature. The solutions were then transferred to polyethylene tubes and volumes created up to 30 mL with ultrapure water ASTM Type I after the containers were cooled to room temperature. The ICP OES quantification procedure was performed in the axial view of plasma with a radio frequency power of 1250 W, sample flow 0.50 L min^{-1}, plasma gas flow 12 L min^{-1}, analysis pump rate 50 rpm, auxiliary gas flow 0.5 L min^{-1}, nebulizer gas flow 0.5 L min^{-1}, integration time 15 s, stabilization time 5 s, and nebulization pressure 20 psi after digestion of the completed samples. Calcium (293.366, 396.847 nm), copper (324.754 nm), iron (259.940 nm), potassium (766.490 nm), magnesium (279.553 nm), manganese (257.610 nm), sodium (588.995, 589.592 nm), and zinc (213.856 nm) were monitored for the execution of the proposed method. The method validation is shown with %RSD, limit of detection (LoD), background equivalent concentration (BEC), and the coefficient of correlation (R^2).

2.4. Colour Analysis

The color of corn silk was measured in triplicates using a Hunter LAB colorimeter (CM-508 d Model, Minolta, Japan). The three-dimensional color space is perceived in L*, a*, and b*, with L* (luminance) expressing brightness along the vertical axis, ranging from total black to complete white (i.e., 100% black to 100% white). The a* and b* axes, respectively, range from greenness (−a*) to redness (+a*), and blueness (−b*) to yellowness (+b*). Each sample was tested in three different ways. The formula, as given in Equation (1), was used to calculate the chroma (c*) and hue angle (h°) [17]. The validation of the methods indicated an R^2 value >0.98. The accuracy and precision of the method, indicated through %RSD, are mentioned in Table 1

$$c^* = \left(a^{*2} + b^{*2}\right)^{1}/_{2}$$

$$h^\circ = \tan^{-1}\left(b^*/a^*\right) \quad (1)$$

where, c* = chroma, h° = hue angle, a* and b* = color axes. Range from −a* = greenness, +a* = redness, −b* = blueness, +b* = yellowness.

2.5. Extraction of Ethanolic Extract

The ethanolic extract of corn silk powder was prepared by dispersing 10 g of powder in 100 mL (1:10 *w*/*v*) of ethanol in a conical flask, which was kept in an orbital shaker (MaxQ 4000, Thermofisher Scientific Pvt. Ltd., Mumbai, India) for 72 h. The extract solution was then filtered through Whatman No. 1 filter paper, and for evaporation of the solvent, vacuum oven drying was employed. The obtained extract was then stored in glass vials at −20 °C temperature. The extract was used to determine the antioxidant content and activity. The methods used for the assay were validated for reproducibility, accuracy, and precision, represented with %RSD in the respective tables.

2.6. Determination of Total Phenolic Content (TPC), Total Flavonoid Content (TFS), and Ascorbic Acid (AA)

For evaluation of the bioactivity of the corn silk extract a stock solution of 10 mg/10 mL ethanol was prepared. Different assays were employed to evaluate the bioactivity of the corn silk powder extract.

2.6.1. Total Phenolic Content

The total phenolic content of corn silk powder was evaluated using the Folin–Ciocalteu colorimetric method and gallic acid as a reference [18]. The ethanolic extract of 200 µL was mixed with 1.0 mL of Folin–Ciocalteu reagent to which 7.5% sodium carbonate (Na_2CO_3)

was added. The samples were kept at room temperature for 30 min and the absorbance was measured at 765 nm. The final values were computed in mg GAE/g.

2.6.2. Flavonoid Content

Corn silk extract solution (2 mL) was mixed with 5% of sodium nitrite (0.2 mL). Further 0.2 mL of aluminum chloride (10%) was added and mixed well. A quantity of 0.1 M of NaOH was added (2 mL) and the sample was kept for 6 min. The solution was raised with 0.275 mL of distilled water and absorbance was recorded at 510 nm by using a UV-Vis spectrophotometer. Quercetin was used as standard and the flavonoid was expressed as mg QE/100 g [19].

2.6.3. Ascorbic Acid

The ascorbic acid content was measured using the 2, 6-dichlorophenol indophenol titration technique [20]. A quantity of 5 mL of ascorbic acid working standard (500 µg/5 mL) and 10 mL of 4% oxalic acid were pipetted into a 100 mL conical flask. The contents of the flask were titrated against the dye solution (V1) until a pale-pink color appeared and lasted a few minutes. Similarly, 5 mL of the corn silk powder sample was titrated against the dye solution (V2). The ascorbic acid content of the corn silk powder was calculated using the following Equation (2).

$$\text{ascorbic acid mg/100 g} = \frac{\text{Dye factor}}{\text{V1 mL}} * \frac{\text{V2}}{\text{5 mL}} * \frac{\text{100 mL}}{\text{Weight of sample}} * 100 \quad (2)$$

where V1 = volume of dye consumed by standard ascorbic acid, V2 = volume of dye consumed by dye solution.

2.7. Antioxidant Activities

2.7.1. Free Radical Scavenging Activity (FRSA)

The antioxidant activity in terms of % inhibition was determined and the absorbance was measured at 517 nm (UV/Vis spectrophotometer, Shimadzu Corporation, Japan) against the blank (mixture without extract). In the test, a 0.1 mM alcoholic solution of 2, 2-diphenyl-1-picrylhydrazyl (DPPH) was utilized. The sample extract (0.1 mL) was mixed with 1.0 mL DPPH solution, which was then diluted with 2.9 mL ethanol. The mixture was violently mixed before being placed in the dark for 60 min. The absorbance was measured against a blank (mixture without extract) at 517 nm (UV/Vis spectrophotometer, Shimadzu Corporation, Japan) [21]. The following Equation (3) was used to determine the antioxidant activity:

$$\text{Antioxidant activity } (\%) = \frac{A^0 - A}{A^0} * 100 \quad (3)$$

where A^0 = Absorbance of DPPH as blank, A = Absorbance of the sample.

2.7.2. ABTS Radical Scavenging Assay

The ABTS radical cation decolorization test was used to determine the free radical scavenging activity of corn silk samples. The ABTS radical cation decolorization assay was used to determine the free radical scavenging activity of plant materials. The reaction between 7 mM ABTS in water and 2.45 mM potassium persulfate (1:1) produced the ABTS+ cation radical, which was kept in the dark at room temperature for 12–16 h before use. After diluting the ABTS+ solution with methanol, an absorbance of 0.700 at 734 nm was obtained. The absorbance was measured 30 min after the initial mixing of 5 µL of plant extract with 3.995 mL of diluted ABTS+ solution. In each test, a suitable solvent blank was

used. All of the tests were repeated at least three times. The formula used to compute the percent suppression of absorbance at 734 nm is mentioned in Equation (4).

$$\text{ABTS} + \text{scavenging effect } (\%) = \frac{AB - AA}{AB} * 100 \quad (4)$$

where *AB* is the absorbance of ABTS radical + methanol, *AA* is the absorbance of ABTS radical + sample extract/standard. Trolox was used as a standard substance and the values were calculated in TEAC mg/gdw [22].

2.7.3. Ferric Ion Reducing Antioxidant Power (FRAP)

The FRAP activity is based on the mechanism of reaction on the reduction of Fe^{3+} TPTZ complex (colorless complex) to Fe^{2+}-tripyridyltriazine (blue-colored complex) formed by the action of electron-donating antioxidants at low pH. A quantity of 3.995 µL of corn silk extract was mixed with 5 mL of FRAP (300 mmol acetates buffer + 10 mL TPTZ in 40 mmol HCl + 20 mmol of $FeCl_3.{}_6H_2O$). The following reaction is measured at an absorbance of 593 nm. The FRAP values were expressed as mg of Trolox equivalent (TEAC) per gram of sample [22].

2.8. Characterization of Corn Silk Powder

2.8.1. Differential Scanning Calorimetry

The thermal investigation of corn silk powder was done using a differential scanning calorimeter (Shimadzu DSC-50 system, Shimadzu, Kyoto, Japan). Thermograms were collected after crumpling 2 mg powdered samples in a standard aluminum pan heated from 30 °C to 450 °C with a 10 °C/min ramping and continual nitrogen purging (20 mL/min) [23]. The correlation coefficient was found to be >0.98 and the relative standard deviation observed was in the range of 0.28–0.76 (%RSD).

2.8.2. Fourier Transform Infrared Spectroscopy (FTIR)

Dried corn silk powder was subjected to FTIR analysis (Shimadzu 8400S FTIR spectrometer, equipped with KBr beam splitter) using approximately 5 mg of each sample and 5 mg KBr for the qualitative analysis [24]. The FTIR spectrophotometer was used with a maximum resolution of -0.85 cm^{-1} and a spectrum range of 400–4000 cm^{-1}. The spectra obtained for the various samples were analyzed according to Stuart's guidelines [25]. The correlation coefficient was 0.995, indicating the linearity of the methods. The relative standard deviation (%RSD) observed was 0.97%, indicating high precision and accuracy.

2.8.3. X-ray Diffraction

An analytical X-ray diffractometer (X'Pert PRO, Panalytical, Almelo, The Netherlands) was used to produce XRD patterns using a Cu-based anode X-ray tube [26]. Using a glass slide and an aluminum holder, the corn silk powder sample was pushed firmly. The experiments were carried out with a scanning rate of 4°/min at 30 mA and 40 kV with a diffraction angle ranging from 4 to 40° (2θ). The correlation coefficient of the methods was >0.998. The accuracy and precision of the methods indicated using RSD (%) were found to be in the range of 0.30–1.8 (%RSD). The instrumental reproducibility was 0.76 %RSD and the intraday reproducibility was 0.85 %RSD, indicating the validity of the method used.

2.9. Statistical Analysis

Each experiment was conducted in triplicates (n = 3). The statistical analysis was performed using SPSS V. 22 (SPSS Inc, Chicago, IL, USA). All data were presented as mean ±standard deviation. One-way analysis of variance (ANOVA) and Duncan's multiple tests were used to evaluate the data. Significant p values of less than 0.05 were considered.

3. Results

3.1. Nutritional Composition of Corn Silk Powder

Moisture is an important component that is linked to the shelf stability of the food. Thus, determining moisture content is vital for the development of value-added products using food ingredients. The prepared corn silk powder showed a moisture content of 7.89 ± 0.49 g/100 g fw (Table 1), making its shelf-life management easier. The chemical composition of corn silk powders reveals the high carbohydrate content of corn silk 56.16 ± 0.66 g/100 gas compared to the other nutrients. It includes high levels of soluble dietary fibers, such as pectin, glucan, and glucomannan, and insoluble dietary fibers such as cellulose, hemicellulose, and lignin. The total fiber content of the corn silk powder samples corresponded to 14.82 ± 0.84 g/100 g. With an average of 15.29% protein and 5.29% ash content, corn silk is one of the best sources of both protein and ash, while the fat content in the stated variety was about 0.55%. The water activity is a significant measure for determining the microbiological stability of food products since it determines the free and available moisture attributable to any type of biochemical reaction. The water activity of the corn silk powder in this investigation was 0.224, which was lower than 0.3 (as shown in Table 1), indicating the high microbiological stability of corn silk powder.

Table 1. Chemical analysis of corn silk powder.

Parameter	Corn Silk Powder	%RSD
Chemical composition (g/100 g fw)		
Moisture	7.89 ± 0.49	0.49
Fat	0.55 ± 0.08	0.08
Ash	5.29 ± 0.29	0.29
Crude fiber	14.82 ± 0.84	0.84
Protein	15.29 ± 1.23	1.23
Carbohydrate	56.16 ± 0.66	0.66
Water activity (a_w) at 25 °C	0.224	0.01
Color		
L*	47.88	0.02
a*	3.16	0.01
b*	12.03	0.01
Chroma (*)	12.44	0.01
Hue angle (°)	75.27	0.02

Fw = fresh weight basis. Data are presented as mean ± standard deviation (n = 3). %RSD= relative standard deviation used for validation of the methods. L* = Lightness, a* = redness, b* = yellowness.

3.2. Mineral Content

The mineral content of the corn silk depends on various factors, including atmosphere, soil type, irrigation, and nutrients through fertigation contacting nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, zinc, manganese, copper, boron, molybdenum, and chlorine obtained from soil minerals and organic matter, as well as from organic and inorganic fertilizers. This corn silk variety is a good source of Na, Mg, K, and Ca, as depicted in Table 2. Corn silk also contains trace metals, such as copper (11.91 ± 1.15 µg/g), iron (41.77 ± 2.67 µg/g), manganese (11.10 ± 2.15 µg/g), and zinc (83.75 ± 1.80 µg/g).

Table 2. Mineral analysis of corn silk powder using ICP-OES.

Parameter	Corn Silk Powder	R^2	BEC (ppm)	LoD (ppm)	%RSD
Macroelements (µg/g)					
Sodium (Na)	3654.21 ± 2.97	0.9948	18.675	0.1789	14.3
Magnesium (Mg)	1169.05 ± 12.94	0.9986	0.069	0.0007	1.1
Potassium (K)	1135.78 ± 6.3	0.9960	0.026	0.0008	1.1
Calcium (Ca)	1338.13 ± 14.23	0.9958	1.826	0.0150	2.2
Microelements (µg/g)					
Manganese (Mn)	11.10 ± 2.15	0.9975	0.002	0.0003	0.8
Copper (Cu)	11.91 ± 1.15	0.9993	0.007	0.0021	0.6
Iron (Fe)	41.77 ± 2.67	0.9993	0.042	0.0011	0.7
Zinc (Zn)	83.75 ± 1.80	0.9895	0.041	0.0002	0.5

R^2 represents the correlation coefficient. BEC = background equivalent concentration represents the background radiation observed in the analysis. LoD = limit of detection represents the lowest amount of analyte detected through the method. %RSD = relative standard deviation used for validation of the methods.

3.3. Color Analysis of Corn Silk Powder

Herein, Table 1 shows the color, lightness (L*), redness (a*), and yellowness (b*) parameters of corn silk powder. The color of dried powder is important as it determines the quality and sensory attractiveness of the product. The hue angle of 75.27° shows the corn silk powder was strongly characterized by a yellow color, as the values were close to 90 °C.

3.4. Total Phenolic Content (TPC), Total Flavonoid Content (TFS), and Ascorbic Acid (AA)

Corn silk is often considered a good source of antioxidant content. These antioxidants include polyphenolic compounds, flavonoids, and ascorbates. These components provide quality and nutritional value, as well as anti-inflammatory, anti-diabetic, antiviral, and antioxidant properties, which are important in human fitness. Secondary metabolites from medicinal plants act as tiny molecular weight antioxidants, although their mechanisms of action vary depending on the structure and environment [27]. Table 3 reveals that the total phenolic content of corn silk powder was 94.10 ± 0.26 mg GAE/g. Corn silk has a lot of flavonoids in it and varying amounts according to the variety, ranging from less than 0.1% to 3% [14]. Current results showed a high flavonoid content in corn silk 163.93 ± 0.83 mg QE/100 g. As reported, maysin, apigmaysin, 3-methoxymaysine, ax-4-OH maysin, and isoorientin-2″-O-a-L-rhamnoside are among the flavonoids extracted and discovered from corn silk [28,29]. Studies suggest that larger amounts of phenolics and flavonoids were found in the top regions of corn silk than in the lower parts [30]. However, the current study used a homogenized sample for the determination of the compounds. Ascorbic acid is a water-soluble vitamin that is required for a variety of physiological processes as well as acting as a powerful antioxidant in the battle against diseases caused by free radicals [31,32]. The vitamin C content of corn silk powder was reported to be high as 270 ± 0.57 mg/100 g, which is significantly higher than the 9.72 mg/100 g reported by Kewawy [33].

Table 3. The antioxidant profile of corn silk powder.

Antioxidant Content	Corn Silk Powder	%RSD
Total phenolic content (mg GAE/g)	94.10 ± 0.26	0.26
Total flavonoid content (mg QE/100 g)	163.93 ± 0.83	0.83
Ascorbic acid (mg/100 g)	270 ± 0.57	0.57
Antioxidant activity		
Free radical scavenging activity (%)	45.40 ± 0.92	0.92
Ferric ion reducing power (%)	86.77 ± 0.88	0.88
ABTS (TEAC mg/gdw)	75.25 ± 0.59	0.59

%RSD= relative standard deviation used for validation of the methods. Data are presented as mean ± standard deviation (n = 3).

3.5. Antioxidant Activities of Corn Silk

3.5.1. Free Radical Scavenging Activity (FRSA)

Oxidation is a worldwide problem that has negative consequences for food quality and human health. According to a previous study, oxidative damage can cause browning, off-flavor, and changes in food's nutritious value, as well as a possible threat to cellular functions and the creation of chemicals linked to aging and cardiovascular disease [33]. The antioxidant activity of corn silk powder was calculated using three different methods, including DPPH, ABTS, and FRAP. The free radical scavenging activity reported by corn silk powder, as shown in Table 3, was found to be 45.40 ± 0.92%. Corn silk extracted with methanol had a higher degree of DPPH scavenging activity (81.7 percent at 1000 g/mL) than corn silk extracted with water (63.5 percent) at the same concentration [34]. In ethanol, DPPH is a stable free radical with a maximum absorbance of 517 nm.

3.5.2. ABTS Activity

Total antioxidant activity has always been measured using the ABTS radical scavenging activities test. The ABTS radical produced by converting ABTS-e to ABTS+ interacts swiftly with electron/hydrogen donors to produce colorless ABTS. The ABTS activity for corn silk powder, as shown in Table 3, was 75.25 ± 0.59 TEAC mg/gdw.

3.5.3. Ferric Ion Reducing Power (FRAP)

As significant as reducing power, the ferric ion reducing–antioxidant power (FRAP) assay is frequently utilized as a measure of phenolic antioxidant activity. The ability of the samples to decrease Fe(III)-TPTZ to Fe(II)-TPTZ was used to determine their antioxidant capacity. Corn silk powder showed 86.77 ± 0.88% of FRAP activity. The total flavonoids extracted from corn silk had a FRAP value of 467.59 µmol/L [35].

3.6. Characterization of Corn Silk Powder

3.6.1. Differential Scanning Calorimetry

The thermal properties of corn silk such as denaturation temperature (T_d) and enthalpy change (ΔH) could be studied using differential scanning calorimetry. The calorimetry method was used to identify the changes in phase transitions. Figure 2 summarizes the differential scanning calorimetry (DSC) parameters obtained for endothermic reaction at on-set temperature (T_{onset}) = 21.9 °C, end temperature (T_{endset}) = 102.80 °C, denaturation peak temperature (T_{peak}) = 70.06 °C, and ΔH = 172.16 J/g, and exothermic reactions at on-set temperature (T_{onset}) = 252.02 °C, end temperature (T_{endset}) = 296.80 °C, denaturation peak temperature (T_{peak}) = 277.48 °C, and ΔH =−33.616 J/g.

3.6.2. FTIR Analysis of Corn Silk Powder

Figure 3 depicts the vibrational and rotational modes of the functional groups present in corn silk powder. N-H stretching vibrations caused the specific intense peaks at 3277.17 cm^{-1}. The C-H stretching vibration absorption was 2920.32 cm^{-1}, indicating that the polysaccharides chains interacted intra- and inter-molecularly [3]. The presence of N-H was suggested by a stretching peak at 1637.62 cm^{-1}, which indicates the presence of protein in corn silk powder [36]. Asymmetrical carbonyl stretching was responsible for the absorption at 1246.06 cm^{-1}. Peaks at 1028.09 cm^{-1} suggested that the sugar was in the pyranose form [34].

3.6.3. X-ray Diffraction

The crystallinity index refers to a material's ordered structure. In biomass, cellulose is the only crystalline component, while hemicellulose and lignin are amorphous components. The crystalline or amorphous form of dry powders is determined using XRD. A crystalline substance usually has multiple distinct peaks in a highly ordered condition, whereas amorphous product molecules have disordered and scattered bands [37]. The peaks are not well resolved, as seen in the XRD diffraction spectra of corn silk powder samples (Figure 4),

and just one peak at 2θ = 21.5° is visible, which reflects the amorphous nature of the corn silk powder.

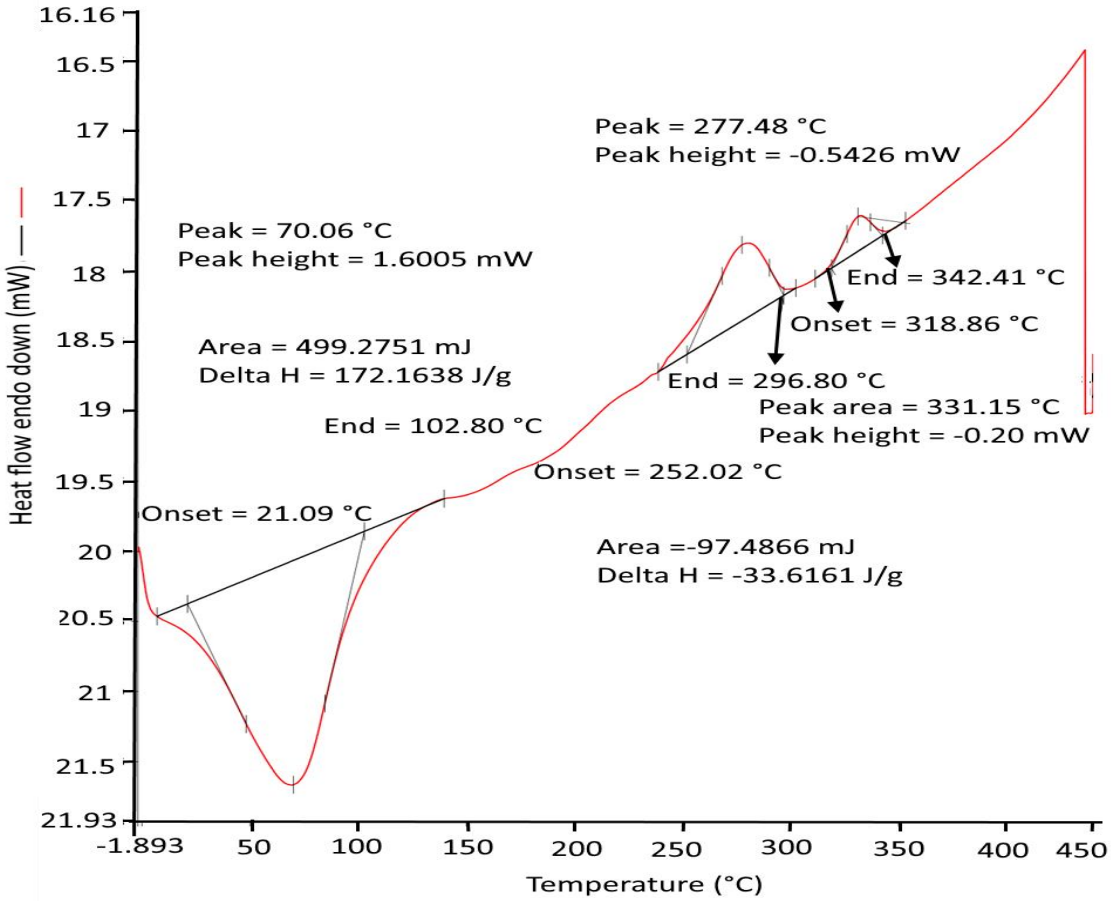

Figure 2. DSC thermograph of corn silk powder. The red line represent the Heat flow and the black line represents the area demarcation for each peak.

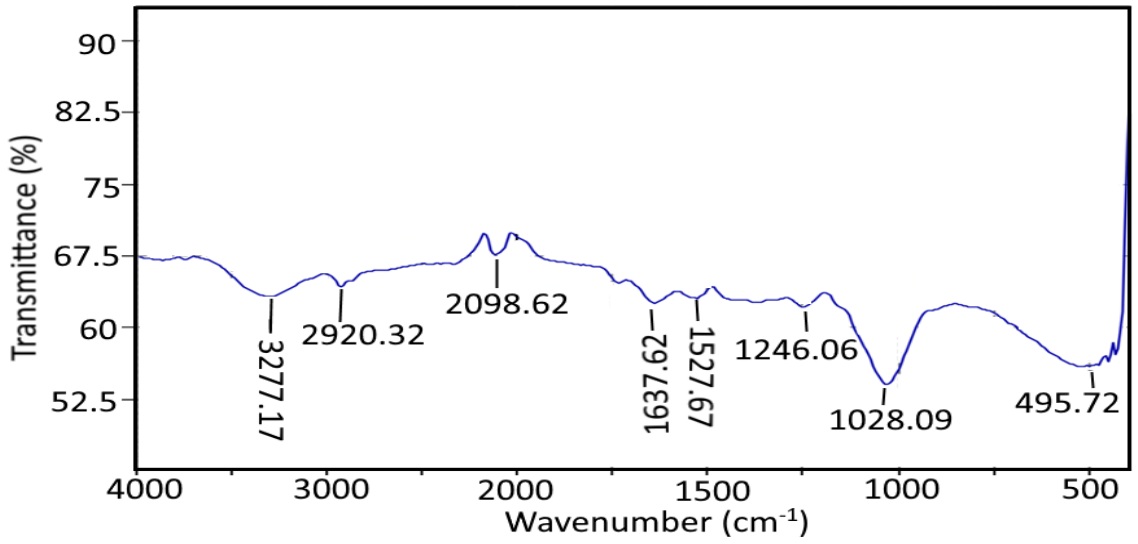

Figure 3. FTIR spectra of corn silk powder.

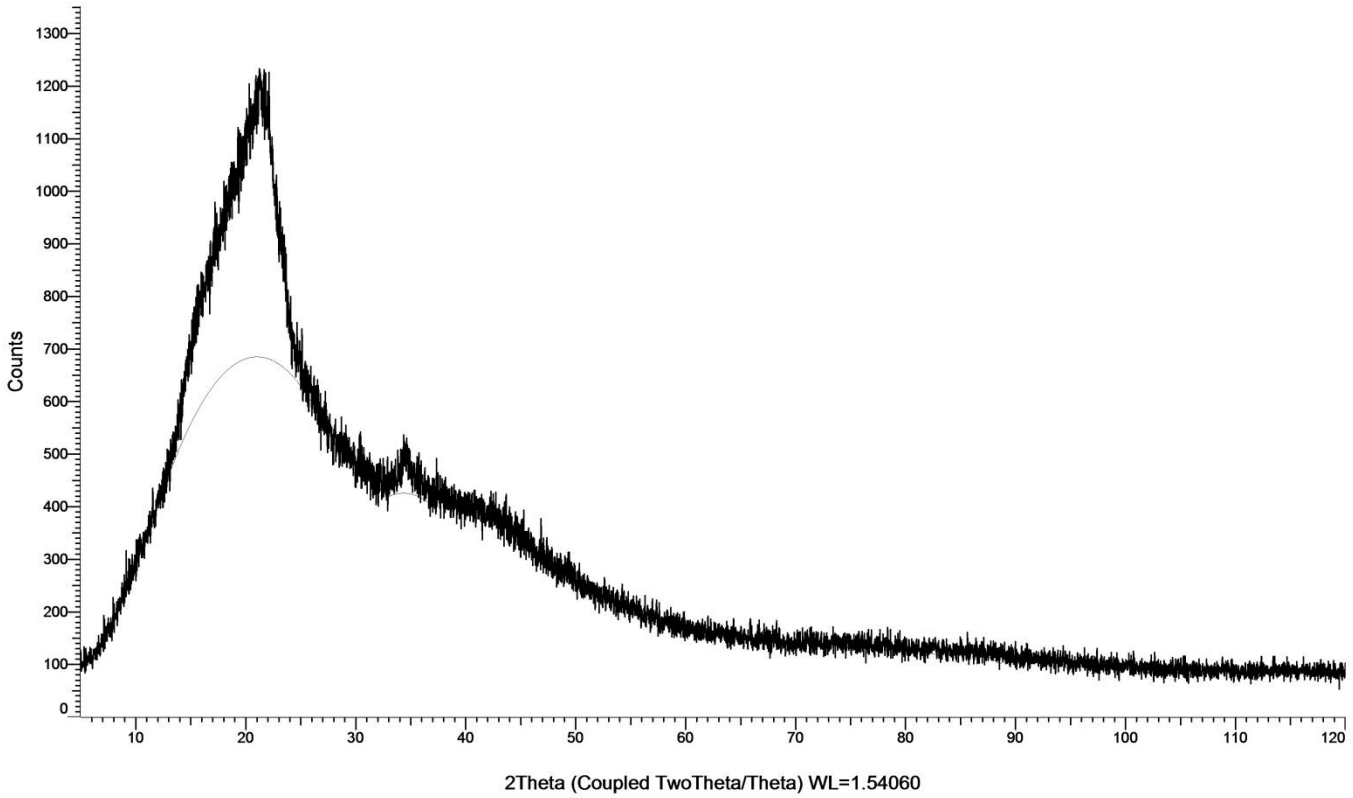

Figure 4. X-ray diffraction pattern of corn silk powder.

4. Discussion

The G5417 has comparable nutritive values to those reported in other corn silk varieties by other researchers. The results were in agreement with the study of the incorporation of corn silk powder in low-fat meatballs [1]. Their findings show the 9.06 g/100 g of moisture, 0.91 g/100 g of fat, 4.60 g/100 g of ash, 16.11 g/100 g of crude fiber, 17.94 g/100 g of protein, and 51.37 g/100 g of carbohydrate. Microelements such as Zn, Mn, and Fe, as well as macroelements such as Ca and K, play critical roles in animal and human physiological functioning. The results were in agreement with the results given by Rahman and Rosli [18], where they reported the nutritional composition of mature and immature corn silk. A similar trend was observed by Rosli et al. [38], and they reported the highest concentration of macrominerals, including Na (0.561 $\pm$ 0.001 mg/kg), Ca (1.123 $\pm$ 0.001 mg/kg), K (0.690 $\pm$ 0.001 mg/kg), and Mg (0.209 $\pm$ 0.001 mg/kg) observed in a blanched corn silk drink. The high amount of K and Ca helps in maintaining blood pressure, bone health, regulating serum levels of harmful lipids, and preventing obesity [39].

Typically, a greater water-activity value indicates a larger concentration of free moisture, and thus, shelf-life may be decreased due to biochemical reactions. Although water activity is largely dependent on moisture content, the varietal difference may play a significant role in it based on moisture-binding components, such as carbohydrates and fiber content. Similar findings for water activity were reported by Castillo et al. [17] in their study of the incorporation of dried corn silk powder in beef patties, where they reported that the water activity of corn silk powder was 0.288. The result depicted that corn silk powder is a good contender to develop highly stable value-added products.

The drying method may reduce the polyphenolic content as it is easily oxidized and sensitive to heat treatments [40]. However, such treatments are required for the preservation of plant produce. Similar results were shown by Haslina et al. [28] in their study of the phytochemical composition of three local varieties of corn silk. The total phenolic content of fresh corn silk was reported to be 93.46 µg GAE compared to 82.62 µg GAE in powdered corn silk. The difference in the ascorbic acid values could be most probably due to varietal

differences. According to Sanahuja et al. [34], the ascorbic acid concentration was higher after 20 days of pollination and reduced considerably ($p < 0.01$) after 40 days of pollination in different maize genotypes. They claim that as the plant develops, the expression of genes required for ascorbic acid production decreases. Phenolic molecules have received a great deal of attention as the primary source of antioxidant action. The findings revealed that the corn silk variety G5417 had a high amount of phenolic and flavonoid content, showing strong antioxidant activity. Corn silk's antioxidant action has previously been attributed to its phenolic and flavonoid levels [24,38]. Our findings corroborated prior findings, indicating that phenolic and flavonoid content are good indices for determining a corn silk's antioxidant activity. Similar results were reported by Nurraihana et al. [41] for the TPC and DPPH activity, i.e., 57.7 ± 0.75 mg GAE/g and 77.47 ± 5.13%, respectively. When DPPH comes into contact with a chemical that donates hydrogen atoms, such as an antioxidant, the radical is scavenged, the absorbance is lowered, and the color is changed from purple to yellow [42]. The overall amount of phenol in plant tissue is connected to the activities of DPPH free radical scavengers [43]. The more hydroxyl groups in an extract, the higher the concentration of phenols and flavonoids. The molecule's capacity will be increased by the presence of hydroxyl groups [44].

For ABTS activity, similar results were reported by Dong et al. [45], namely that corn silk ethanolic extract had the highest ABTS activity, i.e., 244.1 ± 10.2 µmol TE per 100 g dw. The FRAP activity stated by Limmatvapirat et al. [46] for ethanolic extract was 58.16 µg/mL. Maksimovic et al. [42] also reported a high FRAP activity in 10 genotypes of corn silk in a range from 79.8 ± 0.5 to 158.4 ± 4.4 AAE/mg. The occurrence of glass transition temperatures in corn silk powder was observed due to the occurrence of heat changes with increasing temperatures. The exothermic peak with the T_{onset} = 21.09 °C and T_{endset} = 102.80 °C showed moisture loss, and the endothermic peak with a glass transition temperature (T_g) = 277.48 °C reported in the current results were higher than capsules of corn silk dried by freeze-drying (148.25 °C), spray drying (143.40 °C), and the microwave drying (171.09 °C) method, as depicted by Pashazadeh et al. [43], which shows high thermal stability in corn silk powder obtained from the variety G5417.

The vibrational characteristics of sugar C-O stretch bonds were found between the region of 1200 and 900 cm^{-1} while polysaccharide C-O bonds were found to have sovereignty between 1150 and 1000 cm^{-1}. Our results were well supported by the study conducted by Guo et al. [47] for three polysaccharides from corn silk. Therefore, irrespective of a varietal difference, the basic composition of corn silk more or less is unchanged. For the XRD analysis, our results were in agreement with Ali et al. [48], who reported that the cellulose from corn silk showed an amorphous nature at 2θ = 22.5° due to the presence of hemicellulose. The corn husk also showed a diffraction peak at 2θ = 22.6°, as reported by Mendes et al. [49]. Most of the powders prepared using simpler processes with a low level of refinement show an amorphous nature. Senphan et al. [50,51] stated the similar value of L* = 35.11 ± 2.16, a* =5.60 ± 0.28, and b* = 16.89 ± 1.16 for the color parameters. Variations in chemical composition are determined by a variety of factors, including variances in cultivars, the climate in which it grows, soil quality, plant care, and treatment method [51].

5. Conclusions

Current findings convey that the corn silk variety G5417 has a high nutritional bioactive potential owing to its high polyphenol, flavonoid, and ascorbate content, and its potent antioxidant activity, making this plant material highly valuable for use as a natural source of polyphenols, potentially contributing to the development of value-added, functional, and nutraceutical products. As evident through DSC studies, the prepared powder was found to be highly heat-stable. FTIR analysis confirms the components of corn silk powder, XRD analysis provides evidence of the amorphous nature of the powder, and acceptable color values make it an ideal contender to be used as a food ingredient.

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