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Research Article

EXPLORING NUTRITIONAL AND FUNCTIONAL PROPERTIES OF CORN SILK FOR COMPREHENDING ITS USES

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A B S T R A C T

This research explores the nutritional, antioxidant, and functional aspects of corn silk from three varieties of maize (VL Baby corn-1, MCVL Sweet corn-1, and Hybrid Pant DH-192. Aims of the study are to uncover the health benefits of corn silk and its potential in food development. Comparison of corn silk varieties on basis of nutritional and functional properties showed that CMVL Sweet corn-1 had outstanding results among them with the highest protein (16.19%), highest total dietary fiber (55.61%), highest mineral content and antioxidant properties, with the highest free radical scavenging activity (119.65 µg/ml). VL- Baby Corn showed highest antioxidant properties in terms of total antioxidant activity (3.43 mgTE/100g), total flavonoid content (87.22 mg RE/100g) and total phenolic content (292.45 mg GAE/100g). Functional properties of cornsilk were similar to various flours which make its incorporation more convenient in common food items for enhancing their nutritional profile. Compared to conventional cereals like wheat and rice, corn silks showed superior nutritional and antioxidant profiles. The findings suggest that corn silk could be incorporated in high protein and high fiber products.

INTRODUCTION

Corn, also known as *Zea mays*, is one of the world's most essential cereal crops, serving as a staple food for billions of people. While corn kernels are the primary focus of consumption, other parts of the corn plant, such as the silk, are often overlooked. Corn silk, the fine, thread-like structure that emerges from the top of the ear of corn, occasionally been regarded for its potential nutritional and medicinal properties. The uppermost male flowers of corn, known as tassels, produce yellow pollen, whereas the female flowers, located in the leaf axils, yield corn silk (CS), which takes the form of elongated stigmas resembling tufts of hair. Initially, the CS typically appears light green, eventually transitioning to hues of red, yellow, or light brown. The primary role of CS is to ensnare pollen for the purpose of pollination. Each strand of CS has the potential to be pollinated and subsequently yield a corn kernel. Corn silk strands can reach lengths of 30 centimetres or even longer and possess a mildly sweet taste. For medicinal applications, CS is typically collected just before pollination and can be utilized either in a fresh or dried state.

CS is generally regarded as a waste agri-produce which is neglected but it is rich in essential nutrients like carbohydrates, proteins, vitamins, and minerals, and it also contains resins, mucilage, and dietary and natural antioxidants like polyphenols and flavonoids (Vijitha and Saranya 2017). The study of corn silk has gained momentum due to its rich phytochemical content and potential health benefits in alternative medicines. The research on the nutritional and functional properties of different corn silk varieties is crucial for optimizing health benefits, tailoring functional applications, diversifying markets, fostering innovation in the food, pharmaceutical and nutraceutical industry, and raising consumer awareness. This knowledge contributes to a more sustainable and economically viable agricultural sector with potential implications for human health. This research aims to determine and quantify nutritional contents, antioxidants and functional properties of three varieties of corn silk namely VL Baby corn-1, MCVL Sweet corn-1, and Hybrid Pant DH-192. This study aims to shed light on the nutritional and medicinal potential of corn silk and how it varies across different corn varieties. This will facilitate exploration of food formulation for health.

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MATERIALS AND METHODS

In the initial phase, different maize varieties were cultivated at the Norman E. Borlaug Crop Research Centre (NEB CRC) of the University. Corn silk (female inflorescences) harvested from three corn varieties viz. CMVL Sweet corn-1, VL Baby corn-1 and Hybrid Pant DH-291 after 106, 121 and 125 days respectively, just before pollination. The processing of corn silk, nutritional analysis, and were carried out at the Department of Foods and Nutrition, of the University.

Sample preparation

The harvested corn silk was cleaned by washing it with a 0.1% salt solution to remove foreign materials and the natural green flavour of the corn. The corn silk was subjected to drying in a tray dryer for the duration of 6 hours at a temperature of 40°C, resulting in a moisture content of 7-9%. Thereafter, the corn silk was manually crushed, ground using an electric grinder and sieved through a 60-mesh sieve, achieving an approximate particle size of 250 micrometers. The final corn silk powder was stored in air-tight zipper polybags.

Dried corn silk powder obtained from three varieties of corn VL Baby corn-1, CMVL Sweet corn-1 and Hybrid Pant DH-291 were studied for various parameters in triplicate samples.

Functional Properties of Dried Corn Silk Powder

The swelling capacity, water absorption capacity (WAC) and water holding capacity (WHC) were determined by the method given by Robertson *et al.* 2000; Wang and Kinsella 1976 and Quinn and Paton 1979 respectively. The fat absorption capacity (FAC) was determined by the method given by (AOAC, 2000).

Proximate analysis of different varieties of corn silk powder

The moisture level, overall ash, crude protein, crude fat, and crude fibre in the sample were assessed by the method described in AOAC (2010). The total carbohydrate content was determined by deducting the sum of dry matter-based values for total ash, crude protein, crude fibre, and crude fats from 100 and then reported as grams per 100 grams of the sample. The physiological calorific value (Kcal/100g) of sample was calculated by summing up the products of multiplication of per cent protein, fat and carbohydrates present in the sample by 4, 9 and 4 respectively.

Phytochemical and Mineral Estimation

The dietary fiber was determined using the approach described in a study by Asp and Johanson (1981). Calcium, Iron, Zinc and Magnesium in acid digested samples were determined by Atomic Absorption Spectrophotometer according to the method of Lindsay and Norwell (1969). The total antioxidant capacity was determined according to method given by Williams *et al* (1995) using 1, 1-diphenyl-2-picryl hydrazyl (DPPH).

RESULTS AND DISCUSSION

Functional Properties of different varieties of corn silk powders

Among the three different types of corn silk, Hybrid Pant DH-291 exhibited a significantly high swelling capacity of 47.50±0.29 ml/g, while VL Baby corn-1 had the lowest swelling capacity at 38.83±0.44 ml/g. Meanwhile, dried corn silk powder from CMVL Sweet corn-1 displayed a swelling capacity of 41.00±0.29 ml/g. The swelling capacity of corn silk varieties are higher than wheat flour viz., 17.60 ml and rice flour viz. 15.20 ml (Suresh *et al* 2013). The swelling capacity values mentioned are on a similar scale as those observed in cauliflower leaves fiber (Femenia *et al* 1997), as well as carrot fiber (Chantaro *et al* 2008).

Table 1 Different functional properties of corn silk

Varieties of Corn Silk	Swelling Capacity (ml/g)	Water Absorption Capacity (ml/g)	Water Holding Capacity (g/g)	Fat Absorption Capacity (ml/g)
VL Baby Corn-1	38.83±0.44	5.86±0.09	2.17±0.04	1.76±0.09
CMVL Sweet Corn-1	41.00±0.29	3.20±0.06	2.14±0.10	2.73±0.09
Hybrid Pant DH-291	47.50±0.29	6.36±0.09	4.73±0.04	3.73±0.09
SEM	0.347	0.132	0.068	0.099
CD (P≤0.05)	1.04	0.40	0.16	0.25

Values are mean ± SD of three independent determinations, CD=Critical difference

Notably, Hybrid Pant DH-291 exhibited the highest WAC at 6.36±0.09 ml/g, while CMVL Sweet corn-1 had the lowest at 3.20±0.06 ml/g (p≤0.05). The water absorption capacity of corn silk varieties in this investigation falls within the range reported for rice bran, which typically ranges from 1.49 to 4.72 ml/g, as reported by Bhosale and Vijayalakshmi (2015). Rehman *et al* (2007) found that the water absorption capacity of wheat flour was 5.86 g/g, which is close to VL Baby Corn. Dietary fibers with a high WHC can serve as functional ingredients to prevent liquid separation and alter the viscosity and texture of certain formulated foods, (Grigelmo and Martina, 1999).

In the present study, the WHC of dried corn silk powder (ranging from 3.20 to 6.36 g/g sample) were similar to values reported for various fiber sources in previous research. These sources include pear dietary fiber (6.8 g/g sample), apple dietary fiber (6.3 g/g sample) and wheat bran which is ranging from 3.45 to 5.89 g/g sample (Zhu *et al* 2011). Among the three corn silk varieties, Hybrid Pant DH-291 displayed significantly high water holding capacity. Dietary fiber with a high WHC can serve as functional ingredients to prevent liquid separation and alter the viscosity and texture of certain formulated foods.

Significant differences at p≤0.05 were observed in the fat absorption capacity of three varieties of dried corn silk (ranging from 1.76 to 3.73 ml/g). When compared to dietary fiber derived from sources like orange, mango, peach, and sugarcane bagasse, which displayed a fat absorption capacity ranging from 1.09 g/g to 3.26 g/g, the FAC of dried corn silk was relatively low (Elleuch *et al* 2011).The lower FAC of dried corn silk suggests that food products incorporating this ingredient may not retain large amounts of fat.

Proximate Composition of different corn silk powders

The information displayed in table 2.0 indicates that the three types of corn silk, namely VL Baby corn-1, CMVL Sweet corn-1, and Hybrid Pant DH-291, exhibit noteworthy distinctions ($p \leq 0.05$) in terms of moisture content on fresh basis, ash content, crude protein, crude fiber content, carbohydrate content, and physiological calorific value on dry weight basis. However, it's worth noting that the crude fat content is comparable between CMVL Sweet corn-1 and Hybrid Pant DH-291.

1.29%±0.04, and 1.26%±0.05, respectively. These fat content values showed significant differences at $p \leq 0.05$. Fat content of wheat viz. 1.47% is relatively similar to that of corn silk whereas fat content of milled rice i.e.0.52% is lower than corn silk varieties (Longvah *et al* 2017). Crude fat content of mungbean as reported by Raghuvanshi *et al* (2011) was in the range from 1.60% to 1.80%. These products along with corn silk are considered low fat as plant foods contain energy in the form of starch, not in the form of fat.

Table 2 Nutritional and anti-oxidant composition of corn silk on dry matter basis

Varieties of corn silk	VL Baby Corn-1	CMVL Sweet Corn-1	Hybrid Pant DH-291	SEM	CD (P≤0.05)
Moisture*(%)	92.49±0.19	88.09±0.68	84.82±0.42	0.473	1.66
Crude Protein (%)	14.64±0.41	16.19±0.23	12.10±0.35	0.339	1.19
Crude Fat (%)	1.13±0.02	1.29±0.04	1.26±0.05	0.039	0.13
Crude Fibre (%)	16.48±0.24	21.73±0.27	13.55±0.20	0.236	0.83
Total Ash (%)	5.16±0.03	4.99±0.03	4.60±0.08	0.053	0.18
Total Carbohydrates (%)	62.59±0.15	55.80±0.30	68.49±0.46	0.33	1.16
Physiological Calorific value (Kcal/100g)	319.06±1.08	299.57±1.24	333.71±0.84	1.072	3.78
Total Dietary Fiber (g/100g)	52.26±1.50	55.61±0.48	42.93±0.25	0.391	3.25
Soluble Dietary Fiber (g/100g)	3.93±0.24	4.88±1.47	2.40±0.23	0.136	3.07
Insoluble Dietary Fiber (g/100g)	48.33±0.18	50.73±0.24	40.53±0.44	0.305	0.18
Total Calcium (mg/100g)	1090.21±0.72	1141.93±1.02	1013.01±0.75	0.832	2.93
Total Iron(mg/100g)	24.10±0.13	27.90±0.10	23.09±0.03	0.355	0.22
Total Zinc(mg/100g)	48.44±0.09	49.47±0.03	46.00±0.55	0.32	1.13
Total Magnesium(mg/100g)	1212.69±0.38	1278.30±0.51	1166.82±1.71	1.773	4.25
DPPH free radical scavenging activity (µg/ml)	119.65±0.99	114.65±1.01	101.60±0.50	0.865	3.05
Total Antioxidant Capacity (mgTE/100g)	3.43±0.07	3.20±0.01	2.27±0.05	0.007	0.02
Total flavonoid content (mg RE/100g)	87.22±0.51	67.18±0.58	40.47±1.08	0.769	2.71
Total Phenolic Content (mg GAE/100g)	292.45±0.83	283.85±1.19	250.93±1.97	1.413	4.98

Values are mean ± SD, CD=Critical difference, *Moisture content on fresh weight basis

The moisture content in fresh corn silk varied between 84.82% and 92.49% across all three varieties. Similar moisture content trends, ranging from 82% to 88%, were observed in a study conducted by Bhuvaneshwari and Sridevi (2017). These findings align with results reported by Rahman and Rosli (2014), who found that immature corn silks had a high moisture content ranging of 89.31% on a fresh basis.

The CMVL Sweet corn-1 variety exhibited the highest protein content at 16.19%±0.23, while the Hybrid Pant DH-291 variety had the lowest protein levels at 12.10%±0.35, and these values were significantly different from each other. This protein distribution corresponds to the trend by Rahman and Rosli (2014), where protein content of 12.96% was reported. Longvah *et al* (2017) reported 10.57% protein in wheat which is less than the protein content of each variety of the corn silk. Raw and milled rice has almost half of the protein content from con silk varieties viz. 7.94% (Longvah *et al* 2017) making corn silk a product with superior protein profile than conventional cereals. In comparison, mungbean has 22.75% to 24.86% protein which is remarkably higher than that of corn silk (Raghuvanshi *et al* 2011). This attributes to the fact that leguminous plants have more nitrogen to synthesize protein than cereals and other food groups.

The crude fat content in dried corn silk powder varied among the varieties, with VL Baby corn-1, CMVL Sweet corn-1, and Hybrid Pant DH-291 having fat contents of 1.13%±0.02,

The crude fiber content of the corn silk powder for VL Baby corn-1, CMVL Sweet corn-1, and Hybrid Pant DH-291 were 16.48%±0.24, 21.73%±0.27, and 13.55%±0.20, respectively. The data demonstrates that the crude fiber content in CMVL Sweet corn-1 is significantly higher ($p \leq 0.05$) than that in VL Baby corn-1 and Hybrid Pant DH-291. These fiber values are notably higher than the mungbean which has 5.48% to 6.74% of fiber. (Raghuvanshi *et al* 2011).

In the current study, the total ash content, varied among the corn silk varieties. VL Baby corn-1 had the highest total ash content at 5.16%±0.03, followed by CMVL Sweet corn-1 with 4.99%±0.03, and Hybrid Pant DH-291 with 4.60%±0.08. Abarike and Obodai (2016), reported total ash content in groundnut bran at 4.78% and in wheat bran at 5.18%.. Wheat has an ash content of 1.42% and rice has 0.56% which makes corn silk a product with higher mineral content than conventional cereals (Longvah *et al* 2017). Raghuvanshi *et al* (2011) reported ash content in raw mungbean in the range of 3.63% to 4.46%. These findings are higher than conventional cereals but still less than that of corn silk varieties.

The corn silk powder from the three varieties contained carbohydrate content (calculated as the difference) of 62.59%±0.33 for VL Baby corn-1, 55.80%±0.30 for CMVL Sweet corn-1, and 68.49%±0.4 for Hybrid Pant DH-291. Wheat and rice both surpass corn silk in terms of carbohydrates as they contain, 64.17% and 78.24%

carbohydrate content in wheat and rice respectively (Longvah *et al* 2017).

The energy content per 100 grams for the three corn silk varieties ranged from 299.57±1.24 to 333.71±0.84 Kcal. Notably, the Hybrid Pant DH-291 variety had the highest energy content at 333.71±0.84 Kcal per 100 grams, while CMVL Sweet corn-1 had the lowest energy value at 299.57±1.24 Kcal per 100 grams.

Dietary Fibre

The soluble dietary fiber content in corn silk from different varieties, namely VL Baby corn-1, CMVL Sweet corn-1, and Hybrid Pant DH-291, was measured as 3.93±0.24 g/100 g, 4.88±1.47g/100 g, and 2.40±0.23/100 g, respectively. In contrast, the insoluble dietary fiber content was found to be 48.33±0.18 g per 100 g, 50.73±0.24 g per 100 g, and 40.53±0.44 g per 100 g for the respective varieties. Combining both soluble and insoluble dietary fiber, the total dietary fiber in VL Baby corn-1, CMVL Sweet corn-1, and Hybrid Pant DH-291 corn-silk was determined as 52.26±1.50 g per 100 g, 55.61±0.48 g per 100 g, and 42.93±0.25 g per 100 g, respectively. In comparison to corn silk varieties, wheat flour is significantly low in soluble dietary fibre (1.63g/100g), insoluble dietary fiber (9.73g/100g) and TDF (11.36g/100g) (Longvah *et al* 2017). While considering rice, it is also significantly lagging in terms of dietary fibre content with 0.82g/100g soluble, 1.99g/100g insoluble whereas TDF content equal to 2.81g/100g (Longvah *et al* 2017).

Mineral Content

The total calcium content in corn silk extracted from three corn varieties, namely VL Baby corn-1, CMVL Sweet corn-1, and Hybrid Pant DH-291, was measured at 1090.21±0.72 mg per 100 grams, 1141.93±1.02 mg per 100 grams, and 1013.01±0.75 mg per 100 grams, respectively. The study clearly shows that the corn silk of CMVL Sweet corn-1 had significantly higher (at $P \leq 0.05$) calcium content compared to the other two corn varieties. Wheat has 39.36 mg whereas rice has 7.49 mg calcium per 100 gram respectively which are very low in comparison to corn silk (Longvah *et al* 2017). Calcium content of mungbean is between 221-261mg/100g (Raghuvanshi *et al* 2011), this finding is higher than both rice and wheat but much less than that of corn silk varieties.

It is evident that among the three varieties of corn silk, CMVL Sweet corn-1 had the highest total iron content at 27.90±0.10 mg per 100 grams, while the silk of Hybrid Pant DH-291 had the lowest iron content at 23.09±0.03 mg per 100 grams. In a study by Rosli *et al* (2010), the iron content of oven-dried corn silk was reported as 32.1±0.4 mg per 100 grams, which was higher than the iron content in the present study. Iron content of wheat (3.97mg/100g) and rice (0.65mg/100g) and mungbean (5.07-5.42 mg/100g) are significantly less than corn silk (Longvah *et al* 2017, Raghuvanshi *et al* 2011).

The present study highlighted variations in zinc content among different corn silk varieties. Notably, CMVL Sweet corn-1 demonstrated the highest zinc content at 49.47±0.03 mg per 100 grams, followed by VL Baby corn-1 at 48.44±0.09 mg per 100 grams, and Hybrid Pant DH-291 at 46.00±0.55 mg per 100 grams. A significant difference ($P \leq 0.05$) in zinc content emerged among the silk of these three corn varieties. In contrast, Longvah *et al* (2017) reported that both wheat and rice displayed lower zinc content, with 2.85 mg/100g and 1.21 mg/100g zinc which are lower than that of cornsilk varieties.

The study's findings showed that the magnesium content in corn silk varied among three different varieties, ranging from 1166.82±1.71 to 1278.30±0.51 mg per 100 grams for Hybrid Pant DH-291 to CMVL Sweet corn-1. Rosli *et al* (2010) reported a higher magnesium content of 1433±5.7 mg per 100 grams in oven-dried corn silk compared to the present study. Corn silk surpasses both wheat (125mg/100g) and rice (19.30mg/100g) in terms of magnesium content. Moth bean has 205 mg/100g magnesium which is again lower than that of corn silk. (Longvah *et al* 2017)

Antioxidant Content

The study utilized the DPPH assay to assess the free radical scavenging activity, as DPPH is a stable antioxidant. The free radical scavenging activity (DPPH) in three corn silk varieties, namely VL Baby corn-1, Hybrid Pant DH-291, and CMVL Sweet corn-1, was determined as 119.65±0.99 μg/ml, 114.96±1.01 μg/ml, and 101.60±0.50 μg/ml, respectively. There was a significant ($P \leq 0.05$) variation in DPPH free radical scavenging activity among the three corn silk varieties. Studies by Nawaz *et al* (2019) reported DPPH values for corn silk extracts in the range of 46.72±2.98 to 60 μmoL TE/g sample , and DPPH radical scavenging activities of corn silk samples ranging from 40.13 to 52.36 μmoL TE/g sample (Senphan *et al* 2019), which were lower than the values observed in this study. Yu *et al* (2002) found that the free radical scavenging activity of wheat extracts of three varieties were in range of 0.60-0.95 mg/ml.

The total antioxidant capacity of corn silk obtained from three different corn varieties, was found to range between 2.27±0.05 and 3.43±0.07 mg TE/100g with highest being VL Baby corn-1 and lowest for Hybrid Pant DH-291. There was a significant difference observed among the three varieties in their total antioxidant capacity. Similar findings were reported by Nawaz et al. (2019), indicating a range of total antioxidant capacity for corn silk between 0.21±0.025 and 30.8±3.01 mg TE/100g. Rice exhibits an antioxidant activity between 1.05-1.23 mg TE/100g (Parikh and Patel 2015) which is lower than that of corn silk.

Notably, the total flavonoid content of VL Baby corn-1 had approximately double the flavonoid content (87.22±0.51 RE mg/100 g) compared to the hybrid variety. The total flavonoid content of red rice was determined to be 120 mg R.E. per 100 grams (Raghuvanshi *et al*. 2017)

The total phenolic content in corn silk from VL Baby corn-1, Hybrid Pant DH-291, and CMVL Sweet corn-1 varieties was measured at 292.45±0.82, 283.85±1.19, and 250.93±1.69 mg GAE/100g, respectively leaving no significant difference ($P \leq 0.05$). Similar results were reported by Nurhanan et al. (2012), who extracted antioxidant components from corn silk and found polyphenol content in the range of 256.36 to 272.81 mg GAE/100g. Additionally, Ishak and Rahman (2011) reported varying polyphenol content in corn silk, ranging from 6.70 to 101.99 mg GAE/100g extract, depending on the solvent used, which was lower than the values found in the present study. Total phenolic content ranged between 65.31 and 125.13 mg GAE/100 g in wheat flour (Grande *et al* 2023). Both of these attributes are lower than corn silk. The variations observed in phytochemical content can be attributed to a range of factors, including genetic differences, growth conditions, and the specific methods used in each study.

It is important to recognize that corn silk has the potential to be a valuable source of dietary fiber and antioxidants. Furthermore, the study reinforces the idea that the nutritional and antioxidant properties of plants are influenced by a multitude of factors, emphasizing the importance of considering various parameters when assessing the potential health benefits of natural products. This provides valuable insights into the nutritional and medicinal potential of corn silk and serves as a foundation for further exploration and exploitation of this agricultural by-product.

CONCLUSION

Corn silk exhibits diverse properties that render it a versatile ingredient with practical applications in the food industry and beyond. Its high swelling capacity makes it valuable for improving food texture, such as thickening soups and sauces. CMVL-Sweet Corn with low water absorption capacity is ideal for infant foods, enabling thinner gruels with higher nutrient density. With water holding capacity akin to dietary fiber sources, it can enhance the texture, viscosity, and water-holding properties of health-conscious food products. Corn silk, especially varieties like Hybrid Pant DH-291 with high water holding capacity, can serve as functional ingredients, preventing moisture loss and enhancing overall food quality. CMVL Sweet Corn silk which has relatively low-fat absorption capacity makes it beneficial for producing low-fat food items for weight reduction. Moreover, cornsilk could have potential nutraceutical applications as a natural ingredient. Beyond food, corn silk's water-absorbing properties may find uses in pharmaceuticals and cosmetics, such as in skincare products and wound dressings, offering a wide range of practical applications across various industries.

Nutritionally Corn silk has more protein, dietary fibre, different minerals, DPPH free radical scavenging activity, total antioxidant capacity, total flavonoid content, and total phenolic content in comparison to wheat, rice and mungbean. The research findings align with prior studies, but also unveil higher values for total antioxidant capacity and phenolic content, highlighting the potential health benefits of corn silk. Though any recipe may not have large amount of corn silk due to its very high fibre content, but even ten per cent of its addition will improve the quality of product with reference to several nutrients. Notably, CMVL Sweet corn-1 emerged as a standout with its high protein content; it also displayed a significantly higher dietary fiber content compared to other varieties. Incorporation of CS in food products, by replacing wheat, rice or maize, will take it to the direction of high protein, high fibre and high antioxidants products. These products will have a demand among constipated people, diabetic patients, obese subjects as well as old age people.

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