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Cornsilk as an Alternate Functional Ingredient

Wan Rosli Wan Ishak & Nurhanan Abdul Rahman

INTRODUCTION

Corn trees have been cultivated about 5000 years ago and it is known to be derived from a wild grass native to Mexico and Central America (Dermastia *et al*., 2009). The name '*Zea*' comes from the Greek word which means cereal or grain and the word '*mays*' is adopted from a Spanish voyager named Columbus, who collected the grain and brought it over to Europe from America (Desjardins & McCarthy, 2004; Eckhoff *et al*., 2009). Since its domestication, corn plant spreads rapidly around the world in the 15th century, mainly in the temperate regions (Eckoff *et al*., 2009). Corn is introduced into Mediterranean and South East Asia region in the 16th century by the Portuguese (Desjardin & McCarty, 2004).

Corn tree is about 5 to 7 feet tall having long and green leaves attached to its stalk. It requires a warm weather climate, nutrient rich soil and abundant moisture for growth. Corn plant is monoecious which means both male and female flowers develop on the same plant. Its male flower or sometimes referred to as tassel is located on top of the plant while the female flower developed from shoots and arises from between the stalk and leaf sheath. Female inflorescence also refers as an 'ear'. Normally, two to three shoots are found within one stalk of the corn plant. Male inflorescences are seen on top of a corn plant and are actively involved in pollination.

During germination, the male pollen fertilises a young ovule which later grows into an embryonic plant. Grain filling is usually occurring within 55 days after pollination until maturity (Nuss & Tanumihardjo, 2010). Corn fruits can be harvested between 100 and 140 days of planting during the moisture content of corn kernels reaches approximately 70-80% (Almeida *et al*., 2005). At this stage, the corn kernels are fully ripened and lining the whole cob could be in different sizes, depending on its varieties.

The silks start to elongate from an ovule towards the tip of husk and this development occurs in 14 days. Within 3-5 days after emergence of silks from its husk at about 3.8 cm length, the silks are receptive to pollen grains. Majority of successful fertilisations of ovule occur at this early silk emergence that is within 10 days. The elongation of silks, however, starts to decrease over the next several days due to the senescence of silk tissue. However, one or two ear shoots may not be successfully pollinated thus unable to develop into a mature corn fruit. Unlike mature corn, these young corns do not produce corn kernel, instead consumed as a vegetable. These young corns are usually harvested 45 days after planting, while mature corn is harvested after 65-75 days of planting.

Young corn ear grows as an unfertilised ovule. It is one of the popular Asian vegetable dishes or sometimes consumed as a pickle. In Malaysia, the new corn cultivar is grown in several parts of the country. A corn plant usually produces an average of four units of young corn ears. Unfortunately, the production of this vegetable is still insufficient to meet consumers demand. In term of nutritional value, young corn contains 90.1% moisture (fresh weight basis), 0.51% crude lipid, 0.26% protein, 0.44% ash and 30.4% total dietary fibre. Fructose and sucrose compositions are 5.30% and 5.40% respectively. However, the utilisation of young corn has expanded recently since a study has been conducted to include it as part of the ingredients in biscuit making. In that particular study, young corn ear was made into powder form and substituted with flour at 0-30% (Wan Rosli & Che Anis, 2012).

Zea mays hairs or commonly known as cornsilk is a bundle of silky, long and yellowish strands which can be seen on top of corn fruit. The silks function as stigmas of a female flower, whereby every single strand of the silk is attached to the kernel (ovule) (Dermastia *et al*., 2009). As the fruit develops, silk elongates beyond the corn cob covering the edible part. The outermost layer part which is the green husk sheath protects the whole fruit.

A typical cornsilk is 15-17 cm in length and functions as the stigma of a female corn fruit (Tao *et al*., 2006). The silk expression is regulated by a cornsilk-specific gene known as zmgrp5 (*Zea mays* glycine-rich protein 5). This protein plays an important role in maintaining the silk structure during development (Tao *et al*., 2006). Moreover, environmental conditions and accumulation of the female fruit biomass during its development also have a great influence on the silking progress (Lemcoff & Loomis, 1994). On average, a young corn may produce about 40% of silks during its development. By referring to the production of young corn in Thailand for the year 2004, the country could produce nearly 70,000 tonnes of cornsilks which are considered as a large amount of by-product.

Historically, cornsilk infusion is used as a therapeutic remedy. These ailments include inflammation of urinary bladder and prostate and treatment for irritation of urinary system. To date, numerous commercially viable traditional products prepared from cornsilk are available (El-Ghorab *et al*., 2007). In other therapeutic applications, Li *et al*. (2004) reported that infusion of cornsilk could help in elevating prostate problems, bed-wetting, carpel tunnel syndrome, oedema and obesity. It is also used to lessen the effect of premenstrual syndrome and to promote general relaxation. Cornsilk is also reported to be useful for treating urinary tract infections and cystitis. It is thought to be helpful in polyurea and other urinary problems associated with irritation of the bladder and urethral walls including prostate disorders. It is also reported to soothe and to relax the lining of the urinary tubules and bladder, thus relieving irritation and improving urine excretion (Steenkamp, 2003). Cornsilk contains various nutrients and phytochemicals including proteins, vitamins, alkaloids, tannins and mineral salts, carbohydrates, steroids and flavonoids as well as other volatile chemicals (Kwag, 1999).

Biological activities of cornsilk constituents are well reported in the literature. These includes antibiotic activity towards corn earworm by a flavone glycoside such as maysin (Maksimovic & Kovacevic, 2003), attractant activity towards corn earworm Guevara *et al*. (2000), inhibition of IgE formation by glycoproteins (Tsuneo *et al*., 1993), immune enhancement by nonstarch polysaccharides and anticoagulant activity by neutral sugar or amino sugar derivatives (Abdel-Wahab *et al*., 2002). A biological study involving purification and characterisation of anticoagulant from cornsilk have also been reported (Choi & Choi, 2004). The result showed that cornsilk was used to treat benign prostatic hyperplasia which affects glomerular function and potassium urinary excretion (Velazquez *et al*.,

2005) as well as the volatiles derived from cornsilk inhibited cultures of *Aspergillus flavus* (Zeringue, 2000). Other than these reported biological activities, the cornsilk from some corn species are consumed as tea and powdered as food additive and flavouring agents in several regions of the world (Koedam, 1986; Yesilada & Ezer, 1989). This chapter covers food and nutritional components, health benefits and potential applications of cornsilk.

FOOD AND NUTRITIONAL COMPONENTS

Chemical Composition of Cornsilk

Chemical composition of cornsilk is not well documented compared to other parts of corn plant such as corn kernels (Lemcoff & Loomis, 1994; Yoon *et al*., 2006; Eckhoff *et al*., 2009; Nuss & Tanumihardjo, 2010) and husk (Hang & Woodams, 1999: 2000; Haraa *et al*., 2001; Padkho, 2011). However, cornsilk has been reported containing nutritional elements that are essential for human health such as carbohydrate, protein, vitamins, lipids, salts and minerals like calcium, potassium and magnesium (Guo *et al*., 2009). Besides these properties, cornsilk contains diverse classes of secondary metabolites such as sterols, flavonoids and anthocyanins which have embarked researchers to discover the compositions and benefits of the compounds.

As shown in Table 13.1, moisture content of fresh cornsilk accounts for 83.90% while the other extracts record less than 1% moisture. Fresh cornsilk and its ethanolic extracts have minimal amounts of protein (1.13% and 2.57% respectively) while dried cornsilk is the richest source of protein (12.96%) followed by by aqueous extract (8.74%). Cornsilk ethanolic extract records the highest crude fat content compared with the other samples. The ethanolic extract contains 28.63% crude fat and it is significantly higher ($p<0.05$) than that of aqueous extract. Dried cornsilk and fresh cornsilk samples have 1.27% and 0.13% crude fat respectively. Besides, dried cornsilk has the highest percentage of ash (10.28%) compared with the aqueous and ethanolic extracts which have lower percentage of ash (7.60% and 6.11% respectively).

Table 13.1 Chemical compositions of cornsilk

Cornsilk	Moisture content (%)	Crude lipid (%)	Protein (%)	Ash (%)
Fresh	83.90 ± 0.37 [a]	0.13 ± 0.02 [c]	1.13 ± 0.01 [d]	0.90 ± 0.03 [d]
Dried	<1.00 [b]	1.27 ± 0.16 [b]	12.96 ± 0.26 [a]	10.28 ± 0.13 [a]
Aqueous extract	<1.00 [b]	0.17 ± 0.08 [c]	8.74 ± 0.14 [b]	7.09 ± 0.21 [b]
Ethanolic extract	<1.00 [b]	28.63 ± 0.96 [a]	2.57 ± 0.68 [c]	6.11 ± 0.13 [c]

[a-d] Mean values within the same column with different superscript lowercase letters differ significantly ($p<0.05$).

Based on the result presented in Table 13.2, a low level of soluble dietary fibre (SDF), 0.01 and 0.3 g/100 g, are found in fresh and dried cornsilk respectively. Dried cornsilk contains the highest concentration of insoluble dietary fibre (IDF) at 38.1 g/100 g, while fresh cornsilk records the lowest concentration of IDF at 0.03 g/100 g (Table 13.2). In general, dried cornsilk has 38.4 g/100 g total dietary fibre (TDF), whereas the TDF in fresh cornsilk is 0.04 g/100 g.

As shown in Table 13.3, dried cornsilk has total sugar content of 40.60 mg/100 g. Dried cornsilk boiling for 30 minutes records the highest concentration of free sugars (85.40 mg/100 g) compared with the cornsilks boiling for 4 hours (65.02 mg/100 g) and extracted using Soxhlet apparatus (79.64 mg/100 g). The cornsilk boiling for 30 minutes has higher concentration of fructose (26.23 mg/100 g) than the cornsilk boiling for 4 hours (19.83 mg/100 g). However, extraction with a shorter boiling time (30 minutes) results in significantly highest concentration of glucose (42.90 mg/100 g) compared to the longer boiling time of 4 hours which is 32.84 g/100 g. Again, cornsilk boiling for 30 min records the highest concentration of sucrose (16.27 mg/100 g) compared to the cornsilks boiled for 4 hours which recorded 12.35 mg/100 g sucrose. Maltose is not detected in all samples. In addition, the chromatographic profile of sugars detected in cornsilk is shown in Figure 13.1.

Table 13.2 Soluble dietary fibre (SDF), insoluble dietary fibre (IDF) and total dietary fibre (TDF) concentrations in cornsilk

Consilk	**SDF**	**IDF**	**Total DF**
Fresh	0.01 ± 0.00 [f]	0.03 ± 0.00 [f]	0.04 ± 0.00 [g]
Dried	0.30 ± 0.01[a]	38.1± 0.02 [d]	38.4 ± 0.03 [d]

[a-g] Mean values (g/100 g) within the same column with different superscript lowercase letters differ significantly ($p<0.05$).

Table 13.3 Sugars concentration of cornsilk

Sugar	**Dried cornsilk**	**Boiling (30 minutes)**	**Boiling (4 hours)**	**Soxhlet technique**
Fructose	14.20 ± 0.12 [d]	26.23 ± 1.10 [b]	19.83 ± 1.20 [c]	30.42 ± 2.10 [a]
Glucose	22.20 ± 1.10 [c]	42.90 ± 2.10 [a]	32.84 ± 2.30 [b]	39.30 ± 2.30 [a]
Sucrose	4.40 ± 0.20 [d]	16.27 ± 0.15 [a]	12.35 ± 0.11 [b]	9.92 ± 0.60 [c]
Maltose	ND	ND	ND	ND
Total	40.60 ± 1.90 [d]	85.40 ± 2.50 [a]	65.02 ± 2.60 [c]	79.64 ± 2.80 [b]

[a-g] Mean values (mg/100 g) within the same row with different superscripts differ significantly ($p<0.05$); ND: not detected.

As shown in Table 13.4, the compositions of major elements such as Ca, Mg, K and Na in cornsilk are 1087.08 ± 105.51 µg/g, 1219.17 ± 143.07 µg/g, 26281.67 ± 1379.7 µg/g and 190.67 ± 22.61 µg/g respectively. Cornsilk also contain appreciable amount of trace elements such as Cu (5.60 ± 0.40 µg/g), Fe (2.17 ± 0.15 µg/g), Mn (32.17 ± 3.14 µg/g) and Zn (46.37 ± 4.21 µg/g).

Table 13.4 Minerals concentration of cornsilk

Mineral	Concentration (μg/g)
Calcium (Ca)	1087.08 ± 105.51
Magnesium (Mg)	1219.17 ± 143.07
Potassium (K)	26281.67 ± 1379.7
Sodium (Na)	190.67 ± 22.61
Copper (Cu)	5.60 ± 0.4
Iron (Fe)	2.17 ± 0.15
Manganese (Mn)	32.17 ± 3.14
Zinc (Zn)	46.37 ± 4.21

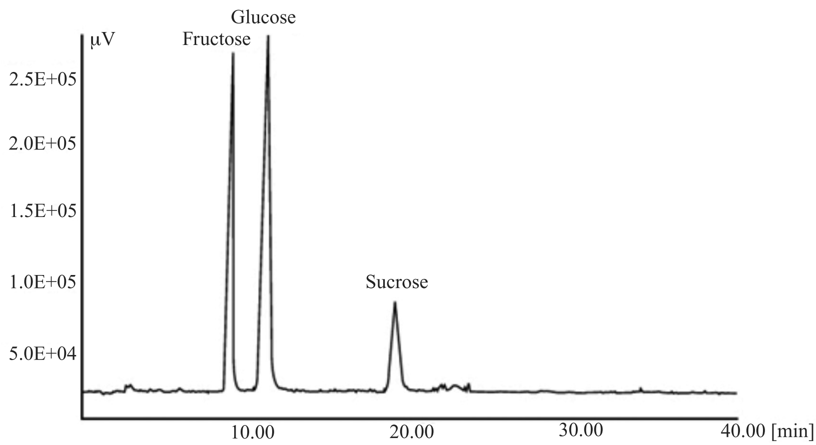

Figure 13.1 Sugar profile of cornsilk (HPLC chromatogram)

Sterols

Sterols or phytosterols occur in plants with increasing numbers of compounds identified. In higher plants, sitosterol, stigmasterol and campesterol are the common sterols occur as free and simple glucosides (Haborne, 1998). Sterol is a 3β-monohydroxy compound-based having the perhydro-1,2-cyclopentano phenanthrene ring system, with methyl substitution at C10, C13 and a side-chain with 8-10 carbon atoms (Piironen *et al.*, 2000). It has multiple functions such as regulating membrane fluidity and permeability, controlling metabolic process associated with membrane, as a precursor in cellular and developmental process in higher plants, and also as a substrate for synthesis of secondary metabolites (Piironen *et al*., 2000).

Cornsilk is reported to contain plant sterols, namely, 24-methylcholesterol, 24-ethyl-5,22-cholestadien-3β-ol, 24-ethylcholesterol and (28Z)-24-ethylidenecholesterol (Knights & Smitt, 1976). Sterols have been identified in the choroform fractions of *Maydis stigma* extract. The fractions contain a mixture of stigmasterol and sitosterol in the ratio of 4:1 and sitosteroline (β-sitosteryl-3-O-β-*D*-glucoside) (Maksimovic *et al*., 2004).

Flavonoids

Flavonoid represents the largest group of secondary metabolites comprising more than 9000 structures, and flavones are part of them (Martens & Mithofer, 2005). Flavone subgroup is naturally distributed in both lower and higher plant tissues and mostly occurs as flavone aglyca and their O- or C-glycosides (Martens & Mithofer, 2005). In plants, flavones can be found in stems, leaves, buds, barks, heartwood, thorns, roots, rhizomes, flowers, fruits, seeds, roots, leaves and resin (Martens & Mithofer, 2005). Flavones show diverse functions in plant breeding, ecology, agriculture, human nutrition and pharmacology. The antioxidative activity of flavones is associated with prevention of cancer and coronary heart disease which is also promising (Birt *et al*., 2001; Quinones *et al*., 2010).

Three flavones have been isolated from cornsilk water extract (Zhang & Xu, 2007). These compounds are identified as 7-hydroxy-4'-methoxyisoflavone, 2"-O-α-L-rham-nosyl-6-C-(6-deoxy-ax-5-methl-xylo-hexos-4-ulosyl)-3'-methoxyluteolin and 2"-O-α-L-rhamnosyl-6-C-(6-deoxy-ax-5-methyl-xylo-hexos-4-ulosyl)-3'methoxyluteolin (Zhang & Xu, 2007). Kwag *et al*. (1999) showed that cornsilk contained volatile compounds that were nine alcohols, seven aldehydes and ketones, 14 terpenes and terpene alcohols, three pyrazines and five hydrocarbons. Two flavone glycosides, isoorientin-2-2"-O-α-L-rhamnoside and 3'-methoxymaysin, were also isolated from the ethanol extract of cornsilk (Liu *et al*., 2011), whereas a flavonoid compound that known as c-glycosylflavones was isolated from methanol extract (Elliger *et al*., 1980). Other compounds present included hexacossanoic acid and 4-hydroxy-4-methyl-2-pentanone (Maksimovic *et al*., 2004).

Other flavonoids isolated from the dichloromethane extract of Egyptian cornsilk which are 36 volatile compounds that identified by gas chromatography-mass spectrometry (El-Ghorab *et al*., 2007). The results showed that main constituents of Egyptian cornsilk were cis-α-terpineol (24.22%), 6,11-oxidoacor-4-ene (18.06%), citronellol (16.18%), trans-pinocamphone (5.86%), eugenol (4.37%), neo-iso-3-thujanol (2.59%) and cis-sabinene hydrate (2.28%).

Anthocyanins

Anthocyanins are important class of plant pigment which responsible for the intense colours of purplish, blue or red in different parts of plants. There are two types of anthocyanins exist in corn which are known as 3-hydroxyflavonoids and 3-deoxyflavonoids (Grotewold *et al*., 1998). The 3-hydroxyanthocyanins occur in almost all corn plant parts, but the 3-deoxyanthocyanins is only found in cornsilk and in a few other plant species (Halbwirth *et al*., 2003). Recently, we identified two types of anthocyanin, namely cyanidin and cyanidin-3-O-glucoside from Malaysian cornsilk. The result showed that freshly prepared Malaysian cornsilk had 25.36 ± 2.41 μg/g and 3.30 ± 0.18 μg/g (fresh weight) of cyanidin and cyanidin-3-O-glucoside respectively. HPLC chromatogram of anthocyanins, namely cyanidin and cyanidin-3-O-glucoside that found in cornsilk is illustrated in Figure 13.2.

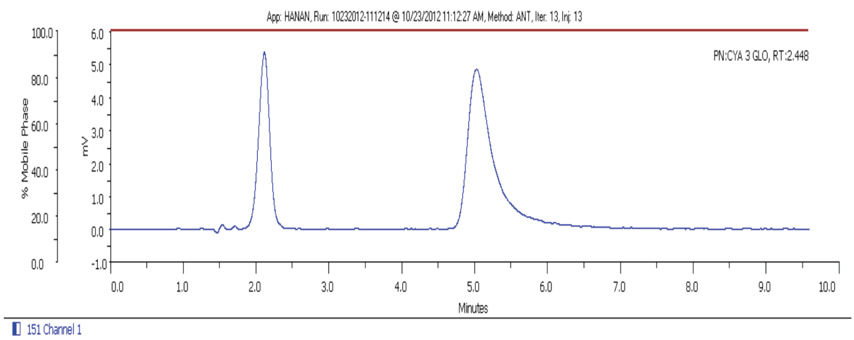

Figure 13.2 HPLC chromatograms of cyanidin (retention time: 2.2 minutes) and cyanidin-3-O-glucoside (retention time: 5.2 minutes)

HEALTH BENEFITS

Cornsilk is used as a medicine for centuries and it is categorised as medicinal herb by practitioners of traditional medicine in many countries. Cornsilk has been documented as a well-accepted traditional medicine in treating diseases related to kidney problems (Abu-Irmaileh & Afifi, 2003; Maksimovic & Kovacevic, 2003; Maksimovic *et al*., 2005). The hairs are also used as a diuretic agent to ease passing of stones or gravel in kidneys and urinary bladder (Maksimovic & Kovacevic, 2003).

In China, cornsilk is very well known as an important traditional Chinese medicine in treating several illnesses related to kidney (Zhao *et al*., 2012). It has been used to treat oedema, cystitis, gout, prostatitis and as antimicrobial agent (Velazquez *et al*., 2005; Fatima *et al*., 2012). Cornsilk has also been used to treat rheumatism and rheumatoid arthritis ailments (Maksimovic & Kovacevic, 2003).

In Jordan, cornsilk is prescribed by some herbalists for treating cold and constipation as well as moderately used to treat kidney stones, oedema and obesity (Abu-Irmaileh & Afifi, 2003). It is known as one of the medicinal plants used to improve women's health condition. Cornsilk is traditionally used in Dominican Republic to treat fibroids and to reduce cramps when combined with other plants (Ososki *et al*., 2002). According to an ethnobotanical survey in certain parts of Iranian provinces, cornsilk is used to treat infections of urinary system (Mosaddegh *et al*., 2012).

India has large diversity of plant resources that are very useful in the early middle ages to treat various types of ailment (Middha *et al*., 2012). Based on an ethnopharmacological survey in Kartanaka, 76 plant species have been used as traditional medicine including cornsilk. The natural healers recommended cornsilk as an ayurvedic remedy, preferably used for treatments of diabetic symptoms and its complications. In ayurvedic medicine, cornsilk is used at a level of 25%, which is lower than other ayurvedic plants such as *Momordica charantia*, *Punica granatum*, gooseberry and *Amaranthus viridus* that need to use 66%, 49%, 33% and 29% of the plants respectively for an effective response (Middha *et al*., 2012). A study carried out in Machang Kelantan revealed that cornsilk was among the other 145 medicinal plants used as folk medicine. Hence, cornsilk has been consumed regularly as a decoction in order to treat high blood pressure (Ong & Nordiana, 1999).

Anti-Hyperglycaemic Effect

Guo *et al*. (2009) determined the effect of cornsilk extract (0.1 g/mL) in induced hyperglycaemic mice. Several parameters such as blood glucose, glycohaemoglobin (HbA1c), insulin secretion, pancreatic β-cells damage, hepatic glycogen and gluconeogenesis in the hyperglycaemic mice were obtained. Based on the reported result, blood glucose level was decreased at higher doses of cornsilk (2.0 and 4.0 g/kg body weight, BW) given to the treatment group compared to the lower doses (0.5 and 1.0 g/kg BW). The level of serum insulin increased (9.8 ± 0.5 μU/mL) after being given 4.0 g/kg body weight of cornsilk extract. It is later found that the effect of cornsilk extract on glycaemic metabolism is via increasing insulin level. Besides these findings, the increase level of insulin and recovery of β-cells are known to be the mechanism involved in glycaemic metabolism.

Cornsilk has anti-diabetic potential. Its polysaccharides exhibited anti-diabetic effect on streptozotocin (STZ)-induced diabetic rats (Zhao *et al*., 2012). Daily treatment of 100-500 mg/kg BW of cornsilk polysaccharide significantly decreased blood glucose level and serum lipid. Evidently, total cholesterol level of the polysaccharide treated group of streptozotocin-induced diabetic rats was found to be significantly lower than the normal and control groups.

Diuretic Activity

Effectiveness of cornsilk as a cure for kidney-related problems in traditional medicine has been shown by several scientific findings; thus, support the rationale for using cornsilk as a diuretic remedy (Fatima *et al*., 2012). The potential of cornsilk as a diuretic agent is first reported by Caceres *et al.* (1987) when increment in diuresis was observed during the administration of cornsilk aqueous extract at 1 g/kg body weight to male rats. Ribeiro *et al*. (1988) reported the increase of diuresis after 50% of ethanol-water extract of cornsilk was given at 40 mL/kg BW orally to female rats.

In another animal study, a synergistic effect was observed when supplemented with 5 g/kg BW of cornsilk in combination with 5 g/kg BW of aqueous extract of *Tribulus terrestris* (puncture wine). It is observed that a combination of aqueous extract of cornsilk with *T. terrestris* resulted in similar diuresis effect as in *T. terrestris* aqueous extract alone (Al-Ali *et al*., 2003). The effective doses of cornsilk extract ranged from 25-500 mg/

kg BW on urine volume (Velazquaz *et al*., 2005), where cornsilk extract was found to exhibit diuretic effect at the dose of 500 mg/kg BW.

Recently, we examined the urine excretions of normal rats that received aqueous extract of cornsilk (AEC) at doses of 100-800 mg/kg BW (Wan Rosli & Solihah, 2017). The result showed that there was no significant increased in the percentage of urine obtained from the rats treated with 100, 200 and 300 mg/kg BW of AEC and at AEC dose of 400 mg/kg BW (14.06 ± 0.37 mL). The effect of diuresis started to increase at a dose of 500 mg/kg BW (15.21 ± 0.96 mL) and 600 mg/kg BW (20.13 ± 0.61 mL). It remained constant at doses of 700 mg/kg BW (19.63 ± 0.53 mL) and 800 mg/kg BW (20.00 ± 0.58 mL). The result also showed that at AEC doses of 600, 700 and 800 mg/kg BW, urine excretion of the rats was significantly higher than the rats given distilled water.

According to Wan Rosli and Solihah (2017), diuretic index of AEC rats ranged from 0.94 to 1.35. Meanwhile, diuretic activity of the rats ranged from 0.66 to 0.94. The doses of AEC at 600, 700 to 800 mg/kg BW have good diuretic efficacy (diuretic index of 0.94, 0.92 and 0.94) compared to hydrochlorothiazide (1.00). Besides, urinary pH of rats from AEC groups was not significantly different compared to distilled water group. However, urinary pH of the AEC groups at doses 600 and 700 mg/kg BW was slightly higher than the distilled water group.

Based on the study reported by Wan Rosli and Solihah (2017), Na^+ excretion by the rats found among different AEC doses were significantly higher compared with distilled water (40.63 mmol/l), except AEC at the dose of 400 mg/kg BW (52.13 mmol/l). However, the rats from all AEC doses ranged from 400 to 800 mg/kg BW had significantly lower urinary Na^+ excretion than the rats of hydrochlorothiazide group (90.38 mmol/l). On the other hand, K^+ excretions of the rats treated with all AEC doses were not significantly different from K^+ excretions of the rats given distilled water or hydrochlorothiazide, except for the group treated with AEC doses of 600 and 700 mg/kg BW which were significantly lower than hydrochlorothiazide. Besides, Cl^- excretion was not statistically differed between AEC control groups. Moreover, the saliuretic index of Na^+ was higher in all AEC treatment groups than the control group. Based on the results, we can conclude that K^+ and Cl^- excretions are lower in all AEC groups than control group. Also, all AEC groups have higher Na^+/Cl^- ratio than control group.

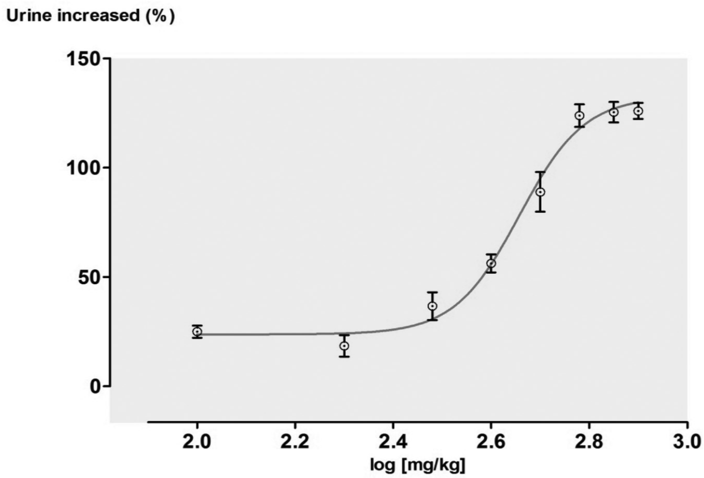

Figure 13.3 Dose-response curve of urine excretion (n=6) generated using GraphPad Prism. Volume at baseline was 11.02 ± 5.26 mL

Antioxidative Capacities

Cornsilk contains polyphenols that responsible for the free radical scavenging activities. As shown in Table 13.5, the polyphenols content of cornsilk varies from 6.70 to 101.99 mg GAE/g extract, depending on the solvent used.

Table 13.5 Polyphenols content of cornsilk extracts

Extract	Total polyphenols (mg GAE/g extract)	Total flavonoids (mg CAE/g extract)
Water	35.35±2.17[b]	8.40±0.48[a]
Methanol	101.99±8.05[a]	9.26±1.23[a]
Ethyl acetate	6.70±0.51[c]	0.66±0.02[b]

[a-c] Different superscript lowercase letters within the same column are statistically different at $p<0.05$.
GAE: gallic acid equivalent; CAE: catechin equivalent

As shown in Table 13.6, methanol, water and ethyl acetate extracts of cornsilk show a concentration-dependant manner based on DPPH, ferric-reducing antioxidant power (FRAP), xanthine oxidase (XOD) system and ABTS free radical scavenging capacity. Inhibition of free radicals increases when a higher concentration of extract is applied. The free radical scavenging capacities of cornsilk obtained from DPPH, FRAP, XOD and ABTS assays could be attributed to the phenolics and flavonoids present in cornsilk powder.

Table 13.6 Antioxdative capacities expressed as EC_{50} values of cornsilk

Sample	EC_{50} value (µg/mL)			
	DPPH	FRAP	XOD	ABTS
MeOH extract	143.55±4.67[c]	1110.97±157.74[c]	261.41±12.55[d]	349.07±15.15[d]
Water extract	195.21±7.48[b]	8422.58±963.31[a]	1174±150.13[a]	829.00±94.26[b]
EA extract	411.69±9.57[a]	31411.7±3371 [a]	412.17±12.97[c]	2870±112.30[a]
BHT/ Trolox	59.08±4.51	83.08±3.22[d]	ND	131.77±16.25*

[a-d] Different superscript lowercase letters within the same column are statistically different at $p<0.05$. EC_{50} value refers to the concentration needed to give 50% of the antioxidative effect. *The value was expressed as µmol/mL; MeOH: methanol; EA: ethyl acetate; BHT: butylated hydroxytoluene; ND: not determined.

POTENTIAL APPLICATIONS

Processed dried cornsilk has been successfully incorporated into food products to enhance nutritional values and physiological functionalities. Incorporation of cornsilk powder results in increasing protein, cooking yield, moisture and fat retention, but decreasing fat content in beef patties. Beef patties with 6% cornsilk-added have the highest cooking yield, moisture and fat retention. This could be attributed to the high retention of moisture and fat during cooking. Addition of cornsilk resulted in an increase in nutritional composition, water and fat holding capacity as well as maintaining sensory quality of beef patties so the patties were acceptable to consumers as normal beef patties (Wan Rosli *et al*., 2011a). Incorporation of cornsilk powder also increases protein, cooking yield, moisture and fat retention but decreases fat content of chicken patties. Chicken patties with 6% cornsilk-added show the highest cooking yield, moisture and fat retention but less acceptable to consumers. This could be attributed to the high retention of moisture and fat during cooking. Consumers may be not able to differentiate all sensory attributes between chicken patties containing different levels of dried cornsilk and control (Wan Rosli *et al*., 2011b).

Cornsilk powder is applied in yeast bread. Incorporation of cornsilk powder results in increased protein, total dietary fibre and firmness but decreases sensory acceptability of yeast bread. Addition of 2% cornsilk powder to yeast bread also slightly increases protein, ash and TDF content, meanwhile their textural properties and sensory acceptability are unchanged compared to control yeast bread. On the other hand, yeast bread with 6% cornsilk-added has the highest content of protein, ash and TDF content but adversely affects the textural and sensory acceptability (Ng & Wan Rosli, 2013). On the other application, addition of cornsilk powder in butter biscuits improves some essential nutrients and health functional properties. Considerable higher polyphenol content (60.4-86.8%) and antioxidative improvement are obtained by incorporation of cornsilk powder in butter biscuits. The cornsilk powder-based biscuits have higher free radical scavenging capacity (24.45-62.73%) and ferric-reducing capacity (16.94-342 μmol TE/g) with higher levels of gallic acid and ferulic acid compared with all-wheat-based biscuits (Nurhanan & Wan Rosli, 2016).

CONCLUSION AND RECOMMENDATIONS

Cornsilk, as co-product of corn consumption or industrial by-product, has been traditionally used to treat various illnesses, specifically in remediating inflammation of urinary bladder, prostate and treatment for irritation of urinary system. This by-product is also being utilised as hyperglycaemia reducing agent, diuretic agent, antioxidant and other therapeutic functionalities. The therapeutic and health benefits exerted by cornsilk may link with the presence of various phytochemicals such as sterols, polyphenols, flavonoids and anthocyanins as well as minerals and other essential nutrients. These substances are able to scavenge free radicals and have shown some significant *in vitro* and *in vivo* antioxidative activities. In addition to that, the processed cornsilk shows some beneficial effects when it is applied in a few food items such as biscuit, bread and patties. The benefits of cornsilk in improving other pharma-nutritional functionalities including prebiotics potential can be recommended for future studies.

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