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CORN SILK: A REVIEW ON BOTANICAL AND HARMACOLOGICAL CONSIDERATIONS

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ABSTRACT

The aim of the review is to demonstrate potential applications of corn silk and its pharmacological activities. *Stigma maydis* also known as corn silk is a plant used in medicine from the time of Ayurveda, the ancient system of Indian medicine. It is a yellowish thread like strand of female flower of maize belonging to *Graminae* family. Phytochemical constituents of corn silk include alkaloids, tannins, phytosterols, vitamin E & K, succinic acid, lactic acid, palmitic acid, proteins, vitamins, flavonoids, terpenoids, carbohydrates, calcium, magnesium and potassium salts. Potential use of corn silk is related to its properties and mechanism of action of its bioactive constituents such as flavonoids and terpenoids. Studies indicate that it possess antihypertensive, antioxidant, anticancer, antidepressant, kaliuretic, neuroprotective properties. This review will cover potential applications of corn silk in phytochemical and pharmacological fields. In addition, botanical description and toxicological study is also included.

KEYWORDS: *Stigma maydis,* corn silk, flavonoids, FRAP assay, anti-hyperlipidemic, DPPH assay.

INTRODUCTION

Corn silk is yellowish thread like strands of maize (also known as corn/ *Zea mays*). Botanically it is called as *Stigma maydis* which belongs to *Graminae* (grass family) that originated in Central America as shown in **Table 1**. Basically it is made of stigma and styles, the yellowish thread like strands of female flower of maize as shown in **Figure 1**. Chemically it contains flavonoids, saponins, tannins, alkaloids, carbohydrates, vitamins, proteins,

calcium, potassium, magnesium and sodium salts etc. It contains high amount of fiber along with other components shown in **Table 2**. It is also known as "maize silk".[1]

Table 1: Taxonomic Position Of Corn Silk.

KINGDOM	Plantae
SUBKINGDOM	Tracheobionta
SUPERDIVISION	Spermatophyta
DIVISION	Magnoliophyta
CLASS	Liliopsida
SUBCLASS	Commelinidae
ORDER	Cyperales
FAMILY	Poaceae
SUBFAMILY	Panicoideae
TRIBE	Andropogoneae
GENUS	Zea
SPECIES	Zea mays

Table 2: Composition Of Corn Silk.

MOISTURE	9.65%
ASH	3.91%
CRUDE FAT	0.29%
CRUDE PROTEIN	17.6%
CRUDE FIBER	40%

The flowers of corn are monoecious in which the male and female flowers are located in different inflorescences on the same stalk. The male flowers (tassel) at the top of the plant produce yellow pollen. Meanwhile, the female flowers produce corn silk and are situated in the leaf axils. The silks are elongated stigmas which look like a tuft of hairs. Basic function of corn silk is to trap pollens for pollination. Immature silk possess light green colour with mature colour range red, yellow and light brown. Basically it is a waste material from corn cultivation and still possesses large number of medicinal properties. It possesses length of 30 cm with a sweetish taste and characteristic odour. It is fully soluble in benzene, chloroform, ether and petroleum ether. It is conventionally used by the rural and tribal people in curing various disorders.[2]

Corn silk was domesticated in Mexico and Central America more than 7,000 years ago. During 17th century maize was introduced in India. From India it went to China, Phillipines and East Indies. Now it is widely distributed all over the world. Corn silk is grown in temperate and tropical countries worldwide with United States being the major producer,

although significant amount is also cultivated by China, Brazil, Mexico and Argentina. The United States is the largest producer of corn silk including 40% of world's total production. Some tribes referred to corn as "giver of life".[1]

Corn requires warm, sunny weather to mature and grows where ample water is available. In Alaska and Northern Canada dwarf varieties can be grown. However its requirement for warm soil and isolation from other types of corn at time of pollination make it more difficult to grow. Generally garden soil is preferred for cultivation but for best results the ground with well-rotted manure and compost is required. It requires generous quantity of potash and phosphorus. Weed, rock and trash is removed from the soil before sowing. Germination takes in about 7-10 days. This crop is generally planted in square block area with at least 6 adjacent rows of same variety with temperature of soil ranging from 50-60 degrees.[1]

Traditionally corn silk was used in China, America, Turkey and France. It was used for the treatment of cystitis, gout, kidney stones, malarial and prostate disorders. It has also been used in the treatment of nephritis, kidney stones, malarial and heart disorder.[2]

Corn silk is used for the treatment of various disorders such as to treat various urinary disorders and is also used as diuretic. It is also used for treatment of prostate hypertrophy and bedwetting in children. It is also used as appetite stimulant and for water retention. Externally it can be made into poultices for treating boils and sores. Corn silk tea is also used for the treatment of obesity. Recent investigation shows use of corn silk in treatment of psoriasis.[3]

Fig 1: Images Of Corn Silk.

Table 3: International Synonyms Of Corn Silk.

ARABIC	Dhurah, Surratul makkah
CHINESE	Yu mixu, Yu shu shu, Paomi
CROATIAN	Kukuruz
DANISH	Majs
DUTCH	Mais, Korrelmais, Turkse tarwe, Turkse koren
ENGLISH	Maize(UK), Turkish wheat, Field corn, Corn(USA),
ESTONIAN	Mais
JAPANESE	Toumorokoshi, Fiirudokoon
KOREAN	Ok soo soo
PORTUGUESE	Milho, Milho forrageiro
SWEDISH	Majs

Table 4: Indian Synonyms Of Corn Silk.

BENGAL	Bhutta
GUJARAT	Makai
HINDI	Anaj, Makka
MALAYALAM	Cholam, Makkacholam
PUNJABI	Makai
SANSKRIT	Makkaya, Mahakaya
TAMIL	Makka cholam, Mokkaiccoolam
TELUGU	Mokkajanna

BOTANICAL DESCRIPTION

Corn silk or the silky styles found on ear of corn. Corn is a monoecious; it is partitioned into separate pistillate, female flower, tassel and male flower. It is protandrous in nature that is male flower matures earlier than female flower.[4] The male flower located at the top of the plant produces yellow pollen while the female flower situated at the leaf axil produces corn silk. It looks like tuft of hairs. Its colour generally first appears to be light green when immature which later on becomes red, yellow and light brown.[5] It is covered with sticky hairs which serve to trap pollens for pollination. Fertilization occurs as soon as pollen grains come in contact with the silk which later on enters embryo sac in 12-28 hours. It is generally harvested before pollination for medicinal purpose. It can be used in fresh or dried form when needed.[6]

MACROSCOPIC CHARACTERS

Shape- With hand lens, appears flattened and ribbon like, or can be grooved and curled up.[7] Colour- Yellowish, brownish or brownish-red [8] Size- 5-30 cm long.[8] Odour- Slight, faint and characteristic.[9] Taste- Slightly mucilaginous, somewhat sweetish.[10]

MICROSCOPIC CHARACTERS

Rectangular epidermal cells, extended into multicellular trichomes which are 200-800 µm in length, basal portion usually consist of 2-5 cells and the upper portion is unicellular in nature, purplish parenchymatous cells containing colouring matter, multiseriate trichomes, and 2 vascular bundles having narrow tracheids with spiral thickening.[7-10]

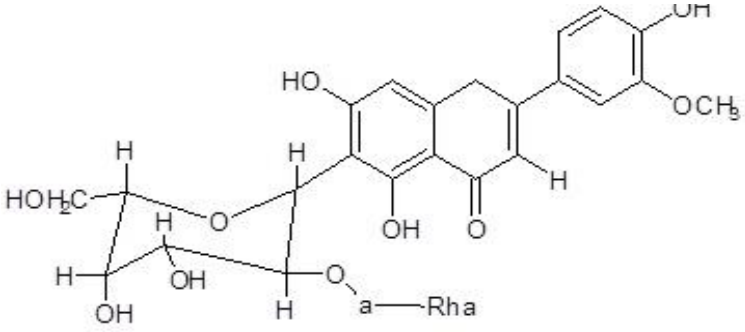
PHYTOCHEMICAL CONSTITUENTS

Corn silk contains fatty acid 2.5%, volatile oil 0.12%, gum 3.8%, resin 2.7%, saponins 3.18%, and alkaloids 0.05%. It is the major source of many bioactive compounds such as flavonoids, saponins, alkaloids, tannins, chlorogenic acid, allantoin, and phytosterols. To date several flavonoids such as maysin, apigmaysin, 3-methoxymaysine and ax-4-OH-maysin have also been identified from corn silk.[11] There is also fixed oil (approximately 2%, pantothenic and linoleic acid), essential oils (approx. 0.2% includes carvacrol, menthol, thymol, α-terpineol), steroids (sigmasterol and sitosterol), vitamin K1, carotenoids. Derivatives of cinnamic acid, glucose, rhamnose and minerals including sodium (0.05%), potassium (15%), iron (0.0082%), zinc (0.016%) and chloride (0.25%) are also present.[12] Recently five different flavonoids have also been discovered such as 2"-*O*-α-L-rhamnosyl-6-C-3"-deoxyglucosyl-3'-methoxyluteolin **(1)**, ax-5"-methane-3'-methoxymaysin **(2)**, ax-4"-OH-3'-methoxymaysin **(3)**, 6, 4'-dihydroxy-3'-methoxyflavone-7-*O*-glucoside **(4)**, 7, 4'-dihydroxy-3'-methoxyflavone-2"-*O*-α -L-rhamnosyl-6-C-fucoside **(5).** It also contains other flavonoid derivatives such as 2"-*O*-α-L-rhamnosyl-6-C-quinovosylluteolin **(6)**, 2"-*O*-α-L-rhamnosyl-6-C-fucosylluteolin **(7)**, 2"-*O*-α-L- rhamnosyl-6-C-fucosyl-3'-methoxyluteolin **(8)**, isoorientin-2-2"-*O*-α-L-rhamnoside **(9)**, 3'-methoxymaysin **(10)**.[13]

Styles of *Zea mays* contain lumichrome, chrysoeriol, genistein, adenosine, guanosine, vanillin, vanillic acid, uracil, stigmastanone, stigmast-4-en-3-one and beta-sitosterol. It is also rich in phenolic compounds such as anthocyanins, protocatechuic acid, derivative of hesperidin and quercetin.[14, 15]

Other constituents include trimethyl-benzenes, dimethoxy-benzenes, 2-methyl-butan-1-ol, 2-methyl-naphthalene, α-terpineol **(11)**, aluminium, ascorbic acid, carvacrol, neo-iso-3-thujanol **(12)**, calcium, chromium, dodecan-1-al, hept-cis-4-en-2-ol, limonene, 6, 11-oxidoacor-4-ene **(13),** manganese, propan-1-ol, *O*-diethyl phthalate, orientin, nonal-n-2-ol, methyl-phenylacetate, trans-pinocamphene **(14),** betaine, apigenidin, 2-methyl-pent-2-en-1-al,

apiforol, 2-methyl-propane-1-ol, citronellol **(15),** 1,8-cineole, hordenine, geraniol, eugenol **(16),** eoergosterole, thiamin, vitexin and cinnamic acid-ethyl-ester.[16]



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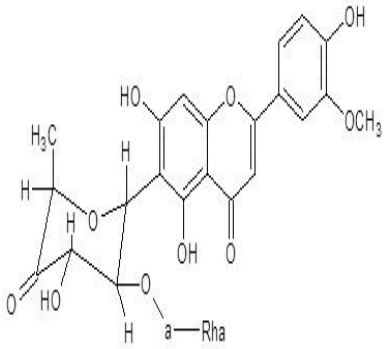

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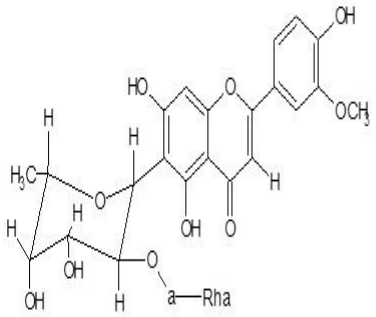

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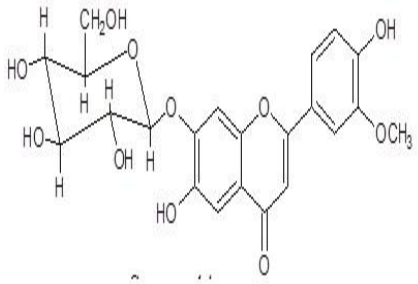

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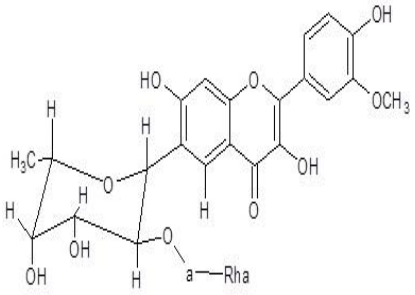

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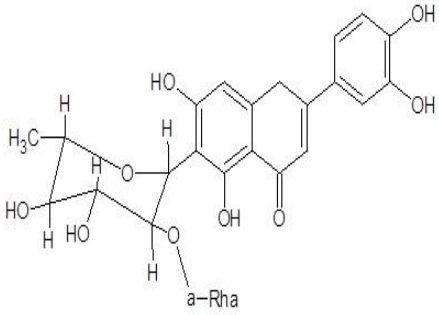

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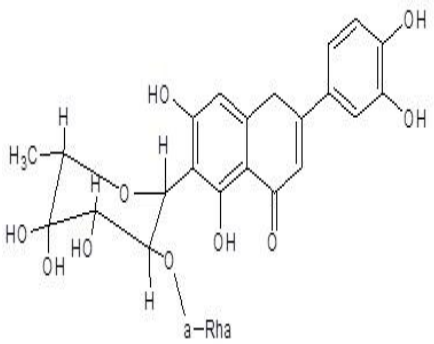

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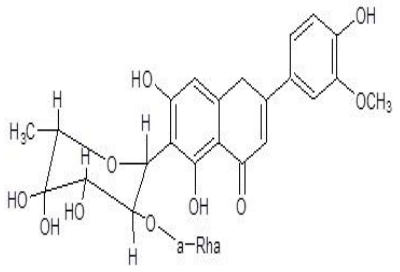
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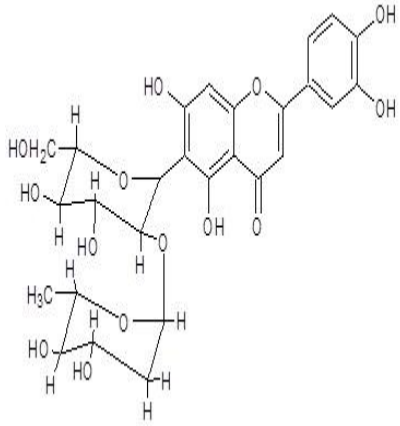
HO
OCH3
H3C
O
OH
O
HO
HO
OH
O
a–Rha

8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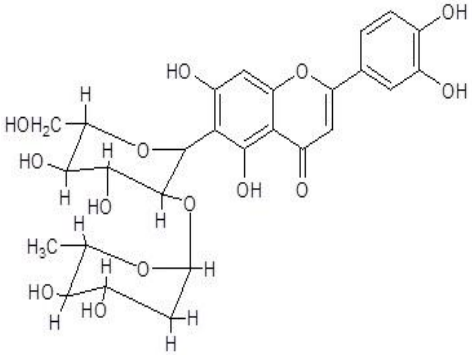
9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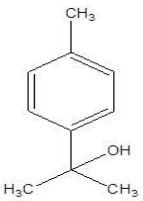
10


CH3
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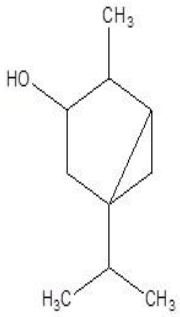
11



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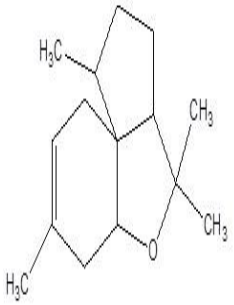

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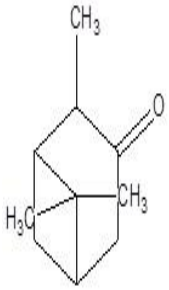

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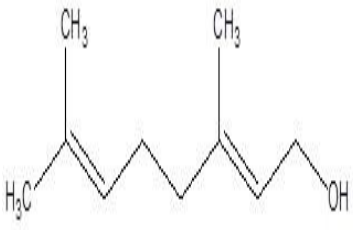

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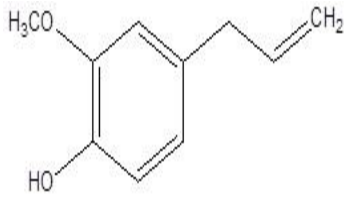

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Fig 2: Chemical Structures Of Constituents Of Corn Silk.

TRADITIONAL USES

- It is used as an analgesic.
- It is effective against skin rash.
- It is used to treat sore throat.
- It is also protective against allergy.
- It is a good emollient.
- It is also effective against hypertension and angina.
- Used to precipitate proteins i.e. a good astringent.
- It is a good remedy for prostatitis and against tumour.
- It is effective against diarrhoea and lithiasis.
- It is also used against biliousness.
- Various urinary disorders like dysuria, cystitis and nocturnal enuresis are also treated by corn silk.
- Its application also helps in smooth texture and maintenance of skin due to zinc oxide.
- It is also used in products of soap, toothpaste and cosmetics.

PHARMACOLOGICAL ACTIVITIES

In-vivo Activities

1) Anti-oxidant activity

Antioxidants are used by aerobic organisms to prevent oxidation that can damage the cells during oxygen metabolism. The latest studies have revealed the potential use of CS extracts as an important bioactive source of natural antioxidants.

a. γ radiation induced oxidative stress in mice species that was treated for 10 days detected activity against γ radiation.[17]

b. Exercise induced oxidative stress treated with flavonoids of corn silk by oral gavage (100 and 400 mg/kg body weight) for 28 days in mice detected activity during acute exercise.[18]

2) Diuresis and kaliuresis effect

Diuresis is a discharge of urine in a large amount, while kaliuresis is the secretion of potassium in a large amount in urine. The effects of corn silk aqueous extract on the urinary excretion of potassium and glomerular function were studied.

a. Wistar rats administered with corn silk aqueous extract by orogastric catheter and urine collected for 3 and 5 hours exhibited diuresis and kaliuresis effect.[19]
b. Anesthetized Wistar rats administered with 1ml of 20% corn silk aqueous extract by intragastric route, cannulation to urinary bladder for urinary flow, collection of urine detected diuretic effect.[20]

3) Hyperglycemic effect

Hyperglycemia is a condition where there is an abnormally elevated level of glucose in the blood. Corn silk aqueous extract has the property to reduce hyperglycemia and it can be used as a hypoglycemic food for diabetic people. Adrenaline induced hyperglycemia in mice treated with corn silk aqueous extract by oral route for 14 and 45 days at dose of (0.5, 1, 2, 4 g/kg of body wt.) lowered blood glucose level at dose of 2 and 4 mg/kg.[21]

4) Nephrotoxicity activity

Nephrotoxicity is a term used to categorize any adverse functional or structural changes in the kidney. The effects of these changes are due to chemical or biological products that are injected, ingested, inhaled or absorbed which yield toxic metabolites with adverse effects on the kidneys. Gentamicin induced nephrotoxicity in mice administered with corn silk methanol (80%) extract at 200- 300 mg/kg for 8 days ameliorates nephropathy.[22]

5) Anti-fatigue activity

Anti- fatigue activity of corn silk was investigated by using swimming exercise in mice administered with flavonoids of corn silk with 100 and 400 mg/kg for 14 days and loaded with 5% of body weight of galvanised wire possessed significant anti- fatigue activity.[23]

6) Anti-depressant activity

Anti-depressant activity of corn silk ethanol extract was investigated by force swimming test (FST) and tail suspension test (TST) on 10 male Swiss mice for 6 and 5 min, respectively, 1 h

after treatment with 125, 250, 500, 1500 mg/kg extract, possessed good activity at the dose of 1500 mg/kg.[24]

7) Anti-hyperlipidemic activity

Anti-hyperlipidemic activity was conducted by feeding the rats with hyperlipidemic feeds containing cholesterol, fat, sodium cholate, and ordinary feed. Total flavonoids from corn silk extracts showed an anti-hyperlipidemic effect on hyperlipidemia rats. The hyperlipidemia rats were treated with flavonoid from CS extract in three dosages (200, 400 and 800 mg/kg) for 20 days showed significant anti-hyperlipidemic activity at the dose of 400 and 800 mg/kg.[25]

8) Anti-diabetic activity

The anti-diabetic effects of polysaccharides from corn silk (POCS) was evaluated by investigating the levels of blood glucose (BG), oral glucose tolerance test (OGTT), TC (total cholesterols) and TG (triglycerides) in streptozotocin (STZ)-induced diabetic rats for 4 weeks. The results revealed that POCS (100–500 mg/kg body wt.) decreased the BG, TC and TG levels.[26]

9) Anti-inflammatory activity

The anti-inflammatory efficacy of corn silk extract was investigated in a rat model of carrageenin (Cg)-induced pleurisy, cellular infiltration, exudates formation, TNF, interleukin-1 beta (IL-1β), IL-17, vascular endothelial growth factor alpha (VEGF-α), C3 and C4 complement protein levels, ICAM-1 and inducible nitric oxide synthase (iNOS) levels, nuclear factor kappa B (NF-κB) activation and total antioxidant activity. Injection of Cg into the pleural cavity of rats induced inflammatory effects characterized by exudate formation and cell migration. Corn silk extract at doses of 2 and 4 g/kg body wt. significantly reduced the cell migration, exudate formation, suppressed pro-inflammatory mediators of TNF levels, IL-1β, IL-17 and VEGF-α. The C3 level increases during inflammatory reactions indicating the development of a defence system. CS extracts (2 and 4 g/kg body wt.) significantly lowered the level of C3 protein that leads to the inhibition of inflammatory processes. However, C4 protein does not show any difference for both CS extract doses. Treatment with CS extracts (2 and 4 g/kg body wt.) significantly reduced ICAM-1 expression. At the same time, corn silk extracts also reduced the protein expression of iNOS in a dose dependent manner.[27]

10) Haemodynamic effect

Haemodynamic effect was investigated by aqueous-ethanol (1:1) extract of corn silk administered to conscious rats by gastric intubation at a dose of 40 ml/kg, which detected hypotensive effect.[28]

11) Anti-tumour activity

Anti-tumour activity of corn silk was investigated by aqueous extract of dried stigma and styles in mice by intraperitoneal route at a dose of 150 mg/kg on days 5, 6 and 7 after start of experiment, which found to possess significant anti-tumour activity.[29]

12) Hepatoprotective effect

Methanolic extract of corn silk in albino rat by oral route at a dose of 200 mg/kg. Hepatoprotective activity is due to inhibitory effect on free radical formation.[30]

13) Anti-hepatoma activity

Corn silk polysaccharides possess desired pharmacological properties, investigation of effects of corn silk polysaccharide on tumor growth and immune functions in H22 hepatocarcinoma tumor bearing mice. Results indicate that corn silk polysaccharides could not only inhibit the tumor growth, but also extended the survival time of H22 tumor-bearing mice. Besides, corn silk polysaccharide administration could increase the body weight, peripheral white blood cells (WBC) count, thymus index and spleen index of H22 tumor-bearing mice. Furthermore, the production of serum cytokines in H22 tumor-bearing mice, such as IL-2, IL-6 and TNF-α, was enhanced by CSP treatment. In addition, no toxicological effects were observed on hepatic function and renal function in CSP-treated mice transplanted H22 tumor cells. Corn silk polysaccharide seems to be a safe and effective agent for the treatment of hepatocellular carcinoma.[31]

In vitro activities

1) Anti-oxidant activity

a) Five CS fractions; ethanol extract (EF), petroleum ether fraction (PF), acetic ether fraction (AF), n-butanol fraction (BF), and water fraction (WF) were investigated in *in vitro* antioxidant models. In the study, BF fraction (100 μg/mL) showed the highest total phenolic and total flavonoids content. Meanwhile, BF exhibited the strongest antioxidant activity compared to other CS fractions, whereby BF showed the highest total antioxidant and reducing power, the radical scavenging activity and iron-chelating activity. These antioxidant

values were comparable with vitamin C (positive control) and ethylenediaminetetraacetic acid (EDTA).[6]

b) Antioxidant activities of the upper part (dark brown parts, expose to the air) and lower parts (light yellow parts not expose to the air) of CS ethanolic extract were evaluated using total antioxidant capacity and DPPH assays. It revealed that the upper parts were found to have highest total antioxidant capacity and highest DPPH scavenging activity. This is due to accumulation of flavonoids and other phenolic compounds to protect maize DNA from the induction of ultraviolet damage in the upper parts of CS since this upper part is exposed to the Sun more than the lower parts.[32]

c) 50% ethanolic extract were tested in DPPH radical scavenging activity, metal chelating activity, nitric oxide-scavenging activity, reducing power determination and ferric thiocyanate (FTC) method. Ethanol extract showed a comparable antioxidant activity to the standard compounds (BHA, BHT, Vitamin C, quercetin, EDTA).[33]

d) Several extracts such as dichloromethane, petroleum ether extract, water extract and 95% ethanol extract were tested for antioxidant activity in DPPH and beta carotene bleaching assay. CS ethanol extract (400 μg/mL) provided a strong antioxidant activity by inhibiting free radical scavenging activity and the β-carotene bleaching. It is believed that the antioxidant activities of CS are contributed to by its polyphenol content and there is a linear correlation between Ferric Reducing/Antioxidant Power (FRAP) values and total polyphenol, tannin, proanthocyanidin and flavonoid contents.[34]

e) Methanolic extract of corn silk were evaluated for antioxidant capacity by lipid peroxidation inhibition in liposomes induced by Fe2+/ascorbate system. Antioxidant activity from matured corn silk is higher than immature corn silk.[35]

f) Antioxidant activity of the silks of four Zea mays varieties (var. intendata, indurata, everta and saccharata) was evaluated by DPPH, superoxide (SO) scavenging activity, iron chelating capacity and ferric reducing antioxidant power (FRAP) assays. All ethanol (EtOH) and ethyl acetate (EtOAc) extracts exhibited low DPPH radical scavenging activity at the tested concentration (500, 1,000 and 2,000 μg/mL) whereas only the EtOH extract of Z. mays var. intendata exhibited SO scavenging activity. The highest iron chelating capacity was for EtOH extract of Z. mays var. indurata. In the FRAP test, EtOAc extract have higher activity

than EtOH extract for all varieties and Z. mays intendata exhibited the highest activity for both extracts.[36]

2) Anti-glycation effect

In a study of 14 maize genotypes, the CS extract exhibited inhibitory activity for AGEs and non-enzymatic antiglycation. The most active maize genotype showed more effective inhibition of glycation than the standard aminoguanidine (known as a glycation inhibitor). Total phenol content of CS extracts and its resistance to certain fungal infections such as Fusarium graminearum (gibberella ear rot) revealed its potential for the development of natural AGE inhibitors in the prevention of diabetic and aging complications.[37]

3) Anti-inflammatory activity

a) Anti-inflammatory activity was investigated by endothelial-monocyte adhesion assay, molecule expression, treatment of TNF-mediated cytotoxicity, LPS-induced TNF released in chloroform, ethyl acetate, butanol and water extract. Ethanol extract inhibits the expression of ICAM-1 and adhesiveness of endothelial cells.[38]

b) COX-2 determination was conducted on macrophages treated with CS and PGE2 production was measured with PGE2 enzyme immunoassay kit. CS stimulated COX-2 and secretion of PGE2.[39]

4) Neuroprotective effect

The neuroprotective effects of ethyl acetate (EtOAc) and ethanol extract (EtOH) of CS from four corn varieties (var. intendata, indurata, everta and saccharata) was investigated by measuring acetylcholinesterase (AChE) and butrylcholinesterase (BChE) inhibition. AChE and BChE are enzymes that degrade the neurotransmitters acetylcholine through hydrolysis and lead to Alzheimer's disease; hence, such diseases might be prevented by inhibition of AChE and BChE.[40]

5) Anti-cancer activity

Anticancer activity was detected by methanol extract and preparative C18 reverse phase column chromatography of maysin (isolated from Korean corn silk) induced apoptosis of PC-3 cells was explored, evaluation of effects on Akt and ERK pathway. Maysin reduce PC-3 cell viability, apoptotic cell death, and DNA fragmentation, attenuated phosphorylation of Akt and ERK pathway.[41]

6) α- amylase inhibitory activity

Water-soluble corn silk polysaccharide were modified to form sulfated, acetylated and carboxymethylated derivatives which were investigated by chemical methods, gas chromatography, gel filtration, scanning electron microscope, infrared spectroscopy, ferric reducing power assay, lipid peroxidation inhibition assay and α-amylase activity inhibitory assay. Carboxymethylated derivative demonstrated higher solubility, low intrinsic viscosity, higher antioxidant and α-amylase inhibitory activity.[42]

TOXICITY

The choice of using herbal drug as a medicine source has increased over years. It is necessary to carry out toxicity studies and to determine safety parameters of herbal drugs. Therefore it is necessary to use safe and harmless drug. Recently used male and female sex of Wistar rats confirmed the non-toxic nature of corn silk. No adverse and histopathological effect at a concentration of 8.0% (w/w) when consumed for period of 9 days was detected. This content corresponds to mean daily Corn silk intake of approximately 9.35 and 10.3 g/day/kg body weight for males and females. This indicates no adverse effect of corn silk and safety for human use.

CONCLUSION

This review highlights potential therapeutic applications of corn silk. In vitro and in vivo studies are also conducted showing remarkable bioactivities of corn silk in various diseases. Toxicological findings showed safety and non-toxic nature for human consumption.

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