

## Maize (Corn)-A useful source of human nutrition and health: a critical review

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### Abstract

Corn (*Zea mays*) is a herbaceous plant which belongs to the grasses family (Poaceae). It originates from Central America and now a days it is cultivated approximately all the regions of the world. Corn is not only used as food or medicine but its waste after the use has a number of exceptional uses for animals and for industries such as medicine, fuel, lubricants, cosmetics, plastic, soap and resins industries. Basically corn has starch, sugar, vitamins and minerals and its chemical constituents between the species varies due to change in cultivation conditions such as types of soil, and weather and horticulture practice and also depends on the type of corn such as yellow, white and purple corn. It has also been shown that corn is not until now scientifically fully investigated for its composition and values, and still necessitate researcher's attention so as to discover this plant for the new age of science.

**Key words:** Poaceae, Starch, Medicine, Cultivation, Horticulture

**Full length article** \*Corresponding Author, e-mail: shafaqnisar12@gmail.com, Tel: +923237628206

### 1. Introduction

*Zea mays* (Maize) is a herbaceous plant which belongs to the grass (Poaceae) family. It has been used for 10,000 years by indigenous people in Mexico. It's origin is a wild grass known as teosinte. Maize is used as the main plant for the production of industrial products and for feeding animals. It is also the basic nutrition for humans. Genus *Zea* contains five well known species and they are all native to Central America and Mexico. Maize is cross pollinated easily [1] and the resulting diversity is manifested in the physiology, colour, shape of kernels and genome structure [2]. Maize is known by different names depending on the country. In Bengali it is known as Bhutta and in Gujrati it is called Makkai. It is known as Toumorokoshi in Japanese and Gaudume makka in Persian. In Punjabi it is called Makai. In English, it is known as corn or maize. It is commonly known as mielie in Africa. In Hindi, it is known as Makka and Barajovar [3]. *Zea* genus has many species such as *Z. perennis*, *Z. diploperennis*, *Z. luxurians*, *Z. mays*, and *Z. nicaraguensis*. There are six main types of corn and these include *Z. mays indentata* Sturt 'dent corn', *Z. mays everta* Sturt 'pop corn', *Z. mays indurata* Sturt 'flint corn', *Z. mays saccharata* Sturt 'sweet corn', *Z. mays amylacea* Sturt 'flour corn', *Z. mays tunicata* Sturt 'pod corn', *Z. mays* 'baby corn', *Z. mays ceratin* Kulesh 'waxy corn' [4]. Maize is an annual grass with kernels of either white, yellow, purple or blue color and top of kernels may be dent or

rounded; kernels have both soft and hard starches which may be more or less sweet in taste. All the varieties of corn such as yellow, purple, blue or white are the major sources of antioxidants or starch. The plants are herbaceous and their sizes vary from 1-4 meters in different species. Leaves are large, narrow or arranged oppositely around the stem. Corn oil is the main oil marketed in vegetable oil. Corn oil is obtained from the germ of corn and from starch and gluten and is used in biodiesel, soaps, paints and the coating industries [5]. Corn oil has linoleic acid and oleic acid as the main fatty acids togetherwith saturated palmitic acid; it has a small amount of stearic acid and myristic acid. Moreover, the bulk of oil production is restricted for direct consumption and is used in the food industry [6]. GC-MS analysis is generally used for the analysis of oil [7-9]. It is clear that maize is highly valuable chemically and morphologically due to its diversity.

### 2. History/Origin

*Zea mays* are derived from the combination of two languages ancient Greek or Taino. *Zea* comes from Greek which means "sustain life" or *mays* from Taino which means "life giver"[10]. *Zea mays* basically known as teosintes ' a wild grass' which is native to Central America and Mexico [11], where it has been used from 10,000 years ago. Maize is derived from the word Arawak mahizi having the meaning 'In which life sustains'. Archaeological records suggest that domestication of maize begin as a minimum

before 6000 years, where it present independently in south western United State, Central America and city of Mexico [12]. Maize mentioned in the Bible almost certainly refers to wheat or barley. Corn was very significant crop from ancient. Mayans say that human was created from the *Zea mays* and also have religious and spiritual attachment. It is one of the two not much familiar attempts that humans create from wood and mud. Old Americans frequently sow together beans, squash and maize and this system known as the 'Three sisters'. These three crops give the complete nutritional diet.

### 3. Demography/location

Corn is grown in a variety of climatic and environmental conditions. Corn considers a warm-weather crop. The best time to sow corn is in mid to late April because it is cold intolerant [13]. Corn is grown in United States, China, Brazil, Mexico, India, Canada, Australia, and New Zealand, Southern Africa, Pakistan, Nigeria, Japan, Malaysia, Thailand, Taiwan Philippines, Colombia, Singapore, Netherlands, Romania, Uruguay, Czech Republic, Egypt, Zimbabwe and Kenya From 1997-2010, 85% maize crop was modified genetically in Canada and United State and in 2011, 32% maize was genetically modified all over the world. Maize production in United States is approximately half of the total harvested crops of the world. Maize is grown in all the states of US and approximately greater than 80% grown in the Indiana, Nebraska, Iowa, Michigan, Ohio, Missouri, South Dakota and Wisconsin. The second large producer of maize is Argentina. The other countries which are the top producer of the maize are Brazil, Chain, Indonesia, France, and South Africa.

### 4. Botany, Morphology, Ecology

Maize is an annual herbaceous plant and its height ranging from 1-4 meters. Leaves are produced, thin large opposite and alternately around the stem. The stem of the maize plant is 3-4 cm in width having short inter nodes at the base. The leaves which originate from upper side of the stem have shown great contribution in photosynthesis. Inflorescence of male flowers is present at the top of the stem in the form of bobble while female flowers are present at the tip of side compressed branches which is also known as shank. Generally, there are three types of root in the maize plant. Seminal roots are originated from the radical part of the plant and continue to grow for long time period. Active roots of the plant are 'adventitious roots' which originate from the lower nodes of the plan and third type of roots is 'Brace roots' which grow quickly up to 60 cm in depth if soil is favourable. Stigmas are elongate present in the form of silk, at the start, it look like a bunch of hair and then turn into purple or green in colour. Ovaries after maturation are converted into kernel of maize and fertilised by pollen when wind blow. Corn requires warm daytime temperatures (25-30°C) and cool nights. Temperature below

8°C (or 0°C after silk) or above approximately 40°C usually cause termination of development. The critical temperature is approximately 32 °C. For germination and early growth of seeds approximately 12°C temperature is required and perfect temperature for tassel ling is 21-30°C. The production of maize is better in the area where the rainfall per year is more than 250-5000 mm and best growing time period is 3-13 months. Corn grows well in the soil with a pH range from 5-8 and its efficiency decreases when the soil becomes acidic.

### 5. Chemistry

Maize is an excellent source of minerals, dietary fibres and vitamins. Due to the presence of high amount of carbohydrates, it is an excellent source of energy and calories. Maize contain many vitamins such as vitamin A, thiamine (vitamin B1), riboflavin (vitamin B2), vitamin C, vitamin E, vitamin K, folate, niacin, pantothenic acid and also have minerals like calcium, zinc, potassium, iron, selenium, and phosphorous. Corn oil is a good source of tocopherols with  $\gamma$ -tocopherol [14].

#### 5.1. Chemical composition

Corn has high carbohydrate and sugar content that provide calories and energy and an excellent source of minerals and vitamin. Carbohydrates are present in the form of sucrose, glucose and fructose which are known as simple sugars [15]. In the endosperm, protein is the second most abundant component having 8-10 % of total weight of maize kernels after the starch [15]. Oil content in corn oil has saturated and unsaturated fatty acids. Saturated fatty acids are present in low concentrations such as palmitic acid and stearic acid. Instead of this, unsaturated fatty acids are present in high amount such as linoleic acid, linolenic acid or arachidonic acids. However their types and amount varies with different seasons [16]. Moreover, corn also have high amount of natural antioxidant.

#### 5.2. Phyto-chemistry

Maize has sweet taste of kernels due to the presence of 2, 4-dihydroxy-7-methoxy-1, 4bezoxazin-3-one. The compounds like galactan, dextrose, xylan and many other such compounds are present in the silk of corn. Oil obtained from the seeds are named as fixed oil and other compound which obtain from seeds are resins, proteins, inositol, maizenic acid, zeaxanthin, hexaphosphoric acid and large amount of sugars. D-glucose-hydroxy-2-indolinone-3-acetic acid and esters of indole-3-acetic acid are present in the corn kernels [17]. Corn contains the allantoin which helps to cell multiply normally. Maize contains many biologically active compounds such as flavonoids, purine derivatives, alkaloids, saponins, volatile compounds, vitamins such as vitamin K, C and A, sugars, acids fats, starch, minerals. Essential fatty acid, isoquercitin, cyanogenetic material, dicarboxilatic acids includes oxalic acid; glycosides, polysaccharide, triterpene cyclosadol, flavonoids glycosides are also present in the maize [18].

Corn silk is rich in phenolic compounds, such as anthocyanins, p- coumaric acid, vanillic acid, protocatechuic acid, derivative of hesperidin and quercetin, and hydroxycinnamic acid derivative composed of p-coumaric and ferulic acid [19]. Pollen contain kaempferol, flavonol, isorhamnetine and glycosides of quercetin [20].

## 6. Post-Harvest Technology

Corn is planted in warm season when temperature of soil reaches 15.5°C. Typically corn is harvested when the range of humidity content is 18-24 %. High humidity content damage the corn kernels during harvesting. Drying, shelling and mechanical harvesting change the physical features of the grain. Corn kernels are also damaged by manual or mechanical harvesting such as pericarp breakdown, or also by the attack of fungi or pest. Drying process of corn may cause damage to kernels and also induced the staining and stress crack which is the drawback of dry milling but reduced the damage of kernels by drying at high temperature or quickly [21]. Traditionally it is dry by bending the corn plant to hold with ear (higher part of the plant) to the down. For secure storage of kernels bring out dehydration to protect the moisture content of shelled kernels which are present at high amounts approximately 12-14 % at 10-30°C through both manual or mechanical harvesting. Low temperature and low storage of humidity provides the favourable conditions for microbial growth or pest attack. So protect the kernels from microbial growth maintain the internal moisture content and temperature by the process of aeration.

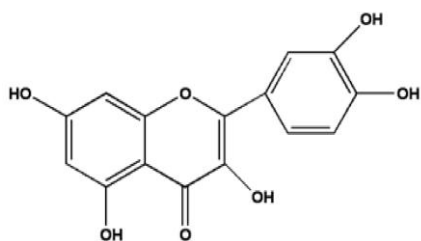


Fig.1. Structure of Quercetin

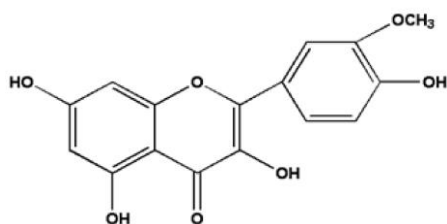


Fig.2. Structure of Isorhamnetin

## 7. Processing

Corn give the maximum production worldwide like other cereals which are useful for humans in different ways and is also used in the fuel industries or in livestock feed. Mechanical processes are used presently to produce corn meal and corn flour in different regions of the world to achieve precooked dry and fermented corn flour and other corn products [22]. Corn products have a large amount of carbohydrates, minerals and vitamins which are obtained

through different processing methods. Separation of components of kernels into germ, endosperm and bran carried out through mechanically dry processing while separation of chemical components such as starch and proteins are done by wet milling processing [23]. Corn raw materials are processed into final food product at large industrial scale or also on small scale at home. Two methods are used for processing of corn for consumption of humans at industrial scale such as dry milling and wet milling [24]. Fermentation of corn products also obtained by the soaking of the corn kernels approximately 1 to 3 days until the kernels become soft and then grind it with stone by adding the water and leaves it for 1 to 3 days for fermentation. Preparation methods of fermented products of corn are slightly changed by changed corn variety but the final product is same. Corn oil is obtained by pre-pressing of corn kernels and then solvent extraction. 2-methylpentane and hexane are used for the extraction of corn oil and these solvents are evaporated after extraction. Process of alkali treatment is used after extraction of corn oil for the removal of phosphatides, colour and also for neutralization of free fatty acids. Finally, deodorization of corn oil done by steam distillation and edible oil is obtained [25]. Corn oil yield is 145 kg/ha every year from corn germs which have 80-85 % corn oil.

## 8. Value addition

Corn is especially used to prepare traditionally value added products such as infant food, snacks, baked products etc. Chemicals such as ethanol and refined corn oil, starch, or industrial products like candies, cake mixtures, carbonated beverage, sorbitol and cosmetics are also prepared by the corn and corn is also used in the form of corn syrup or corn flakes [26]. Corn silk is used best in fresh form according to herbalists but it is also useful in dry form. Corn silk collects from the corn cobs or female flowers but it is also available commercially in the form of extract, in powder form or capsules. Corn silk typically used as a beverage in the form of tea for soothing. Corn is used as snack food in the form of chips and popcorn. In the United State, corn is used in summer as a special food in barbecues or mix corn with any herb, olive oil, organic butter, pepper and salt or yeast to get a delicious or healthy food. Corn used as a side dishes as sauté the corn with onion or green chillies and also used in pizza topping or thicken the soup.

## 9. Uses

In 1960's, corn used in livestock was approximately 75 %, which after decrease in 2000 become 60% and remaining was used in industries or for human food. Corn is also used as baby food, puddings and canned corn. Corn used in industries such as in packing material, material which used for insulation, adhesives, explosives, paste, dyes, paints, antifreeze, organic acids, rayon, insecticide, solvents, soap or in pharmaceutical industries. Corn is comprehensively studied in many educational disciplines as

physiology, biochemistry, soil fertility and genetics. Corn is used for the treatment of digestive disease due to the lack of gluten. Nutritional value of corn, softness and sweetness reserved safe if it is used in fresh form when harvested. Seeds and pollens are edible and healthy part of corn and seeds are good source of carbohydrates in cooked and raw form. Corn is the excellent source of vitamins such as vitamin B-Complex which is used for the treatment of skin, hair, digestion, brain or heart disease, improve immune system and thyroid gland. Corn oil is used in cooking and salads and corn syrup are used for manufacturing of jellies, jams, sweets and in preservation of cane sugar. Secondary metabolites are present in the roasted seeds of maize and used in coffee substitute.

### **9.1. General uses**

Corn and cornmeal is used as food in fresh form or as an important ingredient in a lot of dishes in many regions of the world. Even in Mexico fungus of corn used as a delicious food known as huitlacoche. In Africa, corn was first introduced in 16<sup>th</sup> century and then it became a most important food of Africans. Corn thick porridge is used as a cultural dish of many countries such as Brazil, Italy and Romania etc. Corn flour is used in the place of flour of wheat for the making of corn bread in many other baked products. There are many uses of corn and corn oil in the industries such as resin, fuel, lubricants, medicinal industries, plastic industries and also used in the synthesis of soap, varnishes, paints and linoleum. Corn oil refined in its natural flavour which is more beneficial for health and has tolerance ability of high temperature [27]. Spathes of corn are used in the manufacturing of paper, hats, straw and also used in the making of small baskets. Fibres are used for making the paper which obtained from the husk of seeds and stem. Stem of corn are also used in the packing material. Corn has the rich amount of thiamine which is used in the synthesis of neurotransmitter that is necessary for the memory known as 'acetylcholine'. Corn is not only a good source of thiamine but it also contains panthotanic acid or niacin which are the important components of lipid, protein or carbohydrates metabolism. Foliates present in the corn are used to reduce the risk of heart attack by lowering the cholesterol level or also reduced the possibility of colon cancer. Corn has the significant amount of magnesium which used to minimize the risk of migraine and asthma. Corn's starch is used as diluent in pharmaceutical or cosmetic industries.

### **9.2. Pharmacological uses**

Aromatic plants show various pharmacological activities such as antimicrobial [28], antioxidant and anti cancer etc. Corn silk is used to treat kidney stones and infection or irritation in urinary tract and also used to minimize the creatinine level in the serum [29]. Corn has low fat and cholesterol substances. Corn is the rich sources of vitamins and minerals, magnesium, fibre and multifaceted

carbohydrates. Grains of purple corn have a significant amount of fibres which used to reduce obesity and diabetes by enhancing the immune system. Corn silk extract used to minimize the glucose level in the blood [30].

#### **9.2.1. Diuresis and Kaliuresis effect**

Diuresis is a process in which excretion of urination increased due to increase in the chemical components in the body fluids resulting extra urine production by kidney to maintain the body fluids. Diuresis is caused by the increased level of sugars in the blood or due to certain medicines. Kaliuresis is a process in which potassium excretion from the body increased through urination. Extraction of corn silk used to treat kaliuretic and diuretic effects by maintaining the body fluid components such as  $Li^+$ ,  $Na^+$  and uric acid[31]. When extraction of corn silk was used, it showed the significant increase in the flow of urine and  $K^+$  and  $Na^+$  [19].

#### **9.2.2. Hypoglycemic Agent**

There are two types of cholesterol high quality cholesterol HDL or low quality cholesterol LDL which is formed by liver. Due to intake of high amounts of fatty acids, there is an increase of the risk of low quality cholesterol which raises the risk of cardiovascular diseases or heart attack. Corn has large amount of vitamin-C, bioflavenoids or carotenoids which is used to increase the blood flow and used to maintain the health of heart by lowering the absorption of cholesterol in the body. Corn has low fat and cholesterol substances. Corn is the rich sources of vitamins and minerals, magnesium, fibre and multifaceted carbohydrates. Grains of purple corn have a significant amount of fibres which used to reduce obesity and diabetes by enhancing the immune system. Corn silk extract used to minimize the glucose level in the blood [30]. Corn silk also used to reduce the lipid level in the serum and all the cholesterol and triglyceride [32].

#### **9.2.3. Anti-fatigue Activity**

Fatigue is a disease in which patient all the time feel tired. Disable symptoms is prominent in the fatigue and has diversity in neurological disorder and medical. Corn gives the excellent nutritional value in the diet and also helps to improve nutritional status. Corn has a large amount of carbohydrates so known as a starchy vegetable and it gives short and long term energy. It also helps to brain and nervous system for performing there functions properly. This is more beneficially for athletes because they require more energy from carbohydrates to increase their exercise performance. Furthermore, corn has complex carbohydrates so it is digested at slow rate by stomach, so provide good balance of energy levels which are free of valleys and peaks. Expert advised eat a cup of corn for lasting the energy a couple of hours before exercise Corn silk flavonoids also increase the swimming time in mice by associated decrease in the concentration of level of blood urea, glycogen and blood lactate [33].

#### 9.2.4. Anti-Cancer Activity

Cancer is threatening disease in the world which involve the abnormal growth of the cell that have ability to spread all the body parts. *Zea mays* leaf extracts have the property of anti-cancer agent. The qualitative analysis of *Zea mays* shows the presence of large amounts of phenolic compounds and flavonoids which play an important role in medicine [34-35]. Cancer is one of the main diseases which cause the death in humans. Plants provide the 'new leads' in developments against cancer and other diseases through its bioactive components. The current study focus on the capability of the diverse extracts (aqueous, methanol, and chloroform) of the leaves of *Zea mays* in influence of the procedure of apoptosis encouraged by hydrogen peroxide in Hep2 (laryngeal carcinoma) cells. A range of apoptosis-related parameter, such as cell viability, morphological changes, nuclear changes, and apoptotic index were categorized. sulforhodamine B and MTT assays were used to measure the increase of cell death in the group expose to hydrogen peroxide, plant extracts and their combination [36]. Corn has antioxidant properties which help to remove free radical that cause cancer.

#### 9.2.5. Anti-Inflammatory Activity

Inflammation is a biological complex response of white blood cells and all other cells which protect the body from the infection which is done after the attack of viruses and bacteria, irritation and cell damage. Corn is used in various forms such as pudding, thickeners of sauces, as sweetener in food, beverage products, cooking oil and bio diesel for human consumption. However, specially, extract of corn is little known about its effect on anti-inflammatory [37]. Corn has the anti-inflammatory effect after the change in gene expression. Ethanolic extract of corn silk shows antagonistic effects which effectively eliminate the endothelial cell of monocytic [31]. CS extract eliminated the cell migration, exudates creation, tumor necrosis factor alpha, oxidative stress and inflammation blocked demonstrate the anti-inflammation effect [38].

#### 9.2.6. Anti-Oxidant Activity

Oxidant or oxidizing agent may be a single atom, an element or a compound and its behave in destructive manner by produced reactive species of oxygen. Oxidants are biologically formed during the inflammation and metabolic process[39]. Antioxidant properties of plant are due to the presence of phenolic or flavonoid components [7-40]. Extract of corn silk can be used as a natural source of antioxidant [31]. Vitamin C is present in corn and act as an antioxidant that minimized the injury which is caused by free radicals. It also helps to protect from infection and enhance the immunity and increase the healing rate of wound. Although cold is not curing by vitamin C but it play a significant role in fighting against infections. Vitamin C has a small antihistamine effect, which mild the symptoms of disease and help to short the period of sickness. The

butanolic fraction of the corn silk extract shows the scavenging of free radicals and maximum activity of anti-oxidant. [41]. Corn silk extract of ethanol shows the high intensity toward scavenging activity of free radicals[42]. The antioxidant beta cryptoxanthin protect against lung cancer, while lutein protect vision loss caused by age factor.

#### 9.2.7. Anti- Diabetic Activity

Diabetes is a metabolic disease in which sugar level of blood increase due to insufficient production of insulin by pancreas. *Zea mays* are the major source of bioactive phenols and compound like anthocynins which used in the preparation of drinks and deserts in many cities of United State. The main anthocyanins such as cyandin-3-glucoside, peonidine-3-glucoside and cyanidine-3-dimalonyl-glucoside are present in the seeds, leaves and flower of purple cone and these components shows the intense biological activities such as anti-inflammatory, anti-cancer and anti-oxidant [43]. The ordinary utilization of kernels assists in the supervision of non -insulin dependent diabetes mellitus or also protect against hypertension because phenolic phytochemicals are present in the corn.

### 10. Summery

Corn (*Zea mays*) is a herbaceous plant which belongs to the grasses family (Poaceae). It originates from Central America and now a days it is cultivated approximately all the regions of the world. Corn is not only used as food or medicine but its waste after the use has a number of exceptional uses for animals and for industries such as medicine, fuel, lubricants, cosmetics, plastic, soap and resins industries. Basically corn has starch, sugar, vitamins and minerals and its chemical constituents between the species varies due to change in cultivation conditions such as types of soil, and weather and horticulture practice and also depends on the type of corn such as yellow, white and purple corn. It has also been shown that corn is not until now scientifically fully investigated for its composition and values, and still necessitate researcher's attention so as to discover this plant for the new age of science.

### REFERENCES

- [1] M.K. Campenot, G. Zhang, A.J. Cutler, D.D. Cass. (1992). *Zea mays* embryo sacs in culture. I. Plant regeneration from 1 day after pollination embryos. American Journal of Botany. 1368-1373.
- [2] V. Llaca, M.A. Campbell, S. Deschamps. (2011). Genome diversity in maize. Journal of Botany. 2011.
- [3] D. Kumar, A.N. Jhariya. Nutritional, medicinal and economical importance of corn: A mini review. Research Journal of Pharmaceutical Sciences ISSN. 2319: 555X.
- [4] H.H. Iltis, J.F. Doebley. (1980). Taxonomy of *Zea* (Gramineae). II. Subspecific categories in the *Zea mays* complex and a generic synopsis. American Journal of Botany. 994-1004.

- [5] M. Alam, N.M. Alandis. (2014). Corn oil based poly (ether amide urethane) coating material—Synthesis, characterization and coating properties. *Industrial Crops and Products*. 57: 17-28.
- [6] M. Abdulkadir, G. Abubakar. (2011). Production and refining of corn oil from hominy feed: A by-product of dehulling operation. *J Eng Appl Sci*. 6: 22-8.
- [7] M.A. Hanif, M.Y. Al-Maskari, A. Al-Maskari, A. Al-Shukaili, A.Y. Al-Maskari, J.N. Al-Sabahi. (2011). Essential oil composition, antimicrobial and antioxidant activities of unexplored Omani basil. *Journal of Medicinal Plants Research*. 5(5): 751-757.
- [8] M.A. Hanif, A.Y. Al-Maskri, Z.M.H. Al-Mahruqi, J.N. Al-Sabahi, A. Al-Azkawi, M.Y. Al-Maskari. (2011). Analytical evaluation of three wild growing Omani medicinal plants. *Natural product communications*. 6(10): 1934578X1100601010.
- [9] I. Shahzadi, R. Nadeem, M.A. Hanif, S. Mumtaz, M.I. Jilani, S. Nisar. Chemistry and biosynthesis pathways of plant oleoresins: Important drug sources.
- [10] P. Milind, D. Isha. (2013). Zea maize: A modern craze. *International Research Journal of Pharmacy*. 4(6): 39-43.
- [11] J. Doebley. (1990). Molecular evidence and the evolution of maize. *Economic Botany*. 44(3): 6-27.
- [12] P.C.P.C. Mangelsdorf. (1974). Corn: its origin evolution and improvement. pp.
- [13] J. Sawyer, E. Nafziger, G. Randall, L. Bundy, G. Rehm, B. Joern. (2015). Concepts and rationale for regional nitrogen rate guidelines for corn. Iowa State University—University Extension PM.
- [14] R.A. Moreau. (2011). Corn oil. *Vegetable Oils in Food Technology: Composition, Properties and Uses, Second Edition*. 273-289.
- [15] L.C. Hannah, M. Giroux, C. Boyer. (1993). Biotechnological modification of carbohydrates for sweet corn and maize improvement. *Scientia Horticulturae*. 55(1): 177-197.
- [16] A.Y. Al-Maskri, M.A. Hanif, M.Y. Al-Maskari, A.S. Abraham, J.N. Al-sabahi, O. Al-Mantheri. (2011). Essential oil from *Ocimum basilicum* (Omani Basil): a desert crop. *Natural product communications*. 6(10): 1934578X1100601020.
- [17] P. Lewer, R.S. Bandurski. (1987). Occurrence and metabolism of 7-hydroxy-2-indolinone-3-acetic acid in *Zea mays*. *Phytochemistry*. 26(5): 1247-1250.
- [18] A. Ehmann. (1974). N-(*o*-coumaryl)-tryptamine and N-ferulyl tryptamine in kernels of *Zea mays*. *Phytochemistry*. 13(9): 1979-1983.
- [19] M.A. Ebrahimzadeh, F. Pourmorad, S. Hafezi. (2008). Antioxidant activities of Iranian corn silk. *Turkish Journal of biology*. 32(1): 43-49.
- [20] O. Ceska, E.D. Styles. (1984). Flavonoids from *Zea mays* pollen. *Phytochemistry*. 23(8): 1822-1823.
- [21] M. Paulsen, L. Hill. (1985). Corn quality factors affecting dry milling performance. *Journal of Agricultural Engineering Research*. 31(3): 255-263.
- [22] L. Rooney, S. Serna-Saldivar, P. White, L. Johnson. (2003). Food use of whole corn and dry-milled fractions. *Corn: chemistry and technology*. (Ed. 2): 495-535.
- [23] T. Brubacher. (2002). Dry corn milling: an introduction. *Technical Bulletins*. International Association of Operative Millers. 7857-7860.
- [24] L.W. Rooney, S.O. Serna-Saldivar. (1987). Food uses of whole corn and dry-milled fractions.
- [25] J.F. Ulrich, S.C. Anderson, Extraction of corn oil from flaked corn grain. In Google Patents: 2001.
- [26] V. Yadav, P. Supriya, Value Addition in Maize. In *Maize: Nutrition Dynamics and Novel Uses*, Springer: 2014; pp 141-152.
- [27] F. Orthofer, J. Eastman, G. List. (2003). Corn oil: composition, processing and utilization. *Corn Chemistry and Technology*. Minnesota: American Association of Cereal Chemists, Inc. 671-694.
- [28] E.M. Abdallah, A.E. Khalid. (2012). A preliminary evaluation of the antibacterial effects of *Commiphora molmol* and *Boswellia papyrifera* oleo-gum resins vapor. *International Journal of Chemical and Biochemical Sciences*. 1: 1-15.
- [29] G. Sepehri, A. Derakhshanfar, F.Y. Zadeh. (2011). Protective effects of corn silk extract administration on gentamicin-induced nephrotoxicity in rat. *Comparative clinical pathology*. 20(1): 89-94.
- [30] W. Zhao, Y. Yin, Z. Yu, J. Liu, F. Chen. (2012). Comparison of anti-diabetic effects of polysaccharides from corn silk on normal and hyperglycemia rats. *International journal of biological macromolecules*. 50(4): 1133-1137.
- [31] D. Velazquez, H. Xavier, J. Batista, C. de Castro-Chaves. (2005). *Zea mays* L. extracts modify glomerular function and potassium urinary excretion in conscious rats. *Phytomedicine*. 12(5): 363-369.
- [32] J. Guo, T. Liu, L. Han, Y. Liu. (2009). The effects of corn silk on glycaemic metabolism. *Nutrition & metabolism*. 6(1): 1.
- [33] Q.-L. Hu, L.-J. Zhang, Y.-N. Li, Y.-J. Ding, F.-L. Li. (2010). Purification and anti-fatigue activity of flavonoids from corn silk. *International Journal of Physical Sciences*. 5(4): 321-326.

- [34] I. Ahmad, M.A. Hanif, R. Nadeem, M.S. Jamil, M.S. Zafar. (2008). Nutritive evaluation of medicinal plants being used as condiments in South Asian Region. *JOURNAL OF THE CHEMICAL SOCIETY OF PAKISTAN*. 30(3): 400-405.
- [35] Z. Arshad, M.A. Hanif, R.W.K. Qadri, M.M. Khan. (2014). Role of essential oils in plant diseases protection: a review. *International Journal of Chemical and Biochemical Sciences*. 6: 11-17.
- [36] K. Balasubramanian, P.R. Padma. (2013). Anticancer activity of *Zea mays* leaf extracts on oxidative stress-induced Hep2 cells. *Journal of acupuncture and meridian studies*. 6(3): 149-158.
- [37] K.-B. Roh, H. Kim, S. Shin, Y.-S. Kim, J.-A. Lee, M.O. Kim, E. Jung, J. Lee, D. Park. (2016). Anti-inflammatory effects of *Zea mays* L. husk extracts. *BMC Complementary and Alternative Medicine*. 16(1): 298.
- [38] G.-Q. Wang, T. Xu, X.-M. Bu, B.-Y. Liu. (2012). Anti-inflammation effects of corn silk in a rat model of carrageenin-induced pleurisy. *Inflammation*. 35(3): 822-827.
- [39] G. Cepinskas, J.X. Wilson. (2008). Role of Oxidants. *J. Clin. Biochem. Nutr.* 42: 175-184.
- [40] M.M. Khan, M. Iqbal, M.A. Hanif, M.S. Mahmood, S.A. Naqvi, M. Shahid, M.J. Jaskani. (2012). Antioxidant and antipathogenic activities of citrus peel oils. *Journal of Essential Oil Bearing Plants*. 15(6): 972-979.
- [41] J. Liu, C. Wang, Z. Wang, C. Zhang, S. Lu, J. Liu. (2011). The antioxidant and free-radical scavenging activities of extract and fractions from corn silk (*Zea mays* L.) and related flavone glycosides. *Food Chemistry*. 126(1): 261-269.
- [42] Q. Hu, Z. Deng. (2011). Protective effects of flavonoids from corn silk on oxidative stress induced by exhaustive exercise in mice. *African Journal of Biotechnology*. 10(16): 3163-3167.
- [43] B. Huang, Z. Wang, J.H. Park, O.H. Ryu, M.K. Choi, J.-Y. Lee, Y.-H. Kang, S.S. Lim. (2015). Anti-diabetic effect of purple corn extract on C57BL/KsJ db/db mice. *Nutrition research and practice*. 9(1): 22-29.