CHARACTERIZATION AND UTILIZATION OF CORN SILK TO DEVELOP FUNCTIONAL FOOD PRODUCT

Thesis Submitted For the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Food Technology

By

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DECLARATION

We hereby declare that the work presented in Project entitled **"Characterization and utilization of corn silk to develop functional food product"** is our own and original. The work has been carried out by us at School of Agriculture, Lovely Professional University, Phagwara, Punjab, India under the guidance of **Dr. Sawinder Kaur,** Professor (Food Technology and Nutrition) of School of Agriculture, Lovely Professional University, for the award of the degree Ph.D Food Technology.

Date: 03/11/2022

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I certify that the above statement made by the students is correct to the best of my knowledge and belief.

Date: 03/11/2022 **(Supervisor- Dr. Sawinder Kaur)**

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Signature of External Examiner

CERTIFICATE

This is to certify that work embodied in the PhD report entitled **"Characterization and utilization of corn silk to develop functional food product"** has been carried out by **Jyoti Singh** under my guidance and supervision**.** To the best of my knowledge, the present work is the result of their original investigation and study. No part of the project has ever been submitted for any other degree. The work has been carried out by them at the School of Agriculture, Lovely Professional University, Phagwara, and Punjab, India. They fulfilled the requirement for the award of the degree Ph.D. Food Technology.

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Abbreviations

ABTS	(2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)
AGE	Advanced Glycation End products
ALT	alanine transaminase
APEJ	Asia Pacific Excluding Japan
AST	aspartate aminotransferase
BCS	*n*-butanol fraction
CECS	chloroform corn silk
CS	Corn silk
DC	diabetic control
DPPH	2,2-diphenyl-1-picrylhydrazyl.
DSC	Differential scanning calorimeter
FRSA	Free radical scavenging activity
FTIR	Fourier transform infrared spectroscopy
GAE	Gallic acid equivalent
GC-MS	Gas Chromatography Mass Spectrometry
GLUT4	Glucose transporter type 4
HD	high dose
HFD-STZ	high fat diet streptozotocin
IDF	International Diabetes Federation
LD	low dose
MD	medium dose
MEA	Middle East & Africa

MECS	methanol corn silk
NC	non-diabetic control
NOAEL	no-observed-adverse-effect-level
PCS	petroleum ether fraction
PD	dimethylbiguanide
PDX-1	pancreatic and duodenal homeobox
PECS	petroleum ether corn silk
POCS	corn silk polysaccharides
PPAR	peroxisome proliferator-activated receptors
ROS	reactive oxygen species
TPC	total phenolic content
XRD	X-ray diffraction analysis
YMS-EA	ethyl acetate fraction

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ABSTRACT

Corn silk as an agricultural waste possess numerous health benefits and therapeutic potential. This study evaluates the antioxidant potential of different varieties of corn silk at five developmental stages. Corn silk samples of five major varieties (SWARNA, TATA7009, SHUBHAM EARLY, KESHAR KING, and G5417) grown in Punjab, India, were analyzed for their phytochemical potential and techno-functional properties at five growth stages including stage 1 (immaturity), stage 2, stage 3, stage 4 and stage 5 (maturity). Antioxidant content and activity of these varieties at their physiological stages were analyzed. G5417 showed the highest activity for ABTS, FRAP, FRSA at stage 1 with the inhibitory activity of 84.16±0.55 TEAC (mg/gdw), 123.2±0.56%, and 65.33±1.21%, respectively. The antioxidant content including total phenols, flavonoids, and ascorbic acid showed a significant decrease ($p<0.05$) from the immature to mature stage. The lowest bulk density was observed in G5417 stage 5 (0.314±0.07 g/cm^3), the Carr's index for G5417 stage 1, 4, and 5 were less than 15 which shows good flowability, the angle of repose for G5417 was 32.93±1.07° which showed the good flowability. The water solubility index was observed highest for G5417 stage 1, 24.83±0.70%. The G5417 stage 5 showed the highest stability of emulsion i.e. 37.91±0.82%. The results confirm that the juvenile stage of G5417 (stage 1) showed the highest antioxidant content and activity and techno-functional properties. This makes it most likely a selection for the development of value-added products.

The drying kinetics was performed to choose the best temperature and time for the drying of corn silk. The particle size of best suitable variety was analyzed and the goal of the study was to see how particle dispersion affected the physical, technological, and antioxidant qualities of corn silk powder. Corn silk (variety: G5417) was processed into size fractions of 750, 425, 300, 212, 150 and 75 µm were characterized. The average particle size of the soluble fraction was found to be 364.4 d.nm. The particle size distribution of corn silk powder was found to have a substantial impact on different physical parameters such as bulk density, tapped density, Hausner ratio, Carr's index, and angle of repose. Techno-functional factors such as water absorption and water solubility index, oil absorption capacity, emulsifying activity, emulsion stability, and foam capacity are all affected by particle size distribution. The antioxidant activity increased significantly when the particle size was reduced. The particle size reduction and simultaneous increase in surface area are thus, found to help improve the important industry significant characteristics of the corn silk powder.

Corn silk has long been thought of as a waste product. Therefore, the aim was to assess the bioactivity of dried corn silk powder (*Zea mays*, G5417) in terms of its physicochemical and bio-functional

characteristics. The protein (15.29 ± 1.23 g) and ash (5.29 ± 0.29 %) contents in the corn silk powder were found to be high. The high phenolic content (94.10 ± 0.26 mg GAE/g) and flavonoid content (163.93 ± 0.83 mg QE/100 g) are responsible for its high antioxidant activity. The corn silk powder showed 45.40 ± 0.92% FRSA, 75.25 ± 0.59 TEAC mg/gdw of ABTS, and 86.77 ± 0.88% of FRAP. FT-IR spectroscopy revealed stretching, bending, and vibrations of abundantly present polysaccharides and protein functional groups. Moreover, the DSC thermograph revealed the exothermic reactions at on-set temperature (T_{onset}) = 21.9 °C and end temperature (T_{endset}) = 102.80 °C, and exothermic reactions at on-set temperature (T_{onset}) = 252.02 °C, end temperature (T_{endset}) = 296.80 °C, and denaturation peak temperature (T_{peak}) = 277.48 °C, whereas XRD (2θ = 21.5°) confirmed the amorphous nature of the corn silk powder. Therefore, due to the potential bioactivity and thermal stability, dry corn silk powder can be scaled up at an industrial level. Current findings convey that the corn silk variety G5417 has a high nutritional bioactive potential owing to its high polyphenol, flavonoid, and ascorbate content, and its potent antioxidant activity, making this plant material highly valuable for use as a natural source of polyphenols, potentially contributing to the development of value-added, functional, and nutraceutical products. As evident through DSC studies, the prepared powder was found to be highly heat-stable. FTIR analysis confirms the components of corn silk powder, XRD analysis provides evidence of the amorphous nature of the powder, and acceptable color values make it an ideal contender to be used as a food ingredient. The SEM analysis of corn silk powder revealed the rectangular and porous structure of corn silk due to the presence of polysaccharides and flavonoids. The cytotoxicity study showed that corn silk powder showed the 90.18 % cell viability. The quantitative analysis of phenolic compounds in corn silk depicted the presence of p-coumaric acid and salicylic acid and for the flavonoids rutin and quercetin were present.

Two products viz. instant mix and beverage, using the final powder were developed. The corn silk based instant mix was prepared using corn silk powder, skimmed milk powder and sugar as primary ingredients, with xanthan gum used to derive a porridge like texture when reconstituted. The optimization was conducted using response surface tool post preliminary trials conducted to determine the range of variables. The optimization process determined the optimized product with 14.66% corn silk, 10% sugar and 0.22% xanthan gum in a base of skimmed milk powder (made up to 100% ~ 75.12%). with the desirability of 0.925. The observed values although significantly different are in reasonable agreement with the predicted values for physico-chemical and sensory properties. A ready to serve corn silk-based beverage was developed using the corn silk (dehydrated) aqueous extract

blended with kinnow juice with xanthan gum as stabilizer. The numerical optimization of the beverage yielded the optimum product with 39.358% corn silk, 0.277 % xanthan gum, 40% kinnow Juice and 5% Sugar. The optimized product showed acceptable results on physico-chemcial and sensory basis. The desirability of the obtained optimized beverage formulation was 0.932.

Both the optimized products were subjected to storage study. The instant mix was packaged using different suitable packaging material including Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE) and Metalysed Polyester (MP) were performed for 120 days and the data revealed that metallic polyster showed the better retention of antioxidant content like total polyphenolic content and lower degradation of compounds into degradation metabolites such as hydroxymethul furfural (HMF), free fatty acid (FFA) and thiobarbituric acid (TBA). The microbial analysis revealed that the total plate count and yeast and mould count in the instant mix for all the stored samples at all storage temperatures was lower than the permissible unit for instant mix i.e., $1*10^4$ cfu/g. No coliforms were detected in any sample at any stage of the study. The reaction kinetics was used to predict the chemical shelf life of the instant mix. The study showed the HMF amongst the three chemical indicators is the most suitable chemical compound to predict the shelf life of instant mix. The half-life calculated for the instant mix at 10 °C of storage was predicted to be 94.05 days. The corn silk-based beverage was subjected to shelf life analysis. In addition to microbial analysis the chemical and sensory parameters of the product were studied. The study revealed that the pasteurized (In bottle) product would stay acceptable until 45 days of storage at refrigerated temperature (10°C). The cost analysis showed the total cost for instant mix to be Rs 33 per 100 gm and Rs. 30 for 200 ml of corn silk based RTS beverage.

Keywords: Antioxidant, corn silk, particle size, techno-functional, powder properties, characterization, functional, phenols, flavonoids, instant mix, ready to serve beverage, storage studies, chemical kinetics, drying kinetics

Chapter-1

INTRODUCTION

Cereal grains are important staple foods providing substantial amounts of energy, protein and micronutrients for much of the world's population. Maize (*Zea mays*) is an annual plant which belongs the family Gramineae and Genus *Zea*. *Zea mays* L is one of the most widely grown cereal crops in the world and has become the third most important cereal crops other than wheat and rice (Bawa, 2021). India is one of the beneficiaries of the booming international maize trade. The country exported a record of five million tonnes of maize in 2012/13, valued at Rs. 7,000 crore and is now the fourth-largest maize exporter after the US, Brazil and Ukraine. In the last five years, exports have doubled and by 2025, maize will be the developing world's largest crop and it is expected that the demand for maize in the developing world will be doubled by 2050. Due to its wide applications in variety of products maize is also referred to as the 'Queen of Cereals'. Maize in India, contributes nearly 9 per cent in the national food basket. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc. Maize is cultivated throughout the year in all states of the country for various purposes including grain, fodder, green cobs, sweet corn, baby corn and popcorn in peri-urban areas. The predominant maize growing states that contributes more than 80 per cent of the total maize production are Andhra Pradesh (20.9%), Karnataka (16.5%), Rajasthan (9.9%), Maharashtra (9.1%), Bihar (8.9%), Uttar Pradesh (6.1%), Madhya Pradesh (5.7%) and Himachal Pradesh (4.4%) (Murdia et al., 2016). Corn is a very versatile crop which can be used in various platforms and is used as a feed grain, fodder crop for buffalos and cattle, and industrial purposes (Dowswell, 2019). Yan et al., (2011) shared that the annual global production of corn in recent years has grown up to 826 million.

Maize is regarded as monoecious plant which produces large, narrow and opposite leaves. Although, same pattern of growth and development is followed by all the varieties of maize but the difference in interval between stages, time of growth and total number of leaves could be seen in different hybrids, time of planting and location. Various metabolic reactions take place within the seed after it is sown into the soil. The germination starts after 2 to 3

days of planting depending on temperature (above 50°F) and adequate moisture of soil. The growth of the corn plant is divided into two categories, i.e Vegetative (V stages) and reproductive (R stages). Corn emergence (VE stage) is the stage that takes place under the soil surface and after that, various stages like V1 (first leaf emerged and leaf collar is visible), V2 (two leaves after 7 to 10 days of emergence), V3 (after 10 to 20 days of emergence), V4-V6 (initiation of uppermost ear and tassel and kernel row numbers are visible), V7-V9 (8 leaves are formed), V10 (10 leaves are formed) and V11-V15 (completion of kernel row determination). Pollination starts in 9 or 10 weeks after the emergence of corn and is highly affected by heat stress and moisture. VT stage begins when tassel start appearing, but silk has not emerged. R1 is the silking stage when the silk is visible outside the husk. Pollen shreds over the silk to fertilize the ovules and further forms the kernel. R2 to R6 are the grain fill stage where R2 is the blister stage, appears after 10-14 days of silking, R3 (after 18 to 22 days of silking), R4 also known as dough stage (after 24 to 28 days of silking), the inner fluid begins to thicken due to starch accumulation, R5 known as dent stage (after 35 to 42 days after silking), each kernel has a dent over it and lastly R6, when kernels continue to gain weight until the formation of black layer (after 55 to 65 days of silking) (Dekalb Asgrow, 2020).

Corn silk ascribed as stigmata of maize female flowers of *Zea mays* L. (Gramineae), are fine soft thread 10-20 cm long, commonly cultivated in warm climates. It has been used traditionally in pharmaceutical preparations to treat the human health problems like diuresis, cystitis, gout, kidney stones, nephritis etc. (Bhaigyati et al., 2011). There are different varieties of corn silk from yellowish to green or purple threads of female flowers. These different types of corn silk possess unique properties, like purple corn silk is rich in polyphenolic compounds and is effective in treating diabetes and obesity (Chaiittianan et al., 2017). Corn silk is now becoming a well-known functional food (Chen et al., 2013). There are scientific evidences that consumption of corn silk has no side effects and is safe for human consumption. Many studies have confirmed that corn silk is rich in multiple bioactive compounds including proteins, polysaccharides, flavonoids, vitamins, mineral salts (Guo et al., 2017).

Few traditional culinary uses have been reported for corn silk. Its extracts have been consumed in the form of tea in Korea and recently many studies have reported different anti-inflammatory, anti-infective, anti-diabetic and anti-oxidative properties associated with its

consumption (Hasanudin et al., 2012). Wang et al. (2011) reported that corn silk consists of 9.65% moisture, 17.6% protein, 0.29 % fat, 3.91% ash and 40% dietary fiber, making it a unique combination of healthful ingredients. SFETCU et al., (2014) described corn as a plant which has various parts of its own and produces monoecious flowers, having male and female reproductive parts of plant. It has tassel, stalk, leaves, roots, and cob. Corn includes corn silk, kernels and cob, its outer covering which is also considered as waste.

It has been reported in many investigations that corn silk and its extracts have profound health benefits. It promotes insulin production in animals and supports the recovery of damaged α-cells of pancreas (Sepehoi et al., 2011). Nawaz et al., (2019) also discussed that corn silk is bound to have positive effects in treating hypercholestremia, urinary infections, and different linked diseases. Corn silk powder was used as food additive to improve the content and physical characteristics of patties made up of beef (Wan et al., 2010). Corn silk has optimum amount of potassium which grants it diuretic properties. Many populations like Spain, Greece and India have embraced it to fight against urinary tract infections and kidney stones (Lans, 2006). It is also a rich source of Vitamin C, A and K with high amount of beta-carotene and fair amount of selenium which helps to improve thyroid gland activity and in turns improves immune system (Kumar and Jhariya, 2013). Other than antihypertensive property, there are various other important properties also delivered by corn silk like anti-fatigue (Hu et al., 2010), diuretic effect, asthma prostatitis (Nawaz et al., 2018), helps in Skin Pigmentation (Choi et al., 2014) etc.

Corn silk is counted under an excellent herb portraying many health benefits. It is loaded with nutrients like minerals and vitamins. According to (Rahman et al., 2014), corn silk contains a good amount of moisture content nearly about 89.31%. The moisture content is higher in immature silks as compared to mature silks. The carbohydrate and protein content is reportedly 27.80% and 12.96%. Corn silk contains abundance of mineral content like calcium, phosphorus, potassium, sodium, zinc, copper and many more. Out of all the available minerals, potassium holds the highest concentration i.e. 35.671 mg/g and 0.26 mg/g of sodium respectively. The potassium present in corn silk helps to treat various health problems like urinary tract infections, kidney stones and hypertension.

Corn silk is also rich in fibre content with almost 52-53% in content. It is also rich in several antioxidants and flavonoids like maysin which helps in reducing bad cholesterol from body. Corn silk is beneficial in treating cardio-vascular diseases as well like angina pectoris,

obesity issues, high blood pressure, and high cholesterol etc. Corn silk is marked as an excellent source of many phenolic compounds like anthocyanins, vanillic acid, derivatives of quercitin, *p*-coumaric acid, and hydroxycinnamic acids and many more. The anthocyanins present in corn silk act as a good anti-cancer agent in perspective to colon cancers (Senphen at al., 2019). The polysaccharides present in corn silk helps to cure diabetes in patients by acting as an excellent anti-diabetic agent. (Pan et al., 2017)

Alam et al. (2011) claimed that corn silk is rich in antioxidants and shows antibacterial properties. It is best suited, when used as an antiseptic and uricosuric agent. They also claimed that due to the presence of flavonoids and phenolic in corn silk it is used to treat various health related issues like gout, nephritis, prostatitis, skin pigmentation and many more. Concisely, corn silk is a star herb used to treat various health problems.

The flavonoid Maysin present in the corn silk tea extract contains luteolin which is known for its high antioxidants and anticancer activities. It is also used as an ingredient in making drugs. It can be consumed and used in various forms like powder form, drinks like tea, or can be used as a food additive, corn syrups etc. Corn silk is one of the part which enhances the nutritional and functional qualities of food stuffs. Antioxidants basically are able to scavenge reactive oxygen species (ROS). ROS can be the cause of various health related issues like hypertension, cardiovascular diseases, oxidative stress etc. Thereby these medicinal herbs are used to cure these health related issues (Hasanudin et al., 2012).

In addition to various aforementioned health benefits associated with corn silk, the utlization of this low cost biomaterial would help generate value out of waste and cater to the on-going and upcoming food security concerns. With food secuirty being a global problem along with raising issues like climate change, the world requires potent solution as alternative food crop and reduction in wastes.

Owing to the above information the current project is designed to utilize the profound goodness of this underutilized commodity for developing the functional food products of daily use. With this attempt we intent to project corn silk into scientific limelight and promotes its utilization as a functional ingredient in commonly consumed foods to extend it to a large set of population.

Chapter-2

REVIEW OF LITERATURE

From the ancient times, plants have been used as remedy for different human diseases because they are enriched with components of therapeutic values. Corn silk is one of the most beneficial herbs, used traditionally by the Native Americans and Chinese for the treatment of diseases. Corn silk along with leaf stalk and cob is discarded as waste in the field of agriculture. The different parts of maize plant is shown in Figure 2.1. Exploring the other nutritive values of corn silk could be one of the major aim for the development of the food products.

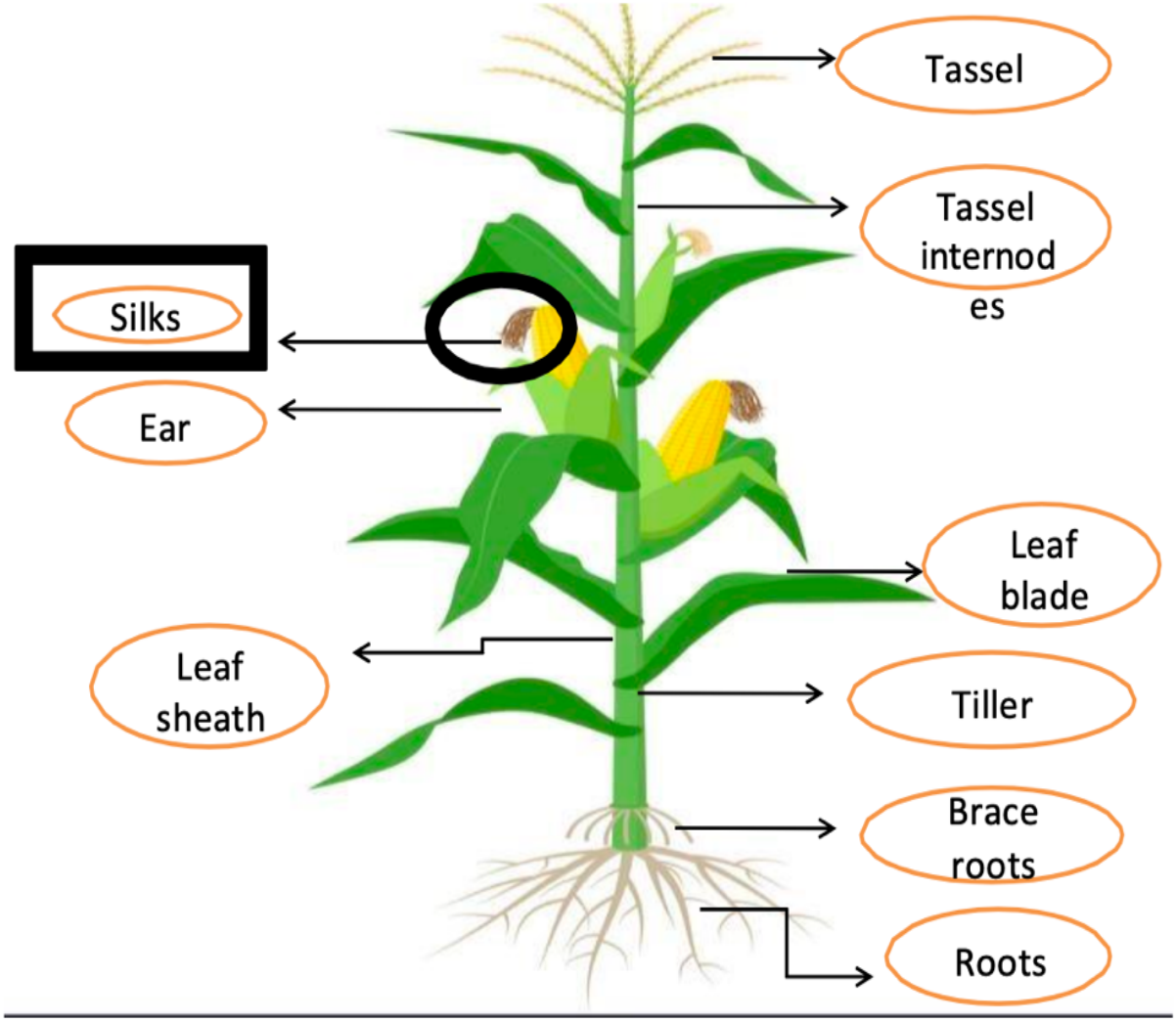


Figure 2.1- Different parts of maize

2.1 CHEMICAL COMPOSITION AND PHYTOCHEMICAL POTENTIAL OF CORN SILK

Corn silk is grown worldwide and slight difference in nutritive and phytochemical composition in different varieties are observed. Table 2.1 and Table 2.2 represent the varieties grown in different countries. The Indonesian corn silk varieties are rich in protein whereas the Mexican corn silk varieties are rich in dietary fiber. Corn silk consists of proteins, vitamins, polysaccharides, Ca, K, Mg and Na salts and bioactive compounds which include alkaloids and tannins, saponins as well as steroids (Guo et al., 2009).

Proximate composition

The difference in proximate composition in mature and immature Malaysian corn silk were analysed by Rahman and Rosli (2014) and the result showed that immature corn silk has high moisture content (89.31±0.74%), crude lipid content (1.27±0.16%), crude protein (12.96±0.38%) than matured corn silk whereas high values for ash content (5.51±0.24), carbohydrate content (29.74± 1.26%)) and total dietary fiber (51.24±1.50 g/100g) were observed in matured corn silk in comparison to immatured corn silk. Three different Mexican maize varieties (Gordo with white kernels, Conico with red kernels, dark red kernels and white blue kernels and Cristalino with yellow kernels) were evaluated by Mendoza-Lopez et al., (2018). The major constituent in corn silk reported was fiber among the carbohydrates ranged from 39 to 53% out of which insoluble fiber percentage was high (36-52%) in comparison to soluble fiber (>3%). The high amount of insoluble fiber is not desirable for recovery of bioactive components until cell wall act as barrier during a liquid-solid extraction (Le Bourvellec et al., 2012). Although the amount of soluble fiber content in corn silk is relatively low, it is sufficient to possess beneficial properties (Hasanudin et al., 2012). Corn silk has 9.65-10.4% of moisture, 9.42-17.6% of protein, 0.29-4.74% of fat, 1.2-3.91% of ash, 7.34% of dietary fibre and 65.5-74.3% of carbohydrates. Corn silk also contains a good amount of vitamin and minerals like sodium (28 mg/100 g dw) and potassium (1360 mg/100 g dw) (Emmanuel et al., 2016; Saeed et al., 2020).

It has been described that silk consists proteins, vitamins, carbohydrates, calcium, potassium, magnesium, fixed and volatile oils, sodium salts, steroids such as alkaloids, saponins, sitosterol, tannins, polyphenols, proanthocyadins and flavonoids. (El-Ghorab et al., 2007). The study conducted by Rahman et al., 2014 has attempted for the nutritional composition for mature corn silk as shown in Table 2.3 and Table 2.4.

Table 2.1 Chemical composition of different varieties of corn silk grown in different regions worldwide

Sr. No.	Country/ Region Name	Varieties	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Total carbohydrate (%)	Total fiber (%)	Reference
1.	Mexico	Gordo with white kernels (RG-w)	83.64 (fw)	16.7 (dw)	0.9 (dw)	5.0	70.9	53.3	Mendoza-Lopez et al., (2018)
		Cónico with red kernels (RC-r)	82.37 (fw)	16.6 (dw)	1.1 (dw)	5.9	68.9	44.9	
		dark red kernels (RC-dr)	85.50 (fw)	14.3 (dw)	0.9 (dw)	5.7	69.3	39.5	
		white-blue kernels (RC-wb)	88.38 (fw)	14.1 (dw)	1.8 (dw)	5.8	68.1	39.4	
		Cristalino with yellow kernels (RCr-Y)	85.93 (fw)	19.1 (dw)	1.6 (dw)	6.1	65.1	43.9	
2.	Malaysia	Baby corn (Immature silks)	89.31 (dw)	12.96	1.27	5.28	27.80	48.50	Rahman and Rosli (2014)
		Sweet corn (Mature silks)	84.42 (dw)	8.95	0.66	5.51	29.74	51.24	
3.	Indonesia	Bisma	11.58 (db)	17.70 (db)	0.30 (db)	3.29 (db)	67.13 (db)	--	Haslina et al., (2017)
		Arjuna	14.66 (db)	12.89 (db)	0.13 (db)	2.66 (db)	69.54 (db)	--	
		Srikandi Putih	8.09 (db)	14.87 (db)	0.21 (db)	3.33 (db)	73.53 (db)	--	

fw= fresh weight; dw= dried weight;
db= dry basis

Table 2.2 Phytochemical composition of different varieties of corn silk grown in different regions worldwide

Country/Region Name	Varieties	Total polyphenolic content (µg GAE/g)* (CGAE/100g)** (mg GAE/g)*** ($\mu g.g^{-1}$ dw^{-1})****	Total flavonoid content (µg RE/g)# (mg CE/100 g)## (mg CAE/g)###	Reference
Thailand	PWC1 (R1, R4, R6 stage)	123.8, 179.6, 149.1*	83.6, 104.6, 100.0#	Sarepoua et al., (2013)
	PWC2 (R1, R4, R6 stage)	112.8, 169.2- 114.7*	74.1, 99.8, 61.8#	
	PWC3 (R1, R4, R6 stage)	127, 185.3, 147.4*	74.4, 94.5, 86.8#	
	PWC4 (R1, R4, R6 stage)	115.6, 147.7, 134.6*	99.0, 129.2, 105.3#	
	PWC5 (R1, R4, R6 stage)	173.4, 206.8, 187.1*	121.5, 136, 101.4#	
	WWC1 (R1, R4, R6 stage)	99.8, 57.3, 26.5*	57.6, 35, 33.2#	
	WWC2 (R1, R4, R6 stage)	89.6, 56.8, 47.6*	50.9, 35.7, 33.6#	
	WWC3 (R1, R4, R6 stage)	85.9, 56.7, 36.1*	87.4, 35.7, 33.8#	
	SSC1 (R1, R4, R6 stage)	85.5, 75.2, 65.5*	117.6, 90.3, 65.5#	
	SSC2 (R1, R4, R6 stage)	69.4, 78.3, 69.4*	119.1, 92.2, 69.2#	
Serbia	ZP Exp (5 days of emergence)	8101.6**	5565.3##	Zilic et al., (2016)
	ZP Exp (25 days of emergence)	3958.9**	3594.2##	
	ZP 555 (5 days of emergence)	8382**	5608.7##	
	ZP 555 (25 days of emergence)	2093.9**	1840.1##	
	ZP 341(5 days of emergence)	10160.8**	6478.3##	
	ZP 341(25 days of emergence)	4347.2**	3644.9##	
	ZP 366 (5 days of emergence)	8372**	5514.5##	
	ZP 366 (25 days of emergence)	3674.7**	2985.5##	
Malaysia	Baby corn (Immature silks)			
	Water	35.35***	8.40###	
	Ethanol	92.21***	7.55###	
	Ethylacetate	6.70***	0.66###	
	Sweet corn (Mature silks)			
	Water	64.22***	2.31###	
	Ethanol	49.88***	1.96###	
	Ethylacetate	4.26***	2.10###	

Portugal	--	Chlorogenic acid- 42.4**** Caffeic acid- 13.7**** Ferulic acid- 48.1**** Apigenin- 7.9**** Pelargonidin- 2.6****		Aires and Carvallo (2016)
Malaysia	Big Fruit (young corn ears)	79.61***	9.31###	Ho et al., (2016)
	Big Fruit (Corn silk)	86.26***	14.66###	
	Supersweet (young corn ears)	82.85***	10.65###	
	Supersweet (Corn silk)	136.32***	26.63###	
	Bi-color (young corn ears)	92.64***	14.41###	
	Bi-color (Corn silk)	143.58***	18.14###	
Indonesia	Bisma	8262.93*	236.03*	Haslina et al., (2017)
	Arjuna	6331.15*	178.33*	
	Srikandi Putih	3367.10*	136.36*	

PWC= Purple waxy corn; WWC= White waxy corn; SSC= Super sweet corn
R1= Baby corn stage; R4= Immature stage; R6- Physiologically matured stage
***= µg GAE/g ; **= CGAE/100g**
#=(µg RE/g); ##= (mg CE/100 g)
***=mg GAE/1g

Table 2.3 Nutritional composition for corn silk

Nutritional component	Amount (% dry basis)
Moisture (oven-dried)	3.90±0.22
Crude lipid	0.66±0.17
Crude protein	8.95±0.21
Ash	5.51±0.24
Carbohydrate	29.74±1.26
Total dietary fiber	51.24±1.50

Source: Rahman et al. (2014)

Table 2.4 Mineral compositions for corn silk

Minerals	Amount (µ/g)
Calcium (Ca)	707.04±94.4
Magnesium (Mg)	361.50±20.53
Potassium (K)	35671.67±2466
Sodium (Na)	266.76±15.65
Copper	4.12±0.38
Iron	4.50±0.49
Manganese	35.57±2.26
Zinc	35.92±4.24

Source: Rahman et al. (2014)

Antioxidant potential

The antioxidant potential are shown in Table 2.5. The relationships between phytochemicals and antioxidant activity in corn silk were studied by Sarepoua et al., (2013). Their objective was to evaluate variability for the contents of phenolic compounds, anthocyanin, flavonoid and their antioxidant activities. Ten different corn hybrids were evaluated with three replications. Variations was observed in all the different corn silk varieties. They observed that purple waxy corn had the highest content of total phenolic content, Total flavonoid content and total antioxidant activity. The highest antioxidant activity was observed in purple waxy corn and baby corn. The study concluded that both of the varieties are superior for corn silk production for the use in the functional food, nutraceutical industries and for breeding program in the future.

The variability in phytochemicals, at three maturity stages of different varieties of corn silk were studies by Sarepoua et al., (2015). Data was recorded for total phenolic content (TPC), total flavonoids (TF), total anthocyanins (TA), and the antioxidant activity (AA) with the help of DPPH free radical scavenging assays. During milky stages, TAC and TPC were highest. On the other side TF and AA were highest at silking stage.

The anti- oxidant effect of corn silk ethanolic extract (MSE) against the oxidative damage, in vivo conditions were analysed by Bai et al., (2010). The oxidative stress was induced in male rats via $^{\gamma}$-radiations. The changes were observed in malondialdehyde (MDA), glutathione/ glutathione disulfide ratio (GSH/GSSG), in blood cells, as well as in the antioxidant enzymes. It was found that the radiation elevates the levels of MDA, decrease in the levels of GSH/GSSG and haematological abnormalities. The administration of corn silk ethanol extract (MSE) has shown significant abolishment of MDA levels in liver. The study indicates the effectiveness or protective property of MSE against the oxidative stress. As a result, the findings were proven to improve the radiation induced oxidative tissue damage in an efficient manner. The protective effect of MSE was found as liver specific. The up regulation of Nrf2 observed as a defense mechanism.

Corn silk has been utilized as natural treatment for many problems (Lopez et al., 2017). The polysaccharide and polyphenolic content of silks is attributed as the reason for its biological activity. The antioxidative and compositional properties of the silk for three races of corn were investigated. Those three races, native to Mexico are mentioned as Conico, Gordo and Cristalino. The phenolic content including flavonoids and anthocyanins and their antioxidant capacity in Conico silks were found higher than any other hybrid maize varieties, founds as 32.530,26.024,0.156 gm/kg respectively. The flavonoids named as maysin was recorded in the silks of landrace Conico, was absent in other two varieties. The polysaccharide amount was found in landrace Cristalino in highest amounts.

The different extraction methods of the flavonoids obtained out of the corn silk by Tian et al., (2021). While harvesting the corn, silk act as a discarded material as it includes some compounds like polysaccharides, flavonoids, sterols, trace elements, volatile oils and some multivitamins. The wastage of such stuff pollutes the environment but along with that also waste the useful resources. The study highlights some of the common extraction methods, utilized as an extraction of flavonoids from the corn silks. The methods mentioned as enzymatic methods, reagent method, and microwave, supercritical CO_2 extraction, ultrasonic and microwave- assisted ultrasonic. Flavonoids have potency to inhibit bacteria and are also capable of scavenging free radicals and in the regulation of blood lipids. The 29 flavonoids were isolated from the corn silks.

The carotenoid content of eight samples of corn silk were analysed and the samples

were taken from the landraces in South Brazil (Kuhnen et al., 2012). The carotenoid extraction was done with a MeOH/ toluene solution in the ratio of 1:1 v/v for 30 minutes and later saponified. The saponification was performed with 15 % of KOH for 12 hours of duration under the 40° C. The RP-HPLC- UV technique of visible analysis was attempted. The revealed results stated that the Lutein as main carotenoid as 88.75% out of total was identified in the silk. The carotenoids such as carotene and zeanthin were found in smaller quantities. The lutein was found as a remedy treatment for many ailments. It has been proved effective in the reducing chances of macular degeneration. The lutein- rich extract is found as an underutilized biomass.

The variability shown for the content of phenolic compounds, anthocyanin, flavonoid and antioxidant properties present in the corn silk by the Sarepoua et al., (2013). Three replications were taken of 10 corn hybrid varieties. The determination of total phenolic content (TPC), total flavonoids content (TFC). The values recorded for TPC were found between 80.8- 117.1µg GAE/ g of dry samples, TFC ranges from (102.2-105.7 µg GAE/g). There were variations observed in different corn silk verities. One of the varieties called Purple waxy corn was recorded with the highest content of TPC, TFC. The corn silk variety purple waxy corn was found superior production to be utilized in the nutraceutical or functional food industries and for breeding programme for the future use.

Nawaz et al. (2019) stated corn silk as a less utilized part of the corn and possesses great medical importance. His study determined the phytochemical composition as well as antioxidant potential for the corn silk extracts by increasing polarity with a series of solvents. The study uses three extraction methods; individual extraction, consecutive extraction in solvents of increasing polarity, consecutive extraction via crude methanolic extract in solvents. The results depicted the presence of bioactive phytochemical compounds which includes phenolic acids, flavonoids, ascorbic acid, tannins and cardiac glycosides. The extraction of phytochemicals was found more in high polarity solvents, having fair phytochemical composition and is potent antioxidants.

The difference in antioxidant content represents that the total phenolic and flavonoid content varies according to maturity. The difference in solvents during the analysis also plays a critical role. Corn silk is enriched with numerous amounts of phytoconstituents and the major compounds are summarised in Table 3. Corn silk shows high polyphenolic content as shown by Sarepoua et al. (2015) in their study of purple maize grown in Mexico. Ten

different corn hybrids including five purple waxy corns, two super sweet corns and three white waxy corns at different growth stages (R1 harvested at silking stage; R4 harvested at immature stage and R6 harvested at physiological maturity stage were evaluated for phytochemical constituents. The total phenolic content increased from 26.5 to 206.8 µg GAE/g of dry samples from R1 to R6 stage as shown in Table 2. The purple waxy corn showed the highest percentage of total phenols among all the other hybrid varieties. They suggested that collecting sample at silking and immaturity reproductive stage gives best results if considered for phytochemical constituents. In a similar study Zilic et al. (2016) assessed four Serbian hybrid corn silk varieties (ZP Exp, ZP 555, ZP 341 and ZP 366) for their phytochemical compounds and compared it with different medicinal herbs and concluded that the corn silk at immature stage (R1stage) has highest total phenolic and flavonoid content which is suitable for its incorporation in food or tea preparation as compared to dough (R4 stage). The polyphenols shows hypoglycemic response that leads to reducing blood glucose levels (Zhang, et al., 2016). Immature and corn silk at baby corn and sweet corn stage grown in Malaysia was studied by Rahman and Rosli (2014) for the difference in their antioxidant potential and they reported that the immature corn silk showed the highest value for moisture, protein and lipid than matured silk but the ash content, total fiber and total carbohydrate was reported to be high in matured corn silk than immature silk. The polyphenolic content for ethanolic extract of immature corn silk showed the significantly highest value and for mature silk water extract reported to be high. For flavonoid content, the immature silk and mature corn silk extracted in water showed the highest value.

Aires and Carvalho (2016) evaluated the polyphenols and antioxidant capacity of corn silk by ultrasound extraction method and mentioned the presence of ferulic acid, chlorogenic acid, caffeic acid, apigenin and pelargonidin out of which apigenin is responsible for inhibiting the cancer growth in pancreas, regulating lipids and glucose levels and ameliorate vascular dysfunction in type 2 diabetic population (He et al., 2015) and pelargonidin and related isomers helps in reducing postprandial inflammation and protect against insulin sensitivity (Edirisingh et al., 2011).

Six samples of three Malaysian corn silk varieties were evaluated for phytochemical constituents (Big Fruit, Supersweet and Bi-color) at young corn ears and corn silk stage. Bio-Co corn silk showed the highest polyphenolic content as compared the other two varieties and

for flavonoid content corn silk of the superweet variety showed the highest value in comparison to other samples.

Table 2.5 Bioactive phytochemical components and nutritive composition of corn silk

Class of phytochemicals	Phytochemical components	Amount present	Functions possessed by phytochemical components	References
Polyphenols	Tannins, flavonoids, saponins, alkaloids, cardiac glycosides, steroids, anthocyanins, allantoins, hesperidin and resins, antioxidant	Total phenolics- 8101.6± 73.5 to 10160.8±250 mg CGAE/100g Flavonoid- 5565±40.9 to 6478.3±409.9 mg CE/100g Anthocyanins- 192.9±0.3 mg CGE/100g Proanthocyanidins- 69.4±6.6	Antioxidant, anti-inflammatory, prebiotic property and act as vasodilator	Emmanuel et al., (2016) Zilic et al., (2016) Landete, 2012
Phenolic acids	Vanillic acid, Para-aminobenzoic acid (PABA), chlorogenic acid, protocatechuic acid, caffeic acid, maizenic acid, hydroxycinnamic acid ester, ferulic acid and 3-O-caffeoylquinic acid	3-O-caffeoylquinic acid- 22.6±0.9 to 49.9±1.4 mg/100 g	Inhibit oxidative damage diseases including coronary heart diseases, cancer, stroke. Antibacterial activity, anti-inflammatory, anti-allergic properties.	Zilic et al., (2016) Goleniowski et al., 2013
Flavonoids	Catechin, protocatechin, quercitin, rutin, 3, 4, 5, 7-hydroxy flavones and isoflavones, cardiac glycosides, Maysin derivatives, methoxymaysin derviative	Rutin- 0.1398 mg/L Quercitin- 0.11 mg/L Maysin derivatives- 1.1±3.6 (593 m/z) Methozymaysin derivative- 1.2±0.1 to 4.9±0.3	The antioxidative capacity of flavones exhibits property against prevention of cancer and coronary heart diseases, osteoporosis, neurodegenerative diseases and postmenopausal bone loss	Ismael et al., (2017) Panche et al., (2016)
Carotenoids	B-carotene and zeaxanthin	Total carotenoid count= 11.3 mg CGE/100 g dw (ethanolic extract)	Treat cardiovascular diseases, cancer, eye related disorders, protects skin and show high antioxidant power and reduces oxidative stress	Laeliocattley et al., (2014) Fiedor and Burda (2014)
Sterols	Stigmasterol and beta-sitosterol	10.5886 mg/g 963.86±198.39 to 1783.37±57.70	Regulation of membrane permeability and fluidity, control metabolic process, substrate for synthesis of secondary metabolites and precursor in cellular and developmental process	Zhang et al., (2017) Haslina et al., (2017)

Tannins	Gallotannins and phlobatannins	-	Improves cardiovascular health, inhibit atherogenesis, treat ischemia, reduce platelet aggregation and lipid peroxidation	Hu et al., (2011) Avila et al., (2018)
Vitamins	Vitamin C, E and K	-	Reduces oxidative stress, helps in collagen synthesis, prevents cancer, sepsis and neurodegenerative diseases, prevents blood clotting and oxidation of LDL	Rahman and Rosli (2014) Traber and Stevens (2011)
Minerals	Sodium, Potassium, Calcium, Magnesium, Copper, Iron, Manganese, Zinc	Sodium- 12.5±0.5 to 28.9±0.3 mg/100 g Potassium- 1359.9±46.6 to 1832.6±37.5 mg/100 g Calcium- 0.1465 mg/g Magnesium- 0.1602 mg/g Copper- 0.0072 mg/g Iron- 0.0198 mg/g Manganese- 0.0187 mg/g Zinc- 0.0136 mg/g		Zilic et al., (2016) Emmanuel et al., (2016)
Sugars	Fructose (Dried corn silk) Glucose (Dried corn silk) Sucrose (Dried corn silk)	14.20 ± 0.12 22.20 ± 1.10 4.40 ± 0.20		Rosli and Rahman (2015)
Miscellaneous compounds	Polysaccharides (galactan), terpenoids, apigenin, anthraquinones, xanthoproteins	-		

The difference in the values might be due to genetic variations and good exposure of sunlight to these varieties (Ho et al., 2016). Three local varieties of Indonesian corn silk (powdered) varieties (Bisma, Arjuna and SrikandiPutih) were studied for their chemical and phytochemical properties and the result showed that Bisma possessed the highest content of protein and fat. The difference in the proximate values were due to genetic variation, growing conditions, soil fertility, harvesting time, storage conditions and production process. The highest moisture content was showed by Arjuna and Srikandi Putih had high content of carbohydrate and ash content. The difference in the proximate content is due to the accumulation of hydrocarbons at a stage of maturity which affects lipid composition and the change in protein content is due to biosynthesis and functioning of amino acids during the growth process. Bisma had highest polyphenolic and flavonoid content than the other two varieties of dried corn silk (Haslina et al., 2017).

The medicinal and pharmaceutical importance of plants is usually recognized by its antioxidant potential. Corn silk shows diversity in the phytochemical content and has high antioxidant activity, including free radical scavenging activity, ferric reducing antioxidant power, ABTS radical scavenging activity and xanthine oxidase as shown in Table 2.4 Hu et al., (2011) has suggested extracts of corn silk improves the antioxidant status of organs by stimulating the antioxidant enzymes activity.

Corn silk has been recognized for its medicinal value for the treatment of prostate problems in China, and to treat urinary tract infections, malaria and heart problems with the Native Americans (Hasanudin et al., 2012). Based on traditional remedies, Chinese has been using CS as an oral anti-diabetic agent for decades (Guo et al., 2009). However, there were some studies related to the mechanism of underlying hypoglycaemic activity of corn silk, but data regarding its anti-diabetic and anti-hyperglycaemic activities are very limited. The presence of diterpenes consisting of carnosic acid and carnosol acting glitazones, makes it suitable for treating diabetes (Rao et al., 2006). The impact of extracts of corn silk on liver markers and plasma glucose of rabbits was studied by Olaniyan and Fadare (2014). Fifteen rabbits were divided into three groups and each group was fed with no extract (control), aqueous and methanolic extract respectively. The methanolic and aqueous extract of corn silk significantly reduced the blood glucose levels as compared to the control group. They reported that the lowering of blood glucose level is due to the presence of phytochemicals like flavonoids, alkaloids, tannins and saponins in corn silk.

Table 2.6 Antioxidant activity of corn silk

Type of Antioxidant activity (AA)	Extracting solvent	% inhibition	Reference
Free Radical Scavenging Activity (FRSA)	Water	195.21±7.48	Rosli and Rahman (2015)
	Ethyl acetate	411.69±9.57	
	Ethanol	68-84	El-Ghorab et al., (2007)
	Methanol	143.55±4.67	Sarepoua et al., (2013)
ABTS	Water	829.00±94.26	Rosli and Rahman (2015)
	Ethyl acetate	2870±112.30	
	Methanol	349.07±15.15	
	BHT/Trolox	131.77±16.25	
Ferric reducing Antioxidant Power (FRAP)	Water	35.01	Nurhanan & Rosli (2012)
	Methanol	56.41	Ho et al., (2016)
	Ethanol	38.90-65.46	
	Ethyl acetate	27.21%	
Xanthine Oxidase (XOD)	Water	1174±150.13	Rosli and Rahman (2015)
	Methanol	261.41±12.55	
	Ethyl acetate	412.17±12.97	

The flavonoids of corn silk were studied for anti-diabetic, anti-oxidant and anti-hyperlipidemic effects by Zhang et al., (2015). The streptozotocin induced diabetic mice were fed with crude flavonoids extracted from corn silk. The total dose of 160 mg/kg of body weight of streptozotocin was mixed in 0.1 mol/L cold citrate buffer of pH 4.2 was given in the abdominal cavity of the mice and the level of blood glucose was recorded on every sixth day. The different groups included, non-diabetic control (NC), non-diabetic corn silk flavonoids high dose group (CS), diabetic control group (DC), diabetic dimethyl biguanide group (PC), diabetic corn silk flavonoids low dose group (LD), diabetic corn silk flavonoids medium dose group (MD) and diabetic corn silk high dose group (HD). The observation stated that the blood glucose levels were reduced in PC, MD and HD groups as compared to the control groups which shows that the ingestion of corn silk flavonoids (300 mg/kg and 500 mg/kg) can possess blood glucose lowering property in diabetic population. The insulin resistance in hyperglycaemic patients causes impaired GLUT4 mechanism which further leads to poor uptake of glucose by the cells (Alam et al., 2016). Corn silk proved to be helpful in increasing the uptake of glucose by showing peripheral action. The *in vitro* study to check the effect of corn silk on glucose uptake by isolated rat hemi-diaphragm was conducted by Ghada et al., (2014). Adults and healthy rats were divided into groups of six rats each and were killed by decapitation. Further, diaphragms were taken out and incubated with 2g % glucose and 2 ml of tyrode solution. Four sets of experiments were performed as a control (tyrode solution and 2% of glucose), insulin (0.25 U/ml), methanolic corn silk extract (200mg/ml) and mixture of insulin and corn silk extract. The result depicted that corn silk extract showed the highest and enhanced uptake of glucose (109 mg/g/30 minute) by isolated rat hemi-diaphragm significantly ($p<0.001$) in comparison with insulin (49 mg/g/30 min).

Due to its high flavonoid activity, the antimicrobial activity of corn silk in comparison with gentamicin was studied by Nessa et al., (2012). The investigation of the antimicrobial activities of different solvents of flavonoids present in corn silk was pursued and compared with the activities of standard antibiotic gentamicin. The extracts prepared included petroleum ether (PECS), chloroform (CECS) and methanol (MECS) of corn silk and testes on twelve pathogenic bacteria, including *Salmonella typhi, Enterobacteraerogenes, Escherichia coli* and one yeast *Candida albicans* for antimicrobial activity. For testing antimicrobial activity, two isolated flavonoid glycosides (2.0 mg/mL) were used. The agar hole-plate diffusion method showed that PECS, MECS and flavonoids showed the antimicrobial activity against eleven bacteria (except *Escherichia coli*) out of twelve bacteria

(*Bacillus cereus, Bacillus subtilis, Staphylococcus aureus, Pseudomonas aeruginosa, Enterobacteraerogenes, Salmonella typhi, Salmonella paratyphi, Escherichia coli, Shigellasonnei, Shigellaflexneri, Proteus vulgaris, Proteus mirabilis and one yeast Candida albicans*). The significant ($p<0.05$) difference with higher sensitivity was reported against a number of bacteria than gentamicin.

The antioxidant activity of corn silk

The antioxidant activity of corn silk includes free radical scavenging activity, ABTS, ferric reducing antioxidant power and xanthine oxidase which helps in the treatment of non-communicable diseases like diabetes, cancer, obesity and cardiovascular diseases. The pharmaceutical application of corn silk is possible because of the diversity of antioxidants present in it. The antioxidant activity of corn silk as shown in Table 2.6 depicts the different antioxidant activity with different solvents. The hypoglycemic effect of corn silk flavonoids on alloxan-induced diabetic mice and the result included reduction in level of blood glucose due to the presence of flavonoids and also the significant reduction was observed in body weight of the diabetic mice. In addition, flavonoids present in corn silk also improves the effect on the activity of superoxide dismutases. The high antioxidant activity of corn silk in combination with Binahong leaves improves the function of β-cells and hence provides hypoglycemic response (Sukandar et al., 2013).

The gamma-irradiated corn silk was investigated in male albino rats for its hypoglycemic and hypolipidemic properties. The significant increment was observed in total phenolic content and total antioxidant activity as a result of irradiation. The damage effects were reduced by increasing the level of insulin, glutathione content, high density lipoprotein and the activity of superoxidase dismutase and catalase. The significant decrease was observed in the glucose level and malondialdehyde (Hamza et al., 2013).

The low levels of antioxidants and glutathione in islets of Langerhans contributes to the accumulation of reactive oxygen species during diabetes (Masuda et al., 2015). Advanced Glycation End products (AGEs) are produced by non-enzymatic glycosylation of proteins which is responsible for creating abnormalities in cells and tissues. AGE helps in improving vascular permeability by adhering to the specific macrophage receptor which further causes the free radical production and endothelial dysfunction (Khan et al., 2012). They are the cause of various diseases including aging and diabetes. The plant derivatives are known for

inhibiting non-enzymatic glycation and the formation of the AGEs. The corn silk contains high amount of flavonoids and total phenols which shows the similar property as studied by Farsi et al., (2008). Thirteen modern maize inbreds and one land race were examined for *in vitro* inhibition of non-enzymatic glycation of bovine serum albumin. The highest genotype (CO441) activity displayed an IC_{50} of 9.5 μg/mL in comparison with aminoguanidine which is a potent inhibitor of glycation. The corn silk possessed this property because of the presence of total phenols. They concluded that high phenolic maize inbreds act as a potent component for the development of natural AGE inhibitors which further prevents and treat diabetic related complications and degenerative effects related to ageing. Oxymatrineis an alkaloid from the class quinolizidine found in the root of Sophora flavescens, reduces the blood glucose, blood urea nitrogen, serum creatinine, urinary protein and albumin excretion in T2DM high fat diet streptozotocin (HFD-STZ) nephropathy model when oral dose of 150 mg/kg/day for 11 weeks were given to the rats (Oza et al., 2016). The oxymatrine is responsible for reducing content of renal AGEs, transforming growth factor- β1 in diabetic rats (Guo et al., 2014). The presence of alkaloid is reported by Limmatvaprit et al., (2020) in the ethanolic extract of baby corn silk.

Polysaccharides have a pronounced effect on delaying the rate of glucose absorption and hence helps in reducing postprandial hyperglycemia. Galactomannan isolated from tubers Amorphophalluskonjac and seeds of Cyamopsistetragonolobus and inulin from Helianthus tuberosus are well known polysaccharides used as remedy for diabetic treatment (Khan and Yadava, 2010; Tarak et al., 2011). Corn silk polysaccharides were also well known for anti-diabetic property and Zhao *et al.,* (Zhao et al., 2012) has utilized the corn silk polysaccharides (POCS) extracted by distilled water and analyzed it for anti-diabetic property on streptozotocin induced diabetic rats. The result showed that 100-500 mg/kg body weight of POCS significantly decreases the blood glucose level compared to the control group.

Corn silk extract for 12 weeks to Orlistat induced obese mice were studied by Ahmed et al., (Ahmed et al., 2016) and the results revealed a significant decline ($p<0.05$) in the glucose level, insulin resistance value, serum insulin levels and the body mass index of HCD fed group with aqueous or methanolic extract of corn silk. The study stated in that the *presence* of phytochemicals are responsible for hypoglycaemic, anti-obesity, hypoglycemic and anti-inflammatory properties.

The analysis of nutrient and phytochemical content in corn silk (*Zea. Mays*) was conducted by Bhuvaneshwari and Sivakami (2017). They stated that dietary plants contain huge amount of antioxidants which helps in scavenging free radicals from the body which get accumulated after taking part in normal physiological functions. Different drying methods like sun drying, shadow drying and microwave drying were used for drying the corn silk. They reported that corn silk can be used as a novel natural antioxidant as well as flavoring agent for food products. It has higher amount of fibre (6g/100g) and low fat (0.36 g/100g). Total antioxidant activity and total phenolic content were analyzed and it was found that phenolic content of shadow dried corn silk was high of about 1.33 mg/g when compared to microwave dries corn silk (1.20 mg/g) and sun-dried corn silk (0.85 mg/g). The antioxidant activity in was observed less in sun dried corn silk (5.61 mg/g) as compared to other samples (using other drying techniques).

History and usage of corn silk was acknowledged by Zhang et al., (2020). They recommended that polysaccharides are known to be one of the most bioactive components presents in corn silk. These polysaccharides hold various properties like immune-enhancement, antioxidant, antitumor, anti-fatigue, diuretic, antihyperglycemic, and liver protection etc. They included all the recent advancements for extraction, purification, knowing structural characteristics of polysaccharides present in corn silk. They also explained the biological activities portrayed by corn silk.

Li et al., (2019) conducted their study in Jilin province in China, which is one of the golden Corn Belt worldwide. Corn silk polysaccharides (CSP) were extracted from corn silk and were divided into three proportions i.e CSP1, CSP2, CSP3. Corn silk polysaccharides are used as an anti-diabetic. Their molecular weights were measured. These CSP contained arabinose, xylose, galactose and glucose. CSP were divided into CSP-S-1 and CSP-S-2 through column chromatography. CSP-1 contained galactose, arabinose, xylose and rhamanose while CSP-2 contained glucose, galactose, arabinose and rhamanose. Through further testing on these polysaccharides, CSP-S-2 containing galactose, arabinose, glucose, and rhamanose possessed highest potential to be considered as a novel antioxidant and also being effective as anti-cervical cancer agent.

The effects of adding corn silk fibres to the soil and checking the mechanical properties of that cemented soil by conducting, compaction, compression and splitting tensile tests were studied by Tran et al., (2018). Different parameters were counted like fibre

content, curing time, compressive strength, & tensile strength. As the results were concluded, they found that adding corn silk threads to the soil improved compressing and tensile strength. The most effective parameter is the cement content if talking on the basis of the performed study and experiment.

2.2 PRODUCTS FROM CORN SILK

In Corn processing, corn silk was usually regarded as waste (Maksimović et al., 2005). Also in recent times, Corn silk products such as tea, powder and cosmetics are being commercialized by the countries like china, Korea, USA and UK. There are uncountable opportunities for the conversion of such waste into value- graded products derived from the corn (Sarepoua et al., 2013). The study conducted by Shi et al. (2019) provided the first evidence-based approach for the CST which stands for corn silk tea as a hypertension treatment. The treatment is likely to be prioritized for the preclinical and clinicalstudies. The study stated that the CST + hypertensive drugs in a combination exert more effect and aid in lowering the blood pressure when compared to the conventional antihypertensive drugs alone.

Corn silk incorporation in chicken patties were studied by Rosli et al. (2011). Corn silk (*Zea mays* Hairs) has found to improve the nutritional quality and physical traits without affecting sensory properties of chicken patties. The different concentration of 2%, 4% and 6% grounded corn silk were added in patties and it was found that protein content was increased in both raw and cooked patties. Cooked patties incorporated with 6% corn silk shows the highest protein content of 28.42% and the lowest fat concentration at 14.60 %. The highest cooking yield of 83.03% was observed in chicken pattie incorporated with 6% corn silk. They concluded that corn silk fibre has showed increased cooking yield and retained moisture and fat of chicken patties. The addition of corn silk does not change the acceptability of the chicken patties.

The stabilization of neem oil biodiesel with corn silk extract during long term storage were analysed by Ali and Anany (2017). The antioxidant efficiency and impact of corn silk on oxidative stability of biodiesel was studied. The highest phenolics, DPPH radical scavenging and reducing power activities were recorded for methanol-water extract. They reported that longest oxidative stability of 10 hour was observed for biodiesel samples blended with 1000 ppm of corn silk extract.

2.3. THERAPEUTIC PROPERTIES OF CORN SILK

Silk has been utilized as a medicinal remedy from Chinese traditional point of view. It has been validated to cure liver disorders, as a diuretic as well as effective for kidney disorders (Aukkanita *et al.* 2015). Luteolin, apigenin and formononetin are the free flavonoids present in corn silk, and Rhamnose, Arabinose, Xylose, Mannose, Galactose and glucose are the monomeric groups of polysaccharides present in the corn silk (Guo et al., 2019). It has been utilized as therapeutic remedy for the procurement diabetes due to the presence of corn silk polysaccharide silk is able to inhibit α- amylase activity, improve insulin effect and restoration of β- cells is done. Antibacterial activity is validated by corn silk due to the presence of maysin, maysin-3' methyl ester, existing flavonoids in corn silk. Native Americans have utilised corn silk as an effective remedy for malaria, urinary tract infection and heart problems (Hasanudin et al., 2012). It is responsible for the better functioning of kidney and therefore renal protective action is induced by decreasing the lipid peroxidation (Karami et al., 2013). The properties of corn silk extract like anti- inflammatory, hypoglycaemic, hypotensic and hypocholterolemic due to the presence of corn silk flavonoids has been confirmed in the silk. Corn silk is validated for exerting antihypertensive effect (Shee et al., 2019).

Maysin act as bioactive flavonoid and, is responsible in weight reduction thus aids in obesity Antifatigue activity by corn silk flavonoids (CSFs) are responsible for lowering the blood lactic acid at the time of exercise as well as retard the formation of BUN (blood urea nitrogen) (Wang et al., 2012). The presence of flavonoid 'maysin' in corn silk has an important bioactive compound called as luteolin which is responsible for exerting antioxidant, antiallergy and anticancer activities (Lee et al., 2016). Maysin also contributes in neuro- protection, exerting anti- apoptotic activity (Lee et al., 2014). Corn silk polysaccharide has validated to exert antitumor activity via enhancing the capacity of immune response (Wang et al., 2012).

2.4 ANTI-DIABETIC POTENTIAL OF CORN SILK

Mechanism of hypoglycaemic response of corn silk

The corn silk in the form of extracts exhibits hypoglycaemic response not only by increasing the insulin level and recovering injured beta cells but also increasing glycogen and inhibiting gluconeogenesis (Guo et al., 2009). The details regarding the mechanism of corn silk are shown in Figure 2.2.

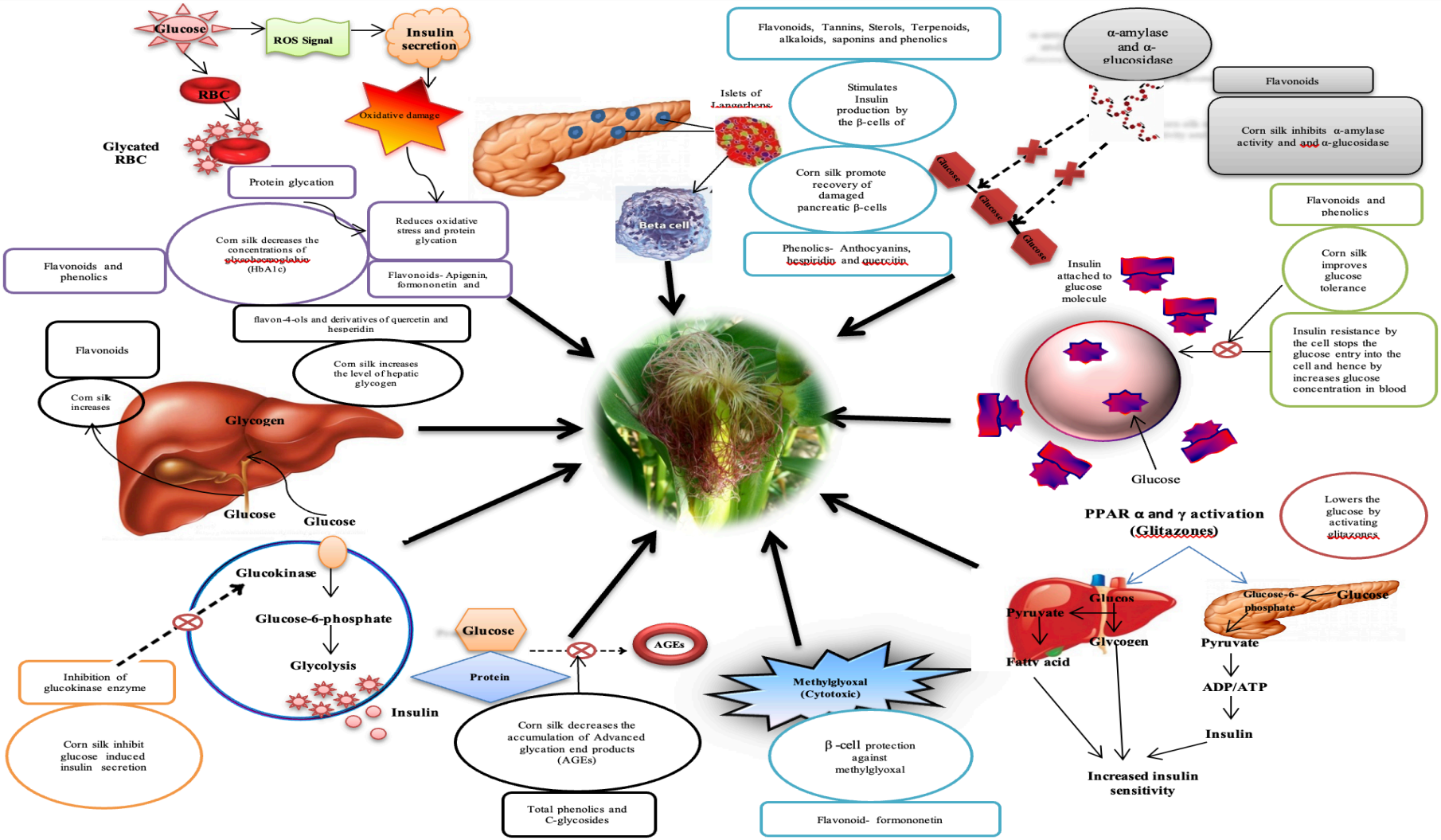


Figure 2.2. Anti-diabetic mechanism and their responsible phytoconstituents of corn silk [Sources: Sani (2016); Chen et al. (2013); Shafi and Tabassum (2013); Vemuri et al. (2018); Farsi et al. (2008); Pan et al. (2017); Ahmed et al. (2016); Chang et al. (2016)]

Corn silk increases glucose uptake, improves glucose tolerance and increases hepatic glycogen by inhibiting glucokinase

Phenolic compounds responsible for enhancing the glucose uptake by the help of mediators, the insulin-signalling pathways and also reduces the intestinal absorption of glucose, regenerate β-cells and act on adipose cells which further stimulate insulin activity [69].Phenolics like Butein isolated from plant species like *Dalbergiaodorifera, Semecarpusanacardium, Toxicodendronvernicifluum, Cyclopiasubternata* and *Creopsistungtoria* helps in improving the blood glucose level by inhibiting the central NF-*k*B signalling pathway (Shahreen et al., 2012). Curcumin, an another polyphenol reduces the blood glucose level and also the levels of glycosylated haemoglobin. It was also reported that Curcumin also helps in reducing diabetes associated complications like diabetic neuropathy, nephropathy, fatty liver, vascular diseases, musculoskeletal and islet viability (Rangika et al., 2015; Doss et al., 2009; Olaokun et al., 2014). Cholorogenic acid, ellagic acid, Emeblin, Erianin, Gambogic acid and Honokiol are some of the polyohenol present in various plant species imparts the hypoglycemic potential bystimulating glucose transport in sekeltal muscle, stimulating the insulin secretion, reducing the elevated plasma glucose, glycosylated haemoglobin and increasing phosphorylations and downstream insulin signalling factors respectively (Ong et al., 2012; Fatima et al., 2017; Yu et al., 2016; Cui et al., 2018). *In vitro* study of peripheral uptake of glucose was estimated by Ghada et al., (2014) where they analysed the effect of the methanolic extract of corn silk on glucose uptake by isolated rat hemi-diaphragm and reported the enhancement in glucose uptake (100 ±1 mg/g/30 minutes) in comparison to insulin (49±8 mg/g/30 minutes). They reported that the methanolic extract of corn silk significantly enhanced the uptake of glucose and found to be more effective than insulin. Similarly, another hypoglycaemic effect of corn silk is shown by increasing the hepatic glycogen level as depicted by Guo et al., (2009). The blood glucose concentration in mammals is maintained by glycogen stored in liver also known as hepatic glycogen. Corn silk extract has reported to increase the liver glycogen in alloxan induced mice by 17.0±4.2 mg/g tissue in comparison to saline treated mice 14.2±3.4 mg/g. They also reported significant ($p<0.05$) decline in blood glucose level after the administration of corn silk extract (11.5±2.1) when compared with Xiaoke pill (Chinese hypoglycaemic drug) (13.4±3.0).Corn silk inhibits glucokinase activity, hence, discouraging glycolysis and promoting glycogen formation (Guo et al., 2009).

The anti-diabetic activity of aqueous extract of *Acacia tortilis* polysaccharide (AEATP) were investigated by Kumar and Singh (2014) . After seven days of administration of AEATP, the blood glucose levels of streptozotocin-nicotinamide male albino Wistar rat significantly reduced. Similarly, hypoglycaemic effects of corn silk polysaccharides were studied in streptozotocin (STZ) induced diabetes mice and different crude polysaccharides were prepared on the basis of molecular weight (PCS1, PCS2 and PCS 3) (Pan et al., 2017). They analysed antioxidant activity, α-amylase inhibitory activity andphysico-chemical properties. They reported that PCS2 with total neutral polysaccharide content 50.1±4.1% showed the highest DPPH scavenging activity and α-amylase inhibitory activity in comparison to PCS1 and PCS3. The insulin levels also decreased significantly ($P<0.01$) in STZ induced diabetic mice, which might contribute to the increment in insulin sensitivity. They stated that polysaccharide of corn silk of molecular weight of 45.5 kDa has potential for the development of functionalor nutraceutical food for treating Type 2 diabetes mellitus.

Corn silk possesses anti-oxidative and anti-glycation effect

Protein glycation as a non-enzymatic reaction occurs in between a free amino group of a protein and carbonyl group of reducing sugar, forms stable structures that further undergo oxidation and forms advanced glycation end products (AGEs). These products play a major role in age related problems and diabetic complications like nephropathy, retinopathy and neuropathy (Meeprom et al., 2013). Similarly, free radicals produced by biochemical catabolic and physiological reactions along with other reactive oxygen species cause oxidative stress which further leads to diabetes, cancer, atherosclerosis and associated complications (Rizvi et al., 2013).

The anti-oxidative and anti-diabetic efficacy of *Zea mays* (corn silk) along with *Artocarpus heterophyllus* (Raw Jackfruit), *Syzygium cumini* (Black plum), and Shilajit (Black asphaltum) *in vitro* and *in vivo* models were studied by Vemuri et al., (2018). They compared the phytoextracts with commercial diabetic drugs like Aminoguanidine, Insulin and Glibenclamide for controlling Streptozotocin induced hyperglycaemia and AGEs. The results showed that corn silk extract showed 96% of anti-oxidant capacity, 85% of superoxide radical scavenging and 42% of hydroxyl radical scavenging activity. They observed that corn silk (50µg/ml) along with the other phytoextracts decreased the glycation of haemoglobin when compared with diabetic drugs. Glycation products like methylgloxal which are responsible for

the formation of AGEs along with oxidative stress leads to cell toxicity and inhibition of these compounds could help in eliminating the metabolic related disorders (Beisswenger, 2014).

The antioxidant potential of corn silk was examined by Chang et al., (2016) against protein glycation and oxidative stress for the protection of β-cells. Four different fractions were prepared from an ethanolic crude extract of corn silk by thin-layer chromatography. Free radical scavenging, cell-based viability test and glycation assay were studied to report the best fraction of corn silk. At last, β-cellfunction was assessed by β-cell gene expression and acute insulin secretion test. The result reported that ethyl acetate fraction (YMS-EA) was the most potent fraction as it decreases the cell viability, inhibited the cell proliferation and under hyperglycemic conditions, YMS-EA significantly reduced ROS levels, improved mRNA expression of insulin, glucokinase and PDX-1 and enhanced glucose stimulated insulin secretion. The dual properties of reducing oxidative stress and protein glycation are due to the presence of bioactive compounds apigenin and luteolin.

Corn silk increases insulin secretion by β-cells of the pancreas and promote recovery of damaged pancreatic β-cells

The depletion in the secretion of insulin leads to high level of glucose in the blood (hyperglycemia) and makes people susceptible to diabetes (Rorsman et al., 2013). Type 1 diabetes is associated with autoimmune destruction of pancreatic β-cell mass, moreover, type 2 results from the combination of a reduction in pancreatic β-cell mass and increased insulin resistance. The cause of destruction to the pancreatic β-cell includes chemical reactions and genetic manipulation (Marrif et al., 2016).

The presence of cardiac glycoside, terpenoids, flavonoids, anthraquinones, steroids and alkaloids in corn silk imparted hypoglycaemic properties as stated by Sani (2016) in their study of cooked corn silk on alloxan-induced diabetes in albino mice. Corn silks were cooked first and then were macerated with methanol and 250 mg, 500 mg and 750 mg/kg body weight were given to albino mice induced with 150mg/kg body weight of alloxan monohydrate mixed in 0.9% physiological saline. Two control groups were served one with glibenclamide, stimulates insulin production and helps in reducing blood glucose levels (positive control) and the other with physiological saline (negative control). The results observed showed that the methanolic extract of doses 500 and 750 mg/kg body weight showed highest anti-diabetic property by reducing the blood glucose level at 72 hours and 96 hours to 6.5 and 5.4 mmol/L respectively when compared with control group administered with glibenclamide. The

phytochemical screening observed showed the presence of saponins, steroids, flavonoids, terpenoids, alkaloids, anthraquinones which holds the hypoglycemic properties and stimulates the insulin secretion. They concluded that the methanolic extract of the cooked corn silk showed dose dependent action and helped in survival of beta cells to stimulate more insulin.

The corn silk aqueous extract also significantly decreased blood glucose levels in hyperglycemic mice induces with Streptozotocin (STZ). The mechanism for the action of anti-diabetic effect includes healing of pancreatic β-cells, increment in insulin levels, decrease in glycohaemoglobin (HbA1c) and regeneration of damaged β-cells (Parle and Dhamijia, 2013).

Corn silk inhibits the α-amylase activity and α-glucosidase activity

Alpha amylases are the calcium metalloenzymes responsible for the cleavage of large starch molecules into smaller molecules of sugar, where the role of insulin comes into action. However, the excess of alpha-amylase activity, the blood glucose level rises which results to hyperglycaemia (Agarwal and Gupta, 2017). Similarly, alpha-glucosidase helps in hydrolysis of oligosaccharides into glucose and other monosaccharides. The inhibitory effect of both of these enzymes produces anti-hyperglycemic effect by decreasing extent and rate of glucose absorption. In diabetic people, these enzymes are given as oral-hypoglycemic drugs for reducing the high blood glucose levels (Rege and Chowdhary, 2014). Chen et al.,' (2013) studied the chemical modification in water soluble corn silk polysaccharides (CSPS) to attain their sulfated, acetylated and carboxymethylated derivatives. The isolated CSPS were fractionated on DEAE-52 cellulose column and four fractions, including CSPS water elution fraction (CSPS-W), CSPS 0.1 M NaCl (CSPS-1), CSPS0.2 M NaCl (CSPS-2) and CSPS 0.5 M NaCl (CSPS-3) were extracted. The fraction with high antioxidant activity named by N-CSPS was used for the further study. Chemical modification in NCSPS was made to obtain sulphated (S-CSPS), acetylated (A-CSPS) and carboxymethylated derivative (C-CSPS). The antioxidant activity and α-amylase inhibitory activity was studied and the results showed that the carboxymethylated derivative (C-CSPS) showed the highest antioxidant and α-amylase inhibitory effect when compared with IC_{50} values in comparison to other derivatives, which showed that polysaccharides of corn silk could slow down the starch digestion of food resulting in delayed synthesis of free glucose by inhibiting the α-amylase enzyme and thus giving hypoglycaemic effect.The inhibitory as well as antioxidant capacity of corn silk on diabetes mellitus and diabetic nephropathy was investigated by Wang and Zhao (2011) where an ethanolic extract of corn silk was fractionated to prepare petroleum ether fraction (PCS), *n*-

butanol fraction (BCS), water fraction (WCS) and petroleum ether fraction (PCS). The extracted result showed the highest total phenolic content (TPC) and total flavonoid content (TFC) values possessed by ECS and BCS fractions and has also displayed the strongest scavenging activity against DPPH and hydroxyl radicals in comparison to corn silk and other fractions. The inhibitory properties on α-amylase and α-glucosidase in enzymatic assays were given by ECS and BCS as anti-hyperglycemic effect and in the BSA-glucose model, these fractions also inhibited the advanced glycation end products (AGEs). The result showed that ECS showed 156.2±12.5 µg/mL and BCS 164.8±10.4 µg/mL alpha-amylase inhibitory activity. For the α-glucosidase inhibitory analysis, ECS and BCS showed the highest values with the IC_{50} values as 151.2±9.0 and 170.8 µg/mL respectively. The anti-diabetic nephropathy activity assay reported the significant inhibition in the production of Col IV, IL-6 and FN in high-glucose stimulated mesangial cells at 200 µg/mL.

The antidiabetic potential of corn silk extracts were also studied for drug properties of bioactive compounds by Adewole et al., (2018). Hexane and methanol extract was prepared of corn silk by GC-MS method after drying. The enzymatic activity such as maltase-glucoamylase, alpha- glucosidase, beta-glucosidase inhibition was studied and the result portrayed that the hexane extract of corn silk was the most potent inhibitor of α-glucosidase with an IC_{50} value of 31.5±0.4 µg/mL. The calculated value in the hexane extract was positively associated with thymol and mannitol present in corn silk, that reduces the blood glucose levels. Sabiu et al., (2016) investigated corn silk extract for α-amylase and α-glucosidase inhibitory potential. The result showed that inhibitory activity was concentration-dependent with respective to the half-maximal inhibitory concentration (IC_{50}) values of 5.89 and 0.93 mg/ml. The inhibitory activity achieved due to the presence of phenols, flavonoids, saponins, alkaloids and phytosterols, which further leads to a reduction in the starch hydrolysis and increased palliated glucose range and revealed the hypoglycaemic candidature of corn silk.

Corn silk stimulates the activation of Glitazones

Glitazones (Thiazolidinediones) prescribed for the treatment of type 2 diabetes are peroxisome proliferator-activated receptors (PPAR) responsible for glucose and lipid homeostasis (Muralidaran and Roy, 2016). Types include PPARα (Fibrates), PPARγ (glitazones) and PPARδ which function as lipid sensors. After activation, PPARγ stimulates the cellular uptake and storage of free fatty acids and glucose in the body tissues. This further

increased cellular glucose uptake, which is advantageous for type 2 diabetes mellitus (Vemuri et al., 2018). Herbal extracts of 52 herbs including *Capsicum frutescens* (chilli) *Urtica dioica* (stinging nettle) and corn silk were screened for the activation of human PPAR of which corn silk was found to be one of the most active herb in terms of drug extract ratio among others. The presence of PPARα and PPARγ in corn silk was reported by Rau et al., (2006).

2.5 ANTI-OBESITY POTENTIAL OF CORN SILK

The use of corn silk to reduce obesity and has anti-adipogenesis effect were studied by Hsu et al., (2018). They further explained Galactin-12 is an adipocyte expressed protein, which possesses adipocyte inducing activity. They used corn silk extract and β-sitosterol to determine their effect in reducing obesity and lowering the expressions of galactin-12. The study showed a positive effect in using corn silk extract. Further, corn silk extract and β-sitosterol helped in reducing the level of lipid droplets. While testing the dosage on mice, a significant loss in weight reduction was also observed. The findings presented in the study, highlight the use of corn silk extract to loosen up the body weight as it has an inhibitory effect on galactin-12. The dosage of corn silk extract (600 and 800μg/mL) and β-sitosterol (100μM) showed positive effect on lowering obesity.

The anti-obese effect of corn silk were analysed by Lee et al., (2016) focused themselves on working and evaluating the effect and mechanism of action of Maysin present in corn silk extract. They determined the effect of Maysin on our body weight and lowering fat deposition. They took a sample of 30 male mice, 4 weeks old. These mice were divided into groups according to their weight and were fed with high Maysin corn silk extract 100 mg per kg body weight. Their body fat and body weight were measured. This diet involving Maysin corn silk extract was fed up to 8 weeks. Different levels and parameters were measured like fat accumulation, fat synthesis, and lipolysis, fat oxidation in adipose tissue and liver, and mRNA expression levels of proteins which were involved in adipocyte differentiation. As a result, the body weight of corn silk fed group was lower than the high fat group. Their kidney fat levels also came to be at lower ends.

2.6 ANTI-HYPERTENSIVE POTENTIAL

Corn silk is a wonder herb consisting of many antioxidants and phytoconstituents (Kılıç et al., 2017). It also possesses an effective anti-hypertensive property i.e. it helps to lower down the blood pressure of the body.

Table 2.7 Blood Pressure lowering properties possessed by corn silk

Name of the property	Compound acting for health property	Results	Sample Size	Intervention	Duration	References
1. Intra Ocular Pressure	High Potassium content in Corn silk extract	Corn silk Aqueous extract has a lowering effect on Intraocular blood pressure	20 systematic and 20 non-systematic hypertensive males.	600ml of 260 mg/kg bodyweight.	44 days	George et al., (2015)
2. Blood Pressure	Amount of potassium in non -pollinated corn silk extract	The potassium in the corn silk extract portrayed positive effects in reducing blood pressure, through Natriuresis.	Adult male Wistar rats	5% and 10% corn silk aqueous extract with 10ml/kg	8 days	Maksimovic et al., (2004)
3. Diuretic and Kaliuresis effect	Corn silk aqueous extract containing potassium	500mg/kg bodyweight dosage showed kaliuresis and diuretic effect.	Water loaded conscious adult restrained rats.	Diuretic at 500mg/kg body weight and kaliuretic at 350-500mg/kg body weight.	5 hours and 3 hours.	Valazquez et al., (2005)
4. Sodium lowering and potassium sparing property leading decrease in blood pressure	Potassium content of corn silk	There was a decrease in the level of sodium electrolyte from the body, decreasing the blood volume.	20 Male albino wistar rats	200-600mg/kg body weight of corn silk aqueous extract.	10-21 days	Mohammed at al., (2015)
5. Hypertension	Corn Silk Bioactive	Boiling water	Not provided	10 g/kg body	90 days	Li et al., (2019).

	Peptides (CSBps)	extracts of corn silk show a great impact on lowering blood pressure by inhibiting Angiotensin-converting enzyme (ACE)		weight.		
6. Cholesterol	Maysin, a flavonoid in corn silk	The mRNA expression levels of HMG-CoA reductase are modified with the help of corn silk extract	Normal fat group rats (NF;n=10), High Fat group rats (HF;n=10) and High Fat CS group rats (n=10)	100mg/kg body weight; 2783.54mg/100g of maysin.	8 weeks	Cha et al., (2016)

The components present in corn silk, which are responsible to bring down the blood pressure of the body are potassium, some bioactive compounds like corn silk bioactive peptide (CSBp5), and flavonoids like Maysin. These components are present in abundance having an astounding effect on reducing hypertension. The anti-hypertensive properties were explained in Table 2.7.

The leading cause of all kinds of cardiovascular diseases in today's world is hypertension. Corn silk administered with pharmacological drugs portray an amazing response in lowering the blood pressure. (George et al., 2013). Corn silk aqueous extract has a blood pressure lowering effect on humans. This effect is due to high amount of potassium content present in corn silk which causes potassium-induced natriuretic and diuresis effect (George and Idu 2015).

Natriuresis is the excretion of sodium in the urine. As we all know, increased sodium content in the body causes hypertension. Interplay of sodium and potassium balance holds a vital place in helping lowering the blood pressure in hypertensive patients. It also helps in maintaining blood volume, hydro electrolyte balance and cell functioning. The main mechanism of action of potassium is portrayed by building a negative sodium balance. Increasing potassium rich diets and consuming KCl in humans' results in urinary sodium excretion and reduction in blood pressure. Some studies have demonstrated that consuming potassium 750-1000 mg/d can reduce blood pressure by 2-3 mm Hg (Houston et al., 2008). In the theory explained by (George and Idu 2015), they performed an experiment involving 20 systematic and 20 non-systematic hypertensive males. These group of hypertensive males were selected voluntarily. The corn silk dosage was given at 600ml of 260mg/kg for a period of 44 days. 260mg/kg was the highest amount of dosage. The observations portrayed that higher the amount of dosage (within a non-toxic level), the better are the results.

Another study explaining the use of corn silk in reducing hypertension is explained by Velazquez et al., (2005). They elaborated the use of corn silk doses in reducing blood pressure due to the presence of generous amount of potassium in corn silk threads. They studied the diuretic and uricosuric effects of cornsilk and how the aqueous extract of corn silk affects urinary excretion of water, uric acid, potassium and sodium levels of the body. They subjected few conscious water loaded rats to test the effect of corn silk containing potassium. These rats were induced with different amount of corn silk aqueous extract doses like, 25, 50, 200, 350, and 500mg/kg body weight. Urine samples were collected after every 3-5 hours. They

observed Kaliuresis on the higher doses like 350-500 mg/kg body weight and diuretic above 500mg. The degree of correlation between potassium induced and potassium excreted resulted the maximum in case of 350mg and 500mg/kg body weight. The amount of urine also increased at 500mg/kg bodyweight dosage level.

Maksimović et al., (2004) also reported the use of corn silk in reducing blood pressure due to the presence of potassium in corn silk aqueous extracts. They concluded that herbal drugs containing diuretic compounds are known as aquauretics, which contain different flavonoids, saponins and tannins. According to their theory, they tested sodium-potassium levels, pH of the urine excreted, amount of urine excreted and creatinine clearance due to the consumption of corn silk decoction. They performed these tests on male wistar rats and administered the corn silk dosage for 8 days. Daily oral decoction of 5% and 10% was given to the rats and were continuously observed. According to the observations notes, administration of 5% decoction of 10ml/kg resulted an increase in amount of urine and also acute diuresis was observed, bringing a decrease in sodium and potassium levels due to potassium creating negative balance with sodium. 10% decoction of corn silk for the same period resulted in a change in pH value of urine but did not affected the amount of urine but definitely resulted in higher potassium concentration.

Mohammed at al., (2015) illustrated in their theory that there can be a decrease in blood pressure by decreasing the blood volume which happens due to excretion of Sodium and Potassium electrolytes. Corn silk acts as a diuretic and results in loss of water and certain electrolytes from the blood, resulting in low blood pressure. A group of 20 normal male albino rats were taken in account which were administered with corn silk doses. These rats were divided into 4 further groups on the basis of amount of corn silk doses. They were: Control (normal Saline), Spironolactone i.e. 0.02mg/kg/day corn silk dose, rats with 200mg/kg/day corn silk dose and rats with 600mg/kg/day corn silk dose.

These amounts of doses were provided to the rats and were evaluated for 10-21 days. The results portrayed that there was an increase in the potassium levels and decrease in sodium levels on administration of 600mg/kg/day of corn silk as compared to the control group of rats. Hence corn silk helps to reduce blood pressure in a body with the help of potassium sparing action.

Another theory explained by (Li et al., 2019) produced that boiling water extracts of corn silk show a great impact on lowering systolic blood pressure by inhibiting Angiotensin-converting enzyme (ACE). In recent studies it was found that ACE inhibitory phytopeptide namely corn silk bioactive peptide (CSBp5) is responsible in lowering systolic blood pressure in humans. This phytopeptide is bound to be present in boiling water corn silk extracts. CSBp5 works by inhibiting ACE activity and thereby lowering the Blood Pressure.

There is a well-known mechanism that helps in regulating the volume of fluid in the body which controls the blood pressure, called the Renin-angiotensin-aldosterone system (RAAS) mechanism. (Sherwood et al., 2011) discussed in their book that renin is a hormone secreted by kidney, released into the blood on the trigger of fall in ECF volume or blood pressure. Once this hormone gets secreted, it converts itself into an enzyme to convert angiotensinogen into angiotensin I. Angiotensinogen basically, is a plasma protein synthesized by liver and is always found in the plasma in greater levels. While passing through the lungs via the pulmonary circulation, angiotensin-converting enzyme (ACE) is an important dipeptidyl carboxypeptidase in RAAS, which converts angiotensin I to the active vasoconstrictor, angiotensin II. Angiotensin II is known to be called as a cornerstone in treating and reducing hypertension. ACE is present in abundance in pulmonary capillaries. Inhibition of ACE activity decreases the production of angiotensin II, leading to vasodilation and reducing blood pressure. This inhibition takes place when CSBp5 occupies the substrate binding channel of ACE by interacting via hydrogen bonds.

Li et al., (2019) also concluded that by consuming a particular dosage of Corn silk extract i.e. 10g/kg body weight, the level of Systolic Blood Pressure came 26.57±9.03 mmHg lower than any blank reading. They also concluded that corn silk extract / corn silk tea proves to be helpful in reducing blood pressure with low toxicity levels. They performed this test for 90 consecutive days and had positive results.

Corn silk has a significant effect in controlling various other cardiovascular health issues like Angina pectoris (Shi et al., 2019), reducing cholesterol levels (Cha et al., 2016), and reducing obesity issues (Chaiittianan et al., 2016). Increasing cholesterol in the body may lead to a higher risk of hypertension. Shimizu et al., (2017) had discussed that high levels of cholesterol are directly associated with hypertension. They have also explained that it is good to have high levels of HDL (High Density Lipoproteins) which are inversely related to hypertension. Therefore, controlling cholesterol metabolism is of utmost importance. Corn

silk can help reduce obesity and improve cholesterol metabolism with the help of the compounds present in it. Corn silk contains flavonoids as already discussed. There is an important flavonoid present in CS which is present in abundance i.e. Maysin. This flavonoid helps in reducing cholesterol levels in the body by following mechanism.

Synthesis and excretion are the two mechanisms which control the cholesterol metabolism. Corn silk extract helps in inhibiting the cholesterol synthesis by formulating mRNA expression levels of HMG-CoA reductase, & sterol-o-acyltransferase (ACAT), both of which are rate limiting enzymes in the process of synthesis of cholesterol. The mRNA expression levels of HMG-CoA reductase are modified with the help of corn silk extract. The first rate limiting enzyme in cholesterol synthesis in body is HMG-CoA reductase, which helps in the conversion of HMG-CoA to Melanovate. Low density lipoproteins (LDL) are lowered by the help of ACAT in which cholesterol esters (CE) are esterified from free cholesterol by the catalyzation done by ACATs. Cholesterol esters are an important source of low density lipoproteins (LDL). This process helps inhibition of production of cholesterol. This theory is well explained by Cha et al., (2016), in which they have used 100mg/kg bodyweight of corn silk dosage containing 2783.54mg/100g of Maysin for their sample study involving 30 rats grouped in three different groups namely; Normal fat grouped rats, High fat grouped rats and high fat corn silk grouped rats. These doses were given for about 8 weeks which showed a positive effect in improving cholesterol, ultimately reducing hypertension.

The effects of corn silk aqueous extract on intraocular pressure of ocular hypertensive human subjects were studied by George at al., (2013). They studied the effects of water only, masked doses of corn silk aqueous extract (60 mg/kg, 130 mg/kg and 260 mg/kg body weight) on the intraocular pressure (IOP) and blood pressure of twenty normotensive and twenty ocular hypertensive subjects. Comparison of the effects of the varied doses of corn silk aqueous extracts (CSAE) with masked doses of acetazolamide on IOP of ocular hypertensive subjects were done. They reported that the last three doses of CSAE lowered IOP and BP significantly ($p<0.001$) withing eight hours of administration. They concluded that CSAE may have some IOP lowering effects that require further investigation in the management of ocular hypertension.

Li et al., (2019) worked on finding the corn silk bio peptides (CSBp5) present in corn silk that help to lower the blood pressure by targeting and inhibiting Angiotensin converting Enzyme present in body. As the ACE gets inhibited the systolic blood pressure automatically

lowers. CSBp5 is present in boiling corn silk aqueous extract. Their study also supported the use of corn silk tea to reduce hypertension. They also concluded that by consuming a particular dosage of Corn silk extract i.e. 10mg/kg body weight, the level of Systolic Blood Pressure came 26.57±9.03 mmHg lower than any blank reading.

The use of corn silk tea for treating hypertensive patients proved to be a beneficial by Shi et al., (2019). Five randomized controlled trials were taken to perform this particular study, containing 567 participants. In this study, they also determined the effect of natural and pharmaceutical dosage combined together. The participants were administered corn silk dosage with antihypertensive drugs. The study including both dosages portrayed a greater and positive effect on lowering blood pressure than the antihypertensive drugs alone.

George et al., (2015) evaluated the effect of corn silk extract on human blood pressure and intraocular pressure. Randomised study was carried out by providing corn silk aqueous extract doses to 20 systematic and 20 non-systematic hypertensive subjects. The doses were in the given amounts like 60, 130, 192.5, and 260 mg per kg body weight. The duration of the dose was administered after every 2 weeks given at an interval of 1 hour for 8 hours a day. The results were calculated amongst the two groups and concluded that corn silk aqueous extract has a blood pressure lowering effect on our body. The reason behind this fall in pressure was due to the potassium content present in corn silk extracts.

2.7 ANTI-HYPERLIPIDEMIC EFFECTS

The effectiveness of corn silk decoction on lipid profile of patients suffering from angina pectoris were reported by Shi et al., (2019). They also assessed the effect of this decoction on different levels like total cholesterol, triglycerides, low density lipoprotein and high-density lipoproteins. Random control trials were taken to test the effectiveness of the corn silk decoction. Study supported the use of corn silk on treating the lipid profiles. The analyses of the study showed that corn silk decoction or corn silk extract used with pharmaceutical treatments helps to lower the lipid profiles of patients. It helped to reduce cholesterol levels and blood lipids in patients suffering from angina pectoris.

The effect of corn silk extract on treating cholesterol metabolism were done by Cha et al., (2016). They worked on some group of rats providing them normal fat diets, and high fat diets. The study declared that corn silk contains high amounts of a flavonoid name Maysin which works wonder for treating and reducing cholesterol. They provided 100mg/kg body

weight of corn silk dosage to the rats daily. Different levels such as glucose, insulin, serum free fatty acid, total cholesterol, total triglycerides, & total lipids levels were determined during the study. The conclusion came out that the corn silk showed a positive effect and improved glucose and insulin levels. It also helped to reduce cholesterol and improved cholesterol metabolism.

2.8 ANTIMICROBIAL POTENTIAL OF CORN SILK

The antimicrobial activity and phytochemical properties of corn silk and has aimed to identify some medical properties of corn silk and has investigated its anti-microbial activities in different solvents like ethanol, chloroform and methanol extracts in comparison to streptomycin. They have reported that all the extracts showed variable degree of inhibitory zone by using disc diffusion method against tested bacteria. The highest inhibition zone from 13.17 and 12.27 mm was observed in 10.0 mg/ml of ethanol and methanol respectively. Ethanol extract showed significant antimicrobial activity against both gram positive bacteria (13.17 to 9.45 mg/ml) and gram negative bacteria (12.36 to 8.15 mg/ml). None of the extract was sensitive against *Escheria coli* and yeast strain as per their report (Morshed and Islam, 2015).

The antimicrobial activity of an ethanolic extract of corn silks were studied by Feng et al., (2011). The choosen bacteria for the detection of germs enlisted as *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Bacillus cereus*, *Bacillus coli* and *Candida albicans*. The method of agar plate diffusion and tube continuous dilution has been used in order to examine the antimicrobial activity and minimum inhibitory concentration (MIC) of ethanolic extract of maize silk. It was concluded from the study that ethanolic content of maize silk is a potent antimicrobial source against the choosen bacteria. The extract was found as potent source of inhibition against the microorganism namely *S.aureus*, *B.subtilis* and *C.albicans*, thus showed the broad- spectrum of antibacterial activity.

2.9 THERAPEUTIC POTENTIAL OF CORN SILK IN RENAL DISEASES

According to the studies conducted by Sahib et al., 2012 corn silk has been extensively used and regarded as traditional medicine in Iraq. The clinical evaluation was done by utilising the aqueous extract of corn silk in the patients' suffering from UTI. Patients of both sexes of age group 30 (±10.5) were assessed, taking time duration from October 2011- marches 2012. The data was taken from the outpatient clinic of Akindy College of

Medicine, Baghdad, Iraq. The UTI was confirmed by the clinical symptoms and each symptom was marked accordingly 0 as none, 1 as mild, 2 as moderate, 3 as severe and very severe as 4. Thecorn silk extract treatment was given to the patients and follow up after every 5 days was analysed. Results indicated that the administration of corn silk extract to UTI patients has shown a significant decrease in the UTI symptoms as scoring done after 5,10,15 and 20 days after the treatment. Corn silk extract was reported as effective and safe in the treatment and it also contributes in decreasing the value for pus cells, and crystals.

2.10 TOXICITY OF CORN SILK

Previous studies have claimed the pharmacological properties of corn silk and being natural and traditionally used medicine. Users have no doubt on the safety of corn silk, but the research associated with corn silk toxicity and safety limits is still lacking (Hasanudin et al., 2012). Some of the studies have also reported toxicity associated with corn silk. *In vivo* study in Wistar rats (male and female) has confirmed that corn silk is non-toxic and no histopathological and side effects were reported at a concentration of 8.0% (w/w) when consumed for 90 days. They stated that mean daily intake of approximately 9.354 and 10.308 g/day/kg of body weight for males and females respectively (Wang et al., 2011). Corn silk extract was analysed for the level of acute and subacute toxicity on mice. Corn silk consisting of high levels of maysin was administered at a dose of 0 to 2000 mg/kg of body weight recorded for the period of 14 weeks. After 4 week intervals, body weight, organ weight, water and food consumption were analysed along with urine and serum concentrations. They reported that no significant change was observed in all the parameters and the histopathological examination also showed no abnormal change after administering 500 mg/kg of corn silk extract for subacute toxicity study (Ha et al., 2018).

The subchronic toxicity of corn silk was also assessed in Wistar rats (males and females) at concentrations of 0.5, 2.0 and 8% (w/w) for 90 days. The parameters tested included overall health, body weight, hematology, organ weight, food consumption, gross microscopic appearance of tissues and blood chemistry were compared between control and test groups. The result showed that no side effects were observed and corn silk could be used as no-observed-adverse-effect-level (NOAEL) and support the safety of corn silk for humans (Wang et al., 2011).

Corn silk extract was tested for acute toxicity, as well and the aqueous extract was orally administered to rats at a dose of 5 g/kg of body weight. The signs of acute toxicity, behavioural changes and mortality were analysed. For the sub-acute toxicity, 500, 1000 and 2000 mg/kg body weight of corn silk extract was administered to rats for 28 days and serum chemistry, lipid profile, hematology, histopathology of the liver and kidney were studied. The result of acute toxicity reported no adverse effect at the doses upto 5 g/kg of body weight, but in contrast, for the sub-acute study, a significant increase ($p<0.05$) in triglycerides, low density lipoprotein and very low-density lipoprotein were observed and the values for high density lipoprotein significantly decreased. The levels of AST and ALT increased significantly and degenerative changes were observed in the liver at 2000 mg/kg of body weight (Ikpeazu et al., 2018).

The therapeutic efficacy of corn silk were reported by Ha et al., (2018). The main objective of their study was to determine the acute and sub-acute toxicity level of corn silk extract. Corn silk extract contains high amount of Maysin which was administered orally to mice at a dose of 0 to 2000 mg/kg to check the acute toxicity of corn silk. For 14 days their clinical symptoms, mortality, and changes in body weight were recorded. Same dosage was provided to check their sub-acute toxicity and their symptoms, weight, water and food consumption was recorded for a 4-week period. In acute toxicity, no death or abnormal symptoms were observed. Thereby lethal dosage of corn silk was estimated by 2000 mg/kg.

The cardio toxicity of corn silk aqueous extract were reported by Adedapo et al., (2016). They studied about its cardio toxicity although it is considered as a healthy herbal tea. In this particular study they prepared corn silk extract doses of 200, 400 and 800 mg/kg. These doses were fed to the rats for seven days. A control group was also set up consisting of rats which were fed with 3ml of distilled water. After the trial ended on eighth day, ECG was done on the rats to keep a check on their heart rate, P- wave duration, P-R interval, R-amplitude, QRS duration, and QT interval. As these reports were studied and observed, the result came out that though corn silk tea is considered a healthy drink, but its overconsumption can cause toxicity and can lead to various other health problems. Extra care should be taken by heart patients especially.

In conclusion, numerous research have shown that corn silk, which was previously thought of as waste material, has therapeutic potential against a number of age-related and

chronic diseases, including diabetes, hyperlipidemia, cancer, cardiovascular disorders, and microbial infections. Therefore, corn silk may have the potential to improve human health.

Chapter-3

HYPOTHESIS OF THE STUDY

Corn silk, an agricultural waste from corn fields could be utilized for the development of value added functional food products. Being a waste commodity, corn silk is not utilised and is dumped in the fields of used as a part of fodder for the cattles. Corn silk contains a lot of potential due to its high antioxidant and nutritional quality to be use for the development of value added and functional food product.

Chapter-4

OBJECTIVES OF THE STUDY

The major objectives of the proposal are:

1. To assess the nutritional status of targeted population through survey studies and nutritional assessment methods
2. To investigate nutritional, physicochemical, structural and antioxidant potential of corn silk
3. To assess the functionality of corn silk for development and characterization of instant mix and beverage by using dry corn silk powder and extract
4. To study the effect of storage conditions and packaging material on shelf life of the developed value added product

Expected Outcome

Expected outcomes to be achieved after the completion of thesis would be:

1. Database for nutritional, physico-chemical, structural and textural properties of cornsilk will be generated.
2. Value added product in form of instant mix and beverage using corn silk will be developed
3. The developed optimized products will be shelf-stable.

Chapter-5

METHODOLOGY

5.1 NUTRITIONAL STATUS OF TARGETED POPULATION THROUGH SURVEY STUDIES AND NUTRITIONAL ASSESSMENT METHODS

The nutritional survey and anthropometry methods will be carried out to assess the dietary habits and nutritional status of adults as well as children. The questionnaire will be developed to check the health status and nutritional deficiencies common in the sample population of Hoshiarpur region and urban population of Jalandhar city. The WHO sampling guidelines (WHO 2002) would be followed as explicit standards of quality. The sample size of at least 500 (equally distributed as males and females) will be taken and questionnaire method. Anthropometric assessment (Heymsfield et al., 2000) and interview method (Alshenqeeti 2014) will be used to assess their health and identification of nutrition-related problem. The questionnaire is attached in the annexure-2.

5.2 NUTRITIONAL PHYSICOCHEMICAL, STRUCTURAL AND ANTIOXIDANT POTENTIAL OF CORN SILK

The different varieties of corn viz. SWARNA, TATA 7009, SHUBHAM EARLY, KESHAR KING and , G5417 were grown at the agriculture farm of Lovely Professional University, Phagwara, Punjab. The average growth period of maize crops was 90-120 days. The reproductive stage of corn has various stages namely silking stage (R1- 60 days after emergence), blister stage (R2- 72 days after emergence), milking stage (R3- 80 days after emergence), dough stage (R4- 86 days after emergence), dent stage (R5- 96 days after emergence) and physiological maturity stage (R6- 115 days after emergence). The only stage used in the experiment were from stage 1 to 5 as stage 6 is not processible and consumable. Figure 5.1 shows growth and different stages of corn silk.

Plot making and sowing of seeds of various varieties of maize

Plot making and sowing of seeds of various varieties of maize

Plot making and sowing of seeds of various varieties of maize

After 60 days of emergence

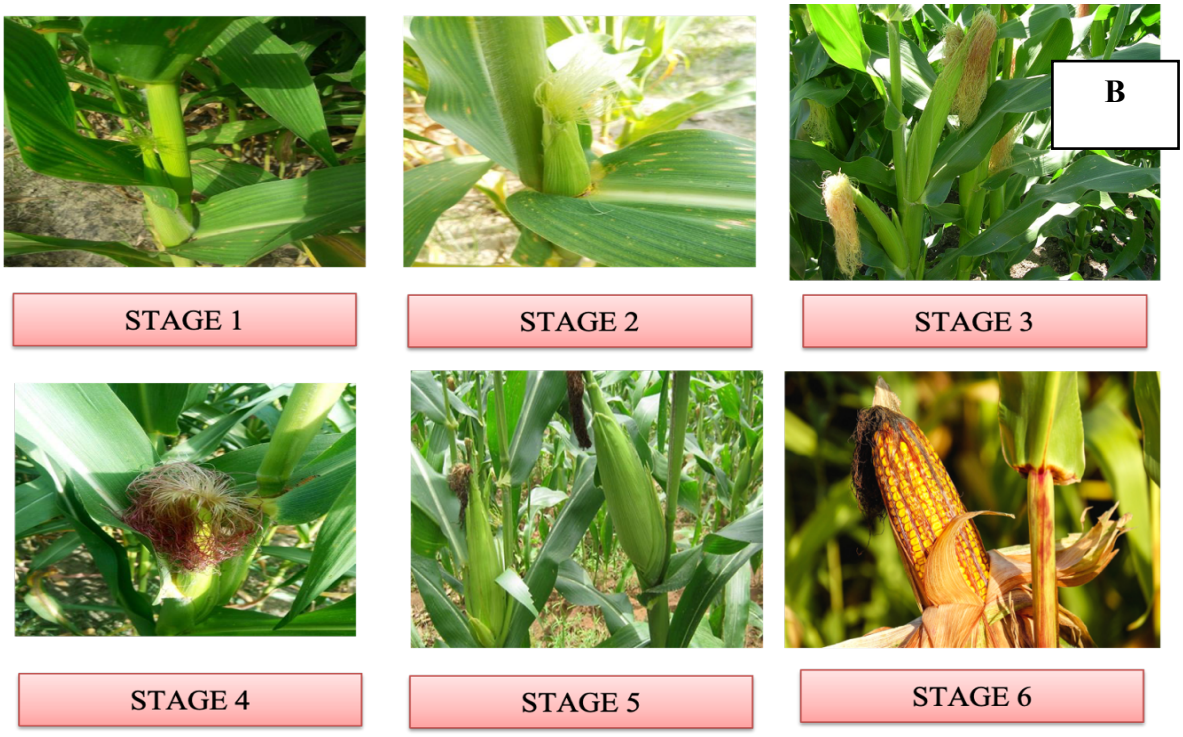


Figure 5.1- A: Sowing of seeds of maize and growth of maize plant; B: Corn silk emergence and its growth stages

5.2.1 Nutritional profiling of corn silk of different varieties at different growth stages

Proximate analysis

The chemical composition (moisture, protein, fat and ash) of the product were determined. Oven dry method in hot air oven (Kaizen Imperial, new Delhi, India) was referred to access moisture content. Kjeldhal's method was referred to access protein content of the samples by multiplying the nitrogen content by a factor of 6.25. Soxhlet method was used for fat determination and petroleum ether was used as extracting solvent (Rahman and

Rosli 2014). Digestion method was used to examine crude fibre (Ranganna, 2000). Carbohydrate content was calculated by the difference method (AOAC 2007).

Moisture content

Initially petri plates were properly washed and air dried (Labfit India Pvt. Ltd., Mumbai, India). After drying, weight of empty petri plate was taken. Then Petri plates with samples were placed in oven for 1 hr at 100 ^{o}C containing 5g of sample in it until two consecutive readings were obtained.

$$\text{Moisture\%} = \frac{\text{quantity of moisture} \times (W2 - W3)100}{\text{weight of material}}$$

Weight of the weighing dish with lid = W1

Weight of the dish with lid and material = W2

Weight of the dish with lid and dried material = W3

Weight of the material = (Weight of the dish with sample – weight of the dish) = $(W2 - W1)$

Quantity of moisture in the material = (Weight of the material before drying-Weight of the material after drying)

Analysis of proteins

Kjeldhal method: This method involves digestion, distillation and titration. It requires various reagents for carrying out the analysis of proteins which are as following-

Digestion:- Conc. H_2SO_4, sample 0.5g and digestion mixture

Distillation:- Digested sample, 4 % of boric acid and mixed indicator (methyl red and bromocresol green)

Titration: - 0.1N of HCl and distilled sample

Digestion: Weighed sample 0.5g of sample were digested with the concentrated sulphuric acid (10ml) and digestion mixture that is potassium sulphate (5g) and copper sulphate (1g) ratio of 5:1 in Kjeldhal's digestion flask. The process was carried out for 2 hrs and bluish greenish colour was appeared. The mixture was cooled down.

Distillation: Digestion tube was fitted in distillation machine. One solution was prepared in 250ml of volumetric flask containing 4% of boric acid and 5 drops of mixed indicator in it. This flask was also fitted in distillation machine. One tube was attached from digestion tube to volumetric flask and process was carried out for 9 min.

Titration: At last, distilled solutions were titrated with 0.1N of HCL and end color was appeared pink.

$$N\% = \frac{(\text{Sample titre} - \text{blank titre}) \times N \text{ of HCl} \times 14 \times 100}{\text{Weight of sample} \times 1000}$$

Protein % = N % × 6.25

Fat content

2g of sample was taken in powdered form. Then weight of empty beaker was taken and 80ml of petroleum ether added in it. Powdered sample was added in the thimble and put the thimble in the thimble holder (beaker). Then beaker was fixed in the Soxhlet (Socs Plus Automatic Solvent and Fat Extraction system, Pelican equipments, Chennai, Tamil Nadu, India) extraction, continuous supply of water was given and closed the knob of apparatus. Machine was started at 80°C and the process was carried out for 1 hr. After an hour, we opened the knob and then again temperature was set at 180°C for half an hour. Beakers with extracted fat were kept in hot air oven at 100°C for half an hour. After this beakers were kept in desiccators for 15min. so that the content gets cooled. At last weigh of extracted fat was taken.

Weight of sample = W (g)
Weight of empty round bottom flask = W1 (g)
Weight of empty round bottom flask + Fat content = W2 (g)

$$\text{Fat content}\% = \frac{\text{amount of ether extract}}{\text{weight of sample(g)}} \times 100$$

Ash content

Initially weight of empty silica crucible had taken. Weighed 1g of sample was put in to crucible and incinerated over an electrical hot plate followed by charring and then ashing in muffle furnace at the temperature of 450°C for 6 hrs until the white residues were obtained.

$$\text{Ash content } \% = \frac{\text{Weight after ashing (g)}}{\text{Weight of sample}} \text{x100}$$

Weight of empty crucible = W (g)
Weight of crucible + sample before ashing = W1 (g)
Weight of crucible + sample after ashing = W2 (g)

Carbohydrate determination

The CHO was calculated by difference (Ranganna, 2000)

$$CHO = 100g - (moisture + crude\ fat + crude\ protein + ash)$$

Crude fibre

Moisture and fat free sample (2 g) were digested with 200 ml of 1.25% H_2SO_4 by gentle boiling for half an hour. The content was filtered and the residue was washed several times with hot distilled water till it became free from acid. Acid free residue was then transferred to the same flask to which 200ml of 1.20% NaOH was added. The content was digested again for half an hour, filtered it and residue was again washed with hot distilled till it became alkali free. The residue was dried in an oven overnight at 100 ^{0}C and weighed.

$$\text{Crude fibre} = \frac{\text{Amount of wt. after drying}}{\text{Wt. of sample}} \times 100$$

5.2.2 Antioxidant content and activity

Antioxidant content

Total phenolic content

The total phenolic content of corn silk was determined by the method explained by Sarepoua et al., 2013 with slight modifications using Folin-Ciocalteu colorimetric method and gallic acid was used as standard. 0.1 g of sample was extracted using 80% of ethanol and the extract was centrifuged at 6000 rpm for 30 minutes. The supernatant was taken out and kept for boiling for few minutes. The residue was collected and added with 5ml of distilled water. 0.5 ml of Folin Ciocalteu reagent was added and kept for 3 minutes. 20% of sodium carbonate (Na_2CO_3) was added in the samples and again boiled for 1 minute. The absorbance was checked at 650 nm using a spectrophotometer and the values were represented as mg GAE/100g.

Flavonoid content

Flavonoid content was examined by taking 0.1 g of corn silk samples and extracted with 80% of ethanol. 0.25 ml of extract was transferred into the test tube and 1.25 ml of distilled water was added. 0.75 ml of 5% of sodium nitrate was added and the mixture was allowed to stand for 5 minutes further 0.15 ml of aluminium chloride (10% w/v) was mixed in the samples and the mixture was left to react for another 5 minutes before added with 0.5 ml of 1N NaOH. The solution was raised with 0.275 ml of distilled water and absorbance

was recorded at 510 nm by using UV-Vis spectrophotometer. Quercitin was used as standard and the flavonoid was expressed as mg QE/100g (Nurhanan and Rosli 2012).

Ascorbic Acid (Vitamin C)

Oxalic acid= 4%

Dye solution= 42 mg of sodium bicarbonate was mixed in small amount of distilled water and dissolve 52 mg 2,6-dichloro indophenol in it and make up the volume upto 200 ml with distilled water

Stock standard solution= 100 mg of ascorbic acid was dissolved in 100 ml of 4% oxalic acid solution in a standard flask (1mg/mL).

Working standard= 10 ml of stock solution was added to 100 mL of 4% oxalic acid. The concentration of working standard is 100 µg/mL.

Procedure: 5ml of working solution was pippeted out into 100 ml of conical flask.10 ml of 4 % oxalic acid was added into it and titrated against the dye (V1ml). End point was noted as the appearance of pink color which persisted for a few minutes. The amount of the dye consumed is equivalent to the amount of ascorbic acid. The sample were extracted (0.5-5 gram) in 4% of oxalic acid and volume was made up upto 100 ml and centrifuge the samples. 5 mL of the supernatant was pipetted out, 10 mL of 4% oxalic acid was added and the mixture was pipetted against the dye (V2mL)

Calculation:

$$\text{Amount of ascorbic acid mg/100 g sample} = \frac{0.5\ \text{mg}}{\text{V1mL}} * \frac{\text{V2}}{5\ \text{mL}} * \frac{100\ \text{mL}}{\text{Weight of sample}} * 100$$

Antioxidant activity

Extraction of corn silk for the determination of antioxidant activity

The extractions were performed by using 80% (*v/v*) ethanol and distilled water and the sample/solvent ratio taken was 1:10. The fresh corn silk samples were weighed and macerated with 80% ethanol at low temperature (0 °C). The extracts were centrifuged at 8000 rpm for 15 minutes and further supernatant was collected for the estimation of antioxidant content and activity. The analysis performed was on fresh weight basis.

Free radical scavenging activity: DPPH method (FRSA)

The antioxidant activity in terms of % inhibition was determined using the method of Singh et al., (2018). Alcoholic solution of 2, 2-diphenyl-1-picrylhydrazyl (DPPH) (90 µmol/L) was used in the assay. Sample extract (0.1 ml) was added with 1.0 ml of DPPH solution, diluted with 2.9 ml of ethanol. The mixture was shaken vigorously and left to stand for 60 min in the dark. The absorbance was measured at 517 nm (UV/Vis Spectrophotometer, Shimadzu Corporation, Japan) against the blank (mixture without extract).

The following equation was used to determine the antioxidant activity:

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

where, A_0= Absorbance of DPPH as blank

A = Absorbance of sample

ABTS radical scavenging assay

Free radical scavenging activity of plant samples was determined by ABTS radical cation decolorization assay. ABTS·+ cation radical was produced by the reaction between 7 mM ABTS in water and 2.45 mM potassium persulfate (1:1), stored in the dark at room temperature for 12-16 h before use. ABTS·+ solution was then diluted with methanol to obtain an absorbance of 0.700 at 734 nm. After the addition of 5 µl of plant extract to 3.995 ml of diluted ABTS·+ solution, the absorbance was measured at 30 min after the initial mixing. An appropriate solvent blank was run in each assay. All the measurements were carried out at least three times. Percent inhibition of absorbance at 734 nm was calculated using the formula, ABTS·+ scavenging effect (%) = ((AB–AA)/ AB)×100 (2), where, AB is absorbance of ABTS radical + methanol; AA is absorbance of ABTS radical + sample extract/standard. Trolox was used as standard substance (Rajurkar and Hande 2011).

Ferric reducing antioxidant power (FRAP)

The antioxidant capacity of the medicinal plants was estimated spectrophotometrically following the procedure of Benzie and Strain. The method is based on the reduction of Fe3+ TPTZ complex (colorless complex) to Fe2+-tripyridyltriazine (blue colored complex) formed by the action of electron donating antioxidants at low pH. This reaction is monitored by measuring the change in absorbance at 593 nm. The Ferric reducing antioxidant power (FRAP) reagent was prepared by mixing 300 mM acetate buffer, 10 ml TPTZ in 40 mM HCl and 20 mM FeCl3.6H2O in the proportion of 10:1:1 at 37°. Freshly

prepared working FRAP reagent was pipetted using 1-5 ml variable micropipette (3.995 ml) and mixed with 5 µl of the appropriately diluted plant sample and mixed thoroughly. An intense blue color complex was formed when ferric tripyridyl triazine (Fe3+ TPTZ) complex was reduced to ferrous (Fe2+) form and the absorbance at 593 nm was recorded against a reagent blank (3.995 ml FRAP reagent+5 µl distilled water) after 30 min incubation at 37°. All the determinations were performed in triplicates. The calibration curve was prepared by plotting the absorbance at 593 nm versus different concentrations of FeSO4. The concentrations of FeSO4 were in turn plotted against concentration of standard antioxidant trolox. The FRAP values were obtained by comparing the absorbance change in the test mixture with those obtained from increasing concentrations of Fe3+ and expressed as mg of Trolox equivalent per gram of sample (Rajurkar and Hande 2011).

5.2.3 Physico-chemical properties of corn silk

Techno-functional properties of various varieties of corn silk

Corn silk samples of G5417 hybrid varriety were collected from the agriculture farm of Lovely Professional University, Phagwara, Punjab, India. The silk was green in colour and was harvested 10 days (silking stage) following their emergence, as illustrated in Figure 1. Fresh silk was soaked in distilled water after being cleaned with tap water. The cleaned corn silk was dried in a vacuum oven (Thermo Scientific Vacuum Oven, Model 3608-5, India) at 50°C and 25 mm Hg until a constant weight was achieved. By using a commercial mixer grinder (Bajaj Electrical and Electronics Pvt. Ltd., Rex 500, Punjab, India), dried silk was grounded to make it in powder form. The resulting corn silk powder was subjected to stainless steel sieves of British sieve sizes 20, 36, 52, 72, and 100 which constituted the particle sizes 750, 425, 300, 212, 150 and 75 µm, respectively for sieve analysis using an electric seive shaker (8" Sieve Shaker SS-15, Gilson Company, Inc., Lewis Center, OH, U.S.A). The corn silk powder was stored at 4°C sealed in zip lock laminates (Wellworth Packers Pvt. Ltd., Delhi, India) until used for analysis. The pictorial presentation of corn silk powder processing is shown in Figure 1.

As the techno-functional properties are affected greatly by the moisture content of the raw material, the moisture content of corn silk was determined using the method described by AOAC (2005). The dehydrated sample was used for the techno-functional analysis. The bulk density was calculated by the method given by Kumar and Saini (2016) using the formula mentioned below

$$\text{Bulk density}\left(\frac{g}{ml}\right) = \frac{\text{Weight of the container and sample} - \text{weight of container}}{\text{Volume of the container}}$$

The Tapped density, Hausner ratio, and Carr index were calculated by the method explained by Tze et al. (2012) by using the formula given below in equations

$$\text{Tapped density}\left(\frac{g}{ml}\right) = \frac{\text{Mass of powder}}{\text{Final tapped volume}}$$

The Hausner ratio expresses the flowability of a powder or granular material and is calculated by the formula given in equation mentioned below

$$\text{Hausner Ration (HR)} = \frac{\text{Tapped density}}{\text{Bulk density}}$$

The Carr index (CI) indicates the compressibility of the powder and is calculated by the given equation mentioned below

$$\text{Carr Index (CI)} = \frac{\text{Tapped density} - \text{Bulk density}}{\text{Tapped density}} \text{x} 100$$

The angle of repose (φ) method described by Brar et al. (2017) was used. The height of the heap (H) and the diameter of the heap (D) of dried corn silk powder was measured by using equation mentioned below

$$\varphi = tan^{-1}\frac{2H}{D}$$

Water Absorption Index (WAI) and Water Solubility Index (WSI)

The WAI and WSI were determined by the method explained by Sharma et al. (2015). The sample (3 g) was added in 30 ml of distilled water and mixed using a vortex mixer. The mixture was kept in the water bath at 30 °C for 30 minutes and then centrifuged at 4500 rpm for 10 minutes at 4 °C by using refrigerated centrifuged. The supernatant was collected and used for the determination of WAI and WSI by using equations mentioned below

$$\text{WAI}\left(\frac{g}{g}\right) = \frac{\text{Weight of hydrated residue}}{\text{Dry weight of sample}}$$

$$\text{WSI}\,(\%) = \frac{\text{Weight of dissolved solids in supernatant}}{\text{Dry weight of sample}} \times 100$$

Swelling capacity

To measure swelling capacity, 2.5 g of sample was measured in a graduated cylinder (50 mL). The test tube was filled with 30 mL of distilled water and the sample was dispersed slowly. The filled test tube was kept for 16 hours to achieve its hydration and the final volume occupied by the sample in the bottom of the test tube was measured (Pineda-Vargas et al., 2020). The result was expressed with equation mentioned below

$$SC = \frac{\text{Final volume } (Vf)(ml)}{\text{Weight of sample (g)}}$$

Whereas, V_f = Final volume after 24 hours

Foaming capacity and stability

Foaming capacity and stability were measured by the method given by Mokhtar et al. (2018). Two grams of samples were whipped with 100 ml of distilled water for 5 min at high speed in a blender. The whipped sample was transferred into a 250 ml graduated cylinder. The total volume of foam after whipping was noted and expressed as a ratio of the original volume before blending as mentioned in equation 12.

$$\text{Foaming capacity } (\%) = \frac{Va - Vb}{Vb} \times \frac{100}{1}$$

Where, Va is the volume of liquid and foam (ml) and Vb is the volume of the mixture before blending. For the measurement of foam stability, the volume of foam one hour after whipping was recorded and expressed as a percent of initial volume foam.

Oil absorption capacity (OAC) and swelling capacity (SC)

OAC and SC were assessed by the method described by Baljeet et al. (2014) and Ishara et al. (2018) respectively. For OAC, 0.3 gm of the sample was mixed in 3 ml of corn oil in a pre-weighted 10mL graduated centrifuged tube for 1 minute. The mixture was centrifuged at 2060 rpm for 30 minutes and the supernatant was discarded. The test tubes were re-weighted and the OAC percent was calculated by the equation 13 mentioned below.

$$\text{OAC } (g/g) = \frac{\text{Weight of sample} + \text{Oil}}{\text{Weight of sample}}$$

5.2.4 Effect of blanching time and temperature on enzyme activity

Process of blanching

The corn silk samples were blanched in water at 80, 90 and 100 and steamed respectively for 30, 60, 90°C and 120 seconds. Approximately 50 g of corn silk were taken in 250 mL f water in a beaker and the beaker were placed in a temperature controlled hot water bath (Macro Scientific Works, New Delhi, India). These blanching treatments were chosen to study the impact of hot water blanching on enzyme inactivation (Shivhare et al., 2009).

Catalase and POD activity

Qualitative test for peroxidase activity (POD)

Following blanching, the blanched corn silk were crushed in a porcelain bowl. A test tube was filled with ten to twenty grammes of crushed material and 20 mL distilled water. The solutions of guaiacol (1%) and hydrogen peroxide (0.3%) were then produced according to Ranganna's instructions (2006). The contents of the test tube were thoroughly mixed with guaiacol solution (1 mL) and hydrogen peroxide solution (1.6 mL). A strong POD activity was indicated by a quick and intense brown-reddish tissue browning within 5 minutes. The gradual emergence of a light pink tint showed that POD inactivation was incomplete or that POD activity was minimal. The reaction was negative and the enzymes were considered inactivated if no colour developed after 5 minutes.

Crushed blanched corn silks (about 2 g) were combined with 20 mL distilled water in a test tube shortly after blanching. After 15 minutes, a 0.5 mL solution of 1 percent hydrogen peroxide was added. The existence of catalase was shown by a strong gas (oxygen) generation for around 2–3 minutes, and the absence of gas indicated that catalase had been completely inactivated.

5.2.5 Drying kinetics

Drying of corn silk

Corn silk samples were dried at 40, 50 and 60°C in a tray dryer (Memmert UF 110 model; Memmert GmbH + Co. KG, Schwabach, Germany) at a constant air velocity of 1m/s. 100 g of corn silk samples were obtained for each drying experiment, and moisture losses were measured at 15 minute intervals throughout the experiment. In single-layer drying, were distributed in rectangular chambers 45 cm long by 30 cm wide. Low, moderate, and high drying temperatures were used to select the drying temperatures.

Thin layer mathematical modelling

The moisture content (MC) of corn silk (drying rate of silk), temperature, and relative humidity in the dryer, as well as the ambient, were used to simulate thin layer drying kinetics in the dryer using experimental models. Following equation was used to compute the moisture ratio (MR) of corn silk.

$$MR = \frac{M-Me}{Mi-Me}$$

Where, *MR*= Moistire ratio, M is the moisture content (% db) at time and *Mi* and *Me* are the initial and equilibrium moisture contents respectively on dry weight basis.

Models

To understand the best and suitable model for the drying characteristics of the corn silk, the experimental data were fitted in 3 models as mentioned in Table 1. These models show the relationship between ratio and drying time. To describe the drying processes of corn silk in the drier, the best model was chosen. To measure the goodness of the fit, statistical parameters such as the coefficient of determination (R^2) and the root mean square error (RMSE) were used to identify the best fit model to the experimental data. The model with the highest R^2 and the lowest RMSE was the best fit (Duc et al., 2011 and Radhika et al., 2011).

Table 5.1: Mathematical drying model

Models	Equations	References
Page	$MR = \exp(-kt^N)$	Darvishi et al. (2014)
Lewis	$MR = \exp(-kt)$	Sayyad et al. (2021)
Handerson-Pabis	$MR = a\exp(-kt)$	Ajala and Abubakar (2018)

Model fitting

Statistical measures such as the root mean square error (RMSE) and coefficient of determination (R^2) were determined using formulas shown in Table 1 to assess the fitness of experimental data to thin-layer drying models, as published by Chayjan et al (2011). Experimentally, the empirical constants for thin-layer drying models were determined from normalised drying curves at various temperatures, which were evaluated using coefficient of determination (R^2). The normalised Page equation takes the following form:

$\ln[-\ln(MR)]=\ln(k)+N\ln(t)$

The drying constants k and N are calculated using the intercept and slope of the ln(MR) vs ln(t) graph, respectively. The normalised Lewis equation takes the following form:

$\ln(MR)= -kt_{+1}$

and of the Henderson-Pabis equation is

ln(MR)= -*kt*+a

The drying constants *k* and *a* are calculated from the slope and intercept of the ln(MR) vs time curve, respectively. The intercept in the Lewis equation is set to one. Extending the drying period until no detectable weight loss was detected yielded the equilibrium moisture content (Me). A temperature/humidity logger (Digisense 91090-00, Cole-Parmer Instrument Co.) was used to measure the air temperature and humidity. Root mean square error (RMSE), chi square (χ^2), and relative percent error (PE) were used to assess each model's quality of fit. Using root mean square error and chi square, the predicted moisture ratio was compared to the experimental moisture ratio as given in the following equations (Roberts et al., 2008):

$$\mathrm{RMSE} = \left[\frac{1}{n\sum_{i=1}^{n}\frac{[(\mathrm{MRexp,i}-\mathrm{MRpredict,i})]_1}{2}}\right]$$

$$\mathrm{X^2} = [1/(N-n)\,\sum\_(i=1)\text{^}n\text{▒}(\mathrm{MRexp,i}-\mathrm{MRpredict,i})\text{^}2$$

The prediction gets closer to experimental data when RMSE and χ^2 approaches zero. Whereas RMSE and χ^2 compare the differences between expected and experimental moisture ratios, relative percent error compares the absolute differences between predicted and experimental moisture contents during the drying process (Cantu-Lozano et al., 2013).

$$PE(\%) = [100/n\backslash sum\_(i=1)\text{^}n\backslash of|Mexp,i-\backslash close\ \backslash open\ \ Mpredict,i\backslash close|/(Mexp,i)"] \qquad (7)$$

Effective moisture diffusivity

Fick's second law equation was used to determine the effective diffusivity value (D_{eff}) as mentioned in equation 8, 9 and 10.

$$MR = \frac{8}{\pi^2} + \sum\_{n=0}^{\infty}\left(\frac{1}{2n+1}\exp\left(-\frac{n(2n+1)\pi^2}{4L^2}D_{eff}t\right)\right) \qquad (8)$$

$$\mathrm{MR} = \frac{8}{\pi^2}\exp\left(-\frac{\pi^2 D_{eff}t}{4L^2}\right)$$

Then equation 9 can be linearized into

$$\ln\mathrm{MR} = \frac{\ln 8}{\pi^2} - \frac{\pi^2 D_{eff}t}{4L^2}$$

Activation energy

Arrhenius equation was used for calculating activation energy which defines the relationship between the diffusion coefficient and the drying temperature as mentioned in equation

$$\mathrm{D_{eff}t} = Do\,\exp\left(\frac{\mathrm{Ea}}{RcT}\right)$$

where Do denotes the Arrhenius equation's pre-exponential factor (m2/s), Ea is the activation energy (kJ/mol), Rc denotes the universal gas constant (kJ/mol K), and T denotes the absolute air temperature (K). The slope of the Arrhenius plot, ln (Deff) vs. 1/T, is used to calculate the activation energy.

5.2.6 Different types of drying of corn silk

The four different techniques namely shade, oven, tray and vacuum drying were used on the corn silk as shown in Figure 5.2. Prior to each experiment, desired temperature conditions inside the drying chambers for oven and vacuum drying were achieved for at least 1 hour. For all of the drying studies, the sample size was kept constant at 500±0.5 g.

Tray drying: The drying experiment was carried out in an oven-drier (Memmert UF 110 model; Memmert GmbH + Co. KG, Schwabach, Germany) at three temperatures (40, 50, and 60°C) with a constant air-flow rate of 2 m/s. In single-layer drying, corn silk samples were distributed in rectangular chambers 45 cm long by 30 cm wide.

***Shade drying*:** The corn silk samples were sliced into small pieces, each about 1 cm long. The samples were placed on a well-ventilated laboratory bench and spread evenly on a single layer sample tray. Before drying, the average air room temperature and relative humidity were 26±1 °C and 35%, respectively. At 1 h intervals, the weight was measured. To prevent moisture absorption, the dried samples were stored in airtight LDPE bags that were sealed thermally.

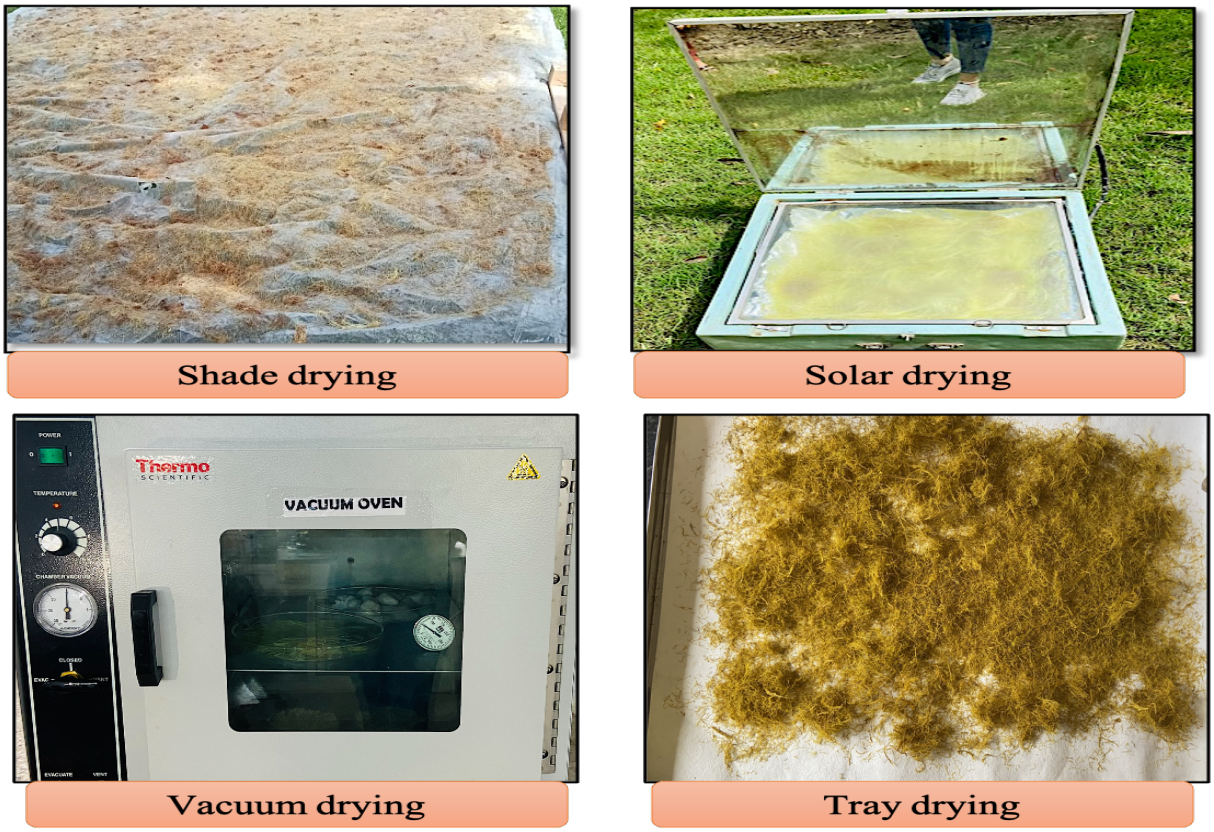


Figure 5.2: Different drying methods for corn silk

***Solar drying*:** In this experiment, a small-scale solar-drier was used. A wooden box with gross dimensions of 1.0 m long, 0.5 m wide, and 0.20 m deep served as the solar collector. The box was constructed of two layers of plywood (0.0003 m thick) with a foam layer (0.03 m thick) insulating the space between the two layers. The box was painted from the inside and out with a background paint containing 50% by weight of talc powder. A corrugated absorber plate with a surface area of 0.62 m^2 was made of 0.5 mm thick galvanised iron sheet. One layer of common glass, 0.003 m thick, was used to cover the solar collector.

***Vacuum drying*:** The cleaned corn silk was dried in a vacuum oven (Thermo Scientific Vacuum Oven, Model 3608-5, India) at 50°C and 25 mm Hg until a constant weight was achieved.

5.2.7 Nutritional composition of corn silk powder

The chemical composition (moisture, carbohydrates, protein, fat, and ash) of the corn silk powder (2 g) was determined (AOAC, 2005) and the values were mentioned in g/100 g. The moisture content of the sample was calculated using the oven-dry method. Protein content was estimated by using Kjeldahl's method and the values were obtained by multiplying the nitrogen content by a factor of 6.25. The fat content of the corn silk powder samples was determined by the Soxhlet method (Nurhanan and Rosli 2014). The digestion method was used to examine the crude fiber content of the corn silk powder samples (Yo et al., 2016). Whereas the carbohydrate content of the sample was calculated by the difference method (Ranganna 2006). The water activity of the dried corn silk powder sample was determined by the water activity analyzer (Testo AG 400, Germany) as per the proposed method of Pant et al. (2021). The calculation of the result was done of the fresh weight basis of the dehydrated powder. The methods used for analysis were validated for reproducibility, accuracy and precision indicated with relative standard deviation (%RSD) in the Table 1. The correlation coefficient for the methods were found to be >0.98.

Mineral analysis

The mineral content of the corn silk sample was determined using the Thermo iCAP 7000 Duo ICP OES (Thermo Fisher Scientific, Germany) (Zhao et al., 2012). For plasma, pure Argon gas was used (Himalayan Gases, Baddi, India). The microwave digestion process was carried out in PTFE vessels utilizing a Multiwave Pro microwave oven (Anton Par, Austria). Deionized water ASM Type I (18.2 mΩ, Aurium mini, Sartorius, Germany) Aurium

mini, Sartorius, Germany) was used to prepare all the solutions. In the digestion of the materials, nitric acid (HNO_3 69 %, Loba Chemie Pvt Ltd, Mumbai) was used. Standard solution dilutions (1000 µg mL^{-1}) of Ag, Al, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, In, K, Li, Mg, Mn, Na, Ni, Pb, Sr, Tl, and Zn were used to make the analytical solutions (Alfa Aesar, Specure, USA). In the PTFE vessels, sample masses of 0.5 g were directly weighed, followed by the addition of 7 mL of HNO_3. The microwave-assisted digestion was carried out utilizing the following five-step heating program: (1) 10 min ramp to 150 °C; (2) 10 min hold at 150 °C; (3) 10 min ramp to 180 °C; (4) 10 min hold at 180 °C; (5) 21 min ramp to 55 °C cooling temperature The solutions were then transferred to polyethylene tubes and volumes created up to 30 mL with ultrapure water ASTM Type I after the containers were cooled to room temperature. The ICP OES quantification procedure was performed in the axial view of plasma with a radio frequency power of 1250 W, sample flow 0.50 L min^{-1}, plasma gas flow 12 L min^{-1}, Analysis Pump rate 50 rpm, Auxiliary gas flow 0.5 L min^{-1}, Nebulizer gas flow 0.5 L min^{-1}, integration time 15 s, stabilization time 5 s, and nebulization pressure 20 psi after digestion of the completed samples. Calcium (293.366, 396.847 nm), Copper (324.754 nm), Iron (259.940 nm), Potassium (766.490 nm), Magnesium (279.553 nm), Manganese (257.610 nm), Sodium (588.995, 589.592 nm), and Zinc (213.856 nm) were monitored for the execution of the proposed method. The method validation represented with %RSD, Limit of detection (LoD), Background equivalent concentration (BEC) and the coefficient of correlation (R^2) are represented.

5.2.8 Colour analysis

The color of corn silk was measured in triplicates using a Hunter LAB Colorimeter (CM-508 d Model, Minolta, Japan). The three-dimensional color space is perceived in L*, a*, and b*, with L* (Luminance) expressing brightness along the vertical axis, ranging from total black to complete white (i.e. 100 % black to 100 % white). The a* and b* axes, respectively, range from greenness (-a*) to redness (+a*) and blueness (-b*) to yellowness (+b*). Each sample was tested in three different ways. The formula as given in equation below was used to calculate the chroma (c*) and hue angle (h°) (Castillo et al., 2020). The validation of the methods indicated r^2 value >0.98. The accuracy and precision of the method indicated through %RSD.

$$c* = (a*^2 + b*^2)^{1/2}$$

$$H^{o} = \tan^{-1} (b*/a*)$$

Extraction of ethanolic extract

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

Determination of Total phenolic content (TPC), Total flavonoid content (TFS), and Ascorbic acid (AA)

Tha antioxidants were analysed as the methods mentioned in section 5.2.2

Antioxidant activities

The antioxidant activities *viz.* FRSA, ABTS and FRAP were analysed by the method mentioned in section 5.2.2.

5.2.9 Characterization of corn silk powder

Differential Scanning Calorimetry

The thermal investigation of corn silk powder was done using a differential scanning calorimeter (Shimadzu DSC-50 system, Shimadzu, Kyoto, Japan). Thermograms were collected after crumpling 2 mg powdered samples in a standard aluminium pan heated from 30 to 450 °C with a 10 °C/min ramping and continual nitrogen purging (20 mL/min) (Chawla et al., 2021). The correlation coefficient was found to be >0.98 and the relative standard deviation observed was in the range of 0.28-0.76 (%RSD).

Fourier Transform Infrared Spectroscopy (FTIR)

Dried corn silk powder was subjected to FTIR analysis (Shimadzu 8400S FTIR spectrometer, equipped with KBr beam splitter) using approximately 5 mg of each sample and 5 mg KBr for the qualitative analysis (Chawla et al., 2020). The FTIR spectrophotometer was used with a maximum resolution of -0.85 cm^{-1} and a spectrum range of 4000–400 cm^{-1}. The spectra obtained for the various samples were analyzed according to Stuart's guidelines

(2004). The correlation coefficient was 0.995 indicating linearity of the methods. The relative standard deviation (%RSD) observed was 0.97%, indicating high precision and accuracy.

X-ray diffraction

An analytical X-ray Diffractometer (X'Pert PRO, Panalytical, Almelo, Netherlands) was used to produce XRD patterns using a Cu-based anode X-ray tube (Suhag et al., 2021). Using a glass slide and an aluminium holder, the corn silk powder sample was pushed firmly. The experiments were carried out with `a scanning rate of 4°/min at 30 mA and 40 kV with a diffraction angle ranging from 4 to 40° (2θ). The correlation coefficient of the methods was >0.998. The accuracy and precision of the methods was inducated using RSD (%) was found to be in the range of 0.30-1.8 (%RSD). The instrumental reproducibility was 0.76 %RSD and the intraday reproducibility was 0.85% RSD indicating validity of the method used.

5.2.10 Microbial profiling

Total plate count, yeast and mould count, and coliform count were determined using plate count agar (PCA), potato dextrose agar (PDA), and violet red bile agar (VRBA), respectively, on samples held at 10, 25, 37, and 45 °C. Using the usual plate count approach, the presence or absence of *Clostridium botulinum, Salmonella sp,* and *Staphylococcus aureus* was confirmed using reinforced clostridial agar, bismulth sulphite agar, and mannitol salt agar, respectively. Himedia Laboratories Private Ltd., Mumbai, India, provided the medium for all of the microbiological testing.

5.2.11 Quantitative analysis of polyphenolic compounds

Ultra-pressure liquid chromatography (Thermo Fisher Scientific, Dionex Ultimate 3000, USA) was used to determine the quantitative analysis of bioactive components of ethanolic corn silk extract. Instrument was equipped with a stationary column 20RBAX Eclipse XDB- C18 (4.6× 250 mm, 5 micron, Agilent) and the mobile phase 1% acetic acid (solvent A, 70%) and acetonitrile (solvent B, 30 %) were used for the quantification of polyphenols. A 20 µl sample volume was injected in sample injector and isocratic run with flow rate of 1ml/min for 10 min was employed. For the detection of polyphenols Diode Array Detector (280 nm) with column oven temperature 30 °C were used. In addition, for the quantification of flavonoids, water (solvent A) and acetonitrile (solvent B) were used as a mobile phase. Herein, gradient system (solvent A: 15, 30, 50 and 15 % and solvent B: 85, 70, 50, 85 %) with flow rate (0.7 ml/min) for 0, 5, 15 and 20 min, respectively were used. Similar

to polyphenolic compounds, Diode Array Detector (350 nm) with column oven temperature 25 °C was used for the detection of flavonoids. The Chromeleon 7.0 installed in Microsoft windows 10 software was used to quantify the polyphenolic and flavonoid components (Bains and Chawla, 2020).

5.3 CHARACTERIZATION OF INSTANT MIX AND BEVERAGE BY USING DRY CORN SILK POWDER AND EXTRACT

5.3.1 Particle size analysis

Average particle size of corn silk powder

The particle size of dispersed components of corn silk was analyzed using dynamic light scattering (DLS) technique by following the method proposed by Chawla et al., (2021). For dispersed components, 2 gm sample was rehydrated in deionized water for 12 h at 27°C, the soluble fractions were collected after centrifugation at 5000 rpm for 10 minutes and sample the was subjected to particle size analysis. The sample was diluted in the ration 1:10 using deionized water and subjected to ultra-sonification. A probe sonicator (Sonics and Materials Inc. new Town, CT, USA) was used for the ultra-sonification where the whole mixture was subjected for the formulation of the final sample at 5°C with a 5-s pulse for 20 minutes. For subsequent examination, the prepared samples were maintained in glass vials at room temperature (25°C). A computer-controlled particle size analyzer was used to investigate particle dispersion in liquid (Zetasizer Nano ZS, Malvern Instruments Ltd. Malvern, WR14 1XZ, UK).

5.3.2 Antioxidant activity of corn silk powder

The antioxidant activity was analysed by the method mentioned in section 5.2.2.

5.3.3 Mineral analysis

The mineral analysis was assessed as the method mentioned in section 5.2.6.

5.3.4 Yield of corn silk

To calculate the yield of corn silk, 5 different maize cobs of G5417 was taken and the weight of different parts of maize cob was noted and by using percentage method, the mean values of various parts of maize cob including corn silk, cob and leaf stalk was noted.

5.3.5 Water activity of corn silk

The water activity of different dried corn silk powder was evaluated by water activity analyzer (Testo AG 400, Germany) as mentioned by Pant et al., (2021).

5.3.6 X-ray Diffraction Analysis (XRD)

An analytical X-ray Diffractometer (X'Pert PRO, Panalytical, Almelo, Netherlands) was used to produce XRD patterns using a Cu-based anode X-ray tube (Suhag et al., 2021). Using a glass slide and an aluminium holder, the corn silk powder sample was pushed firmly. The experiments were carried out with a scanning rate of 4°/min at 30 mA and 40 kV with a diffraction angle ranging from 4 to 40° (2θ).

5.3.7 Differential Scanning Calorimetry (DSC)

A differential scanning calorimeter was used to conduct thermal investigation of corn silk powder (Shimadzu DSC-50system. Shimadzu, Kyoto, Japan). Thermograms were obtained after 2 mg powdered samples were crumpled in a standard aluminum pan heated from 30 to 450 °C with a ramping of 10 °C/min under constant purging of nitrogen (20 mL/min).

5.3.8 Cytotoxicity of corn silk powder

Using a tetrazolium-based colorimetric technique proposed by Chawla et al. (2020), the cytotoxicity of corn silk extract was determined using Caco-2cell culture. Cell monolayer was achieved by growing $1x10^5$ cells in each well of 96 well plates and incubating at 37 °C for 24 h in a CO_2 incubator (95% humidity. 5% CO2). Corn silk (solubilized in medium) in various concentrations (mg/mL) were introduced to the wells and incubated at 37 °C for 20 h in a CO_2 incubator. After incubation, the media was removed by inverting, flipping, and blotting the plate. PBS (100 µL per well) was used to wash the cells. A 90 µL of media and 10 µL of MTT (5 mg/mL of media) were added to the cells, and the plate was gently shaken and incubated at 37 °C for 4 h. After incubation, 70 µL of supernatant were transferred to each well, and 100 µL of dimethyl sulfoxide were added to dissolve the formazan crystals. An absorption spectrum at 570 nm was observed to assess the optical density using a microplate reader.

5.3.9 Antimicrobial assay (Agar well Diffusion Method)

Staphylococcus aureus, Klebsiella pneumoniae, Pseudomonas aeruginosa, Salmonella typhimurium, and *Candida albicans* were tested in vitro for antimicrobial efficacy against pathogenic Gram-positive and Gram-negative bacteria. The antimicrobial assay was carried out using Najda et al (2021) agar well diffusion method. The bacterial strain ($1.5*10^8$

cells/mL) was inoculated on Muller Hinton Agar supplemented with 4% NaCl. Cork borer were used to make the wells on plates. With the use of a micropipette, the corn silk extract (10 mg) was mixed in 10 mL of DMSO (5%) and poured (50 L) into an agar well**.** A 100 µL of corn silk extract solution was poured into different agar wells with the help of a micropipette. Streptomycin (1 g/mL), a commercially available antibiotic, was employed as a positive control, whereas, DMSO was used as a negative control. The pathogenic bacterial strains were inoculated on MHA plates and incubated for 24 h at 37°C. The zone of inhibition in mm was used to measure antibacterial activity.

5.3.10 Corn silk powder preparation

Corn silk samples of G5417 hybrid variety were collected from the agriculture farm of Lovely Professional University, Phagwara, Punjab, India. The silk was green in colour and was harvested 10 days (silking stage) following their emergence. Fresh silk was soaked in distilled water after being cleaned with tap water. The cleaned corn silk was dried in a vacuum oven (Thermo Scientific Vacuum Oven, Model 3608-5, India) at 50°C and 25 mm Hg until a constant weight was achieved. By using a commercial mixer grinder (Bajaj Electrical and Electronics Pvt. Ltd., Rex 500, Punjab, India), dried silk was grounded to make it in powder form. The resulting corn silk powder was subjected to stainless steel sieves of British sieve sizes 20, 36, 52, 72, and 100 which constituted the particle sizes 750, 425, 300, 212, 150 and 75 µm, respectively for sieve analysis using an electric seive shaker (8" Sieve Shaker SS-15, Gilson Company, Inc., Lewis Center, OH, U.S.A). The corn silk powder was stored at 4°C sealed in zip lock laminates (Wellworth Packers Pvt. Ltd., Delhi, India) until used for analysis.

The moisture content of corn silk was determined using method given by AOAC (2005).

5.3.11 Amino acid profiling

Amino acid profiling was analysed by the method given by Mathur et al., (2021). Corn silk powder (5–6 mg) was added to 10 mL of 6 N HCl resulted in protein breakdown. A phenol crystal was added to the =sample vial, which was then vacuum dried for 20 h at 110°C. Following the protocol in the Waters AccQ Tag method manual, hydrolyzed samples were derivatized using borate buffer (pH 8.2–10) and AccQ Tag Fluor reagent (WAT052880) (Waters Millipore Corporation, USA, 1993). Detection was carried out using binary gradient

HPLC-FLD on an AccQ-Tag (Nova-Pak C18) 3.9 150 mm 4 M silica bonded column (WAT052885) (Waters Corporation, USA). The calibration curve (0.02–0.5µmole L^{-1}) was plotted using the total 16 amino acids reference standard (WAT088122).

Table 5.2 Optimization of levels of various constituents in corn silk based instant mix using response surface methodology (RSM)

Experiment Number	Corn silk powder (%)	Sugar (%)	Xanthan gum (%)	Skimmed milk powder (SMP %)
1	5.00	5.00	0.20	89.8
2	15.00	5.00	0.20	79.8
3	5.00	10.00	0.20	84.8
4	15.00	10.00	0.20	74.8
5	5.00	7.50	0.10	87.4
6	15.00	7.50	0.10	77.4
7	5.00	7.50	0.30	87.2
8	15.00	7.50	0.30	77.2
9	10.00	5.00	0.10	84.9
10	10.00	10.00	0.10	79.9
11	10.00	5.00	0.30	84.7
12	10.00	10.00	0.30	79.7
13	10.00	7.50	0.20	82.3
14	10.00	7.50	0.20	82.3
15	10.00	7.50	0.20	82.3
16	10.00	7.50	0.20	82.3
17	10.00	7.50	0.20	82.3

5.3.12 Optimization of corn silk based instant mix

The instant mix were prepared by using corn silk powder, sugar, xanthan gum and skimmed milk powder as filler and different treatments were formulated which were further used for sensory and physico-chemical analysis as shown in Table 5.2 and 5.3.

5.3.13 Optimization of levels of various constituents in corn silk based ready to serve (RTS) beverage using response surface methodology (RSM)

For the preparation of ready to serve beverage, aqueous extract of corn silk kinnow juice, sugar and xanthan gum were used. All the ingredients were mixed together and filled into glass bottles after which the bottles pasteurized in boiling water at 100 ^{o}C for 15 minutes. The formulations were shown in Table 5.4 and 5.5.

Table 5.3 Sensory analysis of the different treatments of corn silk based instant mix

Corn silk Powder (in g)	Sugar (in g)	Colour and and appearance	Body and texture	Flavour and aroma	Overall acceptability
5	5	8	9	8	8.33
5	7.5	8	8	8	8.00
5	10	8	7	8	7.66
5	15	7	7	8	7.33
10	5	8	7	7	7.33
10	7.5	7	7	7	7.00
10	10	6	7	7	6.66
10	15	6	6	6	6.00
15	5	7	8	8	7.66
15	7.5	7	7	7	7.00
15	10	6	7	6	6.33
15	15	6	6	5	5.66
20	5	7	8	8	7.66
20	7.5	7	7	7	7.00
20	10	6	6	7	6.33
20	15	5	5	6	5.33

5.3.14 Responses for Instant mix

Physico-chemical analysis

The moisture content of instant mix was calculate as per the procedure mentioned in section 5.2.3 and in physico-chemical analysis, bulk density, tapped density were performed as mentioned in section 5.2.3.

Antioxidant content and activity

Free radical scavenging activity, total phenolic content were analysed by the procedure already mentioned in 5.2.2.

Microbial assay

Potato dextrose agar (PDA), Violet red bile lactose agar (VRBL), and Plate count agar (PCA) media were used to count total yeast, coliforms, and bacteria, respectively (Teincheu et al., 2021).

Total plate count

In 100 mL of distilled water, 2.4g of Plate Count Agar (PCA) was dissolved. It was autoclaved for 1 hour at 121 °C in an electric pressure steam steriliser (Model No.25X) and then allowed to cool to roughly 45 °C. 70 % alcohol was used to sterilise the work space. Using a micro pipette, 1mL of each sample was pipetted into labelled petri dishes (Gilson

Pipetman, 060087N). The medium (PCA) was put into the Petri plate and gently swirled with the sample to homogenise it. In the Petri plate, this so- lidified and formed a gel. It was then incubated for 24 hours at 37 °C (DHP-9050). The entire bacteria were quantified as colony forming units after 24 hours (CFU).

Total yeast count

4.2g of Potato Dextrose Agar (PDA) was dissolved in 100 ml of distilled water. It was autoclaved for 1 hour at 121 °C in an electric pressure steam steriliser (Model No.25X) and then allowed to cool to roughly 45 °C. 70 % alcohol was used to sterilise the work space. Using a micro pipette, 1mL of each sample was pipetted into labelled petri dishes (Gilson Pipetman, 060087N). To homogenise with the sample, the medium (PDA) was put into the Petri dish and gently agitated. In the Petri plate, this hardened and created a gel. It was then incubated for 24 hours at 37 °C (DHP-9050). The entire yeasts were counted as colony forming units after 24 hours (CFU).

Total coliform count

In 150 mL of distilled water, Violet Red Bile Lactose Agar (VBRL) (6.2g) was dissolved. This solution was allowed to boil over a Bunsen burner flame while being shaken until entirely dissolved. After then, it was allowed to cool to about 45 °C. 70 % was used to sterilise the work space. Using a micro pipette, one millilitre (1mL) of each sample was pipetted into marked petri-dishes (Gilson Pipetman, 060087N). The VBRL medium was put onto the Petri plate and gently swirled to homogenise with the sample before being set. To prevent Oxygen from entering, more medium was added. The formed gel was then incubated for 24 hours at 42 °C (DHP-9050).

Table 5.4 Sensory analysis of the different treatments of corn silk based ready to serve beverage

Corn silk extract (in ml)	Kinnow juice (in ml)	Colour and texture	Body and texture	Mouthfeel	Overall acceptability
10	20	8	8	8	8.00
20	20	7	8	7	7.33
30	20	7	7	7	7.00
40	20	6	6	7	6.33
50	20	6	6	5	5.66
10	25	8	9	8	8.33
20	25	7	8	8	7.66
30	25	7	7	7	7.00
40	25	7	6	6	6.33

50	25	6	6	6	6.00
10	30	8	8	9	8.33
20	30	7	8	8	7.66
30	30	7	7	7	7.00
40	30	6	6	7	6.33
50	30	6	5	5	5.33
10	35	7	7	8	7.33
20	35	7	6	7	6.66
30	35	6	6	6	6.00
40	35	6	5	5	5.33
50	35	5	5	5	5.00
10	40	8	8	7	7.66
20	40	7	7	7	7.00
30	40	6	7	7	6.66
40	40	6	6	6	6.00
50	40	5	6	5	5.33
10	45	8	8	8	8.00
20	45	7	7	7	7.00
30	45	7	6	7	6.66
40	45	6	6	7	6.33
50	45	6	6	5	5.66

Table 5.5: Optimization of levels of various constituents in corn silk based ready to serve beverage using response surface methodology (RSM)

Run	Corn silk extract (ml)	Xanthan gum (g)	Kinnow juice (ml)	Sugar (g)	Water (ml)
1	40	0.4	32.5	5	27.1
2	35	0.4	25	5	39.6
3	35	0.4	40	5	24.6
4	40	0.25	40	5	19.75
5	35	0.25	32.5	5	32.25
6	35	0.25	32.5	5	32.25
7	30	0.4	32.5	5	37.1
8	40	0.1	32.5	5	27.4
9	35	0.25	32.5	5	32.25
10	35	0.25	32.5	5	32.25
11	35	0.25	32.5	5	32.25
12	35	0.1	40	5	24.9
13	30	0.25	40	5	29.75
14	40	0.25	25	5	34.75
15	30	0.1	32.5	5	37.4
16	35	0.1	25	5	39.9
17	30	0.25	25	5	44.75

5.3.15 Physicochemical and phytochemical analysis of beverage

pH, titrable acidity and total soluble solids were calculated by the standard methods as mentioned by Hemalatha et al., 2018.

pH: A pH metre was used to determine the pH of the sample (Model: EUTECH Instruments-pH Tutor, Singapore). The calibrated electrode of the pH metre was dipped in 20 mL of RTS beverage sample, and the observations were recorded in triplicate for each sample.

Titrable acidity: The acidity of RTS beverage samples was measured in triplicate using 0.01 N NaOH solution and quantified as percent anhydrous citric acid using the formula below.

$$Titable\ Acidity\ (\%) = \frac{Titre\ value\ (mL) * N\ NaOH * Volume\ (mL) 8\ Eq.weight\ (Citric\ acid)}{Sample\ weight\ (g) * Aliquot\ taken\ for\ Titration\ (mL) * 100} * 100$$

Total soluble solids: The Total Soluble Solids (TSS) of the various corn silk based RTS beverage samples were determined in triplicate using a calibrated hand refractometer (Model: Erma, Tokyo, Japan), with the result represented in brix.

Antioxidant content and activity

Free radical scavenging activity, total phenolic content were analysed by the procedure already mentioned in 5.2.2.

Microbial assay

Microbial assay was analysed as the method mentioned in 5.3.14.

Viscosity

A Perten Instruments Rapit Visco Analyser Tec Master mix (Sweden) was used to determine the final viscosity of the corn silk based instant. The weight of the standard sample was 3.5 g, the weight of the standard water was 25 g, and the moisture basis was 14%. The slurry was heated and held at 50 °C for 50 seconds after adding the necessary amount of water, then elevated to 91 °C in 7:30 minutes (at 5.47 °C/min heating rate) and held at 91 °C for 5 minutes. In 7:30 minutes (at 5.47 °C/min), the paste was cooled to 50 °C. The instrument paddle revolved at 960 rpm for the first 10 seconds before being decreased to 160 rpm for the remainder of the experiment (Alamri et al., 2014).

5.4 Effect of storage conditions and packaging material on shelf life of the developed value-added product

5.4.1 Sensory evaluation: 9 point hedonic scale and descriptive analysis was used. The panel consisted of 100 semi-trained panelists (n=100; 50=male, 50=female) (Wan Rosli et al. 2011). Shelf life study was be performed for the optimized products using above analytical parameters. Chemical kinetics was used to determine the shelf life of the optimized products (Rasane et al. 2017).

5.4.2 Shelf life analysis

The shelf life of the formed product was determined by analyzing the chemical and functional changes taking place in the food samples packaged using low-density polyethylene (LDPE), high density polyethylene (HDPE) and metallized polyster pouches (MP) for instant mix and glass bottles for ready to serve beverage stored at 10, 25 and 37° for a storage period of three months. Following set of analysis were performed.

5.4.3 Chemical analysis

Hydroxymethylfurfural content (HMF)

The concentration of hydroxyl methyl furfural (HMF) in nstant mix made from was determined using method given by Aggarwal et al., (2019). Three grams of corn silk based instant mix were thoroughly mixed with 7 mL distilled water, then 5 mL 0.3 mol eq/L oxalic acid was added to the tubes, which were then placed in a boiling water bath for 60 minutes. After cooling the tubes, 5 mL of trichloroacetic acid solution (40 g/100 mL) was added. Whatman filter paper number 42 was used to filter the precipitated mixture. The filtrate (0.5 ml) was then placed in a 5 ml test tube with 3.5 ml distilled water and 1 ml 0.05 mol/L thiobarbituric acid solution (aq) and kept at 40 °C for 50 minutes in a water bath. After cooling, the absorbance was measured at 443 nm and reported as μmol/g.

Thiobarbituric acid value (TBA)

TBA value was used to determine the amount of fat oxidation in supplementary foods. In a 250 mL beaker, weigh precisely 2±0.01 g and mix with 50 mL of 20% trichloroacetic acid and 50 mL of distilled water, then let undisturbed for 10 minutes. The contents were then filtered using Whatman No. 1 filter paper. An aliquot of 5 mL was pipetted into a test tube, and 5 mL of 0.01 M 2-thiobarbituric acid was added to it. The test tubes were incubated in a water bath at 100 °C for 30 minutes to develop colour. The test tubes were incubated in a water bath at 100 °C for 30 minutes to develop colour. The contents were chilled to room temperature before being tested for absorbance at 532 nm. Water was used in place of the sample for the blank reading. The optical density (OD) of TBA at 532 nm was calculated (Kumar et al., 2017).

The TBA values were calculated by the following equation:

TBA=7.8 X O.D

Whereas, OD= Optical density of the test sample

Free fatty acid content (FFA)

The free fatty acid content of samples was determined using method given by Bordoloi et al., (2020). In a 250ml conical flask, a 2 g sample was dissolved in 50 g of neutral solvent. A few drops of phenolphthalein indicator (1% in 95% ethanol) were added, and the contents were titrated against a 0.10 N potassium hydroxide solution until a pink colour was obtained that lasted for 15 seconds. The following formula was used to calculate acid value and free fatty acid using the titrate value:

$$\text{Acid value (mg KOH/g)} = \frac{\text{Titrate value} \times \text{Normality of KOH} \times 56.1}{\text{Wt of the sample (g)}}$$

The free fatty acid is calculated as oleic acid using the equation

1ml N/10 KOH = 0.028 g oleic acid.

5.4.4 Computation of Reaction kinetics

The chemical changes in the corn silk based instant mix followed the zero and first order reaction kinetics. The following equations were used to compute the zero and first order re-action rate constants (k).

$$C - Co = -k$$

$$ln\frac{c}{co} = -k$$

where, C0 = Initial concentration of the reactant, C = Concen- tration of the reactant at time 't'

For temperature-dependent processes, the Arrhenius equation was used to create a model. The Arrhenius equation was used to characterise the temperature dependence of '

$$k = A_0 e^{-\frac{E_a}{RT}}$$

where, A0 = Arrhenius equation, R = Universal gas constant, 8.314 J/mol °K

T = Absolute temperature, °K, Ea = Activation energy, J/mol

The thermodynamic equation parameters were obtained using mathematical equations based on absolute reaction rate theory, according to Rasane et al. (2018). thermodynamic equation parameters were derived by using mathematical expressions based on absolute reaction rate theory.

$$k = \frac{k_B.T}{h} e^{\frac{\Delta S^*}{R}} .e^{\frac{-\Delta H^*}{RT}}$$

Where, K_B = Boltzmann's constant, 1.38 x 10^{-23} J/°K

H = Plank's constant, 6.63 x 10^{-34} J.S

ΔS^* = entropy of activation, J/mol °K

ΔH^* = enthalpy of activation, J/mol

The enthalpy was calculated from activation energy (E_a) obtained from the experimentally obtained reaction rate constants using the following relationship:

$$\Delta H^* = E_a - RT$$

The free energy of activation (ΔG^*, kJ/mol) was obtained from the following relationship: $\Delta G^* = \Delta H^* - T\Delta S^*$

5.4.5 Storage stability of the optimized instant mix

The time it takes for quality metrics to degrade to an unfavourable level, i.e. the time it takes for quality parameters to return to the level desired by consumers, is referred to as the product's shelf life. The half-life time explains why 50% of quality criteria have degraded from their original value (Veerapandian et al., 2014). The formula used to calculate half life of the optimised instant mix is mentioned below:

Zero order reaction= $A_\circ/(2k_\circ)$

First order reaction= $\ln 2/k_1$

Second order reaction=$1/(k_2 A_\circ)$

Where as, k=rate constant

5.4.6 Cost economics of developed corn silk products

The product's cost was estimated by taking into account the cost of raw materials as well as other charges like as marketing, taxation (VAT), and so on, and was stated as Rs. 1 kg of product (Darshane, 2021).

Chapter-6

RESULTS AND DISCUSSION

6.1 NUTRITIONAL SURVEY

The qualitative nutritional survey of 500 people of different age group was conducted in different type of population including urban, semi-urban and rural. The WHO guidelines of knowledge attitude and practices were used for reference and survey was conducted on both modes (online and offline). The link of online survey is attached with the questionnaire in the ANNEXURE. The different age categories as shown in Table 6.1 depicts the various age groups with their sample size.

Table 6.1: Demographic characteristics of different group of population

Parameters	(n=500) (%)
Age (years)	
18-30	118 (23.6)
31-40	93 (18.4)
41-50	96 (19.2)
51-60	94 (18.8)
61-70	100 (20)
Gender	
Male	268 (53.5)
Female	232 (46.3)
Income group	
Low income group	110 (22)
Middle income group	211 (42.1)
High income group	178 (35.5)
Body weight	
Normal	189 (37.7)
Underweight	31 (6.2)
Overweight	183 (36.5)
Obesity	97 (19.4)

Out of 500 participants, 110 people from low income group, 211 people from middle income group, 178 people from high income group people, 268 males and 232 females in total participated in the dietary survey as shown in Table 1. The percentage of underweight, normal, overweight and obesity in the population reported was 6.2, 37.7, 36.5 and 19.4%. Kruskal Wallis independent (SPSS) was used to determine the statistical difference between age group and different variables and Table 6.2 (a) shows the significant difference ($p<0.05$) of age with the marital status, weight, sleeping hours, eating breakfast, change of cooking oil,

eating fruits and physical activity was observed. The significant difference ($p<0.05$) among of sex with weight, food preference and fast food consumption was observed as shown in Table 6.2 (b). There was no significant difference observed in the prevalence of hypertension and diabetes in males and females. Because preliminary research revealed significant differences in risk factor prevalence between men and women, subsequent analysis was gender-specific. In chronic disease research, age is a well-known potential confounder, and crude gender-specific models were then adjusted for age. The 8% of population was only involved in healthy eating habits, 33.9% population was indulge in doing physical activity and 31.9% population was not doing anything to loose body weight.

The preference for home-made food among population was 283/500 and the liking for food from restaurant, kiosk, dhaba also existed among ages. 51.9% population occasionally involve in consuming breakfast and 19.2% of population does not consume breakfast which might be the reason of overweight and diabetes. 44.1% population skips lunch at the work places and only 11.4% population brings lunch from home. 70.1% samples were involved in eating fast food few times a week and 4% were consuming it on everyday basis. 56.7% of the adult population was suffering from hypertension and 49.1% was diabetic. The age does not have any significant effect of hypertension and diabetes but the prevalence in males (134/268) was seen higher than in female (112/232) was observed for diabetes. Males (153/268) has showed the high prevalence rate for hypertension as compared to females (131/232). The regular fruit consumption was low among the population and only 34.1% population consumes fruit on everyday basis. The alcohol consumption percentage was 23.6 for everyday basis and 29.7% population was every day smoker. 133 males and 124 females were involved in smoking habits and 81 males and 70 females were consuming alcohol among 500 of sample population. The physical activity observed in the sample population as shown in figure 6.2 (e) and 2 (f) showed that 62 males and 74 females were involved in doing exercise on daily basis and 170 people are does physical activity sometimes and 160 people does not do any kind of physical activity.

Short sleep duration, defined as less than 7 hours of sleep in a 24-hour period (CDC, 2017) was found to be prevalent in 215 people out of 500 people. Short sleep duration has been linked to risk factors such obesity, diabetes, poor mental health, and poor academic performance (Wheaton et al., 2015).

Table 6.2 (a): The hypothesis test summary of dietary survey at different age groups among sample population

Sr. No.	Null Hypothesis	Sig.[a,b]	Decision
1	The distribution of Income_group is the same across categories of Age.	.794	Retain the null hypothesis.
2	The distribution of Marital_status is the same across categories of Age.	.000	Reject the null hypothesis.
3	The distribution of Weight is the same across categories of Age.	.016	Reject the null hypothesis.
4	The distribution of What_do_you_think_about_yourself is the same across categories of Age.	.128	Retain the null hypothesis.
5	The distribution of What_you_to_do_improve_yourself_or_lose_weight is the same across categories of Age.	.869	Retain the null hypothesis.
6	The distribution of How_much_do_you_sleep is the same across categories of Age.	.023	Reject the null hypothesis.
7	The distribution of Food_preference is the same across categories of Age.	.082	Retain the null hypothesis.
8	The distribution of How_often_do_you_eat_breakfast is the same across categories of Age.	.001	Reject the null hypothesis.
9	The distribution of Do_you_change_Cooking_oil_monthy is the same across categories of Age.	<.001	Reject the null hypothesis.
10	The distribution of At_school_University_office_you_usually is the same across categories of Age.	.086	Retain the null hypothesis.
11	The distribution of Do_you_like_fast_food is the same across categories of Age.	.363	Retain the null hypothesis.
12	The distribution of How_often_do_you_eat_fast_food is the same across categories of Age.	.180	Retain the null hypothesis.
13	The distribution of What_influence_your_decision_to_eat_out_most is the same across categories of Age.	.156	Retain the null hypothesis.
14	The distribution of Do_you_have_hypertension is the same across categories of Age.	.343	Retain the null hypothesis.
15	The distribution of Do_you_have_diabetes is the same across categories of Age.	.336	Retain the null hypothesis.
16	The distribution of Do_you_like_fruits is the same across categories of Age.	.161	Retain the null hypothesis.
17	The distribution of How_often_do_you_usally_eat_fruits is the same across categories of Age.	.013	Reject the null hypothesis.

18	The distribution of How_frequently_you_drink_milk is the same across categories of Age.	.564	Retain the null hypothesis.
19	The distribution of How_many_meals_you_consume_in_a_day is the same across categories of Age.	.036	Reject the null hypothesis.
20	The distribution of How_many_times_in_a_day_you_feel_hungry_in_a_day is the same across categories of Age.	.269	Retain the null hypothesis.
21	The distribution of Which_of_The_Following_food_you_consume_ofetn_as_snacks is the same across categories of Age.	.319	Retain the null hypothesis.
22	The distribution of How_many_times_in_a_day_you_crave_for_salty_products is the same across categories of Age.	.240	Retain the null hypothesis.
23	The distribution of How_many_times_in_a_day_you_crave_for_sweet_products is the same across categories of Age.	.422	Retain the null hypothesis.
24	The distribution of While_eating_what_do_you_do is the same across categories of Age.	.144	Retain the null hypothesis.
25	The distribution of How_often_do_you_exercise is the same across categories of Age.	.035	Reject the null hypothesis.
26	The distribution of How_long_do_you_excercise is the same across categories of Age.	.010	Reject the null hypothesis.
27	The distribution of How_many_times_do_you_drink_water_in_a_Day is the same across categories of Age.	.861	Retain the null hypothesis.
28	The distribution of How_many_liters_of_water_do_you_drink_in_day is the same across categories of Age.	.064	Retain the null hypothesis.
29	The distribution of Do_you_drink_alcohol is the same across categories of Age.	.497	Retain the null hypothesis.
30	The distribution of Do_you_smoke is the same across categories of Age.	.760	Retain the null hypothesis.
31	The distribution of How_often_do_you_have_bowel_moments is the same across categories of Age.	.244	Retain the null hypothesis.
32	The distribution of How_often_do_you_urinate_a_day is the same across categories of Age.	.579	Retain the null hypothesis.

Table 6.2 (b): The hypothesis test summary of dietary survey of different sexes among sample population

Sr. No.	Null Hypothesis	Sig.[a,b]	Decision
1	The distribution of Income_group is the same across categories of Sex.	.796	Retain the null hypothesis.
2	The distribution of Marital_status is the same across categories of Sex.	.006	Reject the null hypothesis.
3	The distribution of Weight is the same across categories of Sex.	.002	Reject the null hypothesis.
4	The distribution of What_do_you_think_about_yourself is the same across categories of Sex.	.401	Retain the null hypothesis.
5	The distribution of What_you_to_do_improve_yourself_or_lose_weight is the same across categories of Sex.	.034	Reject the null hypothesis.
6	The distribution of How_much_do_you_sleep is the same across categories of Sex.	.109	Retain the null hypothesis.
7	The distribution of Food_preference is the same across categories of Sex.	.009	Reject the null hypothesis.
8	The distribution of How_often_do_you_eat_breakfast is the same across categories of Sex.	.017	Reject the null hypothesis.
9	The distribution of Do_you_change_Cooking_oil_monthy is the same across categories of Sex.	.073	Retain the null hypothesis.
10	The distribution of At_school_University_office_you_usually is the same across categories of Sex.	.382	Retain the null hypothesis.
11	The distribution of Do_you_like_fast_food is the same across categories of Sex.	.588	Retain the null hypothesis.
12	The distribution of How_often_do_you_eat_fast_food is the same across categories of Sex.	.007	Reject the null hypothesis.
13	The distribution of What_influence_your_decision_to_eat_out_most is the same across categories of Sex.	.356	Retain the null hypothesis.
14	The distribution of Do_you_have_hypertension is the same across categories of Sex.	.912	Retain the null hypothesis.
15	The distribution of Do_you_have_diabetes is the same across categories of Sex.	.457	Retain the null hypothesis.
16	The distribution of Do_you_like_fruits is the same across categories of Sex.	.318	Retain the null hypothesis.

17	The distribution of How_often_do_you_usally_eat_fruits is the same across categories of Sex.	.466	Retain the null hypothesis.
18	The distribution of How_frequently_you_drink_milk is the same across categories of Sex.	.498	Retain the null hypothesis.
19	The distribution of How_many_meals_you_consume_in_a_day is the same across categories of Sex.	.404	Retain the null hypothesis.
20	The distribution of How_many_times_in_a_day_you_feel_hungry_in_a_day is the same across categories of Sex.	.075	Retain the null hypothesis.
21	The distribution of Which_of_The_Following_food_you_consume_ofetn_as_snacks is the same across categories of Sex.	.749	Retain the null hypothesis.
22	The distribution of How_many_times_in_a_day_you_crave_for_salty_products is the same across categories of Sex.	.414	Retain the null hypothesis.
23	The distribution of How_many_times_in_a_day_you_crave_for_sweet_products is the same across categories of Sex.	.067	Retain the null hypothesis.
24	The distribution of While_eating_what_do_you_do is the same across categories of Sex.	.011	Reject the null hypothesis.
25	The distribution of How_often_do_you_exercise is the same across categories of Sex.	.264	Retain the null hypothesis.
26	The distribution of How_long_do_you_excercise is the same across categories of Sex.	.158	Retain the null hypothesis.
27	The distribution of How_many_times_do_you_drink_water_in_a_Day is the same across categories of Sex.	.857	Retain the null hypothesis.
28	The distribution of How_many_liters_of_water_do_you_drink_in_day is the same across categories of Sex.	.076	Retain the null hypothesis.
29	The distribution of Do_you_drink_alcohol is the same across categories of Sex.	.361	Retain the null hypothesis.
30	The distribution of Do_you_smoke is the same across categories of Sex.	.630	Retain the null hypothesis.
31	The distribution of How_often_do_you_have_bowel_moments is the same across categories of Sex.	.278	Retain the null hypothesis.
32	The distribution of How_often_do_you_urinate_a_day is the same across categories of Sex.	.014	Reject the null hypothesis.

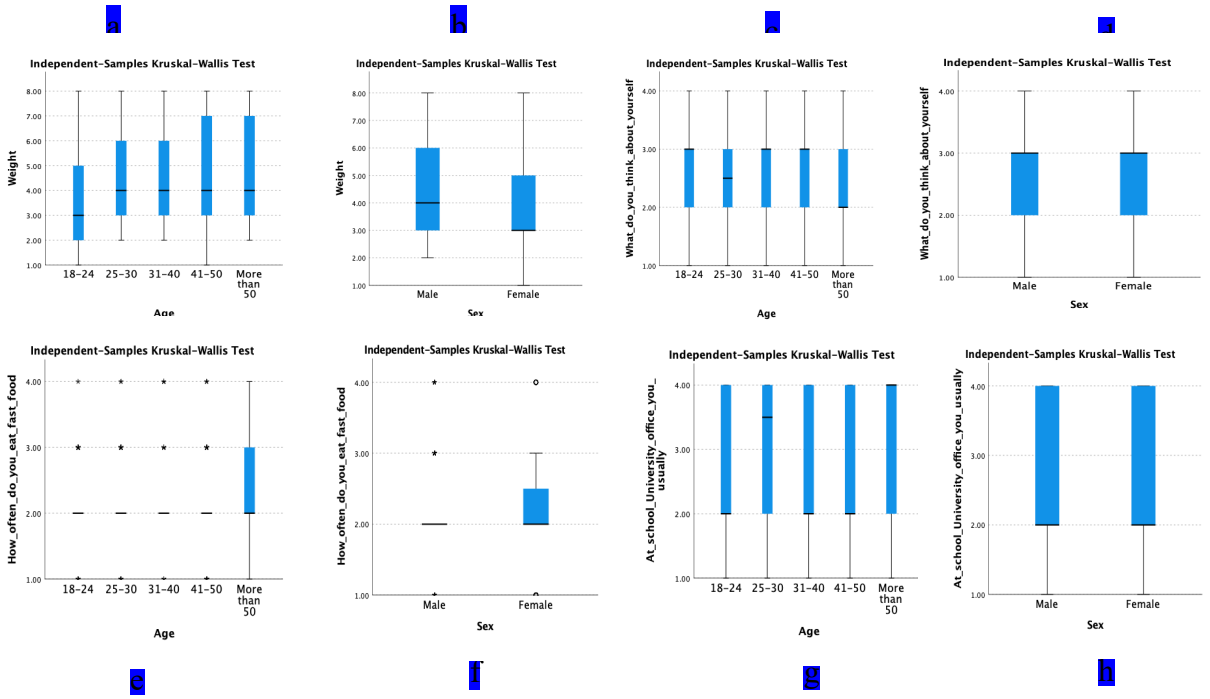


Figure 6.1: Box plots of (a) Age versus weight (b) Sex versus weight (c) Age versus self-assumption about weight (d) Sex versus self-assumption (e) Age versus frequency of fast food consumption (f) Sex versus frequency of fast food consumption (g) Age versus carrying food at work places (h) Sex versus carrying food at work places

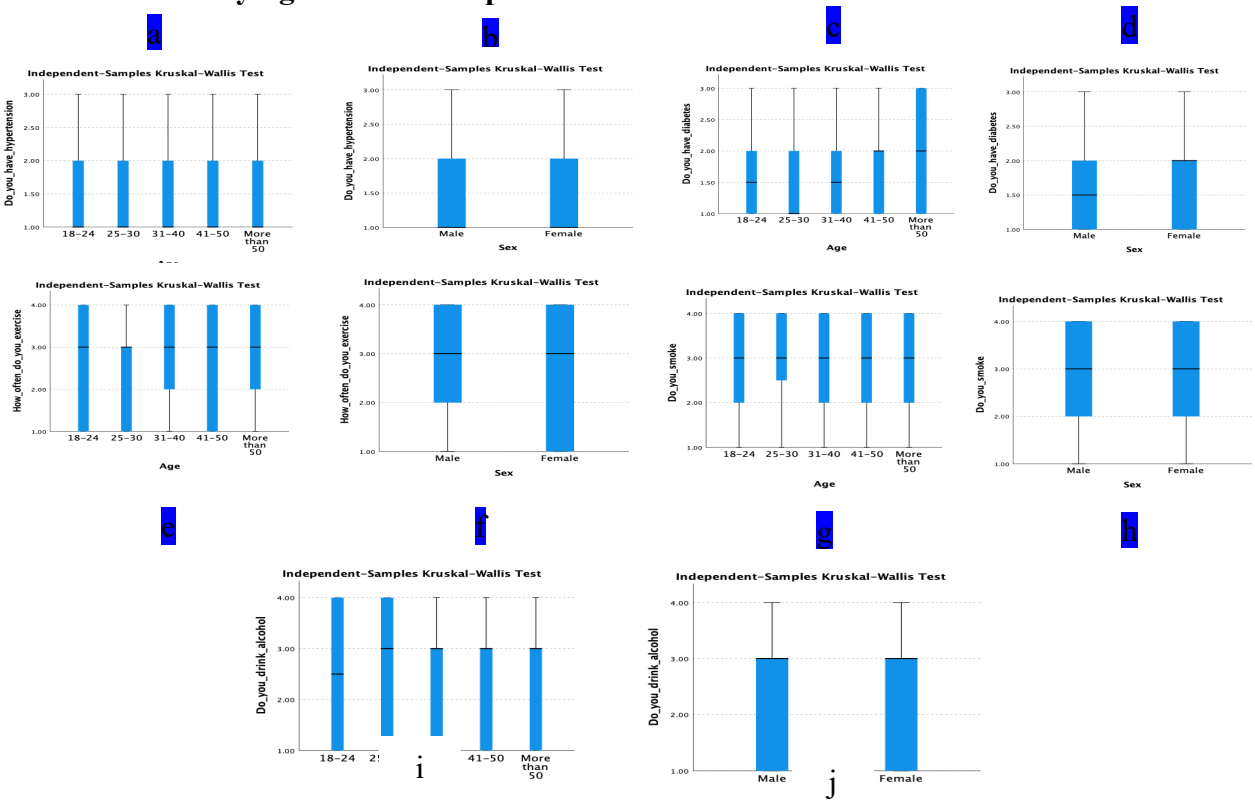


Figure 6.2: Box plots of (a) Age versus hypertension (b) Sex versus hypertension (c) Age versus diabetes (d) Sex versus diabetes (e) Age versus frequency of exercise (f) Sex versus frequency of exercise (g) Age versus smoking (h) Sex versus smoking (i) Age versus alcohol consumption (j) Sex versus alcohol consumption

The hypothesis that a relationship exists between age, sex and prevalence of non-communicable disease namely hypertension, obesity and diabetes among sample population has been supported by the findings of this study. Corn silk can be a best supplement to prevent CVDs, obesity and diabetes. The presence of polysaccharide in corn silk (PCS2 composed of d-galactose, d-mannose, d-glucose, d-xylose, l-arabinose and rhamnose) has anti-obesity and anti-diabetic potential. Corn silk bioactive peptides possess antihypertensive property inhibits the angiotensin converting enzyme which maintains blood pressure.

Therefore, attempt was made to use corn silk which is discarded as agricultural waste despite of its high nutritional and medicinal value in food to prevent and manage non-communicable diseases.

6.2 Nutritional composition of corn silk varieties at different growth stages

The data for nutritional composition as shown in Table 6.3 presents a significant difference ($p<0.05$) among stages and different varieties of corn silk. The moisture content decreased from immaturity to maturity stages of corn silk in all varieties. The highest moisture percentage was observed in TATA 7009 variety stage 1 (84.36±0.17%) which decreased significantly to stage 5 (76.19±0.13%). Similar results were reported by Rahman and Rosli (2014) for the moisture content of immature corn silk (89.31%) which was significantly higher than mature corn silk (84.42%). The ash content of corn silk also reduced significantly ($p<0.05$) among growth stages of all the corn silk varieties. The protein content in stage 1 of all the varieties of corn silk shown in Table 3 was higher which declined significantly ($p<0.05$) to stage 5. The highest content of protein was observed to be in SHUBHAM EARLY stage 1 with the value of 8.16±0.02 followed by SWARNA stage 1 (6.58±0.56 g) and G5417 stage 1 (6.56±0.57 g). The mature silk was extracted from completely ripened and formed maize fruit, whereas the immature silk was collected from unpollinated cob. The roles and biosynthesis of amino acids occurring during the developmental processes of pollinated and unpollinated silk tissue may alter the protein content of immature and mature silks. Amino acids were reported to be actively metabolised in immature cobs during the early stages of silk emergence in order to control seed development. The fat content also decreased significantly ($p<0.05$) among the growth stages of corn silk and the highest content was reported in SWARNA stage 1, 2.78±0.15 g followed by TATA 7009 stage 1 and KESHAR KING stage 1. No significant difference was found in G5417 stages and SHUBHAM EARLY stages of corn silk. Bhuvaneshwari and Sivakami

(2015) also reported the low content of fats in fresh corn silk i.e. 0.36 g. Corn silk cuticle was made up of silk wax hydrocarbons that were involved in hydrocarbon production (Perera et al., 2010). As a result, the build up of hydrocarbons at various stages of maturity may have an impact on lipid composition. The carbohydrate amount present in corn silk was higher in mature stages of G5417 variety which shows that corn silks are good source of carbohydrates.

Table 6.3: Nutritional composition of corn silk varieties at various growth stages

Corn silk varieties and stages	Moisture (% wb)	Ash (%)	Protein (g)	Fat (g)	Carbohydrate (g)
SWARNA 1	82.99 ± 0.296^{e}	2.14 ± 0.06^{k}	6.58 ± 0.56^{ab}	2.78 ± 0.15^{ab}	5.50 ± 0.04^{i}
SWARNA 2	80.22 ± 0.17^{f}	1.83 ± 0.21^{j}	5.16 ± 0.02^{cd}	1.83 ± 0.07^{c}	10.95 ± 0.08^{b}
SWARNA 3	79.33 ± 0.78^{h}	1.07 ± 0.10^{ghij}	4.89 ± 0.42^{def}	1.16 ± 0.07^{ef}	13.54 ± 1.38^{b}
SWARNA 4	76.81 ± 0.48^{ijk}	0.83 ± 0.07^{efg}	3.63 ± 0.49^{efg}	0.87 ± 0.01^{g}	17.85 ± 0.90^{h}
SWARNA 5	74.20 ± 1.33^{kl}	0.70 ± 0.26^{cdef}	2.52 ± 0.50^{g}	0.73 ± 0.03^{i}	21.83 ± 2.12^{j}
TATA 7009 1	84.36 ± 0.17^{g}	3.04 ± 0.08^{ij}	6.35 ± 0.22^{a}	1.38 ± 0.14^{bc}	4.86 ± 0.01^{j}
TATA 7009 2	82.10 ± 0.01^{h}	2.32 ± 0.18^{fghi}	5.52 ± 0.49^{cd}	1.04 ± 0.08^{cd}	9.01 ± 0.40^{b}
TATA 7009 3	81.01 ± 0.48^{jk}	1.81 ± 0.09^{cdef}	4.58 ± 0.55^{efg}	0.91 ± 0.06^{ef}	11.67 ± 1.20^{a}
TATA 7009 4	78.78 ± 0.01^{mn}	1.33 ± 0.16^{bc}	3.19 ± 0.13^{efgh}	0.75 ± 0.04^{gh}	15.94 ± 1.20^{i}
TATA 7009 5	76.19 ± 0.13^{p}	0.49 ± 0.37^{a}	2.44 ± 0.35^{fg}	0.54 ± 0.01^{i}	20.32 ± 0.14^{i}
SHUBHAM EARLY 1	75.65 ± 0.30^{g}	1.34 ± 0.07^{hij}	8.16 ± 0.02^{a}	0.86 ± 0.02^{c}	13.97 ± 0.20^{l}
SHUBHAM EARLY 2	74.71 ± 0.76^{hi}	1.16 ± 0.07^{ghi}	7.88 ± 0.14^{cd}	0.70 ± 0.01^{de}	15.55 ± 0.56^{c}
SHUBHAM EARLY 3	72.78 ± 0.83^{ij}	0.88 ± 0.01^{fgh}	6.22 ± 0.04^{de}	0.63 ± 0.03^{g}	19.48 ± 0.90^{k}
SHUBHAM EARLY 4	72.27 ± 0.41^{mn}	0.73 ± 0.02^{cd}	5.44 ± 0.35^{efgh}	0.55 ± 0.03^{gh}	14.13 ± 0.50^{g}
SHUBHAM EARLY 5	70.25 ± 0.16^{no}	0.50 ± 0.01^{bc}	3.57 ± 0.56^{fg}	0.43 ± 0.02^{i}	21.00 ± 0.05^{m}
KESHAR KING 1	79.10 ± 0.62^{a}	1.03 ± 0.04^{m}	6.53 ± 0.48^{a}	1.13 ± 0.09^{a}	25.24 ± 0.84^{i}
KESHAR KING 2	76.65 ± 0.69^{b}	0.91 ± 0.09^{lm}	5.42 ± 0.36^{c}	0.87 ± 0.03^{de}	16.14 ± 1.19^{fg}
KESHAR KING 3	74.16 ± 0.10^{b}	0.70 ± 0.06^{lm}	3.71 ± 0.22^{de}	0.75 ± 0.04^{f}	20.67 ± 0.02^{de}
KESHAR KING 4	72.88 ± 1.03^{c}	0.50 ± 0.01^{k}	2.48 ± 0.41^{fgh}	0.67 ± 0.01^{g}	23.46 ± 0.64^{c}
KESHAR KING 5	71.05 ± 0.22^{d}	0.33 ± 0.04^{k}	1.89 ± 0.31^{fg}	0.55 ± 0.05^{h}	26.18 ± 0.63^{d}
G 5417 1	81.33 ± 0.47^{jk}	2.33 ± 0.25^{fghi}	6.56 ± 0.57^{a}	0.86 ± 0.02^{c}	8.91 ± 1.32^{b}
G 5417 2	71.97 ± 1.88^{n}	1.98 ± 0.021^{i}	5.33 ± 0.16^{b}	0.69 ± 0.02^{de}	20.37 ± 1.76^{i}
G 5417 3	61.97 ± 2.38^{q}	1.73 ± 0.01^{ij}	3.15 ± 0.06^{e}	0.62 ± 0.04^{g}	32.52 ± 2.50^{m}
G 5417 4	54.90 ± 2.27^{r}	1.26 ± 0.09^{hi}	2.48 ± 0.26^{fgh}	0.47 ± 0.11^{j}	40.84 ± 2.74^{n}
G 5417 5	51.10 ± 0.20^{s}	0.72 ± 0.07^{l}	1.35 ± 0.20^{i}	0.27 ± 0.07^{k}	46.54 ± 0.56^{o}

The values are represented in Mean ± Standard deviation derived for triplicate experiments (n=3).
The values denoted with different superscripts differ significantly at $p<0.05$ in a column

Mineral composition of corn silk at various growth stages

The data for mineral composition of cons silk as shown in Table 6.4 showed that corn silk are the excellent source of potassium and calcium. Sodium content increased significantly (p<0.05) from juvenile to maturity stages of corn silk in all the varieties. The high amount of sodium was present in SWARNA variety among all the stages and lowest content was found in G5417 variety stage 1 i.e. 81.33±0.47 µg/g. For the magnesium content, G5417 showed the highest values at all the stages as compared to all the other varieties. G5417 stage 1 showed 1456.21±1.5 µg/g of Mg which declined significantly to 813.79±2.39 in stage 5. Potassium content increased significantly among all the varieties from stage 1 to stage 5 and the highest value was seen in SWARNA stage 5 (1439.70±2.8 µg/g) followed by TATA 7009(1013.04±1.9 µg/g) stage 5 and G5417 stage 5 (801.91±2.8 µg/g). The calcium was also abundantly present in corn silk samples and reduced significantly (p<0.05) from stage 1 to stage 5 in all the varieties as shown in table 4. The calcium content in SWARNA stage 1 (889.35±2.62 µg/g) was found to be higher than the other corn silk varieties. Manganese content was found to be higher among growth stages and increased significantly (p<0.05) in all the varieties. The manganese was higher in SWARNA stage 5 (20.89±0.94 µg/g). Corn silk varieties also showed decline in copper content from juvenile to maturity stage and the highest content was observed in TATA 7009 stage 1 i.e. 22.90±0.33 µg/g which reduced significantly (p<0.05) to 14.22±0.38 µg/g in stage 5. The lowest copper content was found in G5417 stage 1 i.e. 6.63±0.21 µg/g to 3.38±0.24 µg/g in stage 5. A significant increase (p<0.05) was observed in iron content from stage 1 to stage 5 in all the varieties of corn silk and highest concentration was observed in G5417 stage 5 (28.71±0.03 µg/g).

Our results were in agreement with Rahman and Rosli (2014) who reported higher calcium, magnesium, sodium, iron, manganese in mature corn silk as compared to immature corn silk. The mineral content of the immature and mature sections of the silks differed. Differences in cultivar, plant nutrition, climate, and soil conditions might be the reason for the differences (Hamurcu et al., 2010). The distribution of mineral composition is linked to certain plant functions during development. Ca is a mineral that is required for the structure of cell walls and membranes (Evans et al., 2001). Because potassium is extremely mobile in plants, it plays a vital role in biophysical and biochemical processes (Szczerba et al., 2009).

Table 6.4: Mineral composition of corn silk varieties at different growth stages

Corn silk varieties and stages	Sodium (mg/g)	Magnesium (mg/g)	Potassium (mg/g)	Calcium (mg/g)	Manganese (mg/g)	Copper (mg/g)	Iron (mg/g)
SWARNA 1	764.25±1.05^{r}	641.67±0.78^{j,k}	1112.11±0.31^{t}	890.18±1.17^{t}	13.01±0.79^{f,g,h}	11.20±0.98^{f,g}	6.67±0.74^{a}
SWARNA 2	798.85±0.88^{t}	611.86±1.04^{i,j}	1146.30±0.84^{u}	847.02±1.24^{s}	14.92±0.28^{h,i,j,k,l}	9.73±0.32^{e,f}	9.53±0.58^{b,c}
SWARNA 3	873.90±1.23^{v}	523.21±0.57^{h,i}	1296.63±2.13^{v}	792.09±0.49^{o}	16.78±0.71^{l}	8.84±0.40^{d,e}	11.91±0.99^{d,e}
SWARNA 4	1007.03±0.25^{x}	488.52±1.83^{g,h}	1313.32±0.66^{w}	755.18±0.28^{k}	18.76±0.13^{m}	7.28±0.54^{c,d}	16.09±1.13^{h,i,j,k}
SWARNA 5	1078.56±0.62^{y}	351.96±0.09^{d,e,f}	1438.91±1.12^{x}	701.32±0.8^{h}	21.06±0.23^{n}	7.16±1.17^{c,d}	17.46±1.46^{j,k,l}
TATA 7009 1	573.82±0.71^{n}	293.42±0.99^{b,c,d}	678.31±0.83^{h}	696.33±1.88^{g}	11.15±1.23^{e}	22.00±1.27^{l}	8.59±0.84^{a,b}
TATA 7009 2	697.74±0.79^{q}	241.05±1.29^{a,b,c}	746.27±1.44^{n}	645.36±1.62^{e}	11.31±0.59^{e,f}	18.47±2.04^{k}	10.80±0.98^{c,d}
TATA 7009 3	771.65±0.89^{s}	210.73±0.72^{a,b}	883.33±0.79^{q}	635.18±1.50^{d}	11.97±1.20^{e,f,g}	17.39±1.65^{j,k}	13.48±1.05^{e,f,g}
TATA 7009 4	813.37±1.44^{u}	196.96±0.23^{a,b}	902.55±1.73^{r}	593.15±1.60^{b}	14.58±0.98^{h,i,j}	15.72±0.88^{h,i,j}	15.67±1.10^{h,i,j}
TATA 7009 5	906.82±0.57^{w}	172.35±0.95^{a}	1014.02±1.38^{s}	577.06±0.56^{a}	14.87±0.92^{h,i,j,k}	15.06±1.18^{h,i}	15.83±0.08^{h,i,j}
SHUBHAM EARLY 1	396.56±0.62^{h}	832.23±0.93^{m}	600.68±0.48^{e}	831.13±1.36^{r}	10.25±0.35^{d,e}	18.99±0.37^{k}	11.08±1.15^{e,d}
SHUBHAM EARLY 2	499.80±0.45^{k}	785.39±1.03^{l,m}	646.76±0.68^{g}	814.18±1.01^{p}	11.00±0.33^{e}	17.34±1.25^{j,k}	12.71±1.68^{d,e,f}
SHUBHAM EARLY 3	559.82±0.57^{m}	716.35±0.64^{k,l}	697.28±1.49^{j}	788.74±0.68^{m}	10.92±1.13^{e}	16.25±0.88^{i,j}	14.15±1.23^{f,g,h}
SHUBHAM EARLY 4	598.01±0.30^{o}	682.98±0.20^{j,k}	706.38±0.69^{l}	768.02±1.60^{l}	14.80±1.39^{h,i,j}	13.83±0.42^{h}	16.14±1.20^{h,i,j,k}
SHUBHAM EARLY 5	618.05±1.17^{p}	606.06±1.50^{i,j}	754.04±1.15^{o}	712.09±0.52^{i}	14.75±0.66^{h,i,j}	10.76±0.65^{e,f,g}	16.41±0.73^{i,j,k}
KESHAR KING 1	367.82±0.57^{f}	534.63±0.84^{h,i}	472.02±0.29^{a}	819.18±0.95^{q}	13.50±1.03^{g,h,i}	17.66±0.70^{j,k}	11.04±0.72^{c,d}
KESHAR KING 2	391.89±0.87^{g}	443.88±69.76^{f,g}	490.68±0.77^{b}	789.80±0.65^{m,n}	15.23±1.11^{i,j,k,l}	16.29±1.05^{i,j}	14.22±0.95^{f,g,h,i}
KESHAR KING 3	413.01±1.10^{j}	411.13±1.23^{e,f,g}	540.90±0.54^{c}	755.71±0.65^{k}	16.17±0.49^{j,k,l}	14.03±0.75^{h}	15.45±0.95^{g,h,i,j}
KESHAR KING 4	498.58±0.76^{k}	350.32±0.78^{d,e,f}	580.73±0.70^{d}	700.81±0.83^{h}	16.72±1.17^{k,l}	11.87±0.91^{g}	16.17±0.70^{h,i,j,k}
KESHAR KING 5	511.96±0.37^{l}	326.70±0.64^{c,d,e}	612.89±0.79^{f}	792.83±0.86^{o}	21.25±0.69^{n}	10.69±0.80^{e,f,g}	18.19±0.66^{l}
G 5417 1	81.78±0.63^{e}	1425.94±1.22^{p}	683.17±1.18^{i}	752.66±0.0^{j}	5.79±0.25^{a}	7.04±0.58^{c,d}	19.18±0.49^{k,l}
G 5417 2	72.15±0.25^{d}	1007.08±1.22^{o}	703.94±0.09^{k}	697.84±1.01^{g}	6.79±0.65^{a,b}	6.53±0.51^{b,c}	21.26±1.22^{m}
G 5417 3	62.11±0.20^{c}	964.50±1.03^{n,o}	725.76±1.61^{m}	676.63±2.13^{h}	7.65±0.79^{b,c}	5.87±0.54^{a,b,c}	22.01±0.32^{m}
G 5417 4	55.06±0.23^{b}	876.34±0.64^{m,n}	754.12±1.18^{n}	634.94±0.97^{d}	7.27±0.60^{a,b}	4.91±0.43^{a,b}	24.91±0.37^{n}
G 5417 5	51.83±1.03^{a}	814.17±0.54^{m}	802.73±1.16^{p}	604.97±1.07^{c}	9.11±0.90^{c,d}	3.97±0.83^{a}	29.13±0.59^{o}

The values are represented in Mean ± Standard deviation derived for triplicate experiments (n=3).
The values denoted with different superscripts differ significantly at $p<0.05$ in a column

The K ion is involved in the regulation of pollen tube growth in the stigma (Zienkiewicz et al., 2011). Protein synthesis, genetic entity stability, and glucose and lipid metabolism all require Zn. Mn functions as an enzyme activator in the tricarboxylic acid cycle (Xue et al., 2004), photosynthetic function (Lidon et al., 2004), fatty acid and carotenoid production, and photosynthesis (Lidon et al., 2004). Mg is plentiful in plant tissue and is involved in a variety of cellular functions such as photosynthesis (Gardner, 2003), protein synthesis (which includes ribosome structures and functions), and so on (Maathuis, 2009).

6.3 Antioxidant content

The antioxidant content of corn silk was characterized by the presence of polyphenolic compounds, flavonoids, and ascorbic acid. Following observations were made in the corn silk samples of different varieties at various growth stages as shown in Table 6.5.

Total polyphenolic content

Phenols are considered an important plant constituent due to the presence of hydroxyl groups which imparts free radical scavenging property and increases antioxidant activity in fruits (Meena et al., 2012; Hashemi and Jafarpour, 2020, Hashemi and Jafarpour, 2021). Polyphenols present in plant shows nutraceutical properties from the health point of view and the antioxidant effect is due to their redox properties (Attanayake and Jayatilaka, 2016). The polyphenolic content of different varieties is shown in Table 5 and the data shows that the antioxidant content in all the varieties of corn silk is significantly affected by the stage of growth. The silk of different varieties shows a difference in composition and antioxidant content. A significant decrease of total polyphenolic content in SWARNA variety from stage 1 to stage 5 was observed. A significant decrement ($p<0.05$) in TATA 7009 from immaturity (40.76±0.62 mg GAE/100g) to maturity (23.84±0.17 GAE/100g) was observed. Similarly, for KESHAR KING, significant decrement was observed from immaturity to mature stage. A significant increase for SHUBHAM EARLY from stage 1 (97.43±0.26 mg GAE/100g) to stage 2 (258.46±1.45 mg GAE/100g) but a significant decrease was reported subsequently in stages 3, 4, and 5.

The trend was similar for G5417 and the value decreased from 229.48±0.69 mg GAE/100g (stage 1) to 128.97±1.66 mg GAE/100g (stage 5). Rahman and Rosli (2014) in their study of evaluation of polyphenol content in immature and mature corn silk reported a

significant decrease in total polyphenolic content when extracted in ethanolic and ethyl acetate extract. On the contrary samples extracted from water showed significant increase from 35.35±2.17 to 64.33±2.55 mg GAE/100g in immature and mature corn silk, respectively. Bioactive compounds may be influenced by the maturity stage as shown by Farhoosh et al. (2007). A similar trend has been observed by Xu et al. (2010) where total phenolic content of corn grain decreased from M1 (74 days after sowing) stage to maturity (114 days after sowing). They mentioned that phenolic as secondary metabolites are influenced by different metabolic pathways and the key enzyme phenylalanine ammonia-lyase (PAL) is involved in the pathway, its activity was found to be greatly affected by the growth stages of plants. However, the significant change in phenolic content is also related to plant species and varieties (2005). Bases on the present result G5417 showed a significant higher amount of total phenols at all the growth stages.

Flavonoid content

Flavonoids have been recognized as an antioxidant and their effects are considerable on human health and nutrition. Their mechanism of action is through the chelating and scavenging process (Khettaf et al., 2016). High concentrations of flavones namely apigenin and luteolin and flavone glycosides such as iso-vitexin, iso-orientin, and maysin are present in corn silk (Atanasova-Penichon et al., 2016). The result for flavonoid content showed a significant decrease for all the varieties from immaturity to maturity stage but stage 5 of TATA 7009 and SHUBHAM EARLY showed a significant increase ($p<0.05$) at the end. G5417 showed the highest amount of flavonoid at stage 1 (237.10±0.86 mg QE/100g) after KESHAR KING Variety stage 1 (239.47±2.33 mg QE/100g) and the trend of decline was lesser in G5417 as compared to the other varieties.

Similar results have been reported by Zilic et al. (2016) where they analyzed antioxidant activity, phenolic profile, chlorophyll, and mineral matter content of corn silk when compared with medicinal herbs. They harvested corn silk after 5 and 25 days of emergence and compared it with six medicinal herbs and reported that the total flavonoid content decreased from 5565.3±40.9 (5 days) to 5514.5±92.2 mg CE/100 g (25 days). Physiological and structural changes during the period of growth and fertilization are the reason for the decline in the flavonoid content (Salvador et al., 2007).

Ascorbic acid

Ascorbic acid is an essential vitamin required for various physiological functions and also acts as a powerful antioxidant that fights against free-radical induced diseases (Pisoschi et al., 2008; Dinesh et al., 2015). The ascorbic acid content in different varieties of corn silk as shown in Table 6.5 represents the significant decrease ($p<0.05$) from immaturity to mature stage and the highest content was observed in G5417 from 324±1.57 to 108±1.23 mg/100 g in juvenile stage to matured stage respectively. The ascorbic acid content was higher after 20 days of pollination which decreased significantly ($p<0.01$) after 40 days of pollination in different maize genotypes as mentioned by Sanahuja et al. (2013). They stated that the expression of genes requires for the ascorbic acid synthesis declines during the development of the plant.

Table 6.5: Antioxidant content in different varieties at various growth stages of corn silk

Corn silk varieties and stages	Polyphenol content (mg GAE/100g)	Flavonoid content (mg QE/100g)	Ascorbic acid (mg/100 g)
SWARNA 1	113.07±1.23^{h}	217.89±1.63^{c}	124±0.89^{h}
SWARNA 2	74.10±0.32^{n}	180.52±1.32^{g}	114±1.68^{f}
SWARNA 3	61.28±0.36^{l}	178.68±1.12^{h}	108±1.42^{k}
SWARNA 4	57.43±0.44^{q}	159.73±1.21^{i}	72±0.17^{n}
SWARNA 5	55.64±0.24^{r}	141.31±1.64^{k}	72±0.24^{n}
TATA 7009 1	40.76±0.62^{t}	57.10±0.55^{l}	216±0.49^{d}
TATA 7009 2	67.17±0.51^{o}	37.89±0.26^{n}	144±1.21^{g}
TATA 7009 3	65.38±0.22^{p}	30.00±0.87^{p}	110±0.41^{j}
TATA 7009 4	25.89±0.42^{u}	11.84±0.36^{v}	108±0.86^{k}
TATA 7009 5	23.84±0.17^{v}	195.52±1.44^{e}	79±0.31^{l}
SHUBHAM EARLY 1	97.43±0.26^{l}	24.21±0.72^{q}	154±1.36^{f}
SHUBHAM EARLY 2	258.46±1.45^{a}	23.68±0.21^{r}	110±0.76^{j}
SHUBHAM EARLY 3	220.25±0.33^{d}	19.47±0.45^{t}	108±1.24^{k}
SHUBHAM EARLY 4	93.33±0.21^{m}	15.78±0.24^{u}	74±0.85^{j}
SHUBHAM EARLY 5	53.58±0.22^{s}	35.26±0.55^{o}	72±0.34^{l}
KESHAR KING 1	138.20±0.45^{f}	239.47±2.33^{a}	144±1.57^{g}
KESHAR KING 2	111.5±1.66^{ed}	145.26±0.92^{j}	121±1.26^{i}
KESHAR KING 3	103.84±0.41^{j}	41.57±0.41^{m}	108±1.31^{h}
KESHAR KING 4	100.25±0.95^{k}	35.78±0.11^{o}	75±0.67^{m}
KESHAR KING 5	93.58±0.81^{m}	22.10±0.26^{s}	62±0.55^{o}
G 5417 1	229.48±0.69^{b}	237.10±0.86^{b}	324±1.57^{a}
G 5417 2	224.87±0.52^{c}	212.10±1.31^{d}	288±1.54^{b}
G 5417 3	194.35±0.62^{e}	185.26±1.66^{f}	252±0.89^{c}
G 5417 4	138.97±1.22^{f}	158.42±0.66^{i}	180±0.57^{e}
G 5417 5	128.97±1.66^{g}	158.15±0.51^{i}	108±1.23^{k}

6.4 Antioxidant Activity

Oxidation is responsible for deleterious effects on human health as well as food quality. The oxidative damage causes browning, altering nutrient value of food, gives off flavour, formation of compounds which leads to cardiovascular diseases and fastens ageing process (Cardenia et al., 2013). The antioxidant activity is affected by various factors and there are more commonly used methods that each has their advantages and disadvantages for measuring antioxidant activity which cannot be fully described with single method (Prior et al., 2005). In this assay, the antioxidant activities of corn silk are measured by DPPH, ABTS and FRAP assays. The results found were in agreement with the results stated by Sarepoua et al. (2015). The relative antioxidant ability to scavenge the radical ABTS+ has been compared with Trolox standard**.** Trolox equivalent antioxidant capacity (TEAC) using ABTS (2,2'-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid) activity of corn silk at different growth stages showed declined in all the varieties except SWARNA where, stage 5 (80.74±0.62) showed the significant increase after a significant reduction in the ABTS value (Figure 6.3). The degradation percent was less in G5417 from stage 1 (84.16±0.55%) to stage 5 (77.03±0.58%). The results were in agreement with Rahman and Rosli (2014) where they reported the decrease trend from immaturity to maturity stage of corn silk. The decline can be due to decrement in the flavonoid and total phenols content at maturity stage and as the plant grows, synthesis of polyphenols may interrupt and decrease in total polyphenols is observed. On contrary to this, Simla et al., (2016) has reported the opposite trend of increase in three different waxy corn varieties (KKU-WX111031, KKU-F1 Hybrid and KKU-OP) grown in Thailand. They harvested corn silk after 20 and 35 days of pollination and reported increase in the Trolox equivalent antioxidant capacity (TEAC) from 20 to 35 DAP (days after pollination). These variations in the antioxidant activity are due to genetic variations of different varieties.

The ferric reducing-antioxidant power (FRAP) is an important reducing power activity used for the indication of phenolic compounds and this potential is estimated by their abilities which is to reduce $Fe_{(III)}$-TPTZ to $Fe_{(II)}$-TPTZ (Dong et al 2014). A significant decrease was observed for FRAP activity in all the varieties of corn silk at different growth stages. The highest % inhibition was observed in G5417 stage 1 (123.20±0.56 %) further the values decreased significantly. The decline in reducing power is due to the presence of hydroxyl group in phenolic compounds that might act as electron donor (Tian et al., 2013).

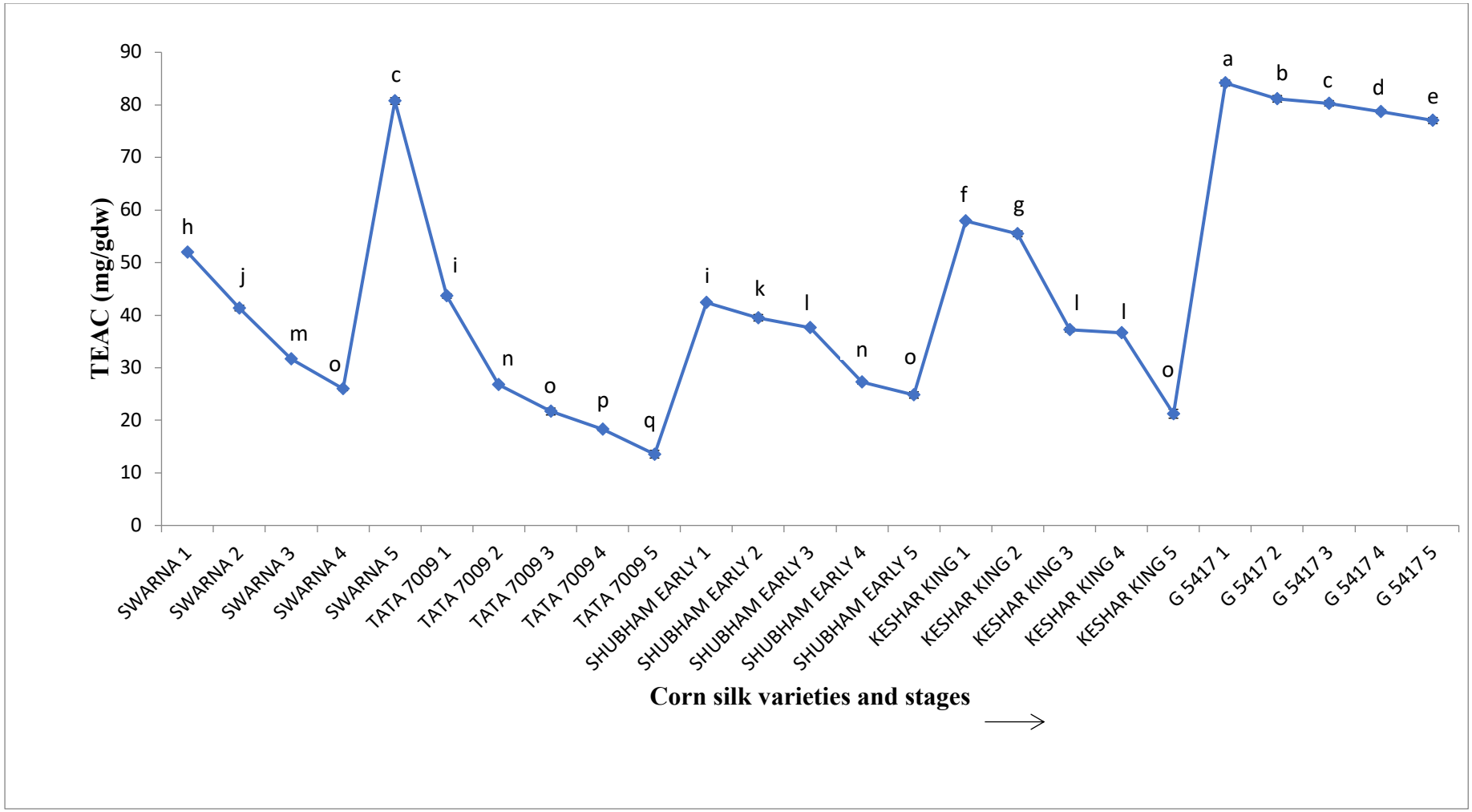


Fig 6.3 ABTS activity of different varieties of corn silk at different growth stages

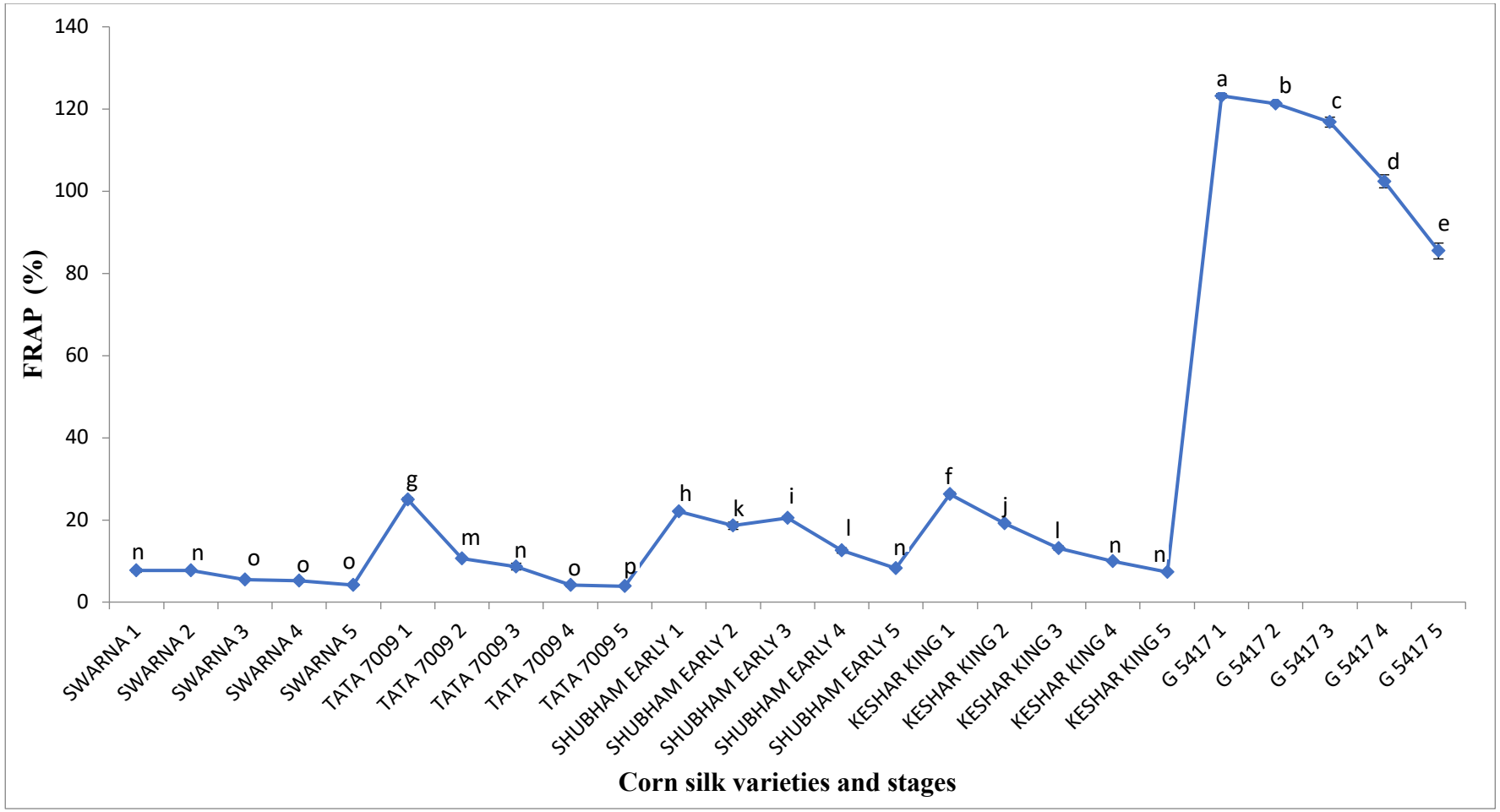


Fig. 6.4 FRAP activity of different varieties of corn silk at different growth stages

The similar trend was observed for all the other varieties where the FRAP activity decreased significantly ($p<0.05$). Our findings were in agreement with the result showed by Tian et al. (2013) in their comparative study on antioxidant and anticancer activities of different varieties of corn silk. The FRAP values showed the similar trend with the content of total phenols and flavonoids.

The free radical scavenging activity as shown in Figure 6.4 depicts the decline in all the varieties of corn silk from immaturity to maturity stage. The highest % inhibition was observed in G5417 stage 1 (65.33±1.21 %) and the lowest was observed in TATA 7009 at stage 5 (20.31±1.54). The results found were in agreement with the results stated by Sarepoua et al. (2015). Three maturity stages of corn silk were studied for the influence on phytochemical content and it was reported that the scavenging activity (% inhibition DPPH) decreases significantly ($p<0.05$) from 70.7 ± 4.1 (silking stage) to 52.0 ± 5.2 (maturity stage). The similar trend has been seen in the study of methanolic extract of corn silk for antimicrobial, antioxidant and chemical properties. The fresh mature corn silk showed the highest FRSA value when compared with matured dried corn silk samples (Emmanuel et al., 2016).

6.5 TECHNO-FUNCTIONAL PROPERTIES

Techno-functional properties includes ability to form and stabilise emulsions and foams, water and oil absorption and solubility in food processing (Kostic et al., 2015) which affects the processing applications directly or indirectly, food quality, and further their acceptance and utilisation in food and food formulations (Sahan et al., 2015). Techno-functional properties of dried corn silk are presented in Table 6.6 (a) and 6.6 (b).

Moisture content

The removal of moisture from the food decreases the weight and volume of the food products. Through drying process, food loses its moisture content and results in increase in concentration of nutrients in remaining mass. The moisture content of dried corn silk was 5.20±0.83% and dry matter was 94.80±0.73%. The moisture content and corresponding dry matter in corn silk varieties although varies has nominal change, however, the change is rather highly significant among maturity levels in all the varieties studied. Rahman and Rosli (2014) reported the moisture content of fresh immature corn silk as 89.31% and 84.42% for mature corn silk.

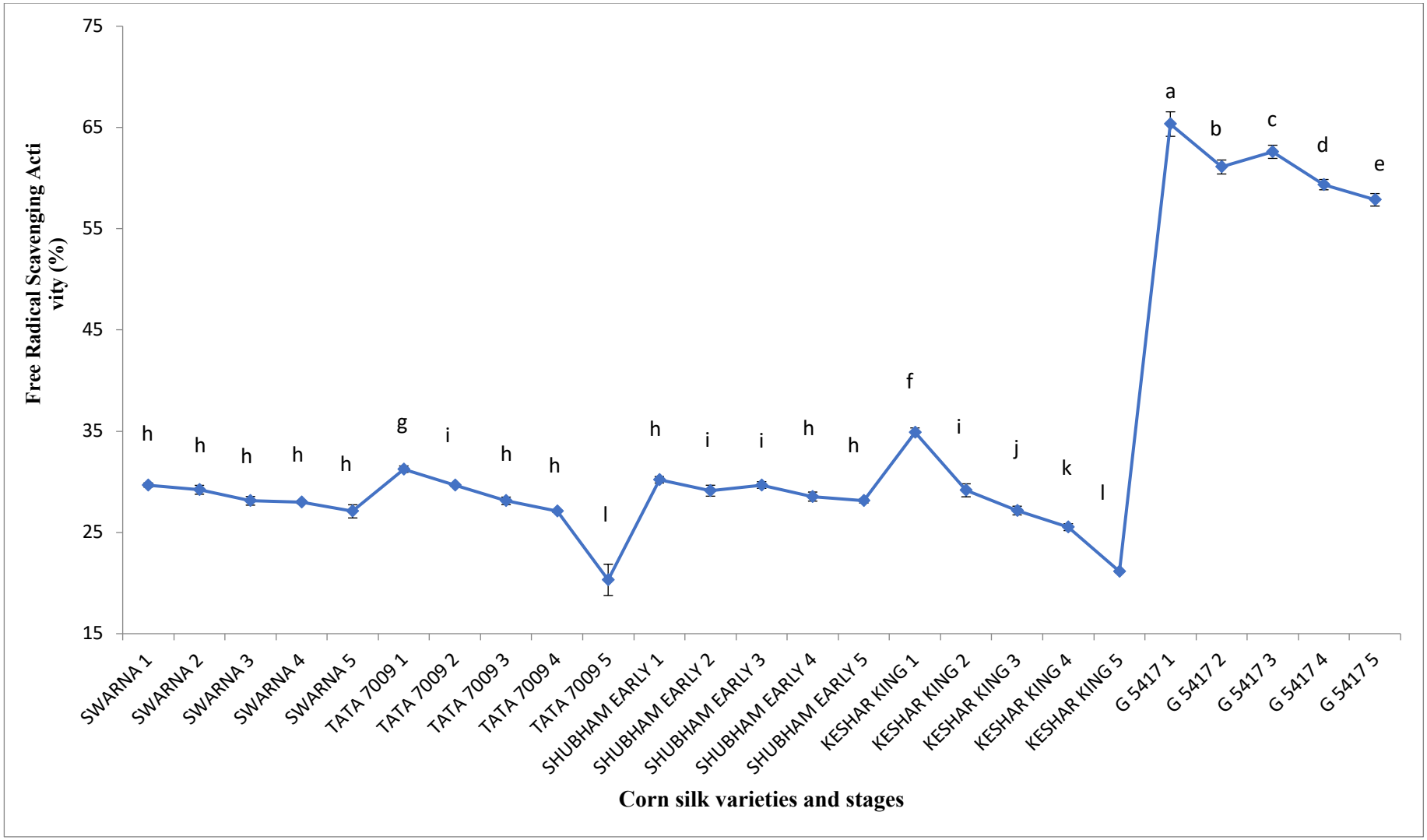


Fig. 6.5 FRSA activity of different varieties of corn silk at different growth stages

Bulk density

The value of bulk density of the corn silk varied significantly in between varieties and reduced significantly from immature to mature samples. The highest bulk density was observed in Shubham Early variety stage 1 (0.481±0.001g/cm^3) and the lowest in G5417 stage 5 (0.314±0.01). The bulk density of foods is related to moisture content and structure and size of particles. The high moisture content in food leads to the stickiness of the particles which further increases the interspaces between them and finally imparts larger bulk volume (Jakubczyka et al., 2011). It measures flour heaviness and evaluates the stability of flours. The low density is desirable for the preparation of infant and complementary food (Nelson-Quartey et al., 2007).

Tapped density Tapped density refers to the real solid density without consideration of spaces between the particles. Samples with fine particles exhibit higher tapped density and less porosity than those with coarser particles due to occupation of the pores between the large particles then fine particles (de Barros Fernandes et al., 2014).This is consistent with the findings of Naji-Tabasi et al. (2021) in their study of physico-chemical properties of barberry juice powder. The tapped density in the corn silk samples varied significantly ($p<0.05$) among varieties. It also decreases significantly ($p<0.05$) from immature to mature corn silk among all the varieties. This decrease implies coarser nature of particles in mature corn silk.

Carr's index (CI) measures the flowability of flour and CI less than 15 shows good flowability on the other hand CI more than 35 shows bad flowability (Ribeiro et al., 2020). In the present study, highest CI was observed in TATA 7003 (22.40±0.75) and lowest for G5417 stage 4 (1.56±0.46). The variety and stage which possess good flowability with the value less than 15 were SWARNA stage 1, stage 4, stage 5, TATA 7009 stage 1, 4, 5, SHUBHAM EARLY stage 1, 3, 4, 5, G5417 stage 1, 4 and 5. Significant differences ($p<0.05$) were observed among the varieties. Flours which have good flowability are suitable for transport and easier mixing and other manufacturing processes (Abe-Inge et al., 2018).

Hausner ratio (HR) measures the compressibility of flours (Muaz et al., 2011) and the values greater than 1.35 shows poor flow properties (Rao et al., 2021). The values as shown in Table 2 for HR was highest for G5417 stage 3 (1.59±0.54) and lowest for SHUBHAM EARLY stage 5 (1.01±0.02). There was no significant difference observed in any of the varieties and their stages and the values attained for HR (range between 1.01±0.021-

1.59±0.54) showed that corn silk has good compressibility and is therefore, suitable for food product development.

Angle of repose is used as indicator of the flowability of the flours and it depended on friction between moving particles during the lift of the initial holding cylinder (He et al., 2020). The lesser the angle of repose, better is the fluidity of the material (Qian et al., 2020) . The values for angle of repose in between 25-30 shows excellent flowability and the values more than 66 shows poor flowability (Igathianathane et al., 2010). The angle of repose of dried corn silk ranged between 32.66±0.69 for KESHAR KING stage 1 to 46.77±1.09 (G5417 stage 5). Overall, corn silk possesses passable flow properties.

Water absorption index of dried corn silk as shown in Table 2 was lowest for KESHAR KING stage 1 (9.54±0.13 g/g) and highest for TATA 7009 stage 5 (12.37±0.68). A non-significant variation was observed among varieties and stages except SWARNA stage 1, 5 and TATA 7009 stage 5. The higher dietary fiber content i.e. 51.25 g of corn silk could be the cause of high water absorption index. The fiber present in food imparts hydration properties which are due to the hydroxyl groups present in the structure of fibre which allows the water interactions through hydrogen bonding (Rosell et al., 2009). Proteins and the carbohydrates enhance the water absorption capacity as they contain hydrophilic parts such as polar or charged side chains (Wani et al., 2013b). The high water absorption capacity imparts properties like bulking, gelling and thickening in the food which are required in bakery products (Sahan, et al, 2015). The high water solubility index indicates the high amount of water soluble components that disperse in aqueous while cooking and it also indicates the higher values for adhesiveness and stickiness in food products (Shafi et al., 2016; Kraithong et al., 2018). Highest value was observed G5417 stage 1 i.e. 24.83±0.70% and lowest value for KESHAR KING stage 5 i.e. 13.21±0.30%.

Foaming capacity and foam stability of dried corn silk is shown in Table 2. A significant difference was observed among varieties like SWARNA and SHUBHAM EARLY, however stages of some varieties do not show a significant difference ($p<0.05$) for foaming capacity. Highest value for SWARNA stage 1 (15.61±0.15%) and G5417 stage 1 (15.44±0.31%) makes these varieties suitable for ice creams and bakery food products. Foams improve the appearance, texture and consistency of the food. The foaming property is calculated as percentage increase in volume of protein dispersion on mixing. The presence of flexible protein molecules is responsible for foaming ability (Kumar et al., 2016). Low foaming

ability is related to globular protein which resists surface denaturation. Foam stability was observed highest in SWARNA stage 1 (63.39±0.54%) and lowest for SHUBHAM EARLY stage 3 (57.24±2.83%). G5417 variety does not show any significant difference among stages, however, significant difference ($p<0.05$) was observed in between stages of SHUBHAM EARLY. The high protein content of corn silk (12.94%) (Rahman and Rosli, 2014) imparts the good amount of foaming capacity and foam stability.

Swelling capacity

There is strong correlation between swelling capacity and water absorption index of food products (Wong and Cheung, 2000). Swelling capacity is dependent on amylopectin content, thus the lower the amylopectin content lower will be swelling capacity. Starch content is responsible for the increased water absorption and enhancing swelling power (Mokhtar et al., 2018). The swelling index varied from 7.12±0.17 ml/g (lowest: SWARNA stage 2) to 9.42±0.59 ml/g (highest: SHUBAM EARLY Stage 4). It can be observed from the Table 2, that the swelling capacity (ml/g) of the corn silk samples was fairly similar with non-significant variation among varieties understudy. However, it varied significantly with sharp increase among stages of all varieties understudy. Swelling capacity allows the establishment of enlargement rate of the flour particles as a result of water absorption and accumulation (Pellegrini et al., 2018). Studies has also confirmed the correlation between moisture content and swelling power, low swelling power results with increase in water absorption in flours (Li et al., 2019). which draws the conclusion that less moisture content in dried corn silk increases the swelling capacity. Flours with good swelling capacity and water absorption capacity are recommended for the production of baked food product and functional ingredients like pasta, dough and food gels (Abe-Inge et al., 2018).

The oil absorption capacity is highly dependent on certain factors which include particle size, overall charge density, thickness, chemical structure of the plant polysaccharides and its surface properties (Sahni and Shere, 2017). Dried corn silk showed oil absorption capacity in the range of 2.57±0.580 g/cm^3 (SHUBHAM EARLY stage 5) to 4.53±0.509 g/cm^3 (KESHAR KING stage 2). The difference among varieties and stages was observed to be non-significant. Oil absorption capacity is highly influential with particle size, finer the particle, more will be the oil absorption capacity (Lucas-González et al., 2017). Due to high OAC, corn silk show potential as an ingredient in fried food products as it will prevent an over greasy sensation.

Table 6.6 (a) Techno-functional properties of corn silk varieties at different growth stages

Corn silk varieties and stages	Moisture (%wb)	Dry matter (%)	Bulk density (g/cm^3)	Tapped Density (g/ cm^3)	Carr's Index	Hausner Ratio	Angle of repose (°)
SWARNA 1	6.85±0.01^{e}	92.96±0.25^{k}	0.460±0.01^{ab}	0.540±0.01^{ab}	11.26±0.09^{i}	1.06±0.09^{a}	33.84±0.06^{cd}
SWARNA 2	6.11±0.02^{f}	93.86±0.01^{j}	0.406±0.01^{cd}	0.513±0.004^{c}	19.76±0.30^{b}	1.404±0.22^{a}	34.51±0.39^{cd}
SWARNA 3	5.35±0.21^{h}	94.25±0.35^{ghij}	0.369±0.01^{def}	0.464±0.001^{ef}	19.82±0.06^{b}	1.36±0.16^{a}	34.40±0.57^{cd}
SWARNA 4	5.04±0.01^{ijk}	94.77±0.28^{efg}	0.352±0.01^{efg}	0.405±0.01^{g}	13.19±0.31^{h}	1.40±0.35^{a}	38.39±0.56^{abcd}
SWARNA 5	4.82±0.04^{kl}	95.08±0.12^{cdef}	0.314±0.02^{g}	0.357±0.01^{i}	9.03±0.51^{j}	1.05±0.07^{a}	42.07±0.10^{abcd}
TATA 7009 1	5.91±0.03^{g}	94.03±0.05^{ij}	0.472±0.01^{a}	0.521±0.01^{bc}	9.75±0.42^{j}	1.12±0.02^{a}	33.92±1.05^{cd}
TATA 7009 2	5.28±0.05^{h}	94.62±0.17^{fghi}	0.405±0.01^{cd}	0.505±0.01^{cd}	19.26±0.43^{b}	1.19±0.07^{a}	34.33±0.47^{cd}
TATA 7009 3	4.87±0.11^{jk}	95.20±0.01^{cdef}	0.357±0.01^{efg}	0.473±0.002^{ef}	22.40±0.75^{a}	1.39±0.14^{a}	35.35±0.50^{bcd}
TATA 7009 4	4.39±0.01^{mn}	95.64±0.04^{bc}	0.346±0.01^{efgh}	0.394±0.01^{gh}	11.91±0.51^{i}	1.15±0.01^{a}	39.16±0.27^{abcd}
TATA 7009 5	3.32±0.01^{p}	96.47±0.19^{a}	0.320±0.01^{fg}	0.360±0.01^{i}	12.14±0.20^{i}	1.35±0.30^{a}	41.04±0.06^{abcd}
SHUBHAM EARLY 1	5.75±0.07^{g}	94.10±0.14^{hij}	0.481±0.01^{a}	0.512±0.002^{c}	6.10±0.17^{l}	1.36±0.42^{a}	33.35±0.50^{cd}
SHUBHAM EARLY 2	5.22±0.04^{hi}	94.47±0.40^{ghi}	0.404±0.01^{cd}	0.486±0.01^{de}	18.03±0.05^{c}	1.42±0.29^{a}	34.05±0.11^{cd}
SHUBHAM EARLY 3	5.05±0.07^{ij}	94.70±0.28^{fgh}	0.372±0.01^{de}	0.404±0.005^{g}	7.58±0.70^{k}	1.20±0.16^{a}	35.82±0.46^{bcd}
SHUBHAM EARLY 4	4.41±0.02^{mn}	95.41±0.23^{cd}	0.346±0.002^{efgh}	0.398±0.01^{gh}	14.13±0.50^{g}	1.19±0.04^{a}	39.65±0.71^{abcd}
SHUBHAM EARLY 5	4.16±0.09^{no}	95.59±0.44^{bc}	0.326±0.01^{fg}	0.341±0.002^{i}	2.88±0.05^{m}	1.01±0.02^{a}	43.79±0.73^{abc}
KESHAR KING 1	8.64±0.20^{a}	91.20±0.01^{m}	0.471±0.02^{a}	0.554±0.005^{a}	11.26±0.01^{i}	1.28±0.23^{a}	32.66±0.69^{cd}
KESHAR KING 2	8.22±0.10^{b}	91.63±0.10^{lm}	0.420±0.00^{c}	0.485±0.01^{de}	14.84±0.37^{fg}	1.22±0.07^{a}	33.84±0.24^{cd}
KESHAR KING 3	8.05±0.07^{b}	91.78±0.16^{lm}	0.380±0.00^{de}	0.456±0.001^{f}	16.19±0.61^{de}	1.53±0.47^{a}	35.46±0.66^{bcd}
KESHAR KING 4	7.41±0.23^{c}	92.60±0.21^{k}	0.333±0.02^{fgh}	0.414±0.01^{g}	17.28±0.59^{c}	1.27±0.09^{a}	43.04±1.22^{abcd}
KESHAR KING 5	7.16±0.12^{d}	92.80±0.21^{k}	0.323±0.004^{fg}	0.387±0.002^{h}	16.37±0.26^{d}	1.43±0.33^{a}	45.14±0.51^{ab}
G 5417 1	5.22±0.04^{hi}	94.40±0.57^{ghij}	0.469±0.01^{a}	0.516±0.02^{c}	9.55±0.31^{j}	1.10±0.005^{a}	32.93±1.07^{d}
G 5417 2	5.04±0.06^{i}	94.85±0.99^{defg}	0.423±0.003^{bc}	0.511±0.002^{c}	16.25±0.17^{de}	1.32±0.17^{a}	34.02±0.03^{cd}
G 5417 3	4.64±0.63^{lm}	95.30±0.10^{cde}	0.372±0.002^{de}	0.452±0.003^{f}	17.68±0.17^{c}	1.59±0.539^{a}	38.07±0.15^{abcd}
G 5417 4	4.18±0.04^{no}	95.62±0.24^{bc}	0.350±0.000^{efgh}	0.400±0.02^{g}	15.40±0.02^{ef}	1.42±0.34^{a}	45.30±0.42^{ab}
G 5417 5	3.80±0.07^{o}	96.12±0.04^{ab}	0.314±0.01^{j}	0.311±0.02^{j}	1.56±0.46^{n}	1.15±0.20^{a}	46.77±1.09^{a}

The vlues denoted with different superscripts differ significantly at $p<0.05$ in a column.

Table 6.6 (b) Techno-functional properties of corn silk varieties at different growth stages

Corn silk varieties and stages	Water absorption Index (g/g)	Water solubility Index (%)	Foaming capacity (%)	Foam stability (%)	Swelling capacity (ml/g)	Oil Absorption Index (g/g)	Emulsifying activity (%)	Stability of emulsion (%)
SWARNA 1	9.35±0.13^{l}	22.48±0.67^{c}	15.61±0.15^{a}	63.39±0.54^{a}	7.62±0.16^{gh}	4.16±0.22^{abc}	43.24±1.27^{a}	34.65±0.71^{d}
SWARNA 2	10.01±0.03^{ijk}	21.37±0.51^{de}	14.11±0.03^{bcd}	59.84±0.70^{bcde}	7.12±0.17^{h}	4.08±0.14^{abcd}	43.20±0.75^{a}	36.84±0.39^{abc}
SWARNA 3	10.68±0.25^{efgh}	19.88±0.32^{fg}	13.41±0.60^{de}	59.37±0.51^{cdefg}	8.32±0.15^{bcdefg}	3.44±0.61^{bcdefg}	42.08±0.10^{abc}	36.84±0.97^{abc}
SWARNA 4	11.32±0.34^{cde}	18.21±0.14^{hi}	13.00±0.31^{efghi}	58.41±0.74^{efghi}	8.49±0.70^{abcdefg}	3.08±0.11^{fgh}	40.11±0.62^{de}	36.82±0.37^{abc}
SWARNA 5	12.17±0.56^{a}	13.15±0.06^{k}	12.43±0.60^{ij}	58.09±0.12^{fghi}	9.17±0.23^{abcd}	2.64±0.41^{gh}	38.16±0.22^{fgh}	37.54±0.50^{abc}
TATA 7009 1	9.71±0.06^{jkl}	22.66±0.15^{c}	13.70±0.19^{cde}	60.84±1.02^{bc}	7.68±0.16^{fgh}	4.14±0.19^{abcd}	43.04±1.25^{a}	37.04±0.68^{abc}
TATA 7009 2	10.25±0.45^{ghij}	21.44±0.61^{d}	13.41±0.28^{de}	59.41±0.60^{cdefg}	7.84±0.27^{fgh}	4.10±0.14^{abcd}	43.16±0.69^{a}	37.85±1.01^{ab}
TATA 7009 3	10.89±0.21^{defg}	20.40±0.56^{ef}	13.19±0.21^{efgh}	59.56±0.63^{cdef}	8.26±0.36^{cdefg}	3.35±0.31^{defgh}	41.19±0.73^{bcd}	36.39±1.33^{bc}
TATA 7009 4	11.45±0.18^{bcd}	19.16±0.02^{gh}	12.45±0.60^{ij}	58.55±0.14^{efghi}	8.74±0.41^{abcdef}	2.90±0.32^{fgh}	41.07±0.09^{bcd}	36.35±0.80^{c}
TATA 7009 5	12.37±0.68^{a}	15.11±0.09^{j}	11.96±0.25^{j}	58.28±0.31^{fghi}	9.36±0.50^{ab}	2.69±0.18^{gh}	37.86±0.42^{gh}	36.84±0.24^{abc}
SHUBHAM EARLY 1	9.61±0.15^{kl}	23.74±0.09^{b}	14.66±0.13^{b}	63.13±0.04^{a}	7.64±0.26^{gh}	4.18±0.25^{abc}	42.96±1.15^{a}	37.44±0.41^{abc}
SHUBHAM EARLY 2	10.07±0.06^{hijk}	21.22±0.25^{de}	13.73±0.23^{cde}	60.81±0.12^{bc}	8.06±0.08^{efgh}	4.19±0.10^{ab}	42.67±0.62^{ab}	38.21±0.99^{a}
SHUBHAM EARLY 3	10.81±0.11^{defg}	19.92±0.80^{fg}	13.31±0.23^{efg}	57.24±2.83^{i}	8.60±0.20^{abcdefg}	3.39±0.35^{cdefg}	42.73±0.86^{ab}	37.36±0.27^{abc}
SHUBHAM EARLY 4	12.21±0.66^{a}	18.40±0.21^{h}	12.61±0.20^{fghij}	58.24±0.34^{fghi}	9.04±0.52^{abcde}	3.13±0.18^{fgh}	39.69±1.44^{def}	36.96±0.25^{abc}
SHUBHAM EARLY 5	12.06±0.04^{ab}	18.42±0.10^{h}	12.38±0.10^{ij}	57.58±0.18^{hi}	9.42±0.59^{a}	2.57±0.58^{h}	39.57±0.01^{def}	36.95±0.55^{abc}
KESHAR KING 1	9.54±0.13^{kl}	24.00±0.14^{ab}	14.50±0.40^{b}	61.41±0.13^{b}	7.55±0.13^{gh}	4.12±0.16^{abcd}	43.80±0.78^{a}	37.01±0.17^{abc}
KESHAR KING 2	10.51±0.23^{fghi}	22.43±0.46^{c}	13.32±0.16^{ef}	60.17±0.06^{bcd}	8.16±0.23^{defgh}	4.53±0.50^{a}	43.54±0.54^{a}	36.88±0.60^{abc}
KESHAR KING 3	10.96±0.10^{def}	20.50±0.70^{def}	13.56±0.43^{de}	58.83±0.38^{efghi}	8.46±0.64^{abcdefg}	3.69±0.18^{bcdef}	40.69±0.88^{cde}	36.84±0.24^{abc}
KESHAR KING 4	11.47±0.12^{bcd}	17.36±0.50^{i}	12.62±0.09^{fghij}	58.40±0.60^{efghi}	9.29±0.41^{abc}	2.98±0.59^{fgh}	40.10±0.13^{de}	37.39±0.20^{abc}
KESHAR KING 5	11.91±0.21^{abc}	13.21±0.30^{k}	12.12±0.01^{j}	57.80±0.33^{ghi}	9.18±1.03^{abcd}	2.78±0.01^{gh}	36.67±0.73^{h}	37.90±0.32^{a}
G 5417 1	9.55±0.07^{kl}	24.83±0.70^{a}	15.44±0.31^{a}	60.74±0.87^{bc}	7.71±0.21^{fgh}	4.02±0.49^{abcde}	43.52±0.37^{a}	37.65±0.21^{abc}
G 5417 2	10.64±0.10^{fghi}	23.66±0.50^{b}	14.37±0.51^{bc}	59.22±0.79^{cdefg}	8.04±0.67^{efgh}	4.11±0.16^{abcd}	42.89±0.30^{a}	37.83±0.38^{abc}
G 5417 3	10.73±0.27^{efg}	20.06±0.09^{fg}	13.17±0.30^{efgh}	58.69±0.49^{efghi}	8.50±0.70^{abcdefg}	3.27±0.38^{efgh}	40.51±0.72^{cde}	37.46±0.65^{abc}
G 5417 4	11.40±0.08^{cd}	18.23±0.31^{hi}	12.59±0.11^{hij}	58.53±0.26^{efghi}	9.23±0.13^{abcd}	2.78±0.47^{gh}	39.25±0.82^{efg}	37.26±0.34^{abc}
G 5417 5	11.93±0.03^{abc}	13.45±0.70^{k}	12.05±0.07^{j}	58.28±0.24^{fghi}	9.39±0.55^{ab}	2.74±0.10^{gh}	37.76±0.438^{gh}	37.91±0.82^{a}

The values are represented in Mean ± Standard deviation derived for triplicate experiments (n=3).
The values denoted with different superscripts differ significantly at $p<0.05$ in a column.

Emulsifying activity and stability of emulsion are imparted majorly by proteins and other amphoteric molecules (Ma, et al., 2011). The highest percentage of emulsifying activity was observed for KESHAR KING stage 1 (43.80±0.778) and lowest for KESHAR KING stage 5 (36.67±0.735%). The difference was not significant among stages of different varieties. For stability of emulsion, no significant difference was observed among the varieties and their stages. The highest percentage was observed in G5417 stage 5 (37.91±0.823%) and SHUBHAM EARLY stage 2 (38.21±0.983%). Carbohydrates such as fiber and starch enhances the stability of emulsion as they act as bulky barriers between oil droplets and further prevent the rate of oil droplet coalescence (Aluko et al., 2009). Current results highlight the possibility of incorporation of corn silk in bakery products beverages, yoghurt and ice cream due to its good emulsifying capacity and stability of emulsion. On the basis of the results, G5417 stage 1 was selected for the further analysis and product development.

6.6 Effect of blanching time and temperature on enzyme activity

To retain the colour of corn silk during different drying methods, the blanching time was optimised by qualitative estimation of catalase reaction and peroxidase reaction. The blanching time as shown in Table 7 was optimised by analysing the stage of no change in colour (for peroxidase reaction) and no bubble formation (for catalase reaction). Our results reported that the optimised blanching time of corn silk was 100°C for 60 seconds when no change in colour and no bubble formation was seen.

Table 6.7: Selection of blanching time and temperature for discouraging browning in corn silk sample

Temperature	Time (seconds)	Catalase reaction	Peroxidase reaction
80°C	30	+ + +	+ + +
	60	+ +	++
	90	+	+
	120	-	-
90°C	30	+ + +	+ + +
	90	+	+
	120	-	-
100°C	30	+ +	+ +
	60	-	-

Where "+"= color change and bubble formation seen
"-"= No color change and no bubble formation

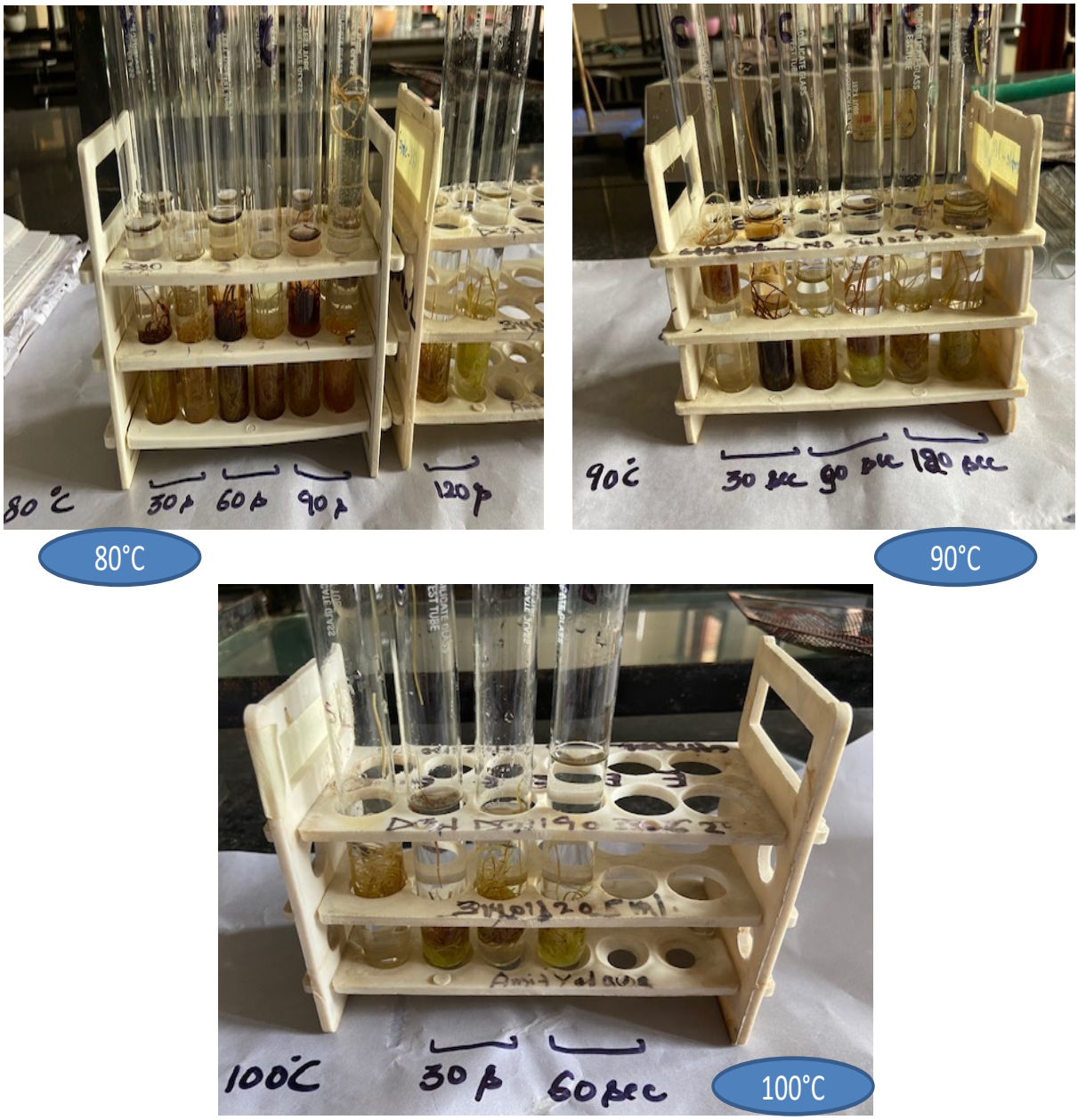


Figure 6.6: Pictorial view of blanching experiment of corn silk

6.7 Thin layer model drying

The results of statistical criteria for the models observed is shown in Table 6.9 and 6.10. The values for chi square (χ^2) ranged from 0.002 to 0.015, 0.160 to 0.390 and 0.031 to 0.063 for Page, Henderson-Pabis and Lewis models respectively as shown in Table 2. The empirical drying constants for corn silk at each temperature are given in Table 3. The coefficients of determination (R^2) for the drying rate constants of all three thin-layer drying models for corn silk were above 0.90 for Page (except 50°C with R^2=0.788) and Henderson-Pabis model at all the mentioned temperature These high coefficients of determination are

due to the highly linear plots of the unaccomplished moisture content, which are perhaps due to accurate equilibrium moisture contents. The drying rate gradually increases and then slowly decreases as the drying progresses. The general trend observed is drying rate reduces with time and decrement in moisture content. The root means square error (RMSE) ranged from 0.123 to 0.053, 0.419 to 0.655 and 0.185 to 0.264 for Page, Henderson-Pabis and Lewis models respectively as represented in Table 2. The goodness of fit for model is calculated when percent error (PE) is less than 10%. All the three models showed good predictions as the PE values ranged from 0.90 to 7.07% for Page model, 0.97 to 6.98% for Handersn-Pabis model and 0.53 to 2.70% for Lewis model. After analysing the models, the RMSE and χ^2 values closest to zero were for Page model which showed the better fit model with percent error values less than 10. The drying curves of corn silk at each temperature and corresponding Page model prediction is shown in Figure 6.8.

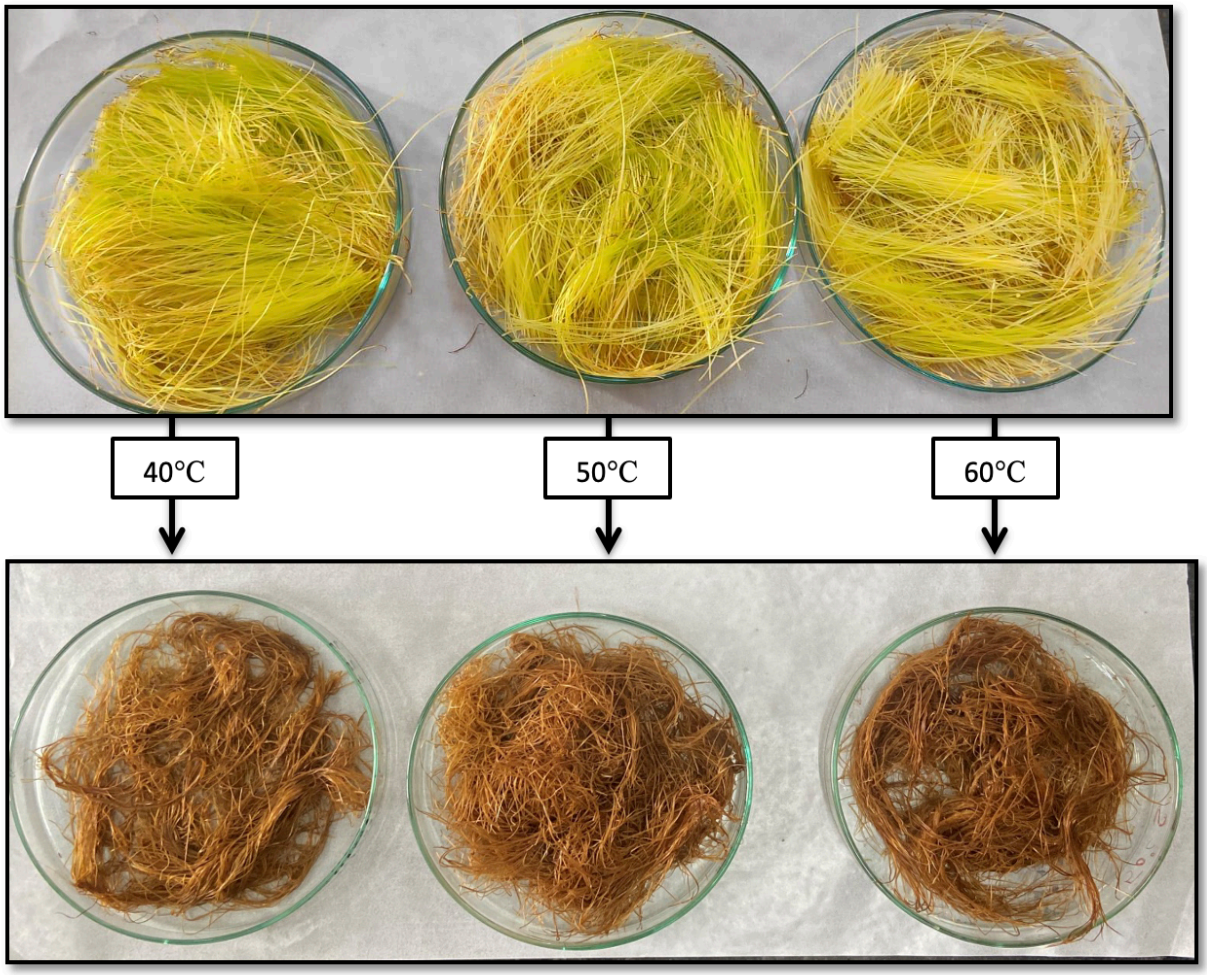


Figure 6.7: Drying of corn silk at different temperatur

Table 6.8: Model prediction evaluation

Temperature (°C)	Page Equation				Handerson-pabis				Lewis			
	RMSE	χ^2	RSS	Percent error (PE %)	RMSE	χ^2	RSS	Percent error (PE)	RMSE	χ^2	RSS	Percent error (PE)
40	0.123	0.015	0.165	0.90	0.655	0.390	0.429	0.970	0.264	0.063	0.702	0.53
50	0.053	0.002	0.030	0.612	0.419	0.160	1.760	6.988	0.203	0.038	0.415	3.11
60	0.041	0.002	0.020	7.076	0.450	0.166	1.828	6.529	0.185	0.031	0.345	2.70

Table 6.9: Empirical constants of the Page, Lewis, Henderson–Pabis equations

Temperature (°C)	Page Equation			Handerson-Pabis			Lewis	
	k (min^{-1})	N	R^2	k (min^{-1})	a	R^2	k (min^{-1})	R^2
40	1.043	1.5099	0.977	0.0218	0.2965	0.959	0.029	0.802
50	1.305	0.951	0.788	0.0074	0.0051	0.974	0.0192	-2.566
60	1.027	1.146	0.961	0.0218	0.218	0.923	0.0302	0.6731

Effect of temperature on moisture content and moisture ratio

As drying progresses, the drying rate rapidly increases, then gradually declines. In general, the drying rate decreases with time or as the moisture content decreases. During the declining phase, the drying process took place. In the drying of many fruits, vegetables, spices and cereal grains similar results have been observed in carrot pomace (Kumar et al., 2011), hazelnut (Uysal et al., 2009), apple pomace (Wang et al., 2007), grape seeds (Roberts et al., 2008), ginger (Hasibuan and Bairuni, 2018), water chestnut (Sayyad et al., 2021), pepper (Darvishi et al., 2014), corn (Song et al., 2013), fermented corn (Ajala and Abubakar, 2018), wheat, maize and barley (Noroña et al., 2018). Figures 6.9 depict the trend of moisture loss in the corn silk samples at different temperature (40, 50 and 60°C). The corn silk samples were seen to have a declining rate pattern on the graph. As reported by Ramaswamy & Marcotte (2006), drying occurred during the falling rate period, which was primarily controlled by an internal factor of grain diffusion mechanism, as opposed to the constant rate period, which could be controlled by external conditions such as temperature, air humidity, and air velocity.

The effect of temperature on the drying properties of the sample showed that at a drying temperature of 60°C, moisture loss from 525 to 31.25 % on dry basis 150 minutes. At 50°C, it took 180 minutes to reduce moisture content from 525 to 18.75 % on dry basis but at 40°C, it took the highest time i.e 210 minutes reduce moisture content from 525 to 187.50 % on dry basis. Higher temperatures resulted in greater moisture loss from the grains, according to this data. Because moisture loss was faster at 60°C than at 50°C and 40°C the drying rate was faster at 60°C than at the other two temperatures. A similar remark has been made in the literature given by Guine et al. (2009). Similarly, the moisture ratio gradient generated by a temperature difference between the solid and the drying medium was smaller at 40°C than at 50°C, and the moisture gradient at 60°C was the steepest. This could help to explain why moisture was removed faster at 60°C than at lower temperatures.

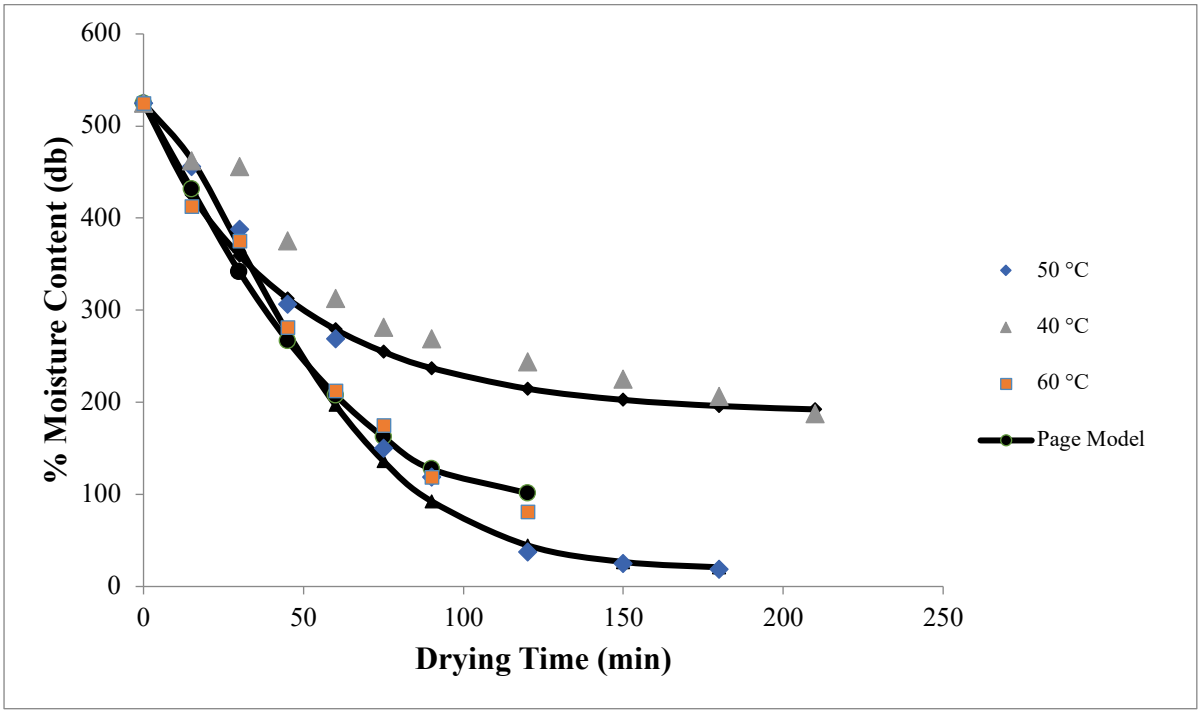


Figure 6.8: Moisture content (db) vs drying time graph for predicted and experimental model fitting for Page model

Effective moisture diffusivity and activation energy

For all experiment variants, Table 4 shows the effective moisture diffusivity (D_{eff}) values. The effective moisture diffusivity for corn silk samples at 40, 50 and 60°C ranged between $4.06x10^{-13}$, $1.38x10^{-12}$ and $1.10x10^{-12}$ m^2s respectively. It can be seen that when the drying temperature rises, the D_{eff} values rise as well. Increased heating energy increased the activity of water molecules, resulting in higher moisture diffusivity when the items were dried at a higher temperature (Mghazli et al., 2017). E_a (Activation energy) was calculated and the value of activation energy was 43.66 kJ/mol as mentioned in Table 6.10.

Table 6.10: Values of effective moisture diffusivity (Deff)

Temperature (°C)	*t* (drying time in minutes)	Deff (m^2/s)	E_a (kJ/mol)
40	300	$4.06x10^{-13}$	
50	180	$1.38x10^{-12}$	43.66
60	120	$1.10x10^{-12}$	

6.8 DIFFERENT TYPES OF DRYING OF CORN SILK

The different drying techniques used to form the corn silk powder as shown in figure 6.7 showed the less time required for the formation of tray dried corn silk powder which can be commercially adopted for the development of value added product by using corn silk.

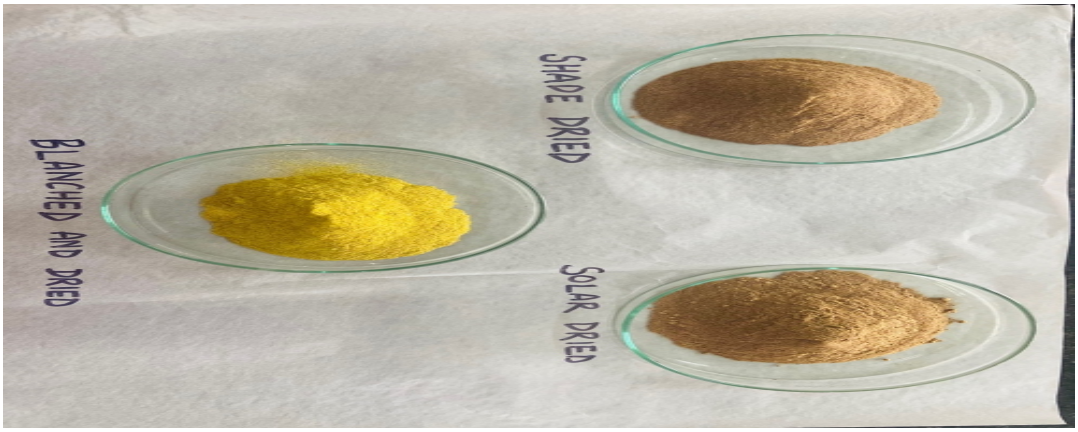


Figure 6.9 Different types of powdered corn silk by using different types of drying

6.9 EFFECT OF DRYING METHOD ON ANTIOXIDANT CONTENT AND ACTIVITY OF CORN SILK

Moisture content of corn silk is shown in Table 6.8 by using different drying methods. The significant difference was found in tray dried, vacuum dried, solar dried and shade dried corn silk samples but the difference between tray dried and solar dried was not significant, highest moisture content was observed in vacuum dried (93.3±0.50) and the lowest moisture content was observed in shade dried corn silk (76±0.89 %).

The results were in agreement with Saifullah et al. (2019) in their study of effects of drying methods on extractable phenolic compounds and antioxidant properties from lemon myrtle dried leaves. They reported the final moisture content of leaves was highest for shade dried samples and lowest for microwave drying.

The retention rate of corn silk by different drying techniques were studied and the data is represented in Table. The total polyphenolic content in fresh corn silk at baby corn stage were 229 mg GAE/g which significantly decreased in tray, vacuum, solar and shade dried samples. There was no significant difference observed between tray dried and vacuum dried corn silk samples. The results revealed that total polyphenolic content decreased at high temperature due to the losses of heat labile phenolic compounds when compared to fresh corn silk samples. Similar reports were reported by Mbondo et al., 2018 where they reported the retention of polyphenolic content was higher in freeze dried followed by tray dried and then the African egg plant.

Total flavonoid content decreased significantly from 237.10 to 95.2 mg QE/100 g in fresh corn silk and solar dried corn silk respectively. Carotenoid content ranged between 0.06

g/litre to 0.08 g/litre and there was no significant difference seen in tray, vacuum and solar dried sample.

Table 6.11: Antioxidant profiling of dried corn silk powder developed from drying technique

Sample	Moisture content (%)	TPC (mg GAE/g)	TFC (mg QE/100 gm)	Carotenoid (g/litre)	Ascorbic acid (mg/100 g)	FRSA (%)	FRAP (mg/TE)
G5417 (stage 1)		229.48±1.22^{a}	237.10±0.95^{a}	0.09±0.92^{a}	324±1.20^{a}	65.33±0.50^{a}	86.77±0.90^{a}
Tray dried sample (50 °C) Time taken- 2.5 Hrs	90.5±0.21^{a}	74.10±0.84^{b}	153.94±0.55^{b}	0.06±0.67^{b}	230±1.53^{c}	44.4±0.71^{b}	80.32±0.81^{c}
Solar dried (8 hours)	91.2±0.45^{a}	75.38±1.24^{b}	151.84±0.88^{b}	0.06±0.80^{b}	234±0.89^{d}	45.34±0.89^{b}	82.96±0.69^{c}
Vacuum dried (40°C) Time taken- 6 hours	93.3±0.50^{b}	67.43±0.69^{c}	95.52±0.69^{d}	0.06±0.59^{b}	180±0.95^{e}	39.92±0.79^{c}	58.06±0.55^{d}
Shade dried (3 days) Rh- 35% Temp- 26°C	76±0.89^{c}	63.58±0.92^{d}	126.84±1.20^{c}	0.08±0.91^{c}	252±1.29^{b}	37.27±0.60^{d}	74.77±0.95^{b}

The values are represented in Mean ± Standard deviation derived for triplicate experiments (n=3).
The values denoted with different superscripts differ significantly at $p<0.05$ in a column.

The ascorbic acid retention rate was higher in tray dried and vacuum dried sample as shown in Table. The antioxidant activity including FRSA and FRAP was also studied and the results obtained showed that the per cent inhibition was high in tray and vacuum dried samples and the lowest per cent inhibition was seen in shade dried corn silk. Similar trend for the FRAP activity was observed in different types of dried corn silk samples. Similar results were reported by Saifullah et al., 2019 that after freeze dried sample, hot air and vacuum dried lemon myrtle at 90°C for 75 min showed the highest retention for antioxidant content and activity.

6.10 PHYSICO-CHEMICAL PROPERTIES OF CORN SILK POWDER

Sieve analysis of corn silk powder

After sifting, the particle mass (percentage) of corn silk revealed the following weight percent of particles: 26, 36, 56, 72, 100, 200, and 300 BSS. The maximum weight percentage for corn silk powder was found to be 31.7% at particle size 212 µm (highest) and the lowest was obtained for 75 µm (3%) as shown in Figure 2. The data are shown in figure clearly depicts that powder had the minimum amount of fine particles.

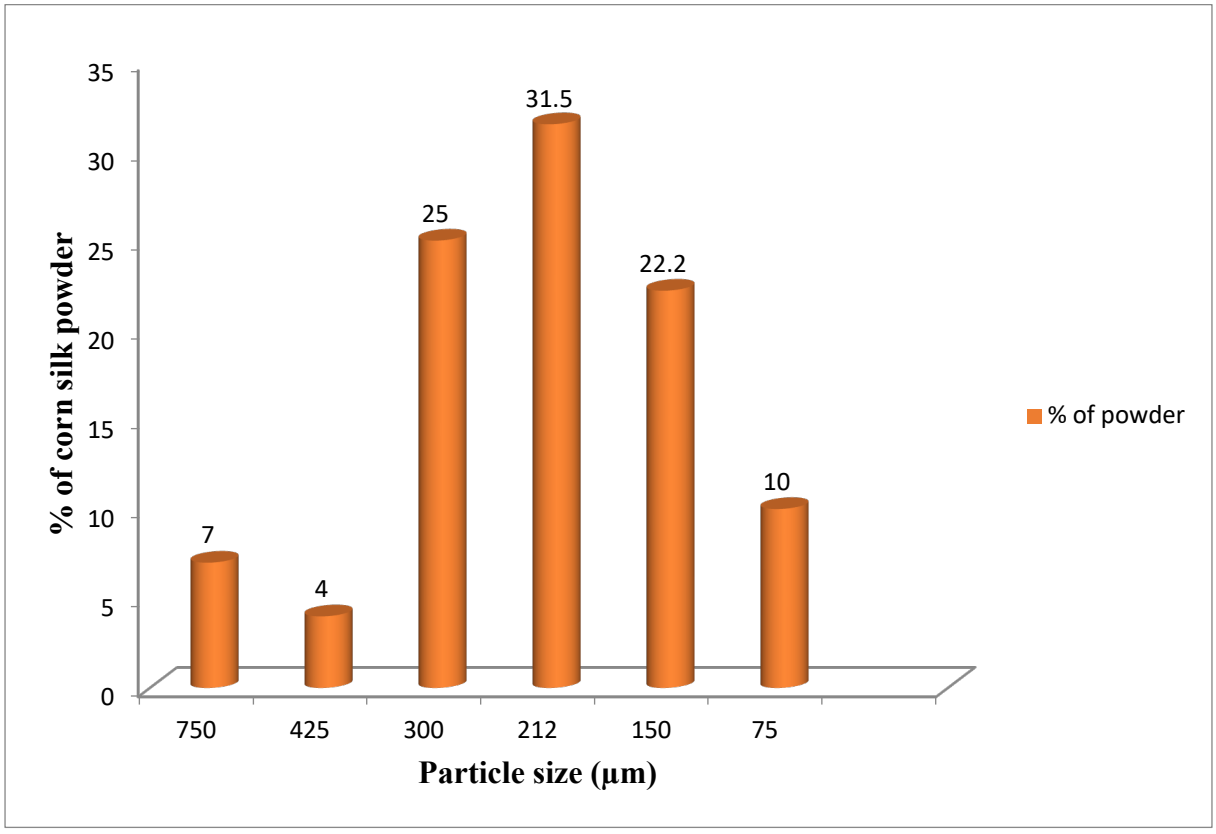


Figure 6.10: Sieve analysis of corn silk powder

Average particle size of corn silk powder

For particle size analysis of corn silk, the dynamic light scattering (DLS) method was applied for the characterization of particles. The principle of DLS is based on the Browninan motion of particles suspended in a liquid which causes the laser light to be spread with various intensities. The particle size is calculated by analyzing the fluctuation in the velocity of Brownian motion (Bento et al., 2018). The result of soluble and dispersed fractions of corn silk average particle size analysis is shown in Figure 3 and the values obtained were 364.4 d.nm. Dispersed soluble fractions of corn silk contain maximum soluble protein and polysaccharides and the mass reduction while analyzing the average particle size of corn silk has given the value of 364.4 d.nm. The current findings matched those of Zhu *et al*., (2019) who found that the mass ratio of zein to maize fiber gum reduced from 455 nm to 309 nm in a 5:1 to 2:1 ratio, respectively due to steric hindrance and electrostatic repulsion of high concentration of polysaccharides reduce the aggregation of dispersed and soluble fractions of corn silk which ultimately lead to reduced particle size.

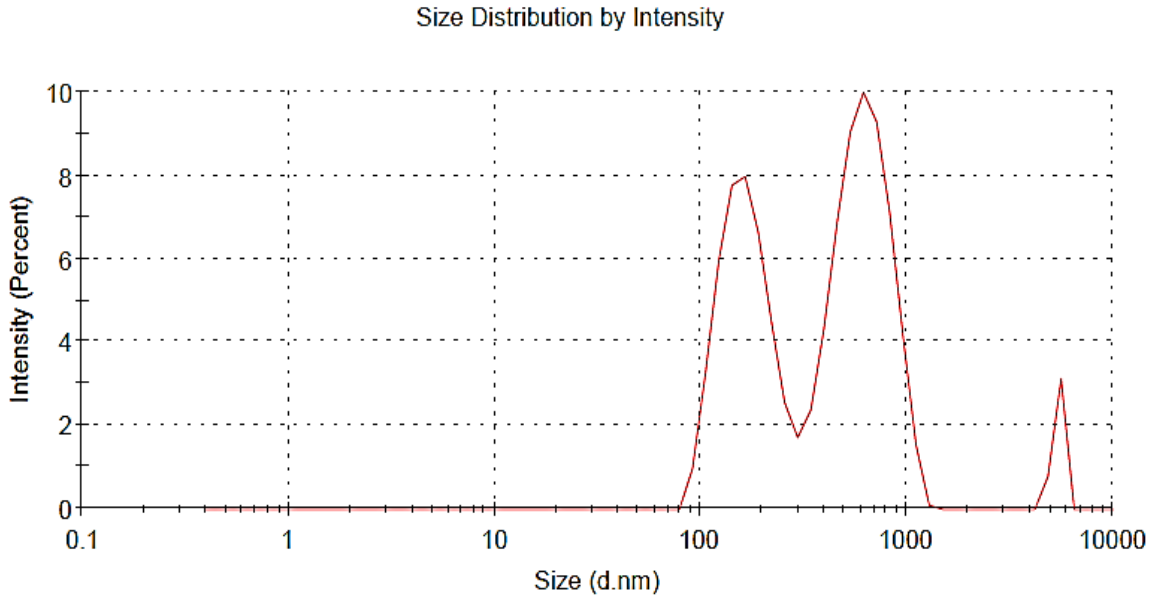


Figure 6.11: Average particle size of corn silk powder

Physical properties of corn silk powder

Bulk and tapped density

Bulk density refers to how much flour expands and how porous a product is. As shown in Table 1, the bulk density of corn silk powder decreased considerably ($p<0.05$)as particle size decreased from 750 µm (05950.02 g/cm^3) to 300 µm (0.4200.02 g/cm^3), and no

significant change was seen in the corn silk samples as particle size decreased from 300 to 75 µm. According to Ahmed *et al.*, (2015) the bulk density of rice flour samples did not change much as particle size decreased, with the exception of the smallest particle size (74 m), which exhibited a significant decline. Our findings were similar to those of Bala *et al.*, (2020) who discovered that when particle size dropped, the bulk density and tapped density of grass pea flour reduced considerably. Coarser particles have higher bulk density values, while finer particles have lower bulk density values, which could be attributed to high ash content (Ahmed et al., 2015).

Tapped density mimicked the trend similar to bulk density as it decreased from 0.725±0.04 (750 µm) to 0.580±0.02 g/cm^3 (75 µm) however, for 750 µm to 212 µm the difference was insignificant. It was also discovered that the tapped density values were higher than the bulk density readings. Free-flowing powders with coarse particle sizes are less compact and finer particles settled quickly due to tapping, powders with reduced bulk and tapped density are recommended for the formulation of supplementary foods with an even and packed texture. The decrease in corn silk samples' mass and tapped density is attributable to particle stickiness during dehydration, as well as product agglomeration (Guola et al.,2004).

Carrs index (flowability) and Hausner ratio (cohesiveness)

Particle size distribution has a significant role in modulating powder properties including flowability and cohesion (Muttakin et al., 2015). The increase in the surface area per unit of powder hinders flowability, owing to increased surface friction and strengthening of intermolecular forces, inhibiting the flow (Fitzpatrick et al., 2005). The result for Hausner ratio and Carr index as shown in Table 1varied between 1.21±0.03 to 1.48±0.17% and 17.83±2.68 to 33.63±0.42%, respectively from coarser to finer particles which have shown the intermediate flowability of corn silk powder.

Angle of repose

The angle of repose represents the fluidity of the powder. The angle of repose of corn silk with a different particle sizes as shown in Table 1. The values ranged from 38.28° (750 µm), 36.14° (425 µm), 33.42° (300 µm), 31.92° (212 µm), 30.18° (150 µm) and 25.77° (75 µm). A significant difference ($p<0.05$) existed in corn silk samples and the values decreased from coarser to finer particles. The increase in the angle of repose shows less flowability in

the granular bulk. The findings matched those of Zhao *et al*., (2009) who found a similar trend in the angle of repose in ginger powder from 300 µm to 8.34 µm.

Techno-functional properties of corn silk powder

Water absorption capacity and water solubility index

Hydration properties denote the characteristics of polysaccharides and are affected by particle size. When flour is mixed with water, the water solubility index measures how quickly the components in the flour dissolve. There was no differences observed in the results for water absorption index among various particle size of corn silk powder, however, the values increased significantly ($p<0.05$) from coarser (12.21±0.14 g/g) to finer particle (14.30 ±0.73 g/g) size of corn silk as shown in Table 2 with the reduction in particle size. The water absorption index also decreased significantly ($p<0.05$) as particle size decreased for corn silk samples. The increase in WAC is due to more surface area after size reduction of particles (Ahmed *et al.*, 2015). Similar results were observed by Carvalho *et al*., (2010) where the water absorption index decreased as particle size increased in cornmeal based extrudates. Martinez-Giron *et al.,* (2021) revealed a considerable rise in WAI and WSI as particle size decreased in peach palm peel flours. Variations in WAI are caused by different types of hydrophilic carbohydrates and protein structures found in the samples. Corn silk samples have a higher water solubility due to the low lipid content, insoluble fiber content, and high soluble fiber concentration.

Table 6.13: Physical properties of corn silk powder at different particle size

Particle size (µm)	Bulk density (g/cm^3)	Tapped density (g/cm^3)	Hausner Ratio (%)	Carr Index (%)	Angle of repose (°)
750	0.595±0.02^{a}	0.725±0.04^{a}	1.21±0.03^{f}	17.83±2.68^{e}	38.28±0.31^{a}
425	0.550±0.04^{a}	0.715±0.04^{a}	1.30±0.10^{e}	23.09±0.61^{d}	36.14±0.77^{b}
300	0.420±0.02^{b}	0.685±0.04^{a}	1.63±0.01^{b}	38.68±0.30^{ab}	33.42±0.37^{c}
212	0.415±0.02^{b}	0.700±0.02 ^{a}	1.68±0.01^{a}	40.72±0.63^{a}	31.92±0.37^{c}
150	0.400±0.01^{b}	0.630±0.02^{ab}	1.57±0.01^{c}	36.49±0.60^{bc}	30.18±1.08^{d}
75	0.385±0.02^{b}	0.580±0.02^{b}	1.48±0.17^{d}	33.63±0.42^{c}	25.77±0.58^{e}

The values are represented in Mean ± Standard deviation derived for triplicate experiments (n=3).
The values denoted with different superscripts differ significantly at $p<0.05$ in a column.

Oil absorption capacity

Fiber has the ability to trap fat in addition to hydration capacity, hence oil absorption capacity is another essential characteristic in fiber characterization. The size, shape, type, and

superficial area of fiber particles, as well as their chemical composition, influence this feature (Martínez-Las Heras et al., 2017). The oil absorption capacity of corn silk decreased significantly ($p<0.05$) from 750 to 425 µm by the values of 5.80±0.18 and 3.96±0.09 g/g, respectively and increased significantly ($p<0.05$) thereafter (in 300 and 212 µm corn silk samples). Corn silk samples with particle sizes of 300 and 75 µm showed no significant difference. By exposing a broad surface area during processing, the ground particles improve oil absorption capacity, functional characteristics, and enzyme release.[33] Current findings were in agreement with Ahmed et al., (2015) who reported a decrease in OAC from 210 to 105 µm sizes of lentil flour fractions. The decrease in the OAC is due to reduction in the protein content and reduced accessibility of hydrophobic chains in finer flour fractions, where the oil is held in nonpolar side chains of proteins. (Bala et al., 2020). The high OAC content is useful for preserving flavor, extending shelf life, and improving the appealing qualities of food goods.

Emulsifying activity and stability of emulsion

The emulsifying properties (Emulsifying activity and stability of emulsion) evaluated in corn silk powder showed a significant decrease ($p<0.05$) from 300 to 75 µm particle size which shows a strong correlation between particle size and emulsifying properties. The emulsifying properties are dependent on the protein and carbohydrate content of corn silk. The capacity to stabilize surfaces is connected to the isoelectric point of proteins, and polysaccharide-protein complexes have good emulsifying properties.[34] Formation of emulsion and its stability is important characteristics in food systems such as salad dressings and the protein responsible for the emulsification properties is useful in food applications such as cakes, coffee whiteners and frozen desserts (2021).

Foaming capacity and foam stability

Foam stability is defined as the ability of proteins to interact with air, creating a surface with air entrapped, preventing any gas exchange (Agbemafle, 2019). The proteins content is responsible for foaming properties and especially surface protein are the most active proteins which contribute to the formation of foam during agitation. Although, in the present context, the foaming capacity and stability were influenced by particle size as the protein content in the sample remained same. The foaming capacity and foam stability of corn silk powder of various particle sizes are shown in Table 2.

Table 6.14: Techno-functional properties of corn silk powder at different particle size

Particle size (µm)	Water absorption capacity (g/g)	Water solubility index (%)	Oil absorption capacity (g/g)	Emulsifying activity (ml/g)	Stability of emulsion (%)	Foam capacity (%)	Foam stability (%)
750	12.21±0.14 ^{b}	3.41±0.21^{c}	5.80±0.18^{a}	39.11±0.62^{a}	31.72±0.23^{a}	30.21±0.76^{bc}	46.04±1.20^{a}
425	13.12±0.33 ^{a}	3.12±0.03^{c}	3.96±0.09^{d}	36.90±0.50^{b}	30.17±0.70^{b}	31.72±1.33^{b}	44.93±3.87^{ab}
300	12.77±0.94 ^{b}	4.44±0.32^{b}	4.21±0.07^{cd}	35.38±0.21^{c}	28.88±0.30^{c}	34.38±0.72^{a}	41.38±0.26^{bc}
212	13.13±0.65 ^{a}	4.42±0.34^{b}	5.51±0.49^{ab}	34.37±0.70 ^{c}	28.05±0.53^{c}	29.94±0.22^{bc}	40.32±0.18^{c}
150	13.14±0.75 ^{a}	5.18±0.14^{ab}	4.86±0.09^{bc}	32.25±0.14^{d}	25.31±0.34^{d}	29.20±0.98^{cd}	38.22±0.09^{cd}
75	14.30±0.73 ^{a}	5.54±0.55^{a}	4.66±0.42^{cd}	30.18±0.01^{e}	24.14±0.05^{e}	27.50±0.56^{d}	35.54±0.50^{d}

The values are represented in Mean ± Standard deviation derived for triplicate experiments (n=3).
The values denoted with different superscripts differ significantly at $p<0.05$ in a column

The highest foam capacity was observed in 300 µm particle size corn silk samples 34.38±0.72% and the lowest foaming capacity was observed in the finer particle size, 27.50±0.56% (75 µm). The foam stability reduced significantly ($p<0.05$) from coarser particles to finer particles and values ranged from 46.04±1.20to 35.54±0.50%. Similar results were reported by Bala et al., (2020) where the foaming capacity decreased significantly by 249 to 74 µm particle size. Because the whipping agent must be able to maintain the foam for an extended amount of time, foam stability is a critical criterion.

6.11 Antioxidant activity

Particle size has a major impact on antioxidant activity, as illustrated in Figure 4, which shows a significant increase ($p<0.05$) in free radical scavenging activity from coarse to fine corn silk particles. From 750 to 75 µm particle size, the values in Figure 4 ranged from 1.82±0.62 to 49.58±0.33%. These findings were in agreement with those of Ahmed *et al.*, (2019) who discovered that the quinoa flour's DPPH scavenging efficacy declined considerably as particle size decreased. Zhao et al., (2018) came up with a similar set of results where the extractability of phenolics and antioxidants was reported to be high for superfine rice bran powder as compared to its coarse counterpart. Size reduction of corn silk samples showed a significant difference ($p<0.05$) for FRAP and ABTS activity as shown in Figure 4.

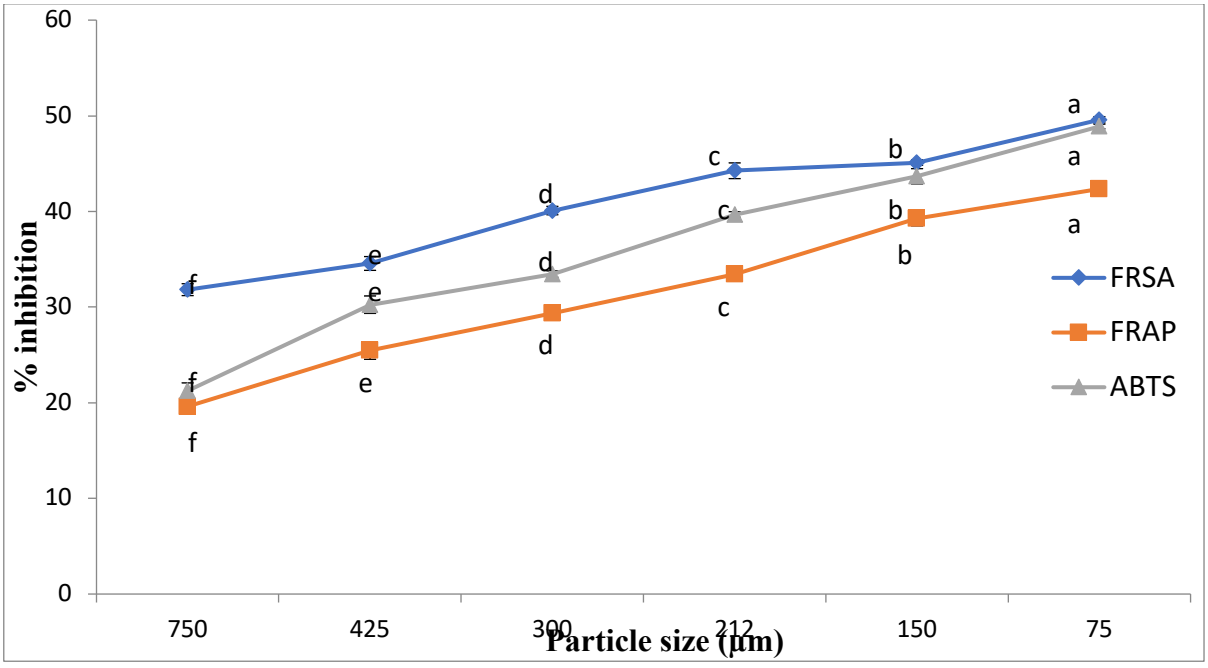


Figure 6.12: Antioxidant activity of corn silk powder at different particle size

This behavior can be explained by the fact that larger particle sizes is larger, resulting in less release of bioactive compounds, whereas smaller particles, result in a larger release of the bioactive compounds, increasing the potential antioxidant effect. Similar results were reported by Botella-Martínez et al., (2021) where the particle reduction increases the antioxidant activity viz. DPPH, FRAP and ABTS in Ghanaian cocoa.

6.12 Nutritional composition of corn silk powder

Moisture is an important component that is linked to the shelf stability of the food. Thus, determining moisture content is vital for the development of value-added products using food ingredients. The prepared corn silk powder showed a moisture content of 7.89±0.49 g/100g fw (Table 6.15) making its shelf-life management easier. The chemical composition of corn silk powders reveals the high carbohydrate content of corn silk 56.16±0.66 g/100 gas compared to the other nutrients. It includes high levels of soluble dietary fiber such as pectin, glucan, glucomannan, and insoluble dietary fiber such as cellulose, hemicellulose, and lignin. The total fiber content of corn silk powder samples corresponded to 14.82±0.84 g/100 g. With an average of 15.29 % protein and 5.29% ash content, corn silk is one of the best sources of both protein and ash. While, the fat content in the stated variety was about 0.55%. The water activity is a significant measure for determining the microbiological stability of food products since it determines the free and available moisture attributable to any type of biochemical reaction. The water activity of the corn silk powder in this investigation was 0.224 which was lower than 0.3 (as shown in Table 1), indicating high microbiological stability of corn silk powder.

Mineral content

The mineral content of the corn silk depends on various factors including atmosphere, soil type, irrigation, and nutrients through fertigation contacting nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, zinc, manganese, copper, boron, molybdenum, and chlorine, obtained from soil minerals and organic matter, as well as from organic and inorganic fertilizers. The corn silk variety is a good source of Na, Mg, K, and Ca as depicted in Table 6.16. Corn silk also contains trace metals such as copper (11.91±1.15 μg/g), iron (41.77±2.67 μg/g), manganese (11.10±2.15 μg/g), and zinc (83.75±1.80 μg/g).

6.13 Color analysis of corn silk powder

Table 6.15 shows the color, lightness (L*), redness (a*), and yellowness (b*) parameters of corn silk powder. The color of dried powder is important as it determines the quality and sensory attractiveness of the product. The hue angle of 75.27° shows the corn silk powder was strongly characterized by yellow color as the values were close to 90°C.

Total phenolic content (TPC), Total flavonoid content (TFS) and Ascorbic acid (AA)

Corn silk is often considered a good source of antioxidant content. These antioxidants include polyphenolic compounds, flavonoids, and ascorbates. These components provide quality and nutritional value, as well as anti-inflammatory, anti-diabetic, antiviral, and antioxidant properties, which are important in human fitness. Secondary metabolites from medicinal plants act as tiny molecular weight antioxidants, although their mechanisms of action vary depending on the structure and environment (Matkowski et al., 2008). Table 3 reveals the total phenolic content of corn silk powder was 94.10±0.26 mg GAE/g. Corn silk has a lot of flavonoids in it and varying amounts according to the variety, ranging from less than 0.1 to 3 percent (Zhang et al., 2021). Current results showed high flavonoid content in corn silk 163.93±0.83 mg QE/100 g. As reported, Maysin, apigmaysin, 3-methoxymaysine, ax-4-OH maysin, and isoorientin-2″-O-a-L-rhamnoside are among the flavonoids extracted and discovered from corn silk (Haslina and Eva., 2017; Ren et al., 2009) Studies suggest larger total phenolics and total flavonoids were found in the top regions of corn silk than in the lower parts (Tian et al., 2021). However, the current study used a homogenized sample for the determination of the compounds. Ascorbic acid is a water-soluble vitamin that is required for a variety of physiological processes as well as acting as a powerful antioxidant in the battle against diseases caused by free radicals (Alam, 2011; Pisoschi et al., 2009). The vitamin C content of corn silk powder was reported to be high as 270±0.57 mg/100g, which is significantly higher than that reported by Kewawy (2018) as 9.72 mg/100 g.

Table 6.15: Chemical analysis of corn silk powder

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

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

Table 6.16: **Mineral analysis of corn silk powder using ICP-OES**

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

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

Antioxidant activities of corn silk powder

Free radical scavenging activity (FRSA)

Oxidation is a worldwide problem that has negative consequences for food quality and human health. According to a previous study, oxidative damage can cause browning, off-

flavor, and changes in food's nutritious value, as well as a possible threat to cellular function and the creation of chemicals linked to aging and cardiovascular disease (El Kewawy, 2018). The antioxidant activity of corn silk powder was calculated using three different methods, including DPPH, ABTS, and FRAP. The free radical scavenging activity reported by corn silk powder as shown in Table 3, was found to be 45.40±0.92%. Corn silk extracted with methanol had a higher degree of DPPH scavenging activity (81.7 percent at 1000 g/mL) than corn silk extracted with water (63.5 percent) at the same concentration (Sanahuja et al., 2013). In ethanol, DPPH is a stable free radical with a maximum absorbance of 517 nm.

ABTS activity

Total antioxidant activity has always been measured using the ABTS radical-scavenging activities test. The ABTS radical produced by converting ABTS-e to ABTS+ interacts swiftly with electron/hydrogen donors to produce colorless ABTS. The ABTS activity for corn silk powder as shown in Table 16 was 75.25±0.59 TEAC mg/gdw.

Table 6.17. The antioxidant profile of corn silk powder

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

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

Ferric Ion Reducing Power (FRAP)

As significant as reducing power, the ferric reducing-antioxidant power (FRAP) is frequently utilized as a measure of phenolic antioxidant activity. The ability of the samples to decrease Fe(III)-TPTZ to Fe(II)-TPTZ was used to determine their antioxidant capacity. Corn silk powder showed 86.77±0.88% of FRAP activity. Total flavonoids extracted from corn silk had a FRAP value of 467.59 μmol/L (Zheng et al., 2016).

6.14 Characterization of corn silk powder

Differential Scanning Calorimetry

Thermal properties of corn silk such as denaturation temperature (T_d) and enthalpy change (ΔH), could be studied using differential scanning calorimetry. The calorimetry method was used to identify the changes in phase transitions. Figure 6.13 summarise the differential scanning calorimetry (DSC) parameters obtained for endothermic reaction at on-set temperature (T_{onset})= 21.9°C, end-temperature (T_{endset})= 102.80°C, denaturation peak temperature (T_{peak})= 70.06°C, and ΔH=172.16 J/g, and exothermic reactions at on-set temperature (T_{onset})= 252.02°C, end-temperature (T_{endset})= 296.80°C, denaturation peak temperature (T_{peak})= 277.48°C, and ΔH=-33.616 J/g. In addition, transition state of corn silk was observed at (T_g)=170.18 °C which was mainly attributed by the polysaccharide composition of corn silk (Osorio et al., 2011).

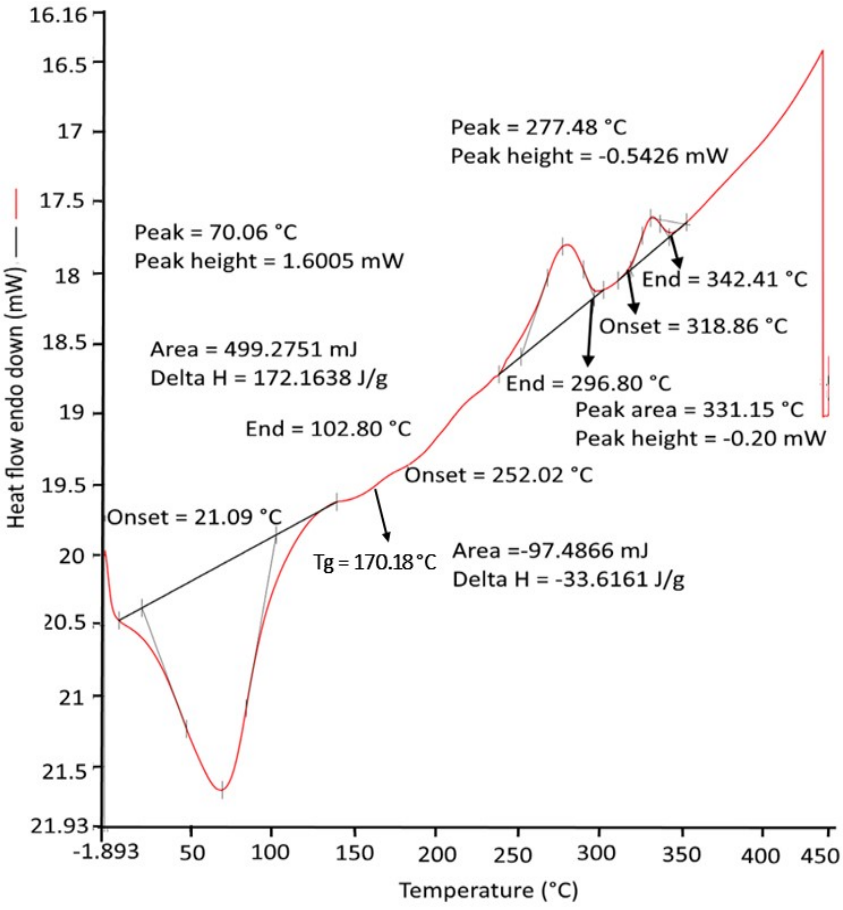


Figure 6.13. DSC thermograph of corn silk powder

FTIR analysis of corn silk powder

Figure 6.14 depicts the vibrational and rotational modes of functional groups present in corn silk powder. N-H stretching vibrations caused the specific intense peaks at 3277.17 cm^{-1}. The C-H stretching vibration absorption was 2920.32 cm^{-1}, indicating that the polysaccharides chains interacted intra- and intermolecularly (Hu et al., 2011). The presence of N-H was suggested by a stretching peak at 1637.62 cm^{-1}, which indicates the presence of protein in corn silk powder (Cardenia et al., 2013). Asymmetrical carbonyl stretching was responsible for the absorption at 1246.06 cm^{-1} Peaks at 1028.09 cm^{-1} suggested that the sugar was in the pyranose form (Sanahuja et al., 2013).

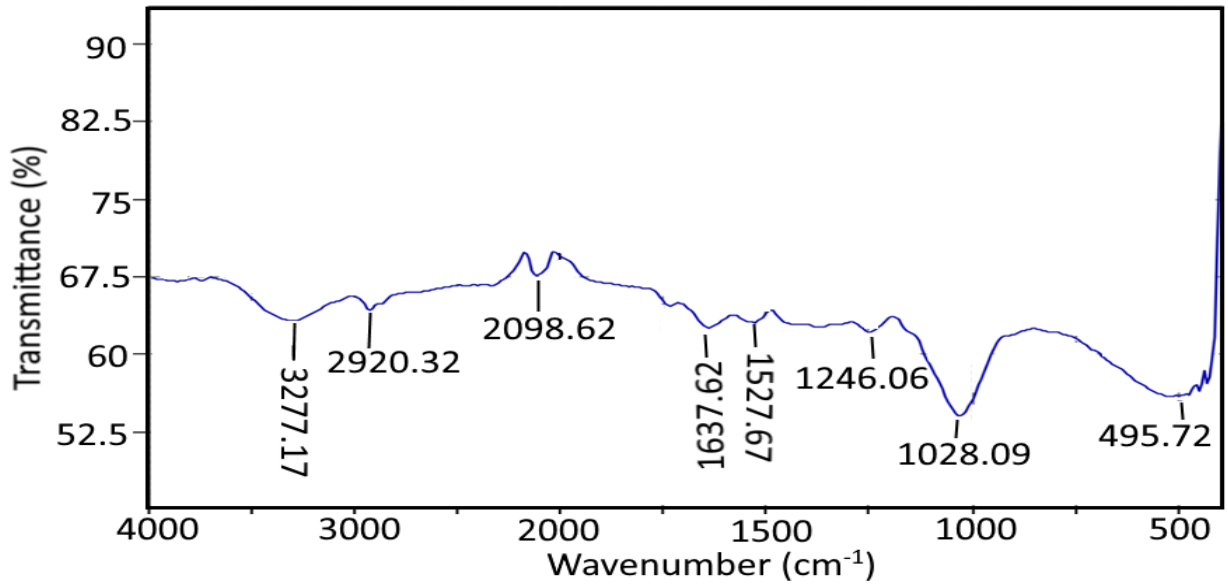


Figure 6.14. FTIR spectra of corn silk powder

X-ray diffraction

The crystallinity index refers to a material's ordered structure. In biomass, cellulose is the only crystalline component, while hemicellulose and lignin are amorphous components. The crystalline or amorphous form of dry powders is determined using XRD. A crystalline substance usually has multiple distinct peaks in a highly ordered condition, whereas amorphous products molecules have disordered and scattered bands (Mao et al., 2006). The peaks are not well resolved, as seen in the XRD diffraction spectra of corn silk powder samples (Figure 6.15), and just one peak at $2\theta=21.5°$ is visible which reflects the amorphous nature of the corn silk powder.

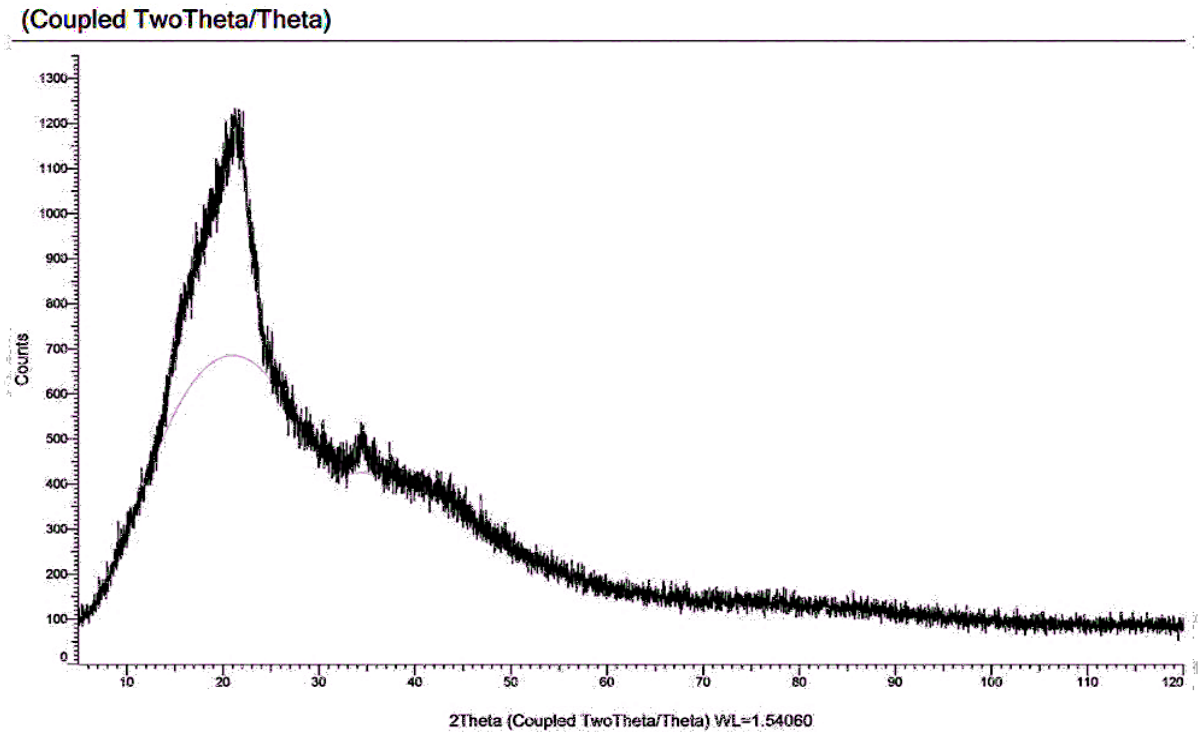


Figure 6.15 XRD pattern of corn silk powder

The G5417 has comparable nutritive value as reported in other corn silk varieties by other researchers. The results were in agreement with the study of the incorporation of corn silk powder in low-fat meatballs. Their findings show the 9.06 g/100 g of moisture, 0.91 g/100 g of fat, 4.60 g/100 g of ash, 16.11 g/100 g of crude fiber, 17.94 g/100 g of protein, and 51.37 g/100 g of carbohydrate. Microelements like Zn, Mn, and Fe, as well as macro-elements like Ca and K, play critical roles in animal and human physiological functioning. The results were in agreement with the results given by Rahman and Rosli [40] where they reported the nutritional composition of mature and immature corn silk. The similar trend was observed by Rosli et al. (2014) they reported the highest concentration of macrominerals including Na (0.561±0.001 mg/kg), Ca (1.123±0.001 mg/kg), K (0.690±0.001 mg/kg), Mg (0.209±0.001 mg/kg) of blanched corn silk drink. The high amount of K and Ca helps in maintain the blood pressure, bone health, regulating serum levels of harmful lipids and obesity (Pashazadeh et al., 2020).

Typically, a greater water activity value indicates a larger concentration of free moisture, and thus, shelf-life may be decreased due to biochemical reactions. Although water activity is largely dependent on moisture content, the varietal difference may play a significant role in it based on moisture-binding components such as carbohydrates and fiber

content. Similar findings for water activity were reported by Castillo et al. (2020), in their study of the incorporation of dried corn silk powder in beef patties where they reported water activity of corn silk powder was 0.288. The result depicted that corn silk powder is a good contender to develop highly stable value-added products.

The drying method may reduce the polyphenolic content as it is easily oxidized and sensitive to heat treatments (Sarepoua et al., 2013). However, such treatments are required for the preservation of plant produce. Similar results were shown by Haslina et al., (2017) in their study of the phytochemical composition of three local varieties of corn silk. The total phenolic content of corn silk fresh was reported to be 93.46 µg GAE to 82.62 µg GAE in powdered corn silk. The difference in the ascorbic acid values could be most probably due to varietal differences. According to Sanahuja et al., (2013) the ascorbic acid concentration was higher after 20 days of pollination and reduced considerably ($p<0.01$) after 40 days of pollination in different maize genotypes. They claim that as the plant develops, the expression of genes required for ascorbic acid production decreases. Phenolic molecules have received a great deal of attention as the primary source of antioxidant action. The findings revealed that corn silk variety G5417 had total phenolic and total flavonoid content had strong antioxidant activity. Corn silk's antioxidant action has previously been attributed to its phenolic and flavonoid levels (Chawla et al., 2020). Our findings corroborated prior findings, indicating that phenolic and flavonoid content are good indices for determining a corn silk's antioxidant activity. Similar result were reported by Nurhanan et al., (2014) for the TPC and DPPH activity i.e. 57.7±0.75 mg GAE/g and 77.47±5.13 %, respectively. When DPPH comes into contact with a chemical that donates hydrogen atoms, such as an antioxidant, the radical is scavenged. The absorbance is lowered and the color is changed from purple to yellow (Dong et al., 2014). The overall amount of phenol in plant tissue is connected to the activities of DPPH free-radical scavengers (Limmatvapirat et al., 2013). The more hydroxyl groups in an extract, the higher the concentration of phenols and flavonoids. The molecule's capacity will be increased by the presence of hydroxyl groups (Guo et al., 2018).

For ABTS activity, similar results were reported by Dong et al., (2014) that corn silk ethanolic extract had the highest ABTS activity i.e., 244.1±10.2 µmol TE *per* 100 g dw. The FRAP activity stated by Limmatvapirat et al., (2020) for ethanolic extract was 58.16 µg/ml. Maksimovic et al., (2005) also reported the high FRAP activity in 10 genotypes of corn silk in the range from 79.8±0.5 to 158.4±4.4 AAE/mg. The occurrence of glass transition

temperature in corn silk powder was observed due to the occurrence of heat change with increasing temperature. The exothermic peak with the T_{onset}= 21.09 °C and T_{endset}=102.80 °C showed moisture loss and the endothermic peak with a glass transition temperature (T_g)= 277.48 °C reported in the current results were higher than capsules of corn silk dried by freeze-drying (148.25 °C), spray drying (143.40 °C) and microwave drying (171.09 °C) method as depicted by Pashazadeh et al. (2020) which shows high thermal stability in corn silk powder obtained for variety G5417.

Vibrational characteristics of sugar C-O stretch bonds were found in between the region of 1200 and 900 cm^{-1} while polysaccharide C-O bonds were found to have sovereignty between 1150 and 1000 cm^{-1}. Our results were well supported by the study conducted by Guo et al. (2018) for three polysaccharides from corn silk. Therefore, irrespective of a varietal difference the basic composition of corn silk more or less is unchanged. For the XRD analysis, our results were in agreement with Ali et al. (2021). where they reported the cellulose from corn silk showed an amorphous nature at 2θ = 22.5° due to the presence of hemicellulose. The corn husk also showed the diffraction peak at 2θ = 22.6° as reported by Mendes et al. (2015). Most of the powders prepared using simpler processes with a low level of refinement show amorphous nature. Senphan et al. (2019) stated the similar value of L*= 35.11±2.16, a*=5.60±0.28, and b*=16.89±1.16 for color parameters. Variations in chemical composition are determined by a variety of factors, including variances in cultivars, the climate in which it grows, soil quality, plant care, and treatment method (2009).

SEM of corn silk powder

The SEM images of corn silk powder are shown in figure 6.16 and the images showed the rectangular shape of individual particles exhibiting complex microporous structure on the intersection. These structures are prominently seen for plants cellulose based material. At the different magnification (200X, 500X and 2000X) the rectangular and porous structure of corn silk was revealed which could be beneficial to the binding of polysaccharides and flavonoids. The similar results were reported by Ali et al., (2021) in their study of extraction of cellulose and zein from corn silk. Guo et al., (2018) also reported the similar kind of results in their study on binding property of polysaccharides from corn silk.

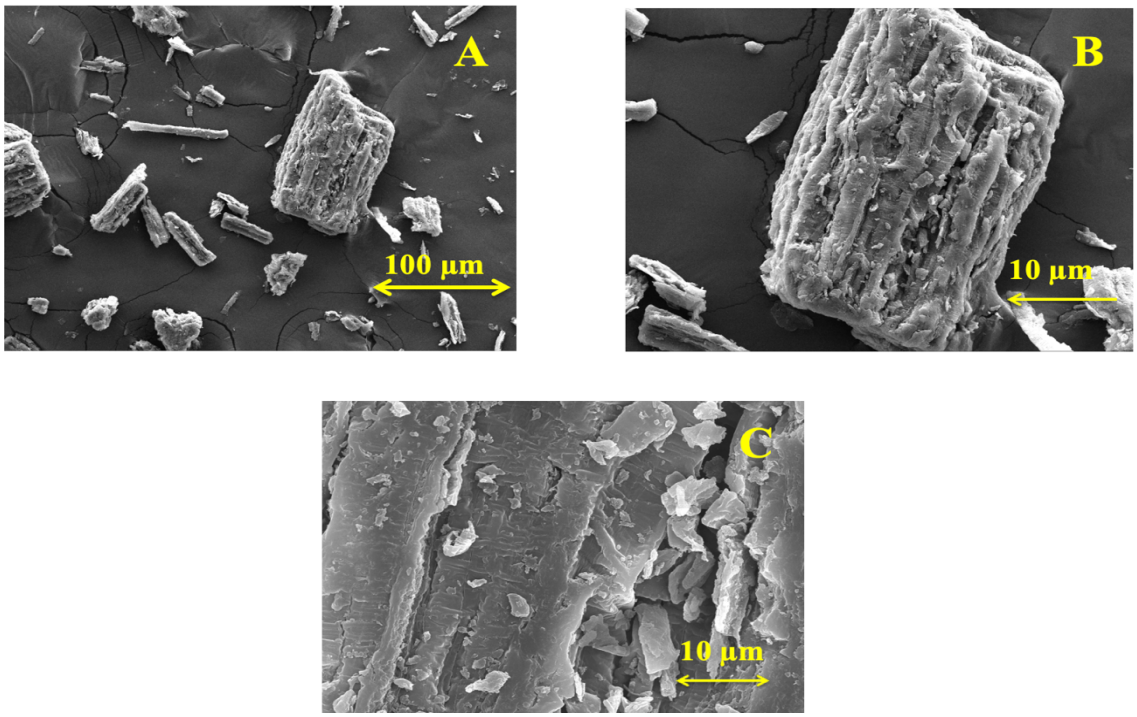


Figure 6.16: Studied corn silk SEM images: A- magnification 200X, scale bar 100 µm, B- 500X, scale bar 10 µm particle size, C- 2000X, scale bar 10 µm

6.14 Cytotoxicity of corn silk powder

The cytotoxicity of corn silk powder was assessed, and the findings of the MTT experiment for cell viability are shown in Figure 6.17. Corn silk powder were found to be non-toxic to Caco-2 cells in this study. Corn silk powder at a higher dosage (400 mg/mL) resulted in 90.18 percent cell viability. Similar reports were given by Al-Oqail et al., (2019), where they reported MCF-7 breast cancer cell viability was significantly reduced in a dose-dependent manner when exposed to 100 g/ml or greater doses of corn silk extract (CSE) for 24 hours, whereas TERT4 cell viability was not affected. The NRU assay indicated a concentration-dependent cytotoxicity in MCF-7, similar to the MTT assay. By NRU assay exposed for 24 hours, CSE concentrations of 100 g/ml or more were found to diminish the viability of MCF-7 cells, however CSE concentrations of 100 g/ml or higher did not reduce the vitality of TERT4 cells. MTT found 75 percent, 65 percent, and 38 percent viability of MCF-7 cells at 250, 500, and 1000 g/ml CSE, and 76 percent, 68 percent, and 42 percent by NRU assay respectively. MCF-7 cells became rounder and decreased in size after being exposed to CSE at 500 and 1000 g/ml. Li et al., (2020) studied cytotoxicity of silver nanoparticles (AgNPs) by aqueous extract of corn silk and they reported that might be due to a synergy between AgNPs and the corn silk extract that covers them. Several studies have shown that biologically active chemicals like flavonoid and phenolic were harmless for

healthy cells yet cytotoxic for malignant cells (Dai amd Mumper, 2010; Madunić et al., 2018). As previously stated, corn silk is high in polyphenols and flavonoids, which is what gives the extract its anticancer properties.

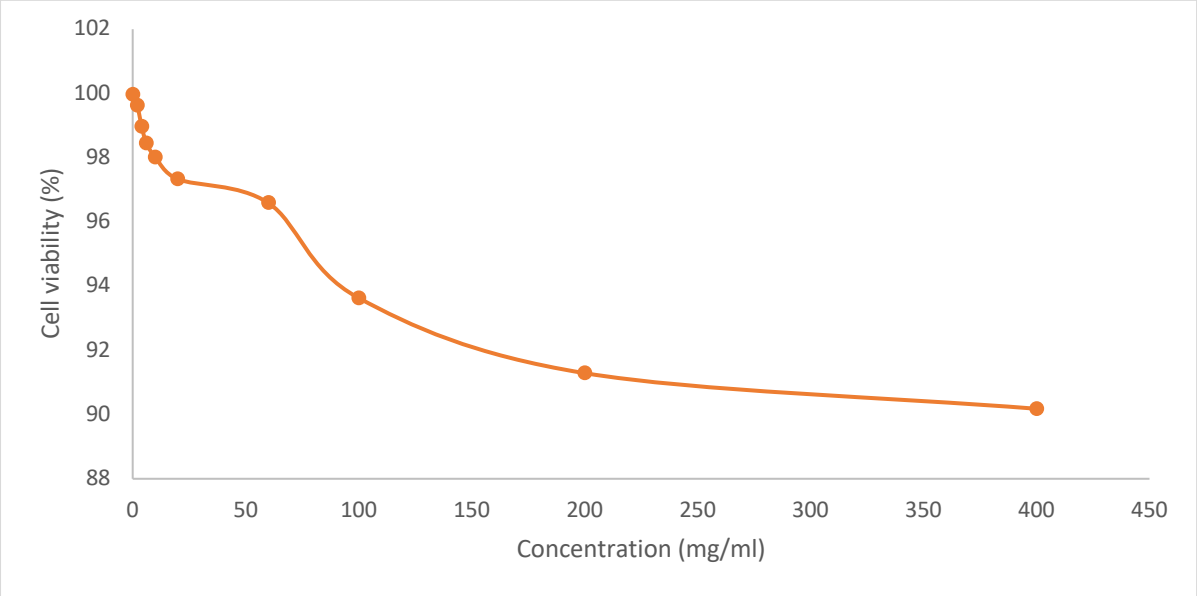


Figure 6.17: MTT analysis of corn silk powder

6.15 Antimicrobial analysis

The antibacterial activity of corn silk powder was tested against *Staphylococcus aureus* (gram positive) and *Escherichia coli* (gram negative) variety of pathogenic bacteria, and the diameter of inhibition zones (mm) around each well is shown in the figure 6.19. Corn silk powder showed reduced zone of inhibition for all bacteria ($p<0.05$). The decreased particle size could explain the significantly ($p<0.05$) greater zone of inhibition. In addition, *Staphylococcus aureus* (18.33 mm) had the highest zone of inhibition followed by *Escherichia coli* (16.66mm). In addition, the positive control had a considerably ($p<0.05$) greater zone of inhibition 22.66 mm for *Staphylococcus aureus* and 20.33 mm for *Escherichia coli*. Corn silk MIC and MBC values are shown in the graph (Fig 6.20). Corn silk had 12.5 mg/ml and 12.5 mg/ml MBC values for *Staphylococcus aureus* and *Escherichia coli* respectively. Furthermore, corn silk had MIC values of 6.25 and 25 mg/ml for Staphylococcus aureus and Escherichia coli respectively. Similar results were reported by Morshed et al., (2015) where they mentioned the 11.45±0.84 mm of inhibition zone in ethanolic extract of corn silk (10 mg/ml) for *Staphylococcus aureus*. Feng et al. (2012) also stated that diameter of inhibition zones varied from 17-28 mm for ethanolic extract of corn silk and for *staphylococcus aureus* 19 mm of inhibition zone was reported. The MIC values of ethanolic extract of corn silk against *S. aureus* were 500 mg/ml. Our results showed that

the larger the inhibition zone, lower is the minimum inhibitory concentration. The ethanolic extract of corn silk was discovered to include fatty acids and flavone, with the latter being the major component. The flavone is reported to have antimicrobial properties (Huang, 2008; Wang et al., 2005). In addition to being selective against Gram-positive organisms by targeting the structure and function of bacterial cell walls and membranes, fatty acids exhibit antibacterial and antifungal activities. These elements could be contributing contributors to the impact seen in the corn silk crude extract.

Figure 6.18: Inhibition zone of A: *Staphylococcus aureus* Figure B: *Escherichia coli*

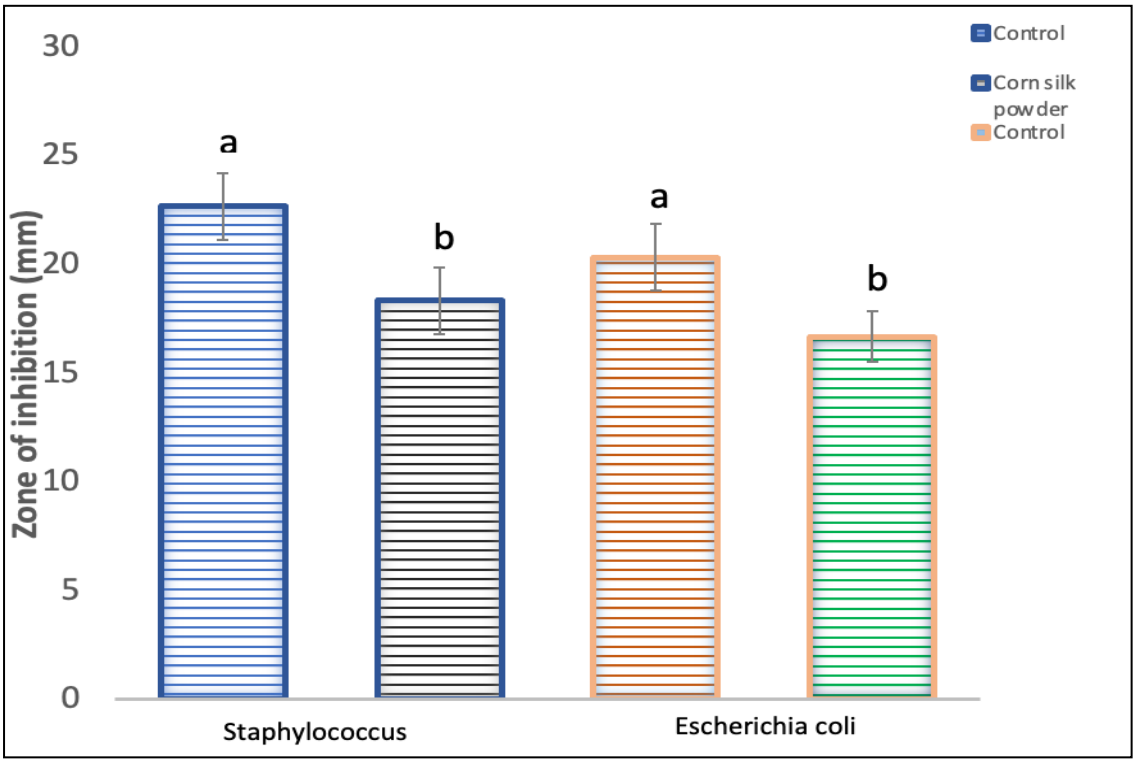


Figure 6.19: Zone of inhibition of ethanolic extract of corn silk

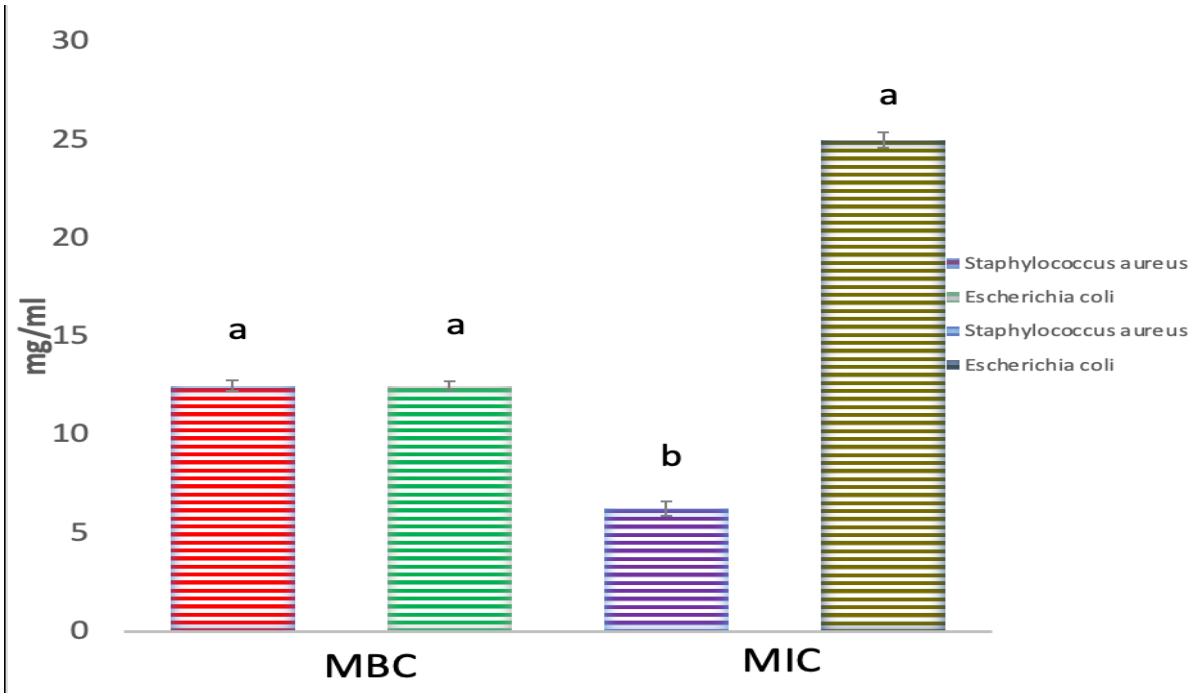


Figure 6.20: Minimum bactericidal concentrations (MBC) and Minimum Inhibitory Concentration (MIC) values of corn silk powder

6.16 Quantitative analysis of phenolic compounds by UPLC technique

UPLC analysis of ethanolic extract was carried out for the quantification of phenolic and flavonoid compounds. UPLC chromatogram of polyphenolic compounds and flavonoids are mentioned in figure 6.21 and 6.22, the data revealed that rutin and quercetin are present in the form of flavonoids and p-coumaric acid and salicyclic acid were present in the form of polyphenols corn silk and respectively. The presence of 233.2±39.2 ng/g of quercetin in corn silk was reported by Gavriil et al., 2021 in their study of antimicrobial activities of plant aqueous extracts and their application to improve safety of pork meat.

To summarise, the method for identifying and quantifying polyphenols in corn silk hairs is accurate and practicable, and UPLC is a very useful approach for extracting the most polyphenols. Our findings support scientific evidence that corn silk hairs have high biological potential due to their high polyphenol content and abundance of p-coumaric acid and salicyclic acid making this plant material highly valuable for use as a natural source of polyphenols and potentially contributing to the development of nutraceutical products. Yang et al., (2018) also reported the presence of p-coumaric acid (11.03±0.02) in immature corn silk and Quercitin (142.4±2.9) in mature corn silk. Mature corn silk (354.3±2.1 mg GAE/100 g FW, 264.2±0.9 mg CE/100 g outperformed immatured corn silk (162.3 ±1.0 mg GAE/100 g FW, 91.50± 0.32 mg CE/100 g FW) in terms of total phenolic and flavonoid content.

According to the research (Alam, 2011), phytochemical dispersion is tightly linked to the colour variation (green or brown) caused by air and sunlight. The phenolic compounds in the correct positions could protect DNA from UV radiation damage. As a result, brown corn silks (MCS) were more likely to be imposed in the presence of air and sunlight, necessitating the use of additional phytochemicals for protection.

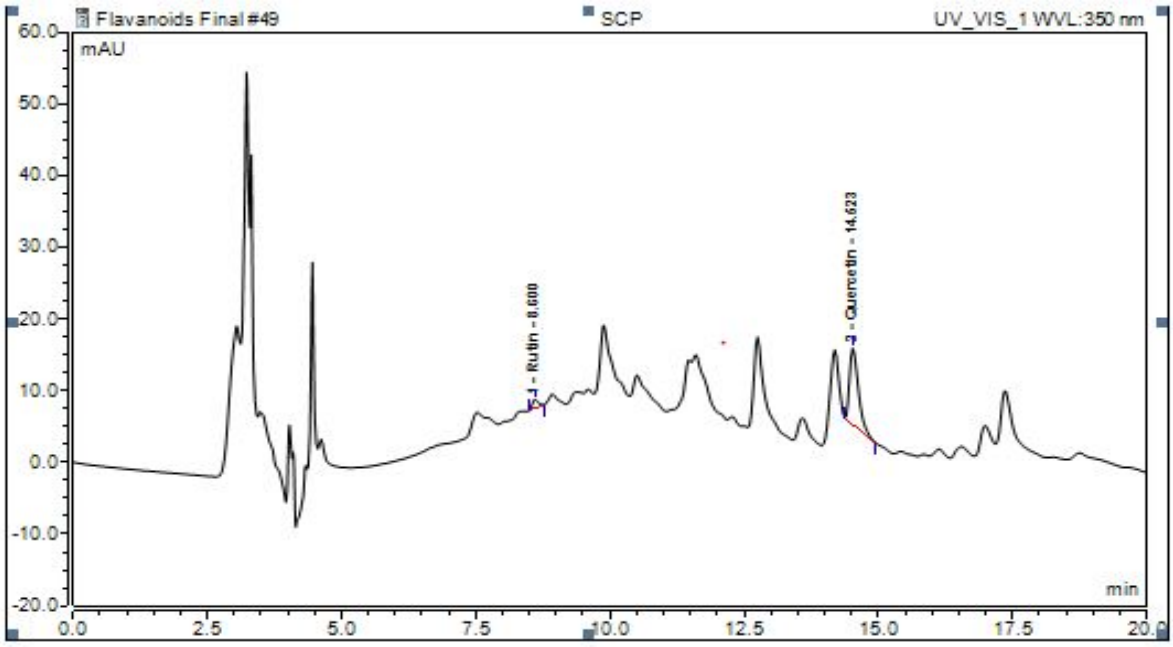


Figure 6.21: UPLC chromatogram of flavonoid content in corn silk powder

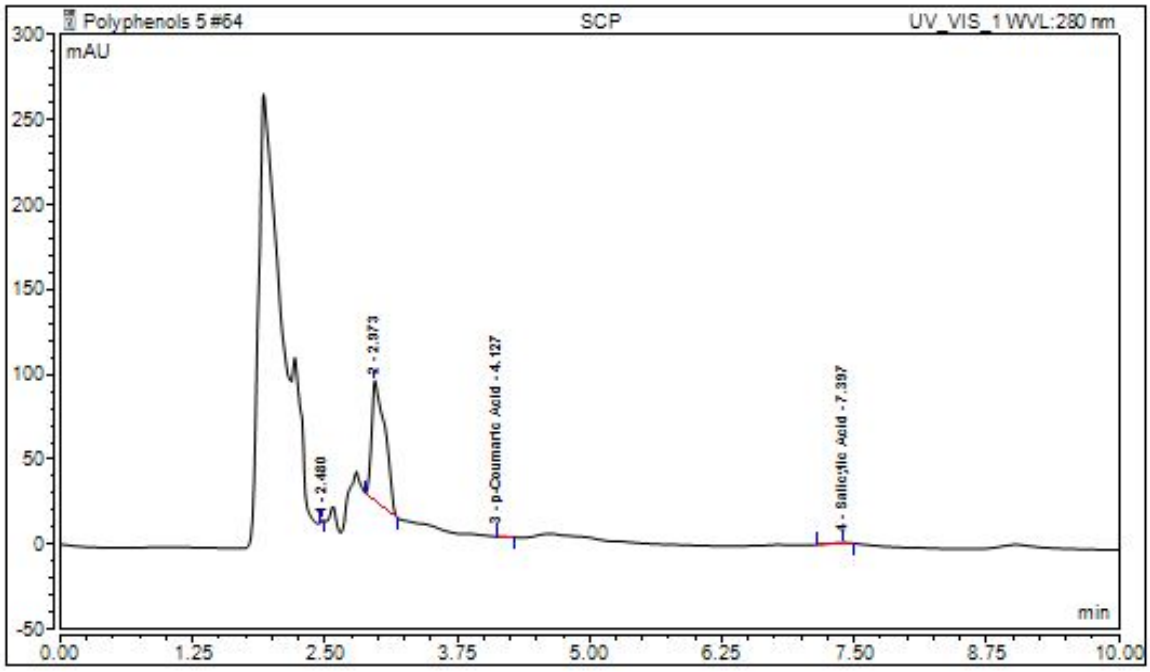


Figure 6.22: UPLC chromatogram of polyphenols content in corn silk powder

6.17 Amino acid profiling

The study revealed the presence of 16 amino acids (AA) out of 20 in corn silk powder as shown in Table 6.18. Glutamic acid was present in the highest amount followed by glycine and leucine. The results were similar with the findings of Kim et al. (2000) in their study of physicochemical characteristics of corn silk. They reported the presence of serine, glycine and thereoine by more than 10% in the corn silk of different corn varieties namely waxy, silage, sweet and sweet corn. Their results were similar to our findings as they also reported that the lesser amount of sulfur containing amino acids like methionine and cysteine in all the varieties of corn silk.

Table 6.17: Amino acid profiling of corn silk powder

Name	Symbol	Name of AA	Result (g/100g)
Histidine	H	HIS	0.377
Serine	S	SER	0.951
Arginine	R	ARG	0.927
Glycine	G	GLY	1.005
Aspartic acid	D	ASP	0.980
Glutamic acid	E	GLU	1.285
Threonine	T	THR	0.987
Alanine	A	ALA	0.853
Proline	P	PRO	0.751
Lysine	K	LYS	0.704
Tyrosine	Y	TYR	0.611
Methionine	M	MET	0.086
Valine	V	VAL	0.583
Isoleucine	I	ILE	0.469
Leucine	L	LEU	0.994
Phenylalanine	F	PHE	0.688
Total			12.250

6.18 Optimization of corn silk based instant mix

A box-behnken design was employed to select optimum levels of variables through 17 experiments (Table 6.19). Corn silk powder along with sugar as sweetener, xanthan gum as stabilizer and skimmed milk powder (SMP) as filler was used to prepare the different treatments of instant mix as shown in Figure 6.23. The sensory scores of powdered instant mix along with physicochemical and antioxidant properties (Table 6.20) were analysed in response to the variables. The sensory properties shows that corn silk based instant mix showed the significant effect on color and appearance as the per cent of corn silk was increasing in the composition of instant mix.

Table 6.19: Sensory attributes of the corn silk based instant mix

Run	Corn silk Powder (%)	Sugar (%)	Xanthan gum (%)	Skimmed milk powder (SMP: %)	Colour and appearance	Body and and texture	Flavour and aroma	Mouthfeel	Overall acceptability
1	5.00	5.00	0.20	89.8	8.8	8.4	6.5	8.4	8.4
2	15.00	5.00	0.20	79.8	8.2	8.1	6.3	8	7.4
3	5.00	10.00	0.20	84.8	8.6	8.2	8	8.1	8.2
4	15.00	10.00	0.20	74.8	7.5	8.7	8.8	8.7	8.8
5	5.00	7.50	0.10	87.4	8.7	7.2	7.5	7.9	7.4
6	15.00	7.50	0.10	77.4	7.7	7.3	7.2	7.6	7.4
7	5.00	7.50	0.30	87.2	8.7	7.2	7.5	7.4	7.8
8	15.00	7.50	0.30	77.2	7.7	7.1	7.8	7.5	7.4
9	10.00	5.00	0.10	84.9	8.5	7.2	6.2	7.4	7.2
10	10.00	10.00	0.10	79.9	7.8	7.6	7.8	7.6	7.8
11	10.00	5.00	0.30	84.7	8.5	7	6.4	7.4	7.8
12	10.00	10.00	0.30	79.7	7.9	6.8	8.4	7	7.9
13	10.00	7.50	0.20	82.3	8.2	8.4	7.4	8.2	8.2
14	10.00	7.50	0.20	82.3	8.3	8.2	7.6	8.3	8.2
15	10.00	7.50	0.20	82.3	8.3	8.4	7.4	8.1	8
16	10.00	7.50	0.20	82.3	8.2	8.3	7.3	8.2	8.4
17	10.00	7.50	0.20	82.3	8.4	8.6	7.8	8.7	8.5

The body and texture, flavor and aroma and mouthfeel of instant mix incorporated with highest amount of corn silk powder (15%) has gained the highest score. The overall acceptability was found to be higher for the sample incorporated with 15% of corn silk.

Figure 6.25 : Different formulation of instant mixes stored in different packaging material

LDPE- Low density polyethylene, HDPE- High density polyethylene, MP- Metallized polyester

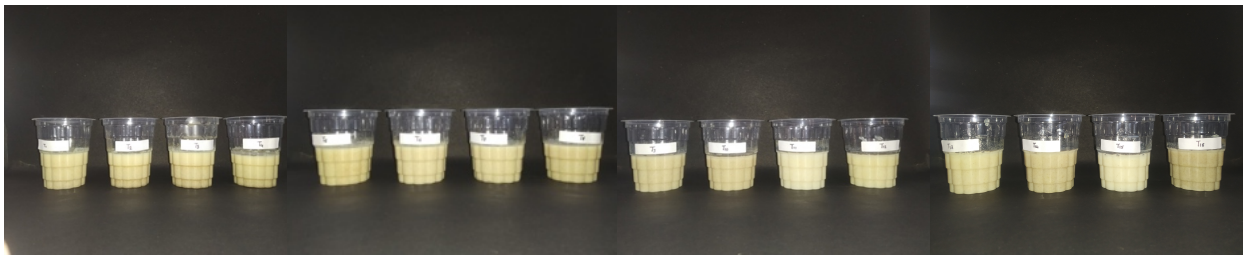


Figure 6.26: Corn silk based instant mix pa ked in different packaging material

Physicochemical properties of corn silk based instant mix

The response values for the experimental design for the physico-chemical properties are shown in Table. It is evident from the Table, shows bulk and tapped densities of the instant mix. Increase in corn silk powder amount in instant mix increases the bulk density and tapped density reduction. The bulk density for 5% corn silk was found to be in the range of 0.333, 0.474, 0.349 and 0.495 g/cm^3, for 10% corn silk the range was 0.348, 0.421, 0.437, 0.601, 0.537, 0.546, 0.598, 0.542 and 0.529 g/cm^3, for 15% corn silk, the values were in the range of 0.516, 0.431 and 0.473 g/cm^3. The similar trend was observed for tapped density also that as increase in corn silk powder incorporation, the tapped density increased. Our results were in agreement with Wadibhasme et al. (2020), in which they also reported the incorporation of amla powder increases the bulk and tapped density of instant drink mix.

The water absorption capacity of corn silk based instant mix increased when the corn silk powder addition increased and the values increased from 0.91 to 1.91 g/g in 5 and 10% corn silk incorporated instant mix. The increase in water absorption capacity could be attributed to the high protein content of corn silk and also the presence of polysaccharides in high amount which increases the sites of interaction and further the water absorption capacity. Sneha et al. (2018) reported the increase in water absorption capacity in germinated amaranth flour based instant dosa mix when compared to untreated and roasted instant dosa mix.

Swelling capacity of corn silk based instant mix increased as the corn silk powder addition increased. The 5% formulation showed the swelling capacity of 12.52 ml/g to 14.55 ml/g which increased in 15% formulation by the range of 13.22 to 15.21 ml/g. The increase in swelling capacity is due to high exposure of the internal structure of starch present in corn silk. The swelling power of native starch and flour may be influenced by the development of a protein-amylose complex. The results were in accordance with Ansari et al. (2020) in their study of *moringa oleifera* flower powder based instant soup mix. They also showed the increase in the swelling capacity as the incorporation of *moringa oleifera* flower powder increased.

The viscosity of corn silk based instant mix increased from 5-15 % incorporation by the range of 6785.43 to 7354.28 cPs respectively. The results were similar to the findings of Kamble et al., (2019) who reported the increase in the viscosity of moringa pod soup supplemented with ashwagandha root powder. The high amount of zinc present in corn silk powder (83.75±1.80 μg/g) might be a reason of increase in increase in viscosity as zinc has a crosslinking impact on starch chains at low doses. Zinc cation is bivalent, meaning it has two extra protons. As a result, it can pull two oxygen atoms from free electron pairs in different starch chains (Kristanti and Herminaiti, 2019).

Total polyphenolic content also increased in the formulations from lower to higher incorporation and the highest value was observed in 15% incorporation (142.16 mg/GAE g). The high concentration of total polyphenolic content of corn silk is the reason of TPC increase in the instant mix treatments. The similar results were reported by Kumar et al. (2021) in the formulation of instant banana milk powder and the values were increased by 7.73 mg/100 g to 9.13 mg/100 g as per increase in banana powder.

Table 6.20: Physico-chemical and antioxidant content of corn silk based instant mix

Run	Corn silk Powder (%)	Sugar (%)	Xanthan gum (%)	Skimmed milk powder (SMP:%)	Moisture (%)	Bulk Density (g/cm^3)	Tapped Density (g/cm^3)	Water absorption capacity (g/g)	Swelling capacity (ml/g)	Titrable acidity	Viscosity (cPs)	TPC (mg GAE/g)
1	5.00	5.00	0.20	89.8	10.6	0.333	0.51	0.91	12.52	1.12	6785.43	34.26
2	15.00	5.00	0.20	79.8	7.4	0.428	0.42	1.02	13.22	1.64	6454.75	127.32
3	5.00	10.00	0.20	84.8	11	0.474	0.56	1.34	14.55	1.15	6542.48	44.56
4	15.00	10.00	0.20	74.8	7.1	0.516	0.75	1.74	14.86	1.63	6432.15	140.21
5	5.00	7.50	0.10	87.4	11.3	0.349	0.56	1.37	13.64	1.21	5661.62	54.97
6	15.00	7.50	0.10	77.4	7.5	0.431	0.61	1.64	14.37	1.66	5428.48	142.16
7	5.00	7.50	0.30	87.2	12	0.495	0.74	1.67	14.23	1.16	7842.76	49.21
8	15.00	7.50	0.30	77.2	7.8	0.473	0.72	1.63	15.21	1.62	7354.28	139.48
9	10.00	5.00	0.10	84.9	8.8	0.348	0.51	1.21	13.42	1.37	5357.26	124.62
10	10.00	10.00	0.10	79.9	7.6	0.421	0.62	1.72	14.29	1.45	5621.18	134.84
11	10.00	5.00	0.30	84.7	8	0.437	0.59	1.33	13.27	1.35	7642.42	126.54
12	10.00	10.00	0.30	79.7	9.4	0.601	0.8	1.91	16.74	1.44	7642.62	137.56
13	10.00	7.50	0.20	82.3	7.6	0.537	0.65	1.62	15.47	1.4	6975.47	127.49
14	10.00	7.50	0.20	82.3	7.5	0.546	0.68	1.43	15.11	1.39	6758.24	129.47
15	10.00	7.50	0.20	82.3	7.4	0.598	0.64	1.47	14.93	1.34	6752.24	134.21
16	10.00	7.50	0.20	82.3	7.4	0.542	0.62	1.34	15.11	1.35	6845.79	129.56
17	10.00	7.50	0.20	82.3	7.6	0.529	0.61	1.39	16.01	1.34	6623.59	127.69

6.19 OPTIMIZATION OF CORN SILK BASED READY TO SERVE BEVERAGE

A box-behnken design was employed to select optimum levels of variables through 17 experiments (Table 6.21). Aqueous extract of corn silk along with kinnow juice, sugar as sweetener, xanthan gum as stabilizer and water as filler was used to prepare the different treatments of ready to serve beverage as shown in Figure 6.24. The sensory scores of beverage along with physical properties (Table) were analysed in response to the variables.

The response values for the experimental design for the physical properties of ready to serve beverage are shown in Table. It is evident from the Table, shows 40% of corn silk extract addition showed 8.8 score for colour and appearance, 8.6 score for body and texture, 8.4 score for flavour, 8.5 score for mouthfeel and 8.7 overall acceptability score. The highest concentration of corn silk showed the maximum overall acceptability score. The pH of the ready to serve beverage was found to be higher as the corn silk extract concentration was increasing and the value ranged from 4.31 to 4.42. The total soluble solids were also high in the samples with maximum concentration of corn silk extract and titrable acidity also increased. The similar results were reported by Sharma et al. (2019) in the study of apple-whey based herbal functional ready to serve beverage.

Effect of variables on physico-chemical parameters of corn silk instant premix

It is evident from the Table 6.23 that corn silk has a significant role in defining the parameters such as moisture content, acidity, total phenolic content, bulk density, water absorption index, swelling capacity and viscosity of the corn silk based instant premix. The linear effect is shown in the Figure 6.25. Therefore it is the principal component of the product. Corn silk has a significant ($p<0.05$) positive effect on acidity, total phenolic content, bulk density, water absorption index and the swelling capacity of the product. It can be observed that corn silk has a significant ($p<0.05$) negative effect on the moisture content and the viscosity of the product. Further it could also be observed that corn silk along with sugar has a significant negative interactive effect on moisture content of the product (Fig. 6.26), whereas the interactive effect on tapped density (Fig. 6.27) was positively significant ($p<0.05$). Sugar on the other hand has a significant ($p<0.05$) positive effect on the bulk density, tapped density, water absorption index and swelling capacity.

Table 6.21: Sensory attributes of corn silk based ready to serve beverage

Experiment No.	Corn silk extract (ml)	Xanthan gum (g)	Kinnow juice (ml)	Sugar (g)	Water (ml)	Colour and appearance	Body and texture	Flavour	Mouthfeel	Overall acceptability
1	40	0.4	32.5	5	27.1	8	7	7.6	7.2	7
2	35	0.4	25	5	39.6	8.2	7.5	7.8	7	7.2
3	35	0.4	40	5	24.6	8.1	8	7.9	7.2	7.2
4	40	0.25	40	5	19.75	8.3	7.9	8.5	7.8	7.4
5	35	0.25	32.5	5	32.25	7.5	8	7.2	8	7.8
6	35	0.25	32.5	5	32.25	7.8	8.2	7.4	8.2	8.4
7	30	0.4	32.5	5	37.1	8.5	8.2	8.4	8.6	8.5
8	40	0.1	32.5	5	27.4	8.8	8.6	8.4	8.5	8.7
9	35	0.25	32.5	5	32.25	7.2	7.6	7	7.2	7.5
10	35	0.25	32.5	5	32.25	7.7	7.8	7.2	7.6	7.4
11	35	0.25	32.5	5	32.25	8.3	7.4	8	7.6	8.1
12	35	0.1	40	5	24.9	8.4	8.2	8.6	8.4	8.4
13	30	0.25	40	5	29.75	8.3	8.4	8.4	8.6	8.5
14	40	0.25	25	5	34.75	8.1	8.1	8	8.5	8.2
15	30	0.1	32.5	5	37.4	7.9	8.4	8.2	8.4	8.1
16	35	0.1	25	5	39.9	7.6	8.3	7.9	8.2	7.9
17	30	0.25	25	5	44.75	8.2	8.5	8.4	8.4	8.3

Table 6.22: Physico-chemical properties of corn silk based ready to serve beverage

Experiment No.	Corn silk extract (ml)	Xanthan gum (g)	Kinnow juice (ml)	Sugar (g)	Water (ml)	pH	Total soluble solids (° Brix)	Acidity (%)
1	30	0.1	32.5	5	27.1	4.15	12.5	0.22
2	40	0.1	32.5	5	39.6	4.38	13.7	0.25
3	30	0.4	32.5	5	24.6	4.41	14.8	0.34
4	40	0.4	32.5	5	19.75	4.35	15.3	0.36
5	30	0.25	25	5	32.25	4.12	11.6	0.27
6	40	0.25	25	5	32.25	4.31	12.7	0.31
7	30	0.25	40	5	37.1	4.38	13.9	0.34
8	40	0.25	40	5	27.4	4.42	13.7	0.37
9	35	0.1	25	5	32.25	4.08	11.3	0.2
10	35	0.4	25	5	32.25	4.18	13.5	0.32
11	35	0.1	40	5	32.25	4.23	14.3	0.28
12	35	0.4	40	5	24.9	4.36	15.4	0.33
13	35	0.25	32.5	5	29.75	4.28	12.8	0.31
14	35	0.25	32.5	5	34.75	4.31	13.1	0.29
15	35	0.25	32.5	5	37.4	4.17	11.9	0.25
16	35	0.25	32.5	5	39.9	4.22	14.4	0.34
17	35	0.25	32.5	5	44.75	4.25	13.6	0.3

The linear effect could be observed in the Figure 6.25. However, the interaction of corn silk with xanthan gum has no significant effect on any parameter of the product. Whereas, xanthan gum has a significant ($p<0.05$) positive role in affecting the parameters including moisture, bulk density, tapped density, water absorption index, swelling capacity and viscosity of the product. Along with sugar, xanthan gum has a positive interactive effect on the moisture content (Fig. 6.28) and the swelling capacity of the product (Fig. 6.29).

Effect of variables on the sensory properties of the instant mix

The Table 6.24 shows that corn silk on its own negatively affected the color and appearance of the premix, however, has no significant ($p<0.05$) effect on either body and texture, flavor and sweetness, mouthfeel and overall acceptability of the product. The linear effect is shown in the Figure 6.30. Although, sugar had profound effect as compared to corn silk on negatively affecting the color and appearance, a significant positive effect on flavor and sweetness and overall acceptability of the premix was observed. Xanthan gum on the other hand had a significant negative effect on the body and texture of the product however the magnitude of the effect seems to be lower than the interactive positive effect of corn silk and sugar (Fig. 6.31). Similarly corn silk and sugar together significantly affected the other sensory attributes such as color and appearance, flavor and sweetness, mouthfeel and overall acceptability of the premix (Fig 6.32). It could therefore, be stated that corn silk and sugar are principle components affecting the sensory characteristics of the corn silk based instant premix.

Optimum levels of variables for corn silk based instant mix

As observed in the Figure 6.33, the optimum level of variables for the most desirable optimum product includes 14.66% corn silk, 10% sugar and 0.22% xanthan gum in a base of skimmed milk powder (made up to 100%). The desirability observed for the said formulation was observed to be high to the rate of 0.925. The observed predicted responses along with the observed values are shown in the Table 6.25. It evident from the Table, that the observed and predicted value holds no significant difference, with an exception of sensory acceptability.

Table 6.23: Coefficient of regression of physico-chemical parameters

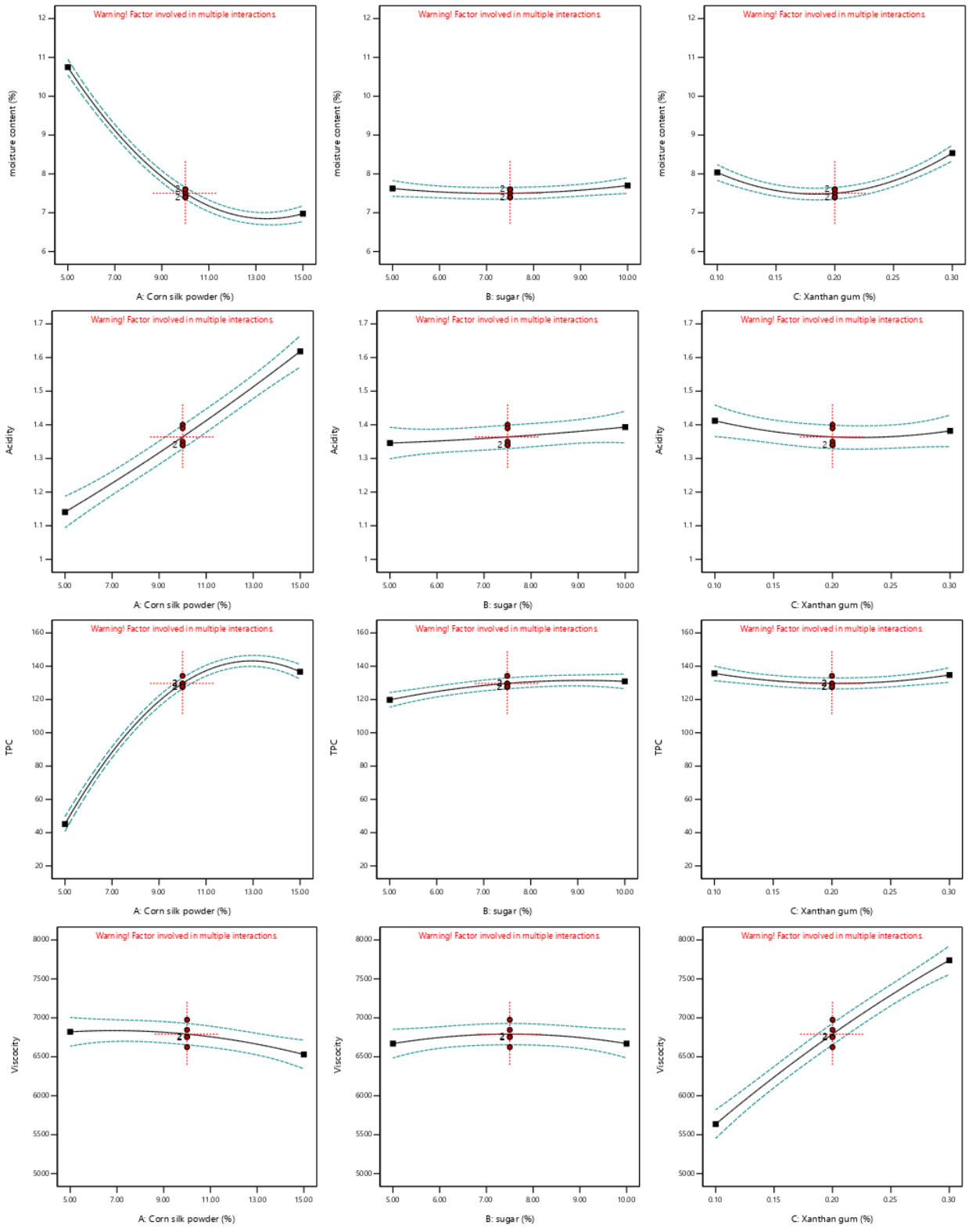
Factor	Moisture	Acidity	TPC	Bulk density	Tapped density	WAI	Swelling capacity	Viscosity
A corn silk	-1.89*	0.2388*	45.77*	0.0246*	0.0162	0.0925*	0.3400*	-14533*
B sugar	0.0375	0.0238	5.55	0.0583*	0.0875*	0.2800*	1.000*	-0.1787
C Xanthan gum	0.2500*	-0.0150	-0.4750	0.0571*	0.0688*	0.0750*	0.4663*	1051.69*
AB	-0.1750*	-0.0100	0.6475	-0.0133	0.0700*	0.0725	-0.0975	55.09
AC	-0.1000	0.0025	0.7700	-0.0260	-0.0175	-0.0775	0.0625	-63.84
BC	0.6500*	0.0025	0.2000	0.0227	0.0250	0.0175	0.6500*	-65.93
A2	1.36*	0.0155	-38.77*	-0.0637*	-0.0263	-0.0813	-0.8030	-115.72
B2	0.1625	0.0055	-4.33*	-0.0490*	-0.0538*	-0.1163*	-0.7355*	-121.64
C2	0.7875*	0.0330	5.54*	-0.0497*	0.0437*	0.2088*	-0.1605*	-103.56

*represents significant difference ($p<0.05$)

Table 6.24: Coefficient of regression of sensory parameters

Factor	Color and appearance	Body and texture	Flavor and sweetness	Mouthfeel	OAA
A corn silk	-0.4625*	0.0250	0.0750	0.0000	-0.1000
B sugar	-0.2750*	0.0750	0.9500*	0.0250	0.2375*
C Xanthan gum	0.0125	-0.1500*	0.1750*	-0.1500	0.1375
AB	-0.1250*	0.2000*	0.2500*	0.2500*	0.4000*
AC	0.0000	-0.0500	0.1500	0.1000	-0.1000
BC	0.0250	-0.1500	0.1000	-0.1500	-0.1250
A2	0.0100	0.0100	0.1000	0.1250	-0.1175
B2	-0.0150	-0.0400	-0.2000	-0.1250	0.0575
C2	-0.0900	-1.19*	-0.1000	-0.8250*	-0.6425*

*represents significant difference ($p<0.05$)


Warning! Factor involved in multiple interactions.
moisture content (%)
A: Corn silk powder (%)
B: sugar (%)
C: Xanthan gum (%)
Acidity
TPC
Viscocity

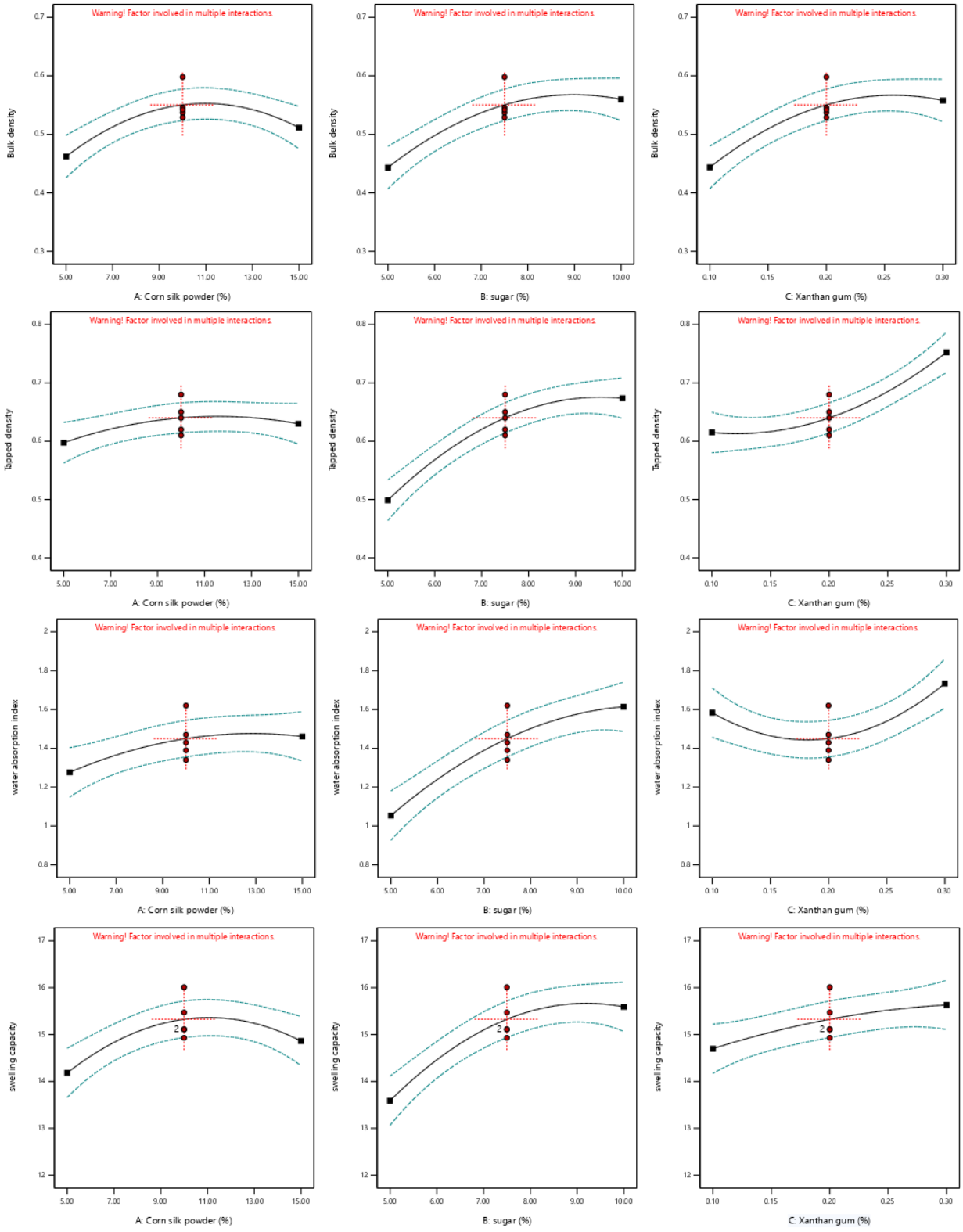


Figure 6.25: Linear correlation between process variables and physico-chemical responses of corn silk instant mix

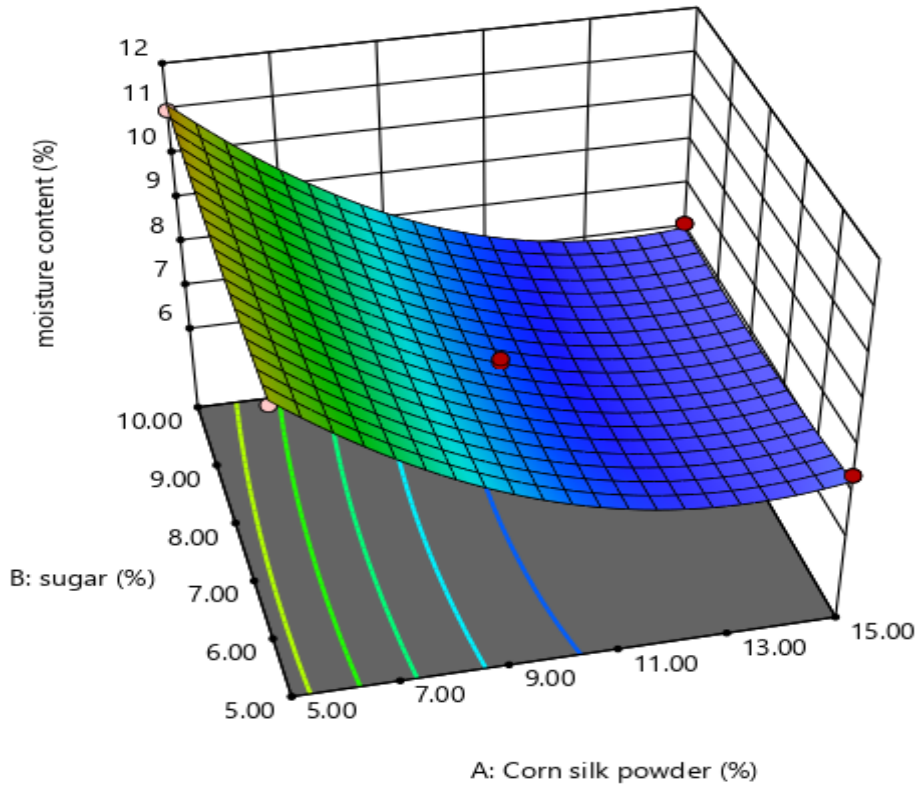


Figure 6.26: Interactive effect of sugar and corn silk powder on moisture content of the instant premix

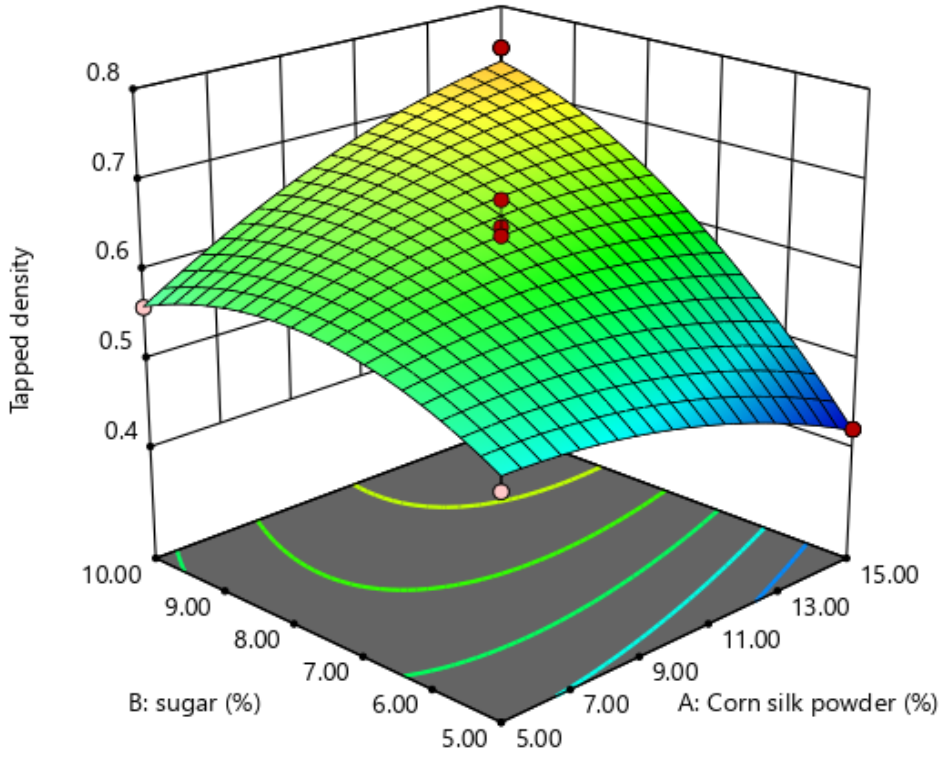


Figure 6.27: Interactive effect of corn silk powder and sugar on tapped density of the instant premix

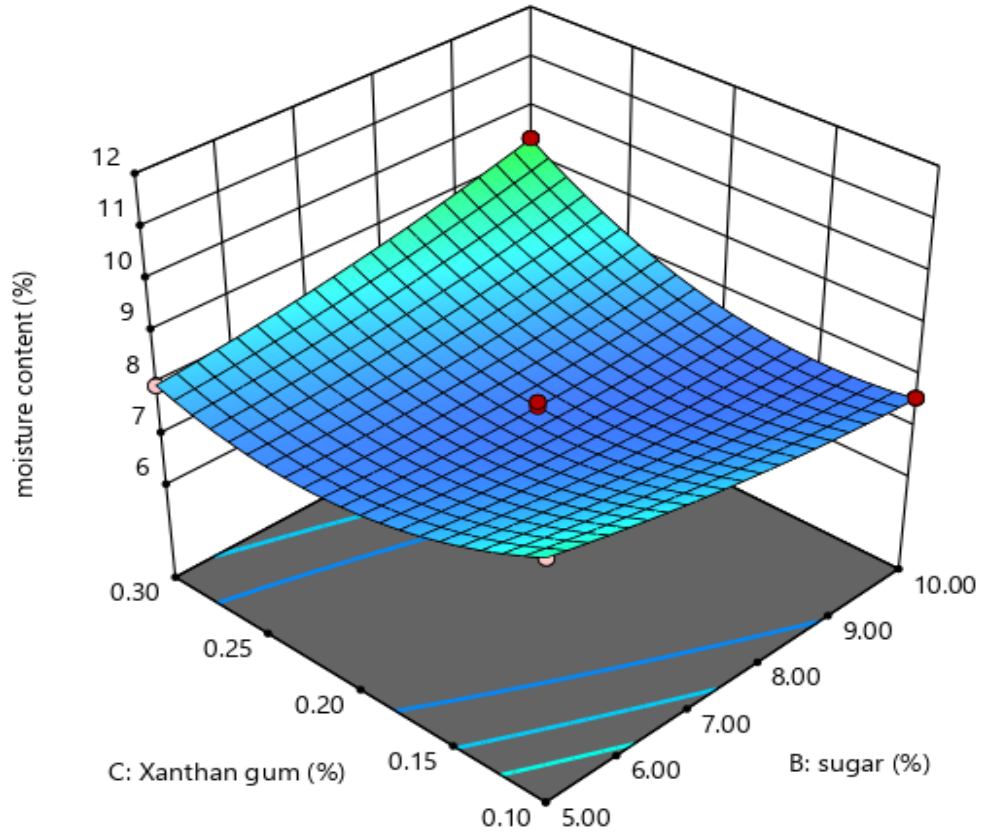


Figure 6.28: Interactive effect of xanthan gum and sugar on moisture content of the instant mix

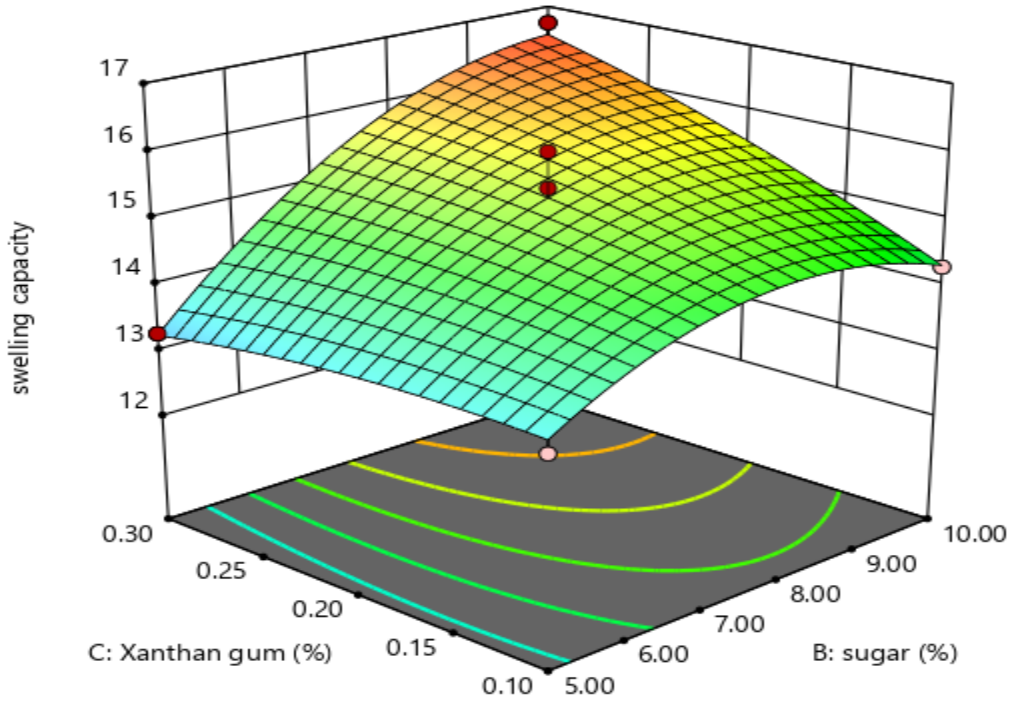


Figure 6.29: Interactive effect of xanthan gum and sugar on the swelling capacity of the instant mix.

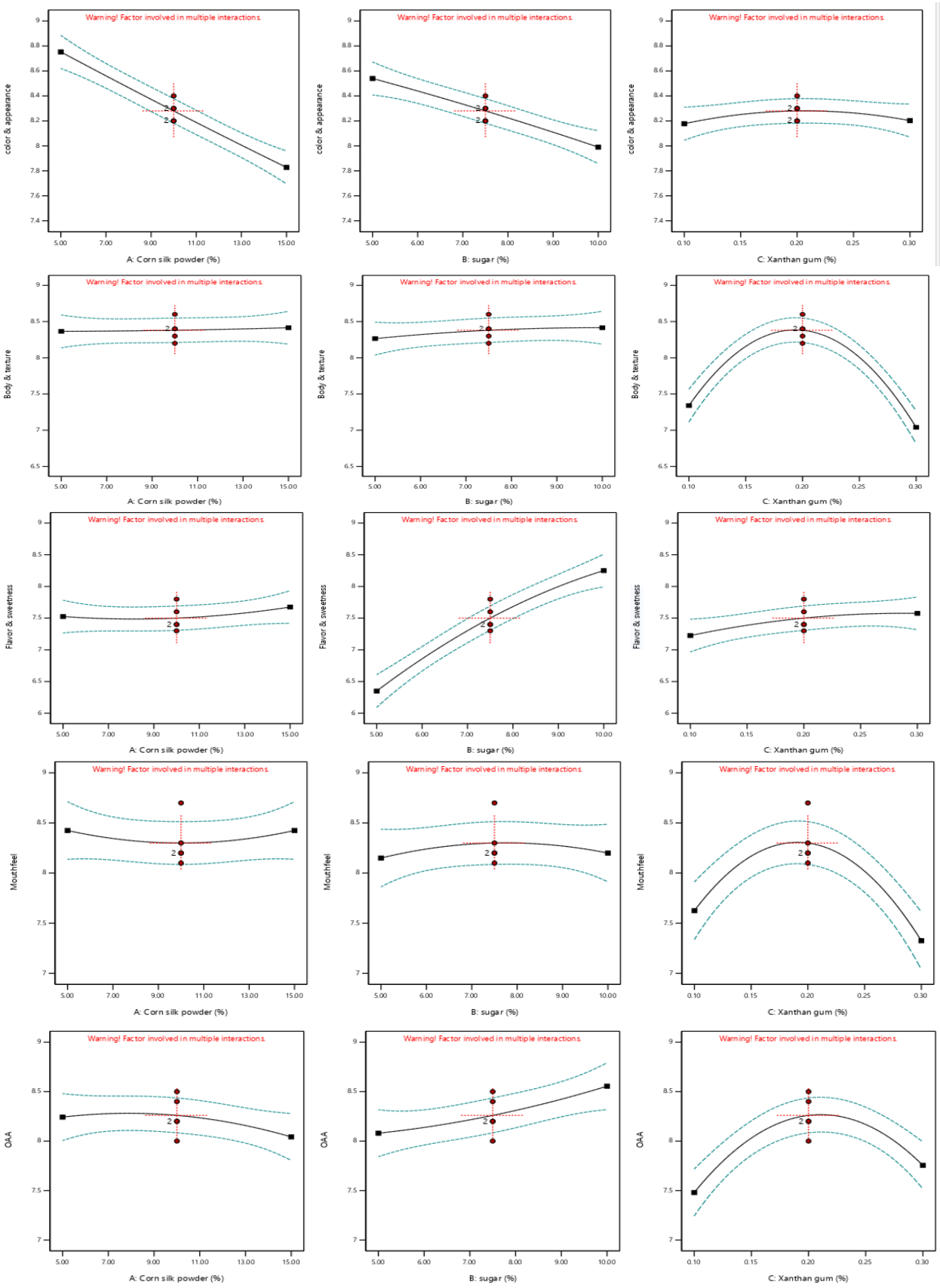


Figure 6.30: linear correlation between variables and sensory responses of instant mix

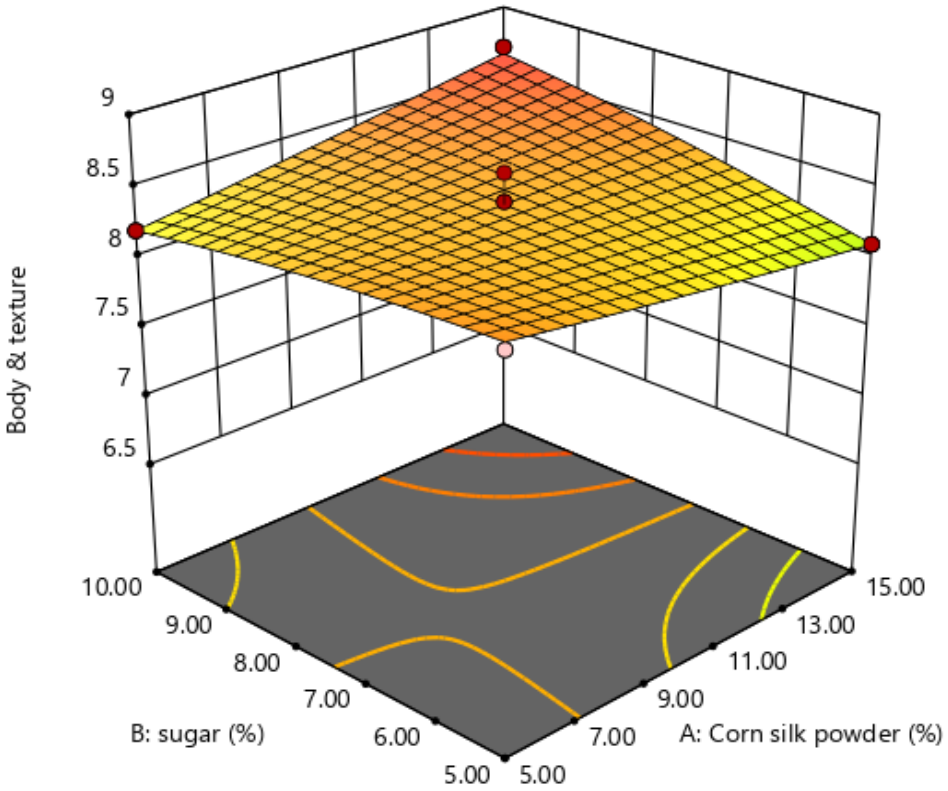


Figure 6.33: Interactive effect of the sugar and corn silk powder on the body and texture of the instant premix

Table 6.25: Predicted and observed optimum responses

Responses	Predicted values	Observed values
Moisture content	7.100[a]	7.0±0.12[a]
Acidity	1.619 [a]	1.59±0.25[a]
Total Polyphenolic content	140.677[a]	146.30±12.14[a]
Bulk density	0.522 [a]	0.49±0.24 [b]
Tapped density	0.744[a]	0.77±0.04[a]
Water absorption index	1.705[a]	1.70±0.17[a]
Swelling capacity	15.292[b]	16.00±0.47[a]
Color and appearance	7.455[b]	8.0±0.22[a]
Body and texture	8.555[a]	8.0±0.21[b]
Flavor and sweetness	8.700[a]	7.5±0.03[b]
Mouthfeel	8.492[a]	8.0±0.27[b]
Overall acceptability	8.706[a]	8.5±0.31[b]

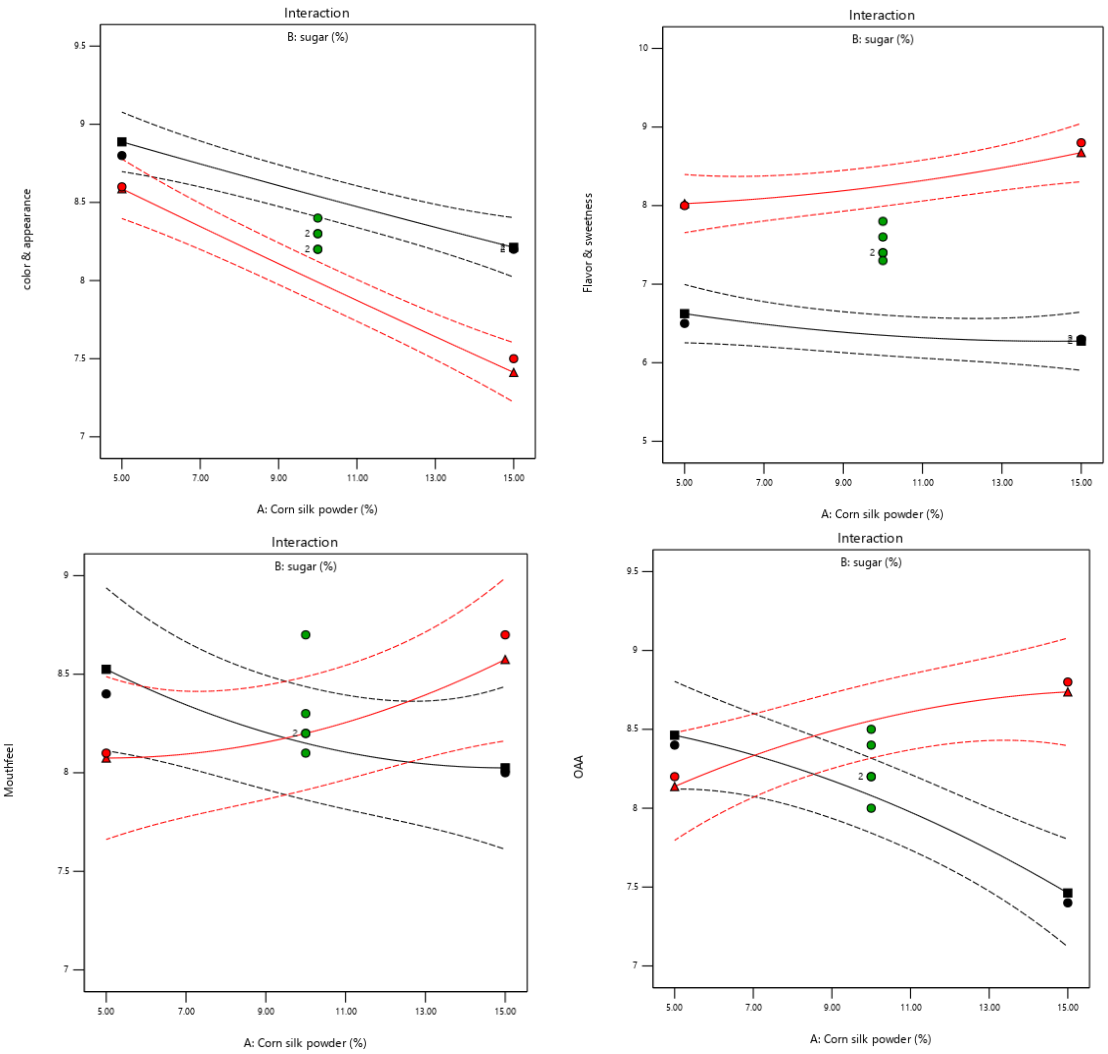


Figure 6.32: Interactive effect of corn silk and sugar on color and appearance, flavor and sweetness, mouthfeel and overall acceptability of the instant premix.

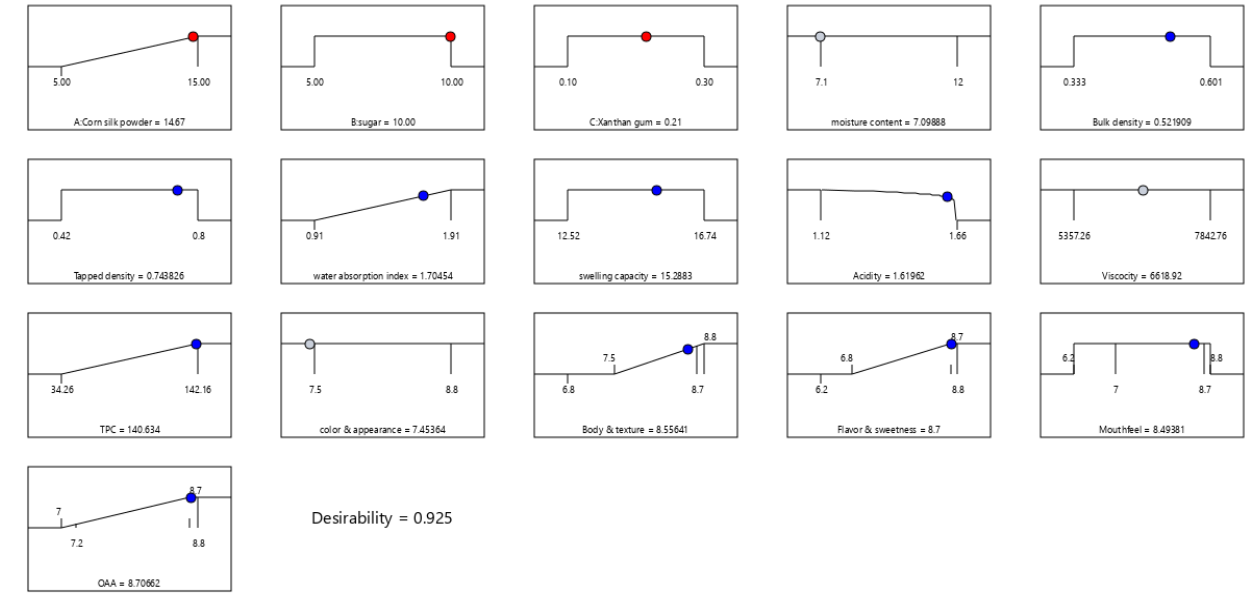


Figure 6.33: Optimized instant mix formulation and its predicted responses

Effect of variables on chemical parameters of corn silk beverage

The different formulations prepared are shown in figure 6.34. The Table 6.26 represents the regression coefficient for the corn silk beverage. It can be observed that all the variables including corn silk, xanthan gum and kinnow juice are significantly affecting the various response parameters of the beverage. Most of these factors have a linear relationship with the variables as shown in the Figure 6.35. Chemical parameters like pH, total soluble solids and acidity are (Fig. 6.36) major factors driving the acceptability of the beverages. It is evident that corn silk has a major impact on the pH and acidity of the beverage. Corn silk affect these parameters significantly ($p<0.05$) on a positive note. Moreover, xanthan gum and kinnow juice has significant positive effect on all the three chemical responses viz. pH, TSS and acidity. Although the magnitude confirms that kinnow juice's role is more significant compare to xanthan gum. It is also interesting to observe that corn silk and xanthan gum together has a significant negative effect on the pH, however none of the other interactions are significant.

Effect of variables on the sensory properties of the corn silk based ready to serve beverage

Sensory parameters are perhaps the most important indicators of acceptability of the product. Attributes such as color and appearance, body and texture flavor, mouthfeel, overall acceptability are studied to optimize the corn silk based beverage. Figure 6.37 depicts the linear correlation between variables and responses of the corn silk beverage. Table shows that corn silk has a key role in determining the body and texture of the beverage along with xanthan gum and kinnow. However, no other component of sensory evaluation was affected by corn silk. On the other hand, xanthan gum has significant positive role in modulating the flavor and mouthfeel along with the body and texture. It is noteworthy that kinnow juice plays the most important role in modulating the color and appearance, flavor, mouthfeel and the overall acceptability of the beverage. Kinnow juice has an overall positive significant ($p<0.05$) effect on all these characteristics. An interaction of corn silk and xanthan gum (Fig. 6.38) has significant effect on the mouthfeel, however none of the other attributes were affected by any interaction and linear effect seems to be prominent in most characters.

Figure 6.34: Corn silk based ready to serve beverage stored in glass bottles

Optimization of corn silk based beverage

Figure 6.39 represents the optimum level of variables analysed for the optimum product attribute. The volume of the beverage was made upto 100% using potable water. The observed desirability for the predicted formulation was 0.932. Table 6.25 depicts the comparative account of the predicted and observed values of the optimized product. It can be seen that with an exception of mouthfeel all other attributes value significantly different, indicating vast difference in the predicted and observed values.

Table 6.28: Coefficient of regression of chemical parameters of corn silk beverage

Factor	pH	TSS	Acidity	Color and appearance	Body and texture	Flavor	Mouthfe	Overall Acceptability
A corn silk	0.0500*	0.3250	0.0150*	0.1250	0.1250*	0.1250	0.0625	0.1500
B Xanthan gum	0.0575*	0.9000*	0.0500*	0.1000	0.3000*	0.2250*	0.2500*	0.0750
C Kinnow Juice	0.0875*	1.03*	0.0275*	04750*	0.1000	0.5750*	02625*	0.3250*
AB	-0.0725*	-0.1750	-0.0025	0.0000	-0.1500	0.1000	0.2000*	0.0000
AC	-0.0375	-0.3250	-0.0025	0.0000	0.0500	-0.0500	-0.0750	-0.1000
BC	0.0075	-0.2750	-0.0175	-0.1000	0.1500	0.1000	0.1000	0.1000
A2	0.0857*	0.1325	0.0172	0.1900	-0.1200	-0.0400	-0.2475*	-0.2500*
B2	-0.0092	0.7825	-0.0228	-0.0600	-0.6200*	-0.1900	-0.8725*	-0.7500*
C2	-0.0242	-0.3175	0.0073	-0.0600	0.0300	-0.2900*	0.1525	0.4000*

*represents significant difference ($p<0.05$)

Table 6.29: Predicted and observed optimum responses of corn silk beverage

Responses	Predicted values	Observed values
pH	4.385[b]	4.52±0.03[a]
TSS	14.078[a]	14.00±0.06[b]
Acidity	0.361[b]	0.41±0.01[a]
Color and Appearance	8.686[a]	8.23±0.13[b]
Body and texture	8.569[a]	8.04±0.27[b]
Flavor	8.568[a]	8.55±0.15[a]
Mouthfeel	8.702[a]	8.12±0.19[b]
OAA	8.786[a]	8.52±0.09[b]

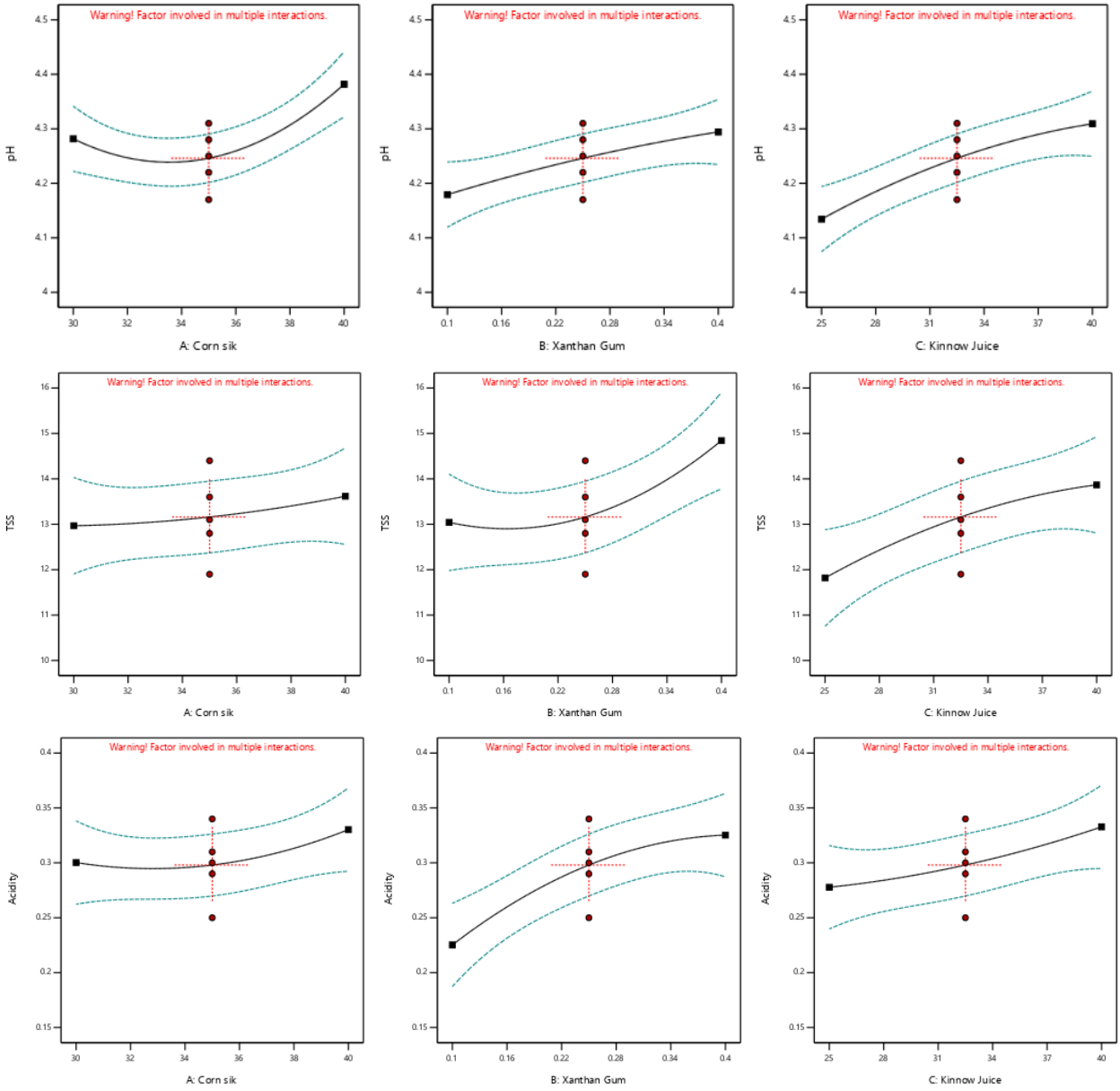


Figure 6.35: Linear correlation between variables and responses of optimized corn silk beverage

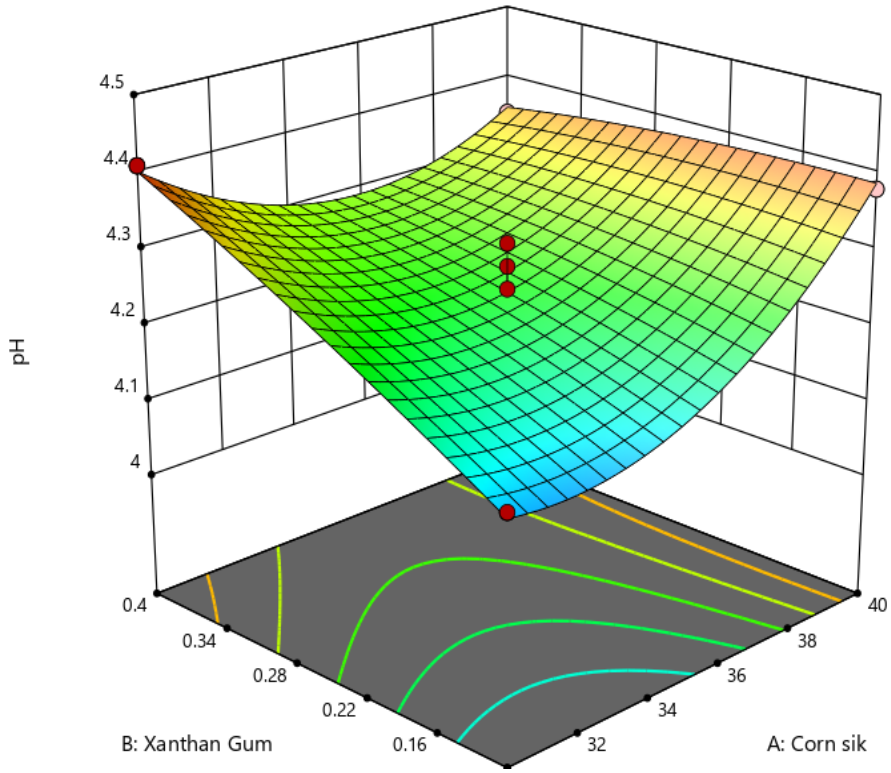


Figure 6.36. Effect of Corn silk and Xanthan gum on pH of corn silk beverage

Effect of storage on corn silk based instant mix

After every 30 days, the moisture, total plate count, yeast and mould count and overall acceptability of the selected formulation of corn silk based instant mix were evaluated as shown in Table 6.27. The moisture level of the product is a significant factor in determining product stability throughout storage. During the storage period, the moisture content varied insignificantly, with a fluctuation of 7.00±0.12 % initially to 8.84±0.10 in LDPE pouches at 37 °C, 8.61±0.17% in LDPE pouches at 25 °C, 7.85±0.15 in LDPE pouches at 10 °C as shown in Table 6.27. Among all the packaging material, the metallised polyster showed the less increase in moisture content during storage at various temperature. The absorption of moisture from the ambient by diffusion of vapours through microscopic pores in packaging materials may cause an increase in moisture content during storage (Sharma et al. 2013).

The total plate count of instant mix was checked on a regular basis throughout storage, and it was shown to be increasing dramatically with time. Our results as shown in Table 6.27 showed the $22.30*10^2$ cfu/g in the instant mix stored in metallised polyester at 37 °C. According to Jay (1992), if the overall microbial count of instant mix is less than $1*10^4$ cfu/g, the product is microbiologically safe.

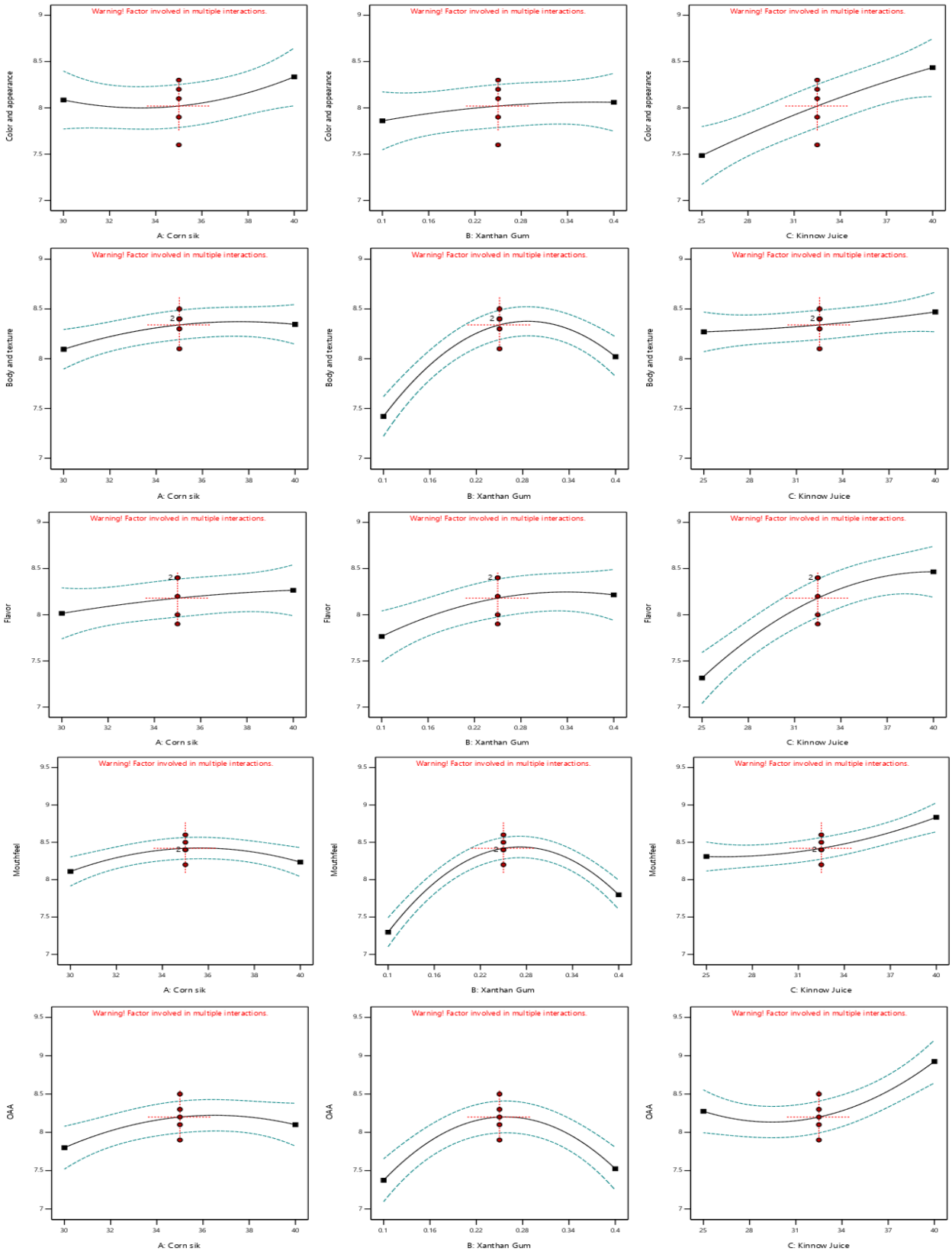


Figure 6.38: Linear correlation of process variables with responses of corn silk beverages

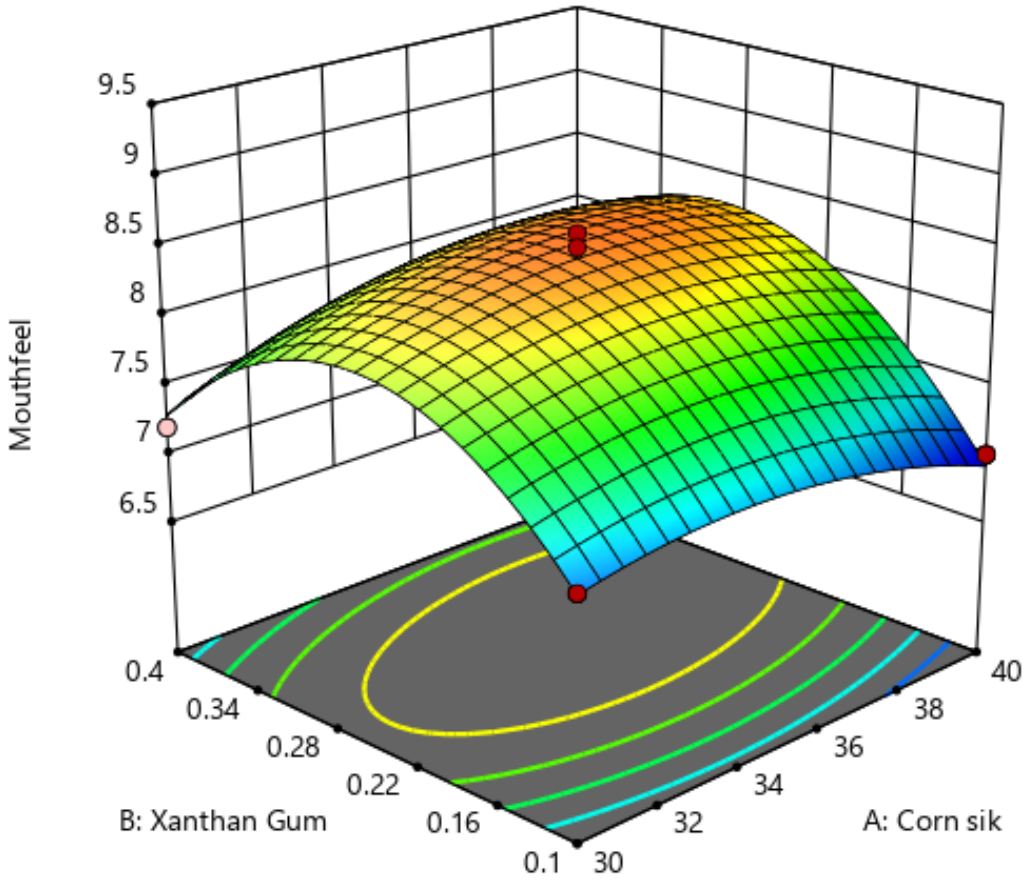


Figure 6.39: Effect of corn silk and xanthan gum on mouthfeel of corn silk beverage

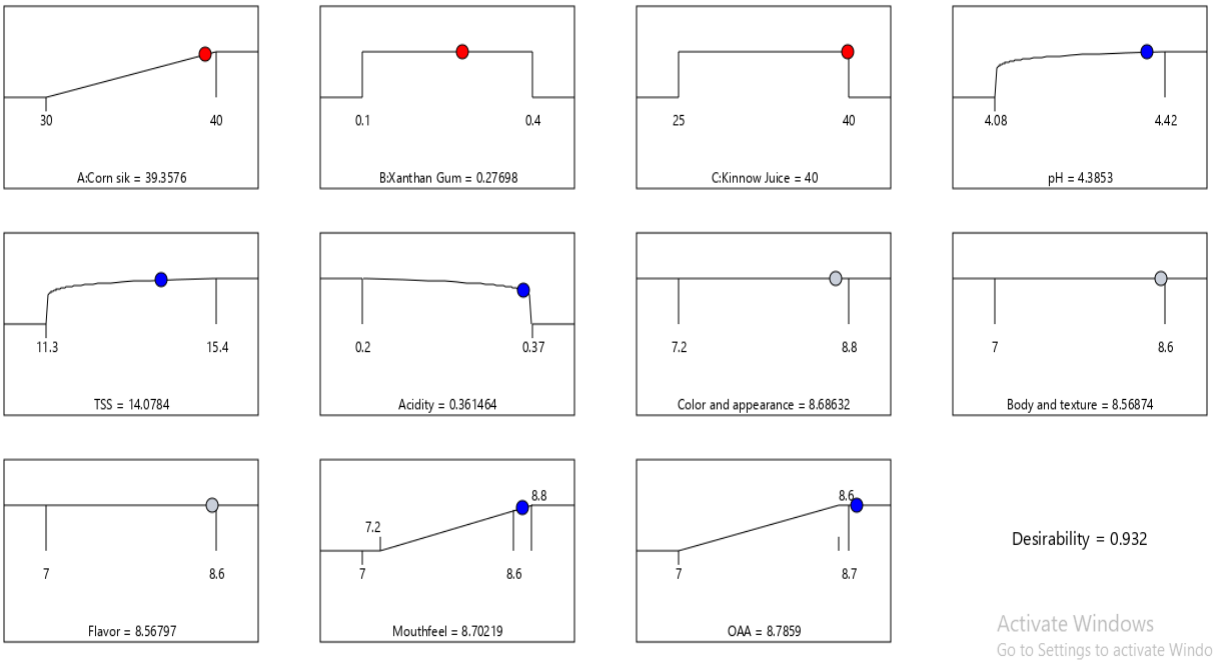


Figure 6.40: Predicted optimized corn silk beverage formulation

Table 6.27: Shelf life study of instant mix

Storage days	Temperature of storage	Packaging material	Moisture (%fw)	Total Plate Count (CFU*10^2/g)	Yeast and Mould count (CFU*10^2/g)	Overall Acceptability
0th day	10	LDPE	7.00±0.12	0.27±0.01	0.05±0.00	8.50±0.25
		HDPE	7.00±0.12	0.27±0.01	0.05±0.00	8.50±0.25
		MP	7.00±0.12	0.27±0.01	0.05±0.00	8.50±0.25
	25	LDPE	7.00±0.12	0.27±0.01	0.05±0.00	8.50±0.25
		HDPE	7.00±0.12	0.27±0.01	0.05±0.00	8.50±0.25
		MP	7.00±0.12	0.27±0.01	0.05±0.00	8.50±0.25
	37	LDPE	7.00±0.12	0.27±0.01	0.05±0.00	8.50±0.25
		HDPE	7.00±0.12	0.27±0.01	0.05±0.00	8.50±0.25
		MP	7.00±0.12	0.27±0.01	0.05±0.00	8.50±0.25
30th day	10	LDPE	7.45±0.23	0.22±0.00	0.05±0.00	8.48±0.17
		HDPE	7.53±0.14	0.26±0.03	0.05±0.00	8.57±0.21
		MP	7.46±0.20	0.31±0.00	0.06±0.00	8.66±0.15
	25	LDPE	7.65±0.73	2.42±0.01	0.14±0.02	8.57±0.25
		HDPE	7.68±0.53	2.38±0.04	0.15±0.01	8.42±0.35
		MP	7.55±0.43	2.47±0.08	0.14±0.01	8.53±0.31
	37	LDPE	7.87±0.13	3.37±0.12	0.11±0.01	8.44±0.25
		HDPE	7.63±0.43	2.33±0.09	0.10±0.02	8.12±0.05
		MP	7.50±0.33	3.41±0.14	0.11±0.02	8.37±0.18
60th day	10	LDPE	7.85±0.15	0.38±0.05	0.04±0.01	8.22±0.35
		HDPE	7.76±0.03	0.34±0.12	0.05±0.04	8.46±0.26
		MP	7.65±0.14	0.17±0.10	0.05±0.02	8.05±0.42
	25	LDPE	8.15±0.04	7.47±0.14	1.52±0.03	8.77±0.06
		HDPE	8.23±0.13	9.57±0.30	1.20±0.08	8.63±0.24

		MP	8.16±0.07	7.61±0.72	1.22±0.06	8.06±0.68
	37	LDPE	8.23±0.17	8.67±0.90	1.26±0.11	7.92±0.42
		HDPE	8.34±0.03	9.11±0.28	1.42±0.08	8.08±0.16
		MP	8.11±0.10	11.31±0.09	1.45±0.03	8.27±0.09
90th day	10	LDPE	8.07±0.09	0.44±0.10	0.08±0.02	7.42±0.51
		HDPE	8.16±0.14	0.63±0.08	0.08±0.02	8.52±0.15
		MP	7.97±0.34	0.37±0.00	0.08±0.03	7.80±0.55
	25	LDPE	8.27±0.37	10.27±0.07	2.56±0.12	8.07±0.35
		HDPE	8.62±0.22	10.07±0.04	2.42±0.17	8.71±0.05
		MP	8.25±0.03	10.33±0.41	2.66±0.11	8.08±0.25
	37	LDPE	8.52±0.16	21.31±0.00	2.48±0.32	7.57±0.05
		HDPE	8.76±0.10	15.16±1.30	2.56±0.21	7.89±0.12
		MP	8.27±0.21	19.31±1.04	2.24±0.07	8.06±0.21
120th day	10	LDPE	8.45±0.41	0.91±0.10	0.12±0.07	8.27±0.15
		HDPE	8.33±0.39	0.67±0.24	0.10±0.01	8.23±0.27
		MP	8.15±0.11	0.55±0.22	0.08±0.01	8.39±0.12
	25	LDPE	8.61±0.17	24.17±2.05	3.72±0.12	7.66±0.35
		HDPE	8.87±0.31	17.41±3.17	4.77±0.12	7.27±0.22
		MP	8.26±0.12	22.38±3.00	4.21±0.11	8.17±0.37
	37	LDPE	8.84±0.10	42.14±6.20	3.95±0.09	7.77±0.24
		HDPE	8.68±0.22	25.31±4.08	4.09±0.12	8.04±0.10
		MP	8.30±0.01	26.31±2.30	4.95±0.11	8.01±0.04

The values were in the safe range henceforth, the total plate count showed even after 180 days of storage the treatments of instant mix were microbiologically safe. Similarly, the yeast and mould count increased as the days of storage increases. At 180th days of storage the total yeast and mould count with the range of 4.95±0.11 also showed the range of safe consumption. Our results showed that corn silk incorporation in the RTS beverage showed the reduction in the microbial count although the values increased with storage time. The findings were consistent with those of a study on the microbiota of steeped and cured baby corn (Kaur et al. 2009) and in the preparation of RTS from orange juice and aloe vera gel (Kausar et al., 2020).

The overall acceptability of the developed instant mix at various temperature showed the reduction in the scores, however, the difference was not significant. The scores ranged from 8.50±0.25 at the initial days has reduced to 8.01±0.04 in the instant mix sample stored at 37 °C in metallised polyester. Among all the packaging material, metallised polyester has shown the highest overall acceptability. However, the values for overall acceptability were more than 5 therefore, for the prediction of shelf life of the developed instant mix, chemical kinetics were performed and prediction values were calculated.

6.20 PREDICTIVE MODELLING BY CHEMICAL ANALYSIS

Changes in thiobarbituric acid (TBA) value of corn silk based instant mix

The development of secondary oxidation products such as carbonyls is measured by thiobarbituric acid reactive substances (TBARS). During processing and storage, milk lipids may undergo chemical and physical changes such as autoxidation and the creation of trans fatty acids, resulting in the generation of low molecular weight molecules (aldehydes, ketones, and lactones) and sensory quality loss (Semma 2002). Table 6.27 shows the increase in TBA values (measured at 532 nm) throughout the preservation of the improved in corn silk based instant mix where skimmed milk powder was used as filler. After 120 days of storage, the TBA value in the fresh optimised baby food formulation grew to 0.656 in LDPE pouches, 0.635 in HDPE pouches, 0.576 in MP pouches at 10 °C, 0.797 in LDPE pouches, 0.725 in HDPE pouches, 0.705 in MP pouches at 25 °C and 0.905 in LDPE pouches, 0.805 in HDPE pouches, 0.803 in MP pouches at 37 °C as shown in Table 6.27. The Arrhenius plot for TBA value is shown in Figure 6.42. Bunkar et al. (2012b) found that after 180 days of

storage in 98 percent nitrogen packaging, TBA values in instant pearl millet kheer mix increased from 0.067 to 0.219, 0.311, 0.432, and 0.613 at 8, 25, 37, and 45 °C, respectively. TBA levels in instant wheat porridge (dalia) increased from 0.05 to 0.116 and 0.089 mg malonaldehyde/kg after 12 months of storage in polypropylene (PP) and metalized polyester (MP) packages, respectively (Khan et al. 2012). In the current investigation, similar findings were made.

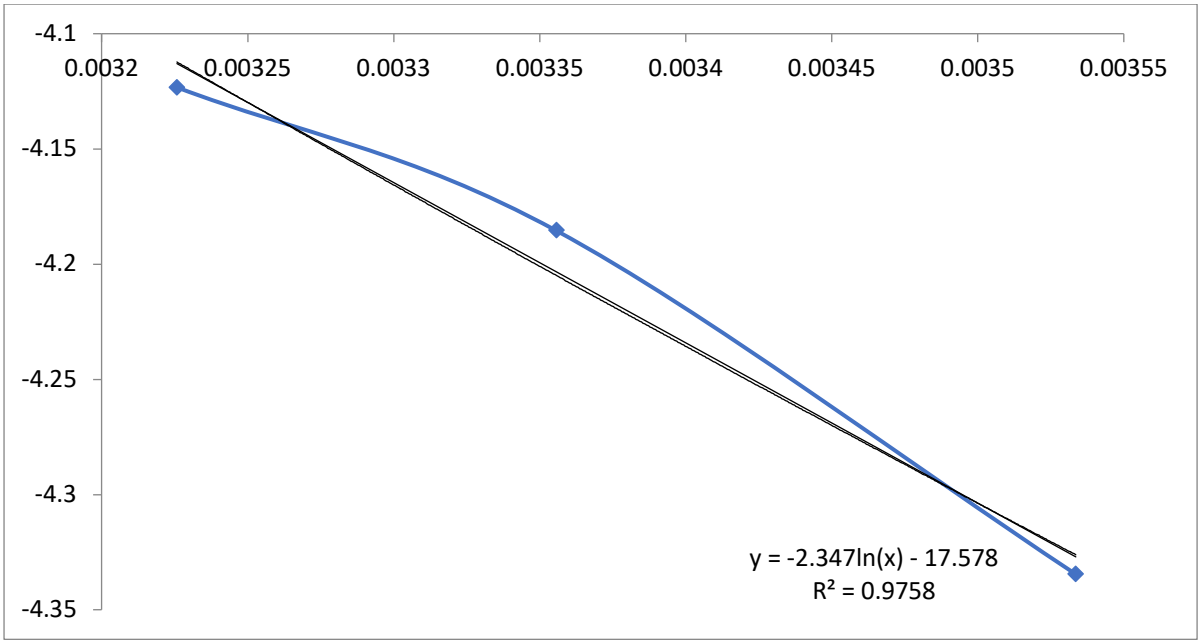


Figure 6.41: Changes in the TBA content of the instant mix from corn silk stored at different temperatures and its Arrhenius plot

Changes in free fatty acid content (FFA) value of corn silk based instant mix

Free fatty acid is an indicator of oxidative degradation of lipids present in the milk products. During storage, lipid in food products is readily hydrolyzed by enzymes such as lipases (Prasad et al., 2015). However, lipases are denatured during thermal processing, therefore, it is hypothesized that the increase in FFA content in stored products could be a result of decomposition of hydroperoxide (Khan *et al*. 2012). The increase in FFA values is shown in Table 6.27 during storage days. The FFA value found in fresh optimized baby food formulation was 0.52 µeq/g, which increased to 1.45, and 1.68 µeq/g at 10, 25, and 37 °C, respectively after 120 days of storage. Similar finding were reported by Khan *et al*. (2012). The Arrhenius plot for FFA value is shown in Figure 6.40.

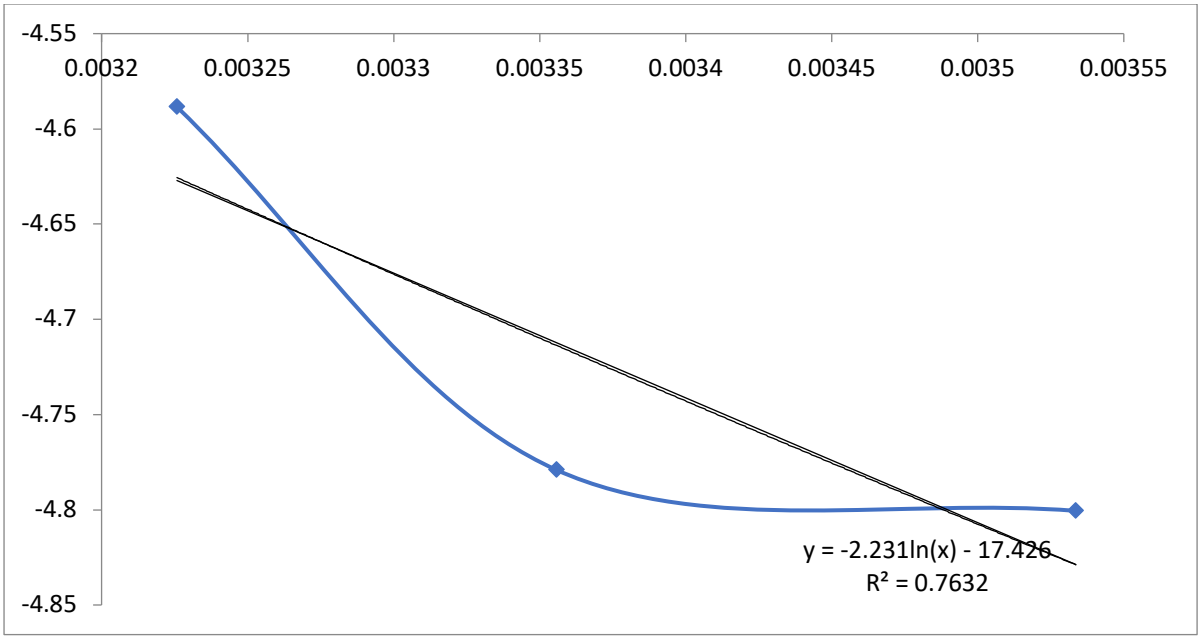


Figure 6.42: Changes in the FFA content of the instant mix from corn silk stored at different temperatures and its Arrhenius plot

Changes in hydroxyl methyl furfural (HMF) content value of corn silk based instant mix

The formation of HMF occurs as a result of the continuation of Maillard reactions, and it increases as storage time and temperature increase (Jha and Patel 2012). Table depicts the increase in HMF values. The average HMF value measured in fresh optimal baby food formulation was 5.2 mol/g, which increased to 12.13, 12.25 and 13.78 mol/g after 120 days of storage at 10, 25, and 37°C, respectively. HMF formation was shown to be lower at 10 and 25 °C than at 37°C. It may be established that the generation of HMF increases as the storage temperature rises. Under 98 percent nitrogen packaging, the HMF level in pearl millet based kheer mix increased from 4.87 mol/g to 11.23, 13.67, 18.13, and 21.43 mol/g at 8, 25, 37, and 45 °C, respectively (Bunkar et al. 2012b). Jha and Patel (2002) found that the total and free HMF concentration in instant kheer mix powder rose with time, with the initial value of total HMF increasing from 5.0 mol/L to 21.74 mol/L at 30 °C after 24 weeks of storage. After 16 and 8 weeks of storage at 37 and 45 °C, total HMF increased to 30.4 and 56.3 mol/L, respectively.

On the basis of shelf life study, in comparison to LDPE, HDPE pouches, MP has shown the less degradation in terms of TBA, FFA and HMF values. Therefore, the values of instant mix stored in metallised polyster has been selected for chemical kinetics and prediction of shelf life.

Table 6.31: TBA, FFA and HMF values of corn silk based instant mix at various temperature during storage

Days of storage	Temperature (ºC)	Packaging material	TBA	FFA (µeq/g)	HMF (µmol/g)
0th day	10	LDPE	0.108	0.52	5.2
		HDPE	0.108	0.52	5.2
		MP	0.108	0.52	5.2
	25	LDPE	0.108	0.52	5.2
		HDPE	0.108	0.52	5.2
		MP	0.108	0.52	5.2
	37	LDPE	0.108	0.52	5.2
		HDPE	0.108	0.52	5.2
		MP	0.108	0.52	5.2
30th day	10	LDPE	0.178	0.7	5.9
		HDPE	0.167	0.66	5.4
		MP	0.155	0.6	5.3
	25	LDPE	0.189	0.75	5.9
		HDPE	0.175	0.73	5.8
		MP	0.162	0.69	5.6
	37	LDPE	0.196	0.8	6.3
		HDPE	0.185	0.82	6.25
		MP	0.177	0.74	5.8
60th day	10	LDPE	0.243	0.78	6.83
		HDPE	0.216	0.7	6.39
		MP	0.203	0.79	6.92
	25	LDPE	0.267	0.8	6.52
		HDPE	0.229	0.79	6.12
		MP	0.214	0.8	7.49
	37	LDPE	0.298	0.89	7.98
		HDPE	0.255	0.9	7.26
		MP	0.202	0.85	7.1
90th day	10	LDPE	0.356	1.2	9.56
		HDPE	0.301	1.28	8.92
		MP	0.278	0.91	8.83
	25	LDPE	0.413	1.48	9.82
		HDPE	0.398	1.85	9.21
		MP	0.365	0.93	9
	37	LDPE	0.498	1.8	11.23
		HDPE	0.456	1.56	10.78
		MP	0.412	1.2	9.84
120th day	10	LDPE	0.656	1.5	12.88
		HDPE	0.635	1.49	12.35
		MP	0.576	1.45	12.13
	25	LDPE	0.797	1.95	13.23
		HDPE	0.725	1.59	12.49
		MP	0.705	1.58	12.25
	37	LDPE	0.905	1.86	14.67
		HDPE	0.805	1.85	14.29
		MP	0.803	1.68	13.78

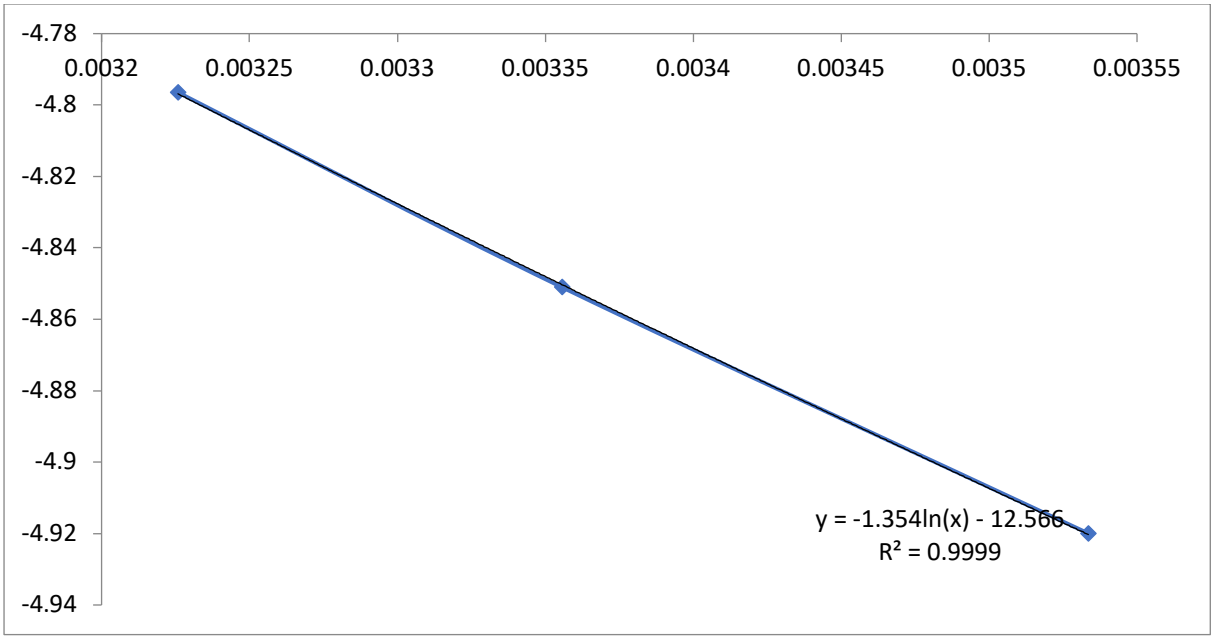


Figure 6.43: Changes in the HMF content of the instant mix from corn silk stored at different temperatures and its Arrhenius plot

Reaction kinetics of the selected corn silk based instant mix

The kinetics of HMF formation in basundi mix was best represented by a first order reaction (n=1), according to Ruhil et al. (2011) and in the nutricereal based fermented baby food pre mix (Rasane et al., 2015). In the current study, similar simplified reaction kinetics for HMF are described. A straight line was revealed by the Arrhenius plot (In versus *k*) (Figure 6.44). The reaction has an apparent activation energy (Ea), and Arrhenius constant (A_0) of 11.25 kJ/mol, 3.48 * 10^6 M/week (Table 6.29). Enthalpy of activation (H) for HMF values ranged from 8.90 to 8.68 kJ/mol, entropy of activation (S) for HMF values ranged from -266.56034 to -261.66444 J/mol °K, and free energy of activation (G) for HMF values ranged from 75.44 to 82.55 kJ/mol at storage temperatures of 10 to 37°C.

The optimised corn silk based formulation's change in TBA values was discovered to follow first order reaction kinetics. TBA has a single straight line in the Arrhenius plot (ln versus *k*). The figure revealed that the Ea and A_0, and for TBA formation were 19.51 kJ/mol and 2.32 * 10^8 M week respectively. For 10 to 37 °C, the activation enthalpy (H) ranged from 17.16 to 16.94 kJ/mol, the activation entropy (S) from -261.66444 to -260.67131 J/mol °K, and the activation free energy (G) from 74.06 to 80.82 kJ/mol (Table 6.29).

The kinetics of FFA generation in corn silk based fermented infant food were discovered to have first order reaction kinetics. FFA was represented by a single straight line

in the Arrhenius plot (Fig 6.43). The plot yielded Ea and A_0 values for FFA of 18.54 kJ/mol and 2.70 * 10^8 M/week respectively. In the temperature range of 10 to 37 °C, the enthalpy of activation (H) varied from 16.20 to 15.97 kJ/mol the entropy of activation (S) varied from -261.66444 to 260.67131 J/mol °K, and the free energy of activation (G) varied from 75.16 to 82.21 kJ/mol (Table 6.29). The table 6.30 showed the half-life of instant mix to be 94.95 days at 10° C. stored in metallised polyster.

Table 6.32: Kinetic parameters related to changes in HMF, TBA and FFA formation in corn silk based instant mix during storage

Variables							
	Temperature (°C)	**Rate constant (k), wk^{-1}**	**Apparent activation energy (E_a) (kJ/mol)**	**Frequency factor (Arrhenius constant, A_0 (M wk^{-1})**	**ΔH (kJ/mol)**	**ΔS (J/mol °K)**	**ΔG (kJ/mol)**
HMF	10	7.29 * 10^3	11.25	3.48 * 10^6	8.90	-266.56034	75.44
	25	7.82 * 10^3			8.78	-266.41872	79.40
	37	8.25 * 10^3			8.68	-266.29451	82.55
TBA	10	1.31 * 10^3	19.51	2.32 * 10^8	17.16	-261.66444	74.06
	25	1.52 * 10^2			17.04	-260.85762	77.75
	37	1.61 * 10^2			16.94	-260.67131	80.82
FFA	10	8.22 * 10^3	18.54	2.70 * 10^8	16.20	-261.66444	75.16
	25	8.40 * 10^3			16.07	-260.85762	79.22
	37	1.01 * 10^2			15.97	-260.67131	82.21

Table 6.33. The shelf life prediction of corn silk at the different storage temperature

Storage temperature (°C)	k	T(K)	ln (k)	1/T	half life t (days)	t (months)
10	0.00729942	283	- 4.919961	0.00353357	94.9592133	3.2
25	0.00782024	298	- 4.8510399	0.0033557	88.6350266	3
37	0.00825906	310	- 4.7964449	0.00322581	83.9256744	2.79

Effect of storage on corn silk based ready to serve beverage

TSS increased as storage time passed, possibly due to the breakdown of polysaccharides into monosaccharides and oligosaccharides. TSS increased by the amount (15.32±0.17) in the corn silk based ready to serve beverage stored at 37 °C, which was statistically superior to the other treatments (Table 6.31). Similar results were reported by Bhardwaj and Mukharjee (2011) where they reported 14.13 °Brix in the mixture of kinnow,

aonla and ginger juice stored for four months. During storage, the titratable acidity content decreased significantly (Table 6.31). This could be due to enzymes, particularly invertase, converting acids into salts and sugars and also the due to fermentation by microrganisms.
The pH value decreased significantly at all the temperature store in glass bottles and the lowest value was observed in the ready to serve beverage stored at 37 °C as shown in Table 6.31. Titrable acidity increased significantly ($p<0.05$) and ranged from 0.41±0.01 at 10°C on the 0^{th} day to 0.82±0.05 on 60^{th} day of storage at the same temperature. The increase in acidity of the product was synchronous with these results (Sri Vidhya and Sri 2018). Similar results were reported in the case of kept beetroot juice. The ginger variety showed the least amount of pH change, which could be attributable to the antioxidant qualities of ginger (Nwachukwu and Ezejiaku 2014).

The RTS beverage is well-known as a non-Newtonian fluid in general (Hemalatha et al., 2018). The viscosity of samples (Table 6.31) stored at low temperature (10 °C) increased significantly, whereas viscosity values in high temperature (37 °C) i.e. 43.88±0.15 cP which could be due to the enzymatic and bacterial degradation of polysaccharides like pectin and starch in beverage samples (Lalit et al., 2014). With a rise in temperature, there will be an increase in strain and shearing rate, a drop in flow index, and a decrease in product inconsistency.

At 10^3 dilution, total plate counts of corn silk RTS were done after 0, 15, 30, 45 and 60 days of storage (Table 6.31). The RTS beverage had the highest bacterial count after 60 days of storage (8.89 x 10^3 cfu/ml). At 45 days of storage, the TPC count was in the permissible limit (6.76 ±0.01) i.e. less than $1*10^3$ cfu/ml as per FSSAI limit. The results for yeast and mold count at 45 days of storage were also reported to be in permissible limit, $0.97±0.02^{*}10^3$ cfu/ml as per FSSAI guidelines. The coliform colonies were not detected in the beverage at any period of storage. The results show that adding corn silk extract to ready to serve beverage lowers bacterial growth, as corn silk is known to have antibacterial and antioxidant effects. However, the microbial burden increased with storage time in all samples. The best suitable temperature for the storage of corn silk based ready to serve beverage was 10 °C and till 45 days it was safe for consumption.

Table 6.34: Shelf life study of ready to serve corn silk based beverage

Days	Temperature (°C)	Packaging material	pH	TSS (°Brix)	Titrable acidity	Viscosity (cP)	Total plate count (cfu*10^3/ ml)	Yeast and mould count (cfu*10^3/ml)	Total coliform count (cfu*10^3/ml)
0th day	0	Glass bottle	4.53 ± 0.03^{a}	14.00 ± 0.06^{f}	0.41 ± 0.01^{e}	35.04 ± 0.11^{k}	3.23 ± 0.02^{m}	0.3 ± 0.01^{l}	ND
	25	Glass bottle	4.53 ± 0.03^{a}	14.00 ± 0.06^{f}	0.41 ± 0.01^{e}	35.04 ± 0.11^{k}	3.23 ± 0.02^{m}	0.3 ± 0.01^{l}	ND
	37	Glass bottle	4.53 ± 0.03^{a}	14.00 ± 0.06^{f}	0.41 ± 0.01^{e}	35.04 ± 0.11^{k}	3.23 ± 0.02^{m}	0.3 ± 0.01^{l}	ND
15th day	0	Glass bottle	4.43 ± 0.01^{b}	14.04±0.03f	0.43 ± 0.02^{e}	37.29 ± 0.12^{j}	4.56 ± 0.05^{l}	0.45 ± 0.05^{k}	ND
	25	Glass bottle	4.40 ± 0.02^{b}	14.42 ± 0.05^{d}	0.52 ± 0.05^{cd}	38.34 ± 0.11^{g}	4.89 ± 0.04^{k}	0.79 ± 0.02^{j}	ND
	37	Glass bottle	4.40 ± 0.04^{b}	14.45 ± 0.03^{d}	0.57 ± 0.09^{c}	37.15 ± 0.04^{i}	5.87 ± 0.02^{i}	0.77 ± 0.03^{j}	ND
30th day	0	Glass bottle	4.42 ± 0.00^{b}	14.12 ± 0.02^{e}	0.51 ± 0.04^{d}	38.15 ± 0.01^{h}	4.92 ± 0.07^{j}	0.88 ± 0.07^{i}	ND
	25	Glass bottle	4.40 ± 0.02^{b}	14.86 ± 0.16^{c}	0.67 ± 0.11^{bc}	38.67 ± 0.10^{f}	6.21 ± 0.01^{h}	1.20 ± 0.10^{h}	ND
	37	Glass bottle	4.39 ± 0.03^{b}	14.84 ± 0.07^{c}	0.72 ± 0.15^{b}	38.21 ± 0.21^{e}	7.33 ± 0.03^{f}	1.89 ± 0.08^{f}	ND
45^{th} day	0	Glass bottle	4.41 ± 0.02^{b}	14.22 ± 0.01^{e}	0.57 ± 0.07^{c}	41.03 ± 0.14^{d}	6.76 ± 0.01^{g}	0.97 ± 0.02^{g}	ND
	25	Glass bottle	4.35 ± 0.01^{c}	15.02 ± 0.02^{b}	0.77 ± 0.10^{b}	41.46 ± 0.03^{d}	10.09 ± 0.01^{e}	2.25 ± 0.04^{e}	ND
	37	Glass bottle	4.32 ± 0.03^{cd}	15.10 ± 0.07^{ab}	0.84 ± 0.02^{a}	40.22 ± 0.17^{d}	10.87 ± 0.10^{c}	2.79 ± 0.03^{b}	ND
60^{th} day	0	Glass bottle	4.35 ± 0.00^{c}	14.85 ± 0.01^{c}	0.59 ± 0.02^{c}	42.88 ± 0.12^{c}	10.15 ± 0.02^{d}	2.28 ± 0.07^{d}	ND
	25	Glass bottle	4.33 ± 0.01^{cd}	15.24 ± 0.23^{a}	0.85 ± 0.03^{a}	42.47 ± 0.06^{bc}	12.45 ± 0.04^{b}	2.65 ± 0.10^{c}	ND
	37	Glass bottle	4.31 ± 0.01^{d}	15.32 ± 0.17^{a}	0.82 ± 0.05^{a}	43.88 ± 0.15^{a}	12.25 ± 0.01^{a}	2.90 ± 0.08^{a}	ND

Data is represented as Mean±SD

Data represented with different superscripts are significantly different ($p<0.05$)

*ND- Not detected

6.21 Cost analysis of corn silk based developed product

The product's computed cost is Rs. 33 per 100 g, or Rs. 345 per kilogramme. The product's net weight each pack is 100 grammes, hence the cost per pack is Rs. 34.55. In comparison to other instant mixes on the market, the current product is less expensive. The majority of quick mixes cost Rs. 60 or more. For instance, Milkmaid's instant firni mix costs Rs. 98, Nestlé's instant kulfi mix costs Rs. 68, Gits instant kheer mix costs Rs. 62, and so on. As a result, the product achieves its cost-cutting goal. The total cost for corn silk instant mix beverage was 14.92/100 ml and the one bottle of 200 ml will cost Rs. 30.

Table 6.35: Cost analysis of developed products from corn silk

Type of product	Ingredients	Amount used (g)	Cost as per amount used (Rs)	Total cost per kg (Rs)
Corn silk based instant pre mix	Corn silk powder	15	1.5	10
	Skimmed milk powder	77.2	20	255
	Sugar	7.50	3.0	47
	Xanthan gum	0.30	0.6	2000
TOTAL			33/100 g	
Corn silk based RTS	Corn silk	2	0.35	10
	Kinnow juice	40 ml	4	40
	Sugar	5	2.5	47
	Xanthan gum	0.25	0.5	2000
Overhead charges	Electricity supply (for tray drying, grinding of sugar)	17.2	12.3	6.1
	Cooking gas		2.25	62.5
	VAT charges (2%)			
TOTAL			14.92/100 ml	

Conclusion

The prevalence of metabolic related disorders due life lifestyle change and dietary pattern has increased the demand of nutritional interventions and healthy food products with high antioxidant content and presence of essential nutrients in abundance. The survey conducted in the current study in the Hoshiarpur and Jalandhar region of Punjab, identified prevalence of erratic eating habits and incidence of non-communicable diseases such as diabetes, obesity and cardiovascular disease and there is a need to address this issue with an

sustainable, attainable and economic solution. On the other hand mankind is guilty of producing large amount of agricultural organic waste that has this potential nutrients and active compounds that could be harnessed to address these problems. Corn silk is one such massive organic waste generated out of corn cultivation. It has various hypoglycaemic and hypertensive properties that could aid addressing these non-communicable diseases in the society.

The current work therefore, utilized local corn silk varieties (SWARNA, TATA 7009, KESHAR KING and G5417) to test them for their phytochemical potential. The study reveals a high degree of variability in its antioxidant content and activities. The varieties at different growth stages showed that corn silk at its immature stage has the highest content of polyphenol, flavonoid and ascorbic acid and consequently showed better ABTS, FRAP, and FRSA activities. It could therefore be assumed to provide optimal health benefits when compared to its matured counterpart. However, taking into consideration the economic point of view, where, the harvest at its physiological maturity form the majority byproduct of the corn harvest, it could be concluded that a significantly good amount of phytochemicals are present in it to justify its use in functional and nutraceutical food products. The study also shows high water absorption capacity, swelling capacity, emulsification activity, water solubility index and oil absorption capacity in dried corn silk making it suitable for the development of food mixes. This work highlights potential bioactive compounds and important techno-functional properties of corn silk that would seed future research for the development of value-added products using corn silk and enable its benefits to consumers. Current findings convey that the corn silk variety G5417 has a high nutritional bioactive potential owing to its high polyphenol, flavonoid, and ascorbate content, and its potent antioxidant activity, making this plant material highly valuable for use as a natural source of polyphenols, potentially contributing to the development of value-added, functional, and nutraceutical products. As evident through DSC studies, the prepared powder was found to be highly heat-stable. FTIR analysis confirms the components of corn silk powder, XRD analysis provides evidence of the amorphous nature of the powder, and acceptable color values make it an ideal contender to be used as a food ingredient.

In order to achieve its conversion to value added products, the selected variety (G5417) was subjected to further techno-functional analysis post drying. The drying kinetic study revealed that the most suitable temperature for drying of corn silk to achieve its

optimum drying was 50°C at tray drying conditions. Post drying the corn silk was powdered and the variability in its particle size was analysed and the result showed that particle size has a significant effect on the physical, techno-functional, and antioxidant properties of corn silk powder. The techno-functional properties are reduced owing to increased surface area per volume unit. The work demonstrated that corn silk possesses good physical, techno-functional, and antioxidant properties and could be processes into powdered form. Corn silk, therefore, could find suitable applications in the food systems as an ingredient for the development of nutraceutical and functional foods.

The developed corn silk powder was used as a basic ingredient to develop two products viz. instant mix and beverage. The corn silk based instant mix constituted of corn silk powder along with skimmed milk powder, sugar and xanthan gum showed that the optimum acceptable concentration of powdered corn silk in the product was 14.67 %. The product showed desirability of 0.925 and was acceptable on physico-chemical and sensory parameters. The optimization of corn silk based beverage revealed that aqueous extract of corn silk could be potentially used to develop ready to serve beverage along with fruit base. In the current study kinnow juice was used as the base along with sugar and xanthan gum as stabilizer. The study proposes use of 39.35 % of aqueous corn silk extract as optimum for the formulation of the beverage with a desirability of 0.932.

Both the optimized products were subjected to shelf life study under variable accelerated conditions and suitable packaging materials. The instant mix was packaged in LDPE, HDPE and Metalized polyester showed comparatively better results when packaged in metalized polyester pouches and stored at refrigerated temperature (10°C). The chemical reaction kinetics was conducted to predict the half life of the product revealed that amongst HMF, FFA and TBA, HMF is a better indicator of the shelf life of the instant mix product and the predicted half life of the product accounted to be 94.95 days. Whereas, the optimized beverage packaged in glass bottles and pasteurized (in bottle), stayed acceptable for 45 days based on microbial count at refrigerated conditions (10°C). The cost analysis of the both the products suggest a cost of production Rs 33 per 100 gm for the corn silk based instant mix and Rs. 30 for 200 ml of corn silk based RTS beverage. However, scaling up procedures and industrial production could significantly lower this cost.

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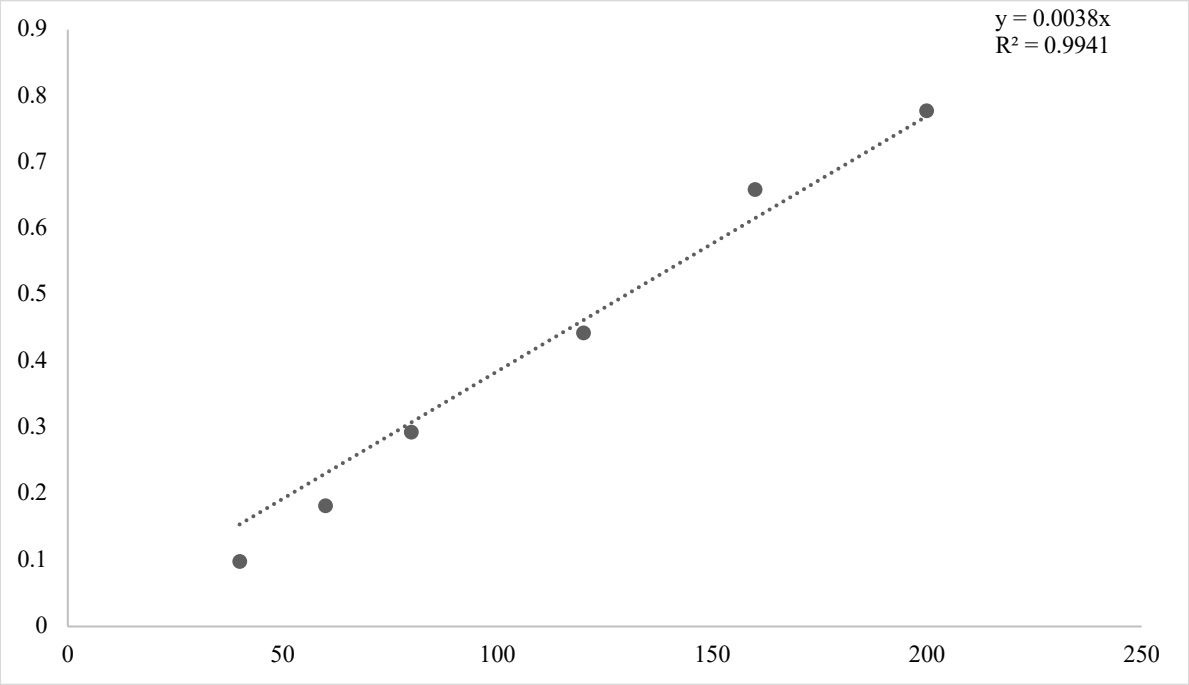
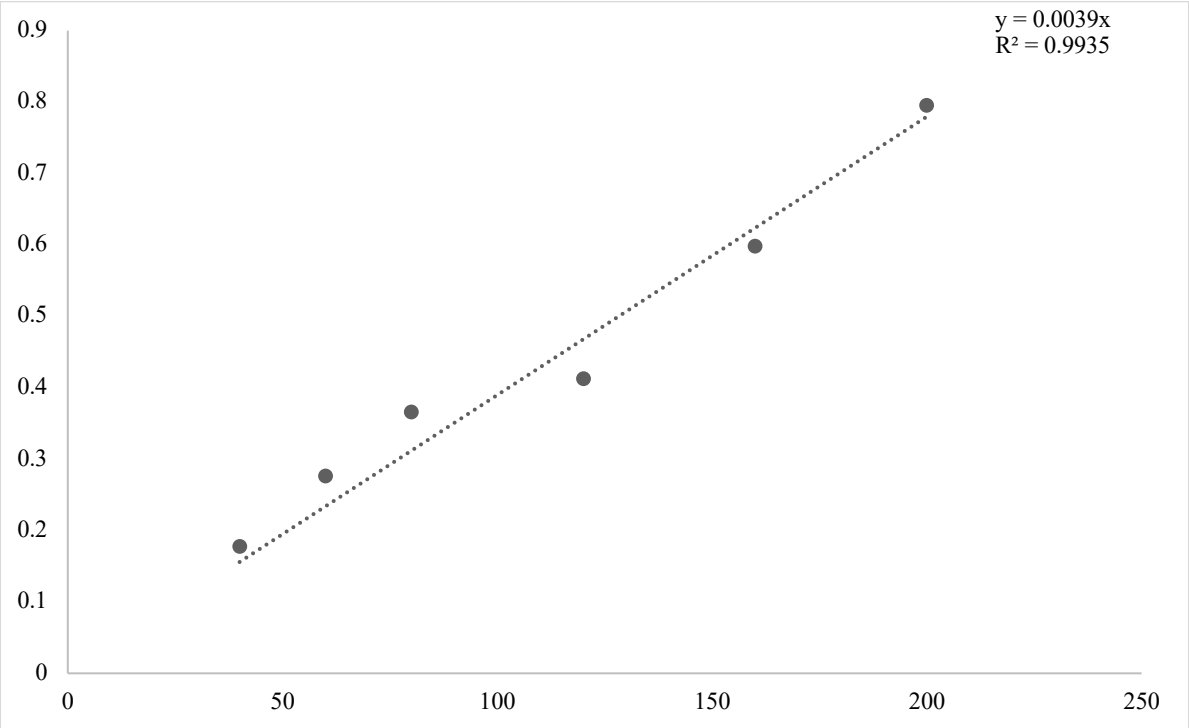
APPENDICES

STANDARD CURVE



Flavonoid standard graph



Polyphenol Standard Graph

Online Nutritional Survey link

https://docs.google.com/forms/d/e/1FAIpQLSfbehwj1Ep6duaD4mK2h_U89VlqlsRtSeO-lhiiDOSSZJbRjQ/viewform?usp=pp_url

NUTRITIONAL ASSESMENT QUESIONNAIRE

PART I

1. RESPONDANT'S INFORMATION:

a. First name _____

b. Last name _____

c. Guardian's name _____

d. Date of birth _____

e. Age: <25/ 25-35/ 35-45/ 45-55/>55 ()

f. Sex: Male/Female/Transgender

g. Occupation: Owner Cultivator/ Land Lord/ Landless Agricultural Labour/Tenant Cultivator/ Service/ Business/ others

h. Income group: LIG/MIG/HIG ()

i. Marital status: Married/ unmarried/ Widow/ Divorced/ Height

j. Weight _____

k. Address _____

l. Phone number _____

m. Physiological status: Non Pregnant/ Non Lactating/ Pregnant/ Lactating/ Breast fed/ Healthy/ Diseased

n. Physical activity:

a. Sedentary: Landlord / Service/ Housewife/ Clerk/ Teacher etc

b. Moderate: Agricultural Labour/ Other Labour/ Maid etc.

c. Heavy: Worker

o. Annual Income**:** (Personal/ Household)

p. Religion: Sikh/ Hindu/ Muslim/Christian/ others

q. Locality of the residence: i. Urban ii. Semi-urban iii. Rural iv. Slum

PART II

Read the questions carefully and put (✓) if yes

1. Do you do any physical activity where your body moves over long time periods?

a. Yes

b. No

c. Very often

d. Sometimes

If Yes, mention the name of physical activity name and time

2. How do you describe your weight?

a. Very underweight

b. Slightly underweight

c. About the right weight

d. Slightly overweight

e. Very overweight

3. Which of the following are you trying to do about your weight?

a. Stay the same weight

b. Gain weight

c. Lose weight

d. You are not trying anything about your weight

If yes, mention the method/way

4. How many fruit juices did you have in the past 7 days?

a. No drink

b. 1 to 3

c. 4 to 6

d. 7 to 9

e. 10 to 15

f. 16 to 20

g. 21 or more

5. How many fruit serving do you consume in the past 7 days?

a. No drink

b. 1 to 3

c. 4 to 6

d. 7 to 9

e. 10 to 15

f. 16 to 20

g. 21 or more

6. How many vegetable serving do you consume in the past 7 days?

a. No drink

b. 1 to 3

c. 4 to 6

d. 7 to 9

e. 10 to 15

f. 16 to 20

g. 21 or more

7. How many servings of soda/cold drinks do you consume in a past 7 days?

a. No drink

b. 1 to 3

c. 4 to 6

d. 7 to 9

e. 10 to 15

f. 16 to 20

g. 21 or more

8. How many glasses of milk do you consume in a past 7 days?

a. No drink

b. 1 to 3

c. 4 to 6

d. 7 to 9

e. 10 to 15

f. 16 to 20

g. 21 or more

9. Do you consume breakfast everyday?

a. yes

b. No

c. Very often

d. Do not know

If yes, mention the menu

10. How many meals (including snacks)you consume in a day?

a. 1 to 2

b. 2 to 5

c. 5 to 7

d. More than 7

11. At school/university/office/any other institute, you usually:

a. Bring your lunch from home

b. Buy meal from canteen

c. Buy fast food from canteen

d. Skip lunch

12. Would you consider any of the following people in your life over weight?

a. No

b. Grandfather / Mother (Maternal/Paternal)

c. Mom/Dad

d. Yourself

13. Which oil do you prefer for cooking?

a. Mustard oil

b. Vegetable oil

c. coconut oil

d. soya bean oil

14. Do you change oil for cooking monthly?

a. No

b. Yes

c. Sometimes

d. Occasionally

15. How often do you eat fast food?

a. Never

b. Few times in a week

c. Few times in a month

d. Everyday

16. If you eat from outside, what influences your decision to eat out most?

a. It is convenient for me

b. My parents do not cook food at home

c. It tastes better than anything

d. To satisfy my desire

17. How many liters do you drink water in a day?

a. Below 1 Lt.

b. 1 Lt.

c. 2 Lt.

d. Above 2 Lt.

18. Do you drink alcohol?

a. No

b. Yes

c. Occasionally

d. Everyday

19. Do you smoke?

a. No

b. Yes

c. Very rare

d. Often

20. How often do you have bowel moments?

a. Once in a day

b. Twice in a day

c. Once in two days

d. None of above

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LIST OF PUBLICATIONS

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1.	Phytochemical Analysis and Characterization of Corn Silk (*Zea mays*, G5417) Jyoti Singh [1], Baskaran Stephen Inbaraj [2], Sawinder Kaur [1,*], Prasad Rasane [1] and Vikas Nanda 3	*Agronomy*	23 March 2022	2022 (12) https://doi.org/ 10.3390/ agronomy 12040777	Scopus and Web of Science
2.	Comparative analysis of antioxidant potential and techno-functional properties of selected corn silk varieties at different developmental stages Jyoti Singh[1] · Prasad Rasane[1] · Sawinder Kaur[1] · Vikas Nanda[2]	Journal of Food Measurement and Characterization	01 April 2022	https://doi.org/10 .1007/s11694- 022-01382-6	Scopus and Web of Science
3.	Bioactive compounds of corn silk and their role in management of glycaemic response Jyoti Singh[1] • Prasad Rasane[1] • Vikas Nanda[2] • Sawinder Kaur[1]	Journal of Food Science and Technology	10 April 2022	https://doi.org/10 .1007/s13197- 022-05442-z	Scopus and Web of Science

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Article

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

Jyoti Singh [1], Baskaran Stephen Inbaraj [2], Sawinder Kaur [1,*], Prasad Rasane [1] and Vikas Nanda [3]

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

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

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1. Introduction

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

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https://doi.org/10.1007/s11694-022-01382-6

ORIGINAL PAPER

Comparative analysis of antioxidant potential and techno-functional properties of selected corn silk varieties at different developmental stages

Jyoti Singh[1] · Prasad Rasane[1] · Sawinder Kaur[1] · Vikas Nanda[2]

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Abstract

This study evaluates the antioxidant potential of different varieties of corn silk at five developmental stages. Corn silk samples of five major varieties (SWARNA, TATA7009, SHUBHAM EARLY, KESHAR KING, and G5417) grown in Punjab, India, were analyzed for their phytochemical potential and techno-functional properties at five growth stages including stage 1 (immaturity), stage 2, stage 3, stage 4 and stage 5 (maturity). Antioxidant content and activity of these varieties at their physiological stages were analyzed. G5417 showed the highest activity for ABTS, FRAP, FRSA at stage 1 with the inhibitory activity of 84.16 ± 0.55 TEAC (mg/gdw), 123.2 ± 0.56%, and 65.33 ± 1.21%, respectively. The antioxidant content including total phenols, flavonoids, and ascorbic acid showed a significant decrease ($p < 0.05$) from the immature to mature stage. The lowest bulk density was observed in G5417 stage 5 (0.314 ± 0.006 g/cm^3), the Carr's index for G5417 stage 1, 4, and 5 were less than 15 which shows good flowability, the angle of repose for G5417 was 32.93 ± 1.07° which showed the good flowability. The water solubility index was observed highest for G5417 stage 1, 24.83 ± 0.700%. The G5417 stage 5 showed the highest stability of emulsion i.e. 37.91 ± 0.823%. The results confirm that the juvenile stage of G5417 (stage 1) showed the highest antioxidant content and activity and techno-functional properties. This makes it most likely a selection for the development of value-added products.

Keywords Corn silk · Phytochemicals · Nutraceuticals · Developmental stages · Antioxidant · Techno-functional

Introduction

Corn silk is the stigmata of the female maize flower of *Zea mays* L. of the *Gramineae* family, commonly cultivated in warmer climates. These are soft threads of 10–20 cm in length, are usually discarded as waste [1]. However owing to its phytochemical constituents, corn silk has potential to be used for the treatment of kidney stones, nephritis, cystitis, diabetes, celiac disease, jaundice, measles, hematuria and prostatitis [2]. Additionally, it has proven pharmacological applications in reducing blood glucose, blood pressure, anti-tumour, delaying senility and anti-oxidation [3, 4]. The major phytochemicals present in corn silk include flavonoids, saponins, alkaloids, polypentose, and some volatile oils [5]. The presence of polyphenolic compounds in corn silk affirms its medicinal value. Corn silk is found in abundance as corn is a major crop around the world, thus, could be used as an alternative dietary supplement and as a functional food additive. Corn silk has various growth stages and its reproductive cycle could be classified from R1 to R6 stages where silking emerges at the R1 stage and captures the pollen dispersed by the tassel and further fertilizes ovules on the cob within 24 h which forms the kernel. The physiological maturity (R6) stage arrives after 55–65 days of silking when the kernel dry weight has reached its maximum (30–35%) [6]. Numerous studies on corn silk have focused on its antioxidant content and antioxidant activities [7, 8] and extraction of polysaccharides from corn silk [9]. Few studies compare these antioxidants and their activities with prominent medicinal herbs and have proven the potential of corn silk as a potent functional ingredient [10]. These studies

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REVIEW ARTICLE

Bioactive compounds of corn silk and their role in management of glycaemic response

Jyoti Singh[1] · Prasad Rasane[1] · Vikas Nanda[2] · Sawinder Kaur[1]

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Abstract Management of glycaemic response is perhaps the most critical part of antidiabetic therapy. Hypoglycaemia is an avoidable complication caused by conventional drugs used in the treatment of diabetes. It triggers commonly during the intensification of anti-hyperglycemic therapy used to render glycemic control in diabetic patients. The commercial oral hypoglycaemic drugs, insulin, herbal medicines and plant extracts are therefore used as a part of the treatment of diabetes. The demand for treating diabetes, through herbal and plant resources is due to their lesser adverse reactions and better phytochemical benefits. Corn silk has been shown to have anti-allergic, anti-inflammatory, and anti-hypertensive effects when extracted in various solvents. Corn silk has medicinal characteristics and has long been used as a traditional medicine in many nations, although the mechanism of action is unknown. The hypoglycaemic effects of corn silk are investigated in this review. The phytochemical components present in corn silk-like flavonoids, phenolics, terpenoids, tannins, sterols, and alkaloids are phytochemical components that have hypoglycemic activity and a mechanism for lowering blood glucose levels. There is a lack of a homogenized database on the hypoglycemic properties of corn silk thus the present review attempts to critically analyse it and provide specific recommendations of its doses.

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Keywords Hypoglycaemia · Corn silk · Phytochemicals · Toxicity · Recommendations

Abbreviations

IDF	International diabetes federation
MEA	Middle east & Africa
APEJ	Asia pacific excluding Japan
GAE	Gallic acid equivalent
ABTS	(2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)
CS	Corn silk
NC	Non-diabetic control
DC	Diabetic control
LD	Low dose
HD	High dose
MD	Medium dose
PD	Dimethylbiguanide
GLUT4	Glucose transporter type 4
PECS	Petroleum ether corn silk
CECS	Chloroform corn silk
MECS	Methanol corn silk
AGE	Advanced glycation end PRODUCTS
HFD-STZ	High fat diet streptozotocin
POCS	Corn silk polysaccharides
DPPH	2,2-Diphenyl-1-picrylhydrazyl.
YMS-EA	Ethyl acetate fraction
ROS	Reactive oxygen species
PDX-1	Pancreatic and duodenal homeobox
PCS	Petroleum ether fraction
BCS	*n*-Butanol fraction
TPC	Total phenolic content
GC-MS	Gas chromatography mass spectrometry
PPAR	Peroxisome proliferator-activated receptors
NOAEL	No-observed-adverse-effect-level
AST	Aspartate aminotransferase

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LIST OF CONFERENCES

Sr. No.	Name of the conference	Organised by	Title of oral/poster presentation	Date of conference
1.	National Women's Food Science & Technology Conference	Indian Institute of Food Processing Technology	Comparative analysis of antioxidant potential of corn silk varieties at various developmental stages-POSTER	08/03/2021
2.	International Conference On Emerging Techniques in Food Processing (ETFP)	Ghani Khan Choudhury Institute of Engineering and Technology Malda	Corn silk a potential source of valuable nutrients: a comparative account of varieties and silk stages-ORAL	25/03/2021
3.	INTERNATIONAL SCIENCE AND INNOVATION CONGRESS	INTERNATIONAL SCIENCE AND ART RESEARCH CENTREE	Effect Of Particle Size On Techno-Functional And Antioxidant Properties of Corn Silk Powder	22/05/2021
4.	Food Biotechnology: Trends and Challenges	ITLS Academy, Lucknow	Effect of particle size on physico-chemical and functional properties of corn silk powder	21/06/2021


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