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Kapil Kumar
Department of Agricultural Engineering, College of Post-Harvest Technology and Food Processing, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Jaivir Singh
Department of Agricultural Engineering, College of Technology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

B. R. Singh
Department of Agricultural Engineering, College of Technology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Suresh Chandra
Department of Agricultural Engineering, College of Post-Harvest Technology and Food Processing, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Neelash Chauhan
Department of Agricultural Engineering, College of Post-Harvest Technology and Food Processing, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

M.K. Yadav
Department of Agricultural Biotechnology, College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Pankaj Kumar
Department of Agricultural Engineering, College of Technology Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Corresponding Author:
Kapil Kumar
Department of Agricultural Engineering, College of Post-Harvest Technology and Food Processing, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Consumption and processing patterns of maize (*Zea mays*): A review

Kapil Kumar, Jaivir Singh, BR Singh, Suresh Chandra, Neelash Chauhan, MK Yadav and Pankaj Kumar

Abstract
Corn or Maize (*Zea mays*) is the most important cereal in the world, its protein name is "Zein" It is a very good source of nutritional components and photochemical compounds. It is a source of more than 3,500 products including specialized Maize like QPM (Quality Protein Maize), contains nearly twice as much lysine and tryptophan, amino acids that are essential for human consumptions. At present, maize is consumed in poultry feed (47%), cattle feed (13%), starch (14%) and processed food (7%), these sectors utilizes 81% of total maize production in India. Many traditional and industrial maize processing methods exist. Industrial processing includes wet and dry milling to produce a wide variety of products. Now days, corn flour and corn starch is widely used in food industry mainly for bakery products.

Keywords: Maize, corn, starch, QPM, zein and feed

Introduction
Maize (Zea mays) is an important crop which is grown annually in world and it belongs to the family Poaceae (Abdel-Aal *et al*., 2006) [1]. The word Zea is a Greek language word which means "sustaining life" and Mays is Taino language word which means "life giver". It is the product of human selection over centuries, which made it have unique features such as a big, massive cob with hundreds of kernels (Nelson *et al*., 2017) [32]. Corn is one of the sources of carbohydrates that are widely used as raw material in the feed and food industries, it is also widely used as a staple food in several regions in Indonesia (Hidayah *et al*., 2019) [15]. Maize is a major source of starch. Maize flour is a major ingredient in home cooking and in many industrialized food products. Maize is also a major source of cooking oil (corn oil) and of maize gluten (Thompson *et al.*, 2010) [23]. Maize is widely cultivated throughout the world, and a greater weight of maize is produced each year than any other grain. Nowadays, corn continues to be one of the most important grain crops in the world, and corn is a central part of the diet of many people. In some cases, corn is eaten as a side dish, and in some places like Mexico, Central America, Colombia, and some African countries, corn makes up the main component of their cuisine (Nelson *et al*., 2017) [32].The demand is constantly increasing for food, fuel, and feed, and corn is a common crop grown both in the US and globally that is often used to meet these demands (Fromme *et al*., 2018) [3]. It is grown over an area of 132 million hectare and second highest produced cereal grain crop of the world with the total annual production of 570 million tons (Watson and Ramstad, 1987) [26]. India has an average area of about 5.99 million hectares under coarse cereals (i.e. sorghum, ragi, jowar maize and bajra) cultivation. In India, the major maize growing states are Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Punjab, Haryana, Maharashtra, Andhra Pradesh, Himachal Pradesh, West Bengal, Karnataka, and Jammu and Kashmir, jointly accounting for over 95% of the national maize production (Milind and Isha, 2013) [14].
Maize alone accounted for much larger production of 15.35 million tonnes in 2020-21. Uttar Pradesh, Madhya Pradesh, Bihar, Rajasthan, Punjab are the leading states in India growing maize on large scale. Jammu and Kashmir, Andhra Pradesh, Gujarat and Himachal Pradesh also grow considerable amount of maize.
Maize (both yellow and white) are produced in abundance in India but is not being utilized properly and most of the produce is used for cattle feed, especially in Bihar. There is a need of developing a ready to eat food from the yellow corn, which would not only help to utilize this available maize but also help in solving the problem of food shortage (Thompson *et al.* 2010) [23].

Maize is a coarse grain and after initial resistance, it is now being accepted as staple diet and its demand is increasing, consumption of maize in the form of various types of traditional foods such as bread, porridge, steamed products, beverages and snacks. In India, maize grains are roasted and ground to prepare a traditional food *Sattu* (roasted grain flour) which is consumed as a breakfast item by mixing either water or milk with salt or sugar (Nelson *et al*., 2017) [32]. Maize is also ground whole to make flour and is consumed in the form of chapatti (unleavened Indian bread) at rural level. Grits were first produced by Native Americans and quickly became an important part of early Southern agriculture. The word "grits" comes from the old English term "grytt" meaning "bran" and the term "greot" meaning "something ground (Wolf *et al*., 1952) [27].

Laria *et al*.(2005) [29] studied on the kinetics of the overall water uptake by three corn varieties (Cacahuazintle corn, yellow dent corn and chalco corn) soaked in water and in alkaline solution with two different concentrations of $Ca(OH)_2$ results showed that the uptake of water takes place in different kinetic stages of reaction and diffusion process. Each stage was correlated with a specific structural change that occurs in the pericarp, in the aleurone layer and in the outermost structure of the endosperm. Roasting and puffing of cereals and pulses to produce snack foods are common in India at the rural level. Sand roasting by dry conduction heating is capable of imparting proper gelatinization to grains. It is a dry conduction heating and cooking of food grains without causing any appreciable reduction in various amino acids (Kumar *et al*. 2018) [12]. Proper roasting and grinding processes render the grain digestible without much loss of nutritious constituents.

Dry conduction heating to impart desired degree of starch gelatinization in maize grains requires initial pre-conditioning of grains to an optimum level of moisture content and roasting under controlled conditions of sand temperature and dry heating time. Subsequent milling of the pre-cooked grains into grits with specific particle size distribution was developed ready to eat food (Thompson *et al.*, 2010) [23]. There are two distinct processes for processing corn, wet-milling and dry-milling and each process generates unique co-products. Dry milling aims at separation of anatomical parts of grains as cleanly as possible, whereas wet milling attempts to make cleaner separation of bran and germ from the endosperm (Zhang *et al.* 2021) [25]. In addition, it also separates the endosperm into its chemical constituents of starch and protein. A number of products resulting from wet and dry-milling of maize are starch, dextrin, dextrose, sorbitol, high-fructose syrup, malto dextrine, germ oil, germ meal, maize grits, flour and fiber.

In the dry milling processes, a clear separation of hull from grits and germ is always desirable, and depending on the efficiency of the milling process, small quantities of hull are found adhering to the grits fractions (Zhang *et al.* 2021) [25]. The close adherence of the germ to the germ to the endosperm creates separation problem. Since his hull, the endosperm and the germ are structurally distinct; their tissues are not continuous with each other thus facilitating their separation from each other during processing. In dry milling of maize, it is desirable to obtain the grits of maximum size, generally larger than 4 mm, as large size grits are preferred for the manufacturing of flakes (Brekke, 1970) [30]. The procedure of conditioning and tempering of kernels vary considerably depending upon characteristics of the maize being milled, the yield and the types of products desired. Several studies have shown that the temperature, kernel structure and initial moisture content affect the rate of absorption as well as distribution of moisture (Stenvert and Kingwood, 1977; Abdelrahman and Farrell, 1981) [28].

Table1: Corn Production in India

Year	Production (MT)	Growth Rate
2016	25900	14.77%
2017	28753	11.02%
2018	27715	-3.61%
2019	28766	3.79%
2020	31210	9.54%
2021	30000	-4.7%

***Source*:** U.S. Department of Agriculture, 2022

Types of Maize

Different types of maize are grown throughout the world, with one important difference being color. (Ranum Peter *et al.*, 2014) [19].

Dent corn (*Zea mays var identata sturt*): It also known as field corn, dent formation on the top of the kernel having yellow and white colour. The depression or dent in the corn of the seed in the result of rapid drying and shrinkage of the central soft starch. It is primarily used for animal feed, processed food, and ethanol. (Parle Milind *et al.*, 2013) [14].

Flint corn (*Zea mays var idurate sturt*): It is widely grown and cultivated in India. Endosperm of kernel is soft and starchy in the center and completely enclosed by a very hard outer layer. The kernel is rounded on top. The colour may be white or yellow. It can also be "popped" when heated, but often the kernels will open rather than explode. The hardness of the kernel allows these varieties to store very well and be less susceptible to insect and rodent predation. (Ranum Peter *et al.*, 2014) [19].

Popcorn (*Zea mays everta Sturt*): Size of kernel is small but the endosperm is hard. The popcorn kernel has a hard yet brittle, slightly translucent that is glass-like. When they are heated, the pressure build up within the kernel suddenly results in an explosion and the grain is turn out and grains are used for human consumption and is the basis of popcorn confectionery. (Parle Milind *et al.*, 2013) [14].

Flour corn (*Zea mays var anylacea sturt*): It is mainly grown and cultivated in USA and South Africa. It possesses a soft endosperm. Kernels are soft and though all coloured corns are grown but white and blue are the most common. White it is sweeter and tender than flint type; it is not as sweet as sweet corn types. (Ranum Peter *et al.*, 2014) [19].

Sweet corn (*Zea mays var saceharata sturt*): It is mainly grown and cultivated in North half of the USA. The sugar and starch makes the major component of the endosperm that results in sweetish taste of the kernels before they attain the maturity, the kernels becomes wrinkled. The cobs are picked up green for canning and table purpose. Sweet corn is the ideal corn to be eaten fresh in its green or milk stage, but it can also be roasted and dries. (Parle Milind *et al.*, 2013) [14].

Pod corn (*Zea mays var tunicate kulesh*): Each kernel is enclosed in long, membranous husks known as glumes. It is a primitive type of corn and hence of no importance. (Ranum Peter *et al.*, 2014) [19].

Waxy corn (*Zea mays var certain kulesh*): The endosperm of the kernel when cut or broken gives a waxy appearance. It produces the starch similar to tapioca starch for making adhesive for articles. (Parle Milind *et al.*, 2013) [14].

Baby corn (*Zea mays*)
Grown for young babies (cobs) to be used for vegetable soup and salad. Boby corn rich in minerals and vitamins.

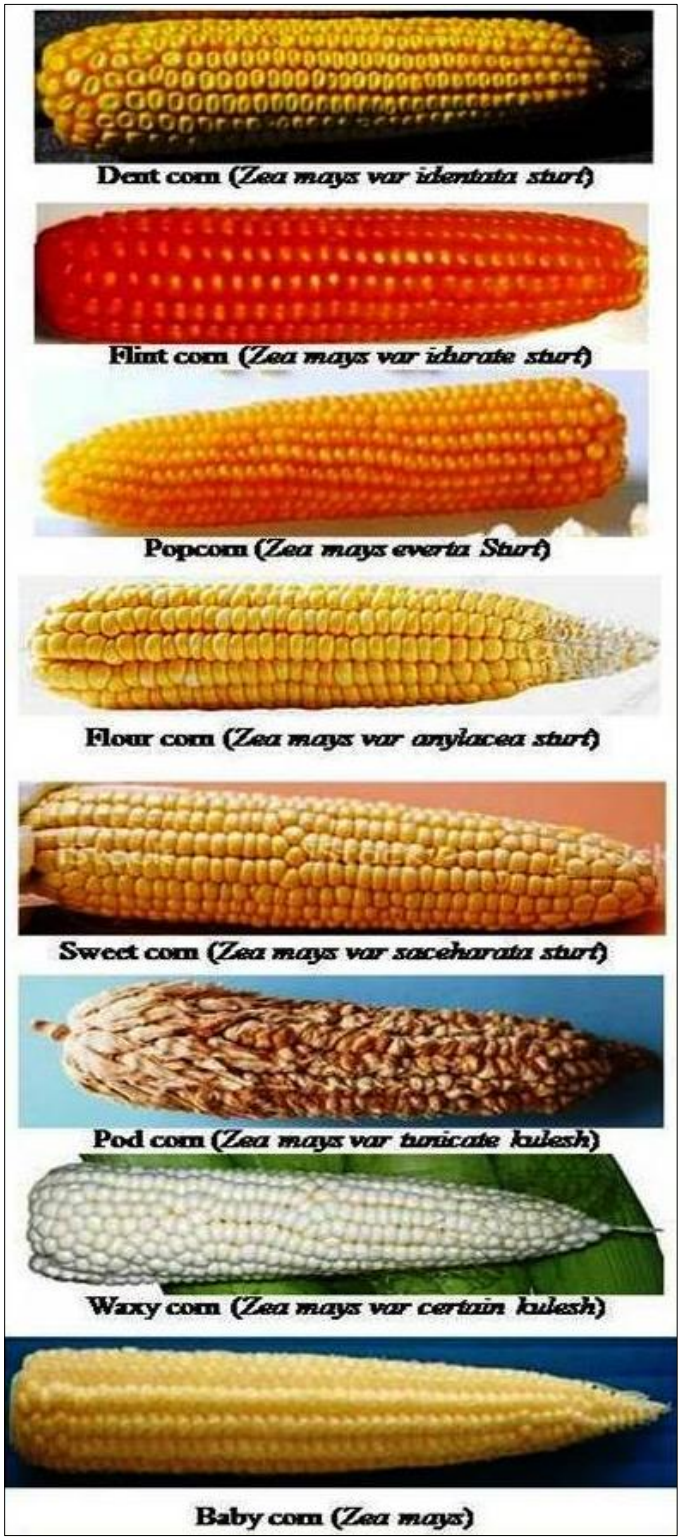
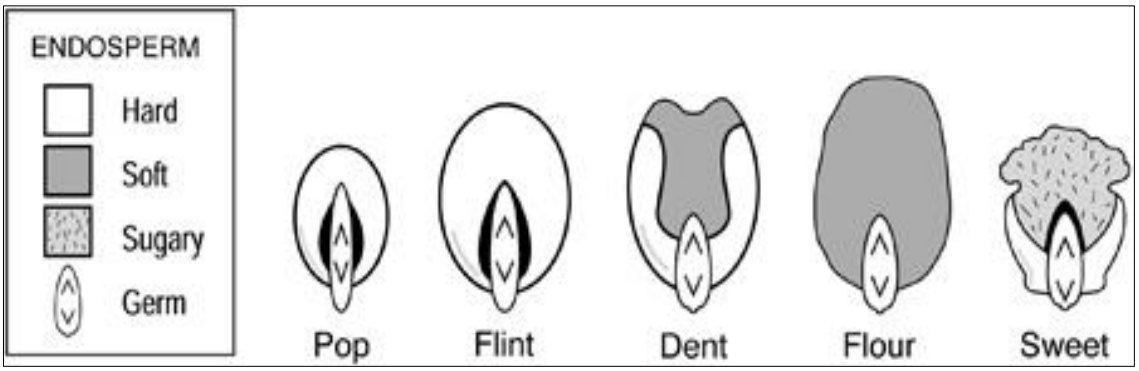


Fig 1: Classification of corn



***Source*:** https://pubs.nmsu.edu/_h/H232/index.html)

Fig 2: Endosperm distribution in five types of corn kernels

Nutritional Composition in Maize

Maize kernel is an edible and nutritive part of the plant, major protein of maize known as zeins. The zein proteins located in endosperm are very low in lysine and tryptophan contents (Kaul *et al*., 2019) [8].

Table 2: Percentage proximate compositions of different varieties of maize

Contents	Sweet Corn	Pop Corn	White Corn	Yellow Corn
Crude protein, %	8.7	7.88	7.0	7.88
Ash, %	0.5	0.5	1.0	0.5
Crude fiber, %	8.0	5.5	6.5	2.5
Crude fat, %	0.5	1.0	1.5	----
Moisture content, %	13.0	11.0	8.0	12.5
Carbohydrate, %	69.25	74.12	76.0	76.0

(Source: Nweke and Nwalo, 2010)[16].

It is used as human food and also as feed for animals. It provides nutrition to both humans (33.3%) and animals (66.6%). The principle constituents of whole-maize kernel are protein, lipid and carbohydrate. Small quantities of minerals and miscellaneous organic substances including vitamins are also present. (Watson and Ramstad 1987) [26]

have reported the constituents as protein, oil, sugars, starch, and ash in the range of 8.1 to 13.6%, 3.9 to 5.8%, 1.61 to 2.22%, 66.8 to 74.2% and 1.27 to 1.58% respectively.

Table 3: Weight and average composition of maize kernel (Watson and Ramstad 1987) [26].

Part	% dry wt. of whole kernel	Composition of maize kernel parts (%d. b)				
		Starch	Fat	Protein	Ash	Sugar
Endosperm	82.9	87.6	0.8	8.0	0.3	0.6
Germ	11.1	8.3	33.2	18.4	10.5	10.8
Pericarp	5.3	7.3	1.0	3.7	0.8	0.3
Tip cap	0.8	0.8	5.3	3.8	9.1	1.6
Whole kernels	100	73.4	4.4	9.1	1.4	1.9

***Source*:** Watson and Ramstad 1987 [26].

Maize processing and value addition in India

Maize is used for both human consumption as well as animal feed, and other corn products like starch, grits, flour, meal, and other products which serves as a raw material to major snack industry, which the world use to provide wholesome food and a better life to millions of people around the globe. There are >3000 products in USA while in India only over 1000 products are being made using the maize. In India, a high growth is expected in various linked sector utilizing maize.

Maize can be used for human consumption, animal feed, and industrial purposes. Many traditional and industrial maize processing methods exist. Industrial processing includes wet and dry milling to produce a wide variety of products (E & Okoruwa, 1997) [17].

Wet milling

The principal food products from the wet milling industry are corn starch, corn syrup, high fructose syrup, dextrose and corn oil. By-products are used for livestock feed and other applications. Corn starch is used primarily to thicken and stabilize other ingredients (E, A., & Okoruwa.1997) [17].

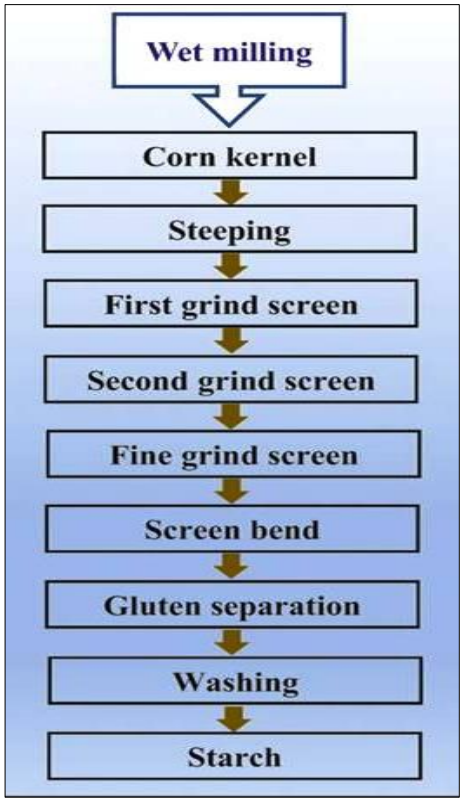


Fig 3: The wet milling processes (Zhang *et al.*, 2021) [25].

Dry milling

Primary products derived from dry milling of maize are maize meal, flour and maize grits. Other products are oil and by-products for animal feed. The endosperm fractions are characterized by their particulate dimensions and sizes which affect composition and utilization (Okoruwa 1997) [17].

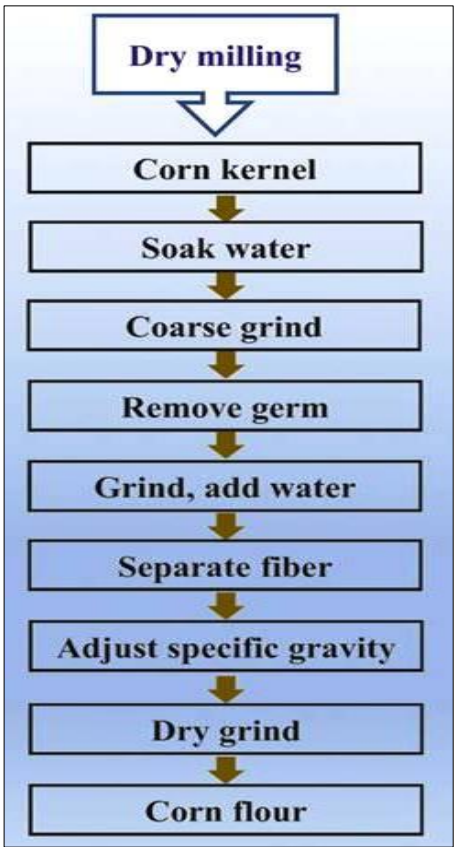


Fig 4: The dry milling processes (Zhang *et al.*, 2021) [25].

Application of corn

Historically maize was used more for local consumption. Concurrently, the use of maize in poultry feed and industrial applications have gone up (Kaul *et al.*, 2019) [8]. Maize is an integral component in making both food as well as non-food industrial products which have good commercial value. Maize is preferred staple food for 900 million poor, 120 - 140 million poor farm families, and about one- third of all malnourished children globally (Murdia *et al.*, 2016) [30]. It is understood as the staple food in many countries (Dupont *et al.*, 1990) [4]. These are used in many countries as to treat kidney problems, jaundice and fluids retentions (Chew *et al.*, 1996) [2].

Application of corn starch: are in Food Industry are canned and Powder soups, instant desserts, custard powder, Ice cream, sauces and gravies, bakery, snacks, baby foods and Baking powder, flavor, encapsulation; As a thickener, As a binder, As a Filler and As a stabilizer.

It is used in various food industries as additive or to make various types of syrups, More than 90% of the commercial starch is used from maize due to the low cost of the grain (Saldivar, 2016) [21].

Corn starch is used in a wide range of products and applications. In recent years, the use of nanotechnology for applications in the food industry has become more apparent; it has been used for protecting against biological and chemical deterioration, increasing bioavailability, and enhancing physical properties, among other functions (Palanisamy *et al.*, 2020) [18].

Starch is an edible polymer derived from plant basis. It is commonly used in food industry as it offers good stabilising effect. For instance, its capability to be easily modified and coming from low cost source making starch as one of the most important ingredient in food preparation. There are currently varieties of commercially modified starch available in Malaysian market. For example, potato, corn, wheat and tapioca starch are presently on the top list (Yazid *et al.*, 2018) [24].

Applications of the corn flour: are in Bakery Dusting, Breads and Batters, Pancake and Waffle Mixes, Beverages, Alcohol, Confectionery Toppings, Confections, Baby Foods and Snacks.

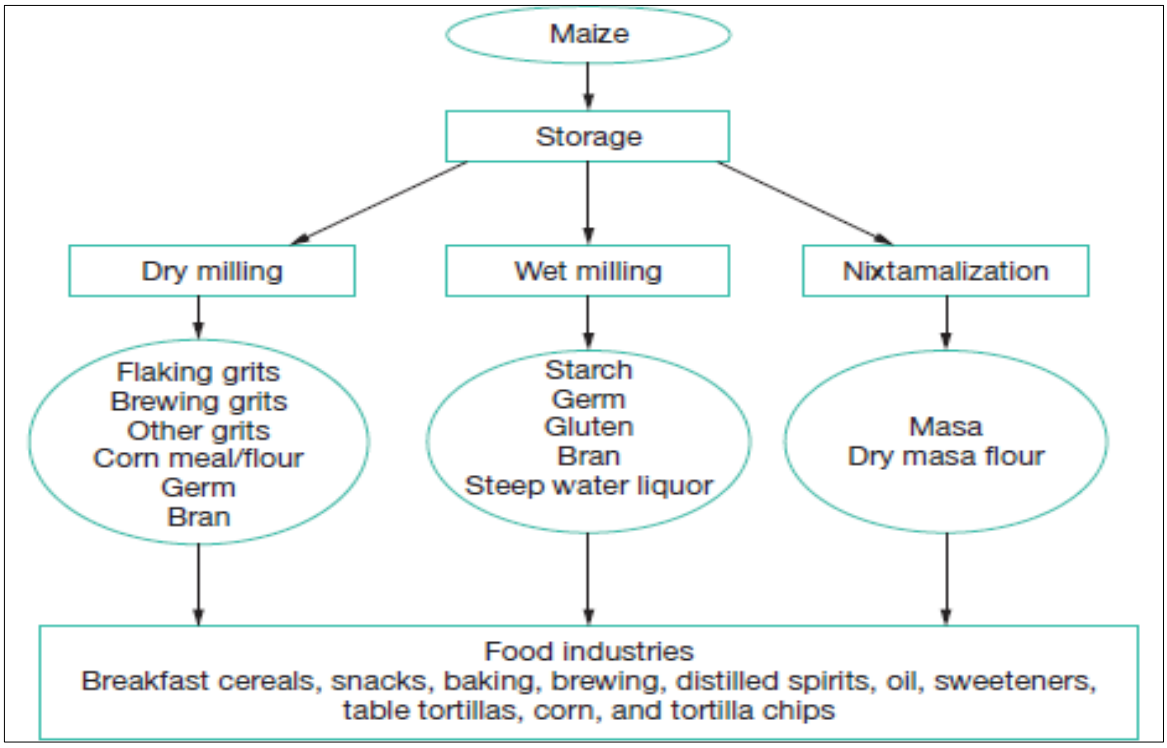


Fig 5: Flowchart of the postharvest management and processing of maize for human foods. (Saldivar, 2016) [21].

Value added product of Maize in India

- Recipes for Eastern Region: Chatpati, maize roll, Chutney, Hilsa corn chat, Pakodi, Jalebi etc.
- Recipes for Northern Region: Sweet Dalia, Khichari, Kheer, weaning mixture, laddoo, sev, cheela, dhokla, pasta, fryums and poori.
- Recipes for Western region: dhokla, Bati, Rab, Papadi, Paratha, Gatta, Pakodi, Halwa, sev and muffins.
- Recipes for Southern region: (Malt mix, Poustic mix, Chakkuli, sweet and salt biscuits, chutney powder, health mix, idli, dosa Sheera and besan laddo.

Application of Quality Protein Maize (QPM)

It is also used in skin problem and cancers (Dupont *et al*., 1990) [4]. Corn contains significant amounts of bioactive compounds providing desirable health benefits beyond its role as a major source of food (Sheng *et al*., 2018) [22].Maize is generally used for animal feed. It is widely processed into various types of products such as cornmeal, grits, starch, flour, tortillas, snacks, and breakfast cereals. Maize flour is used to make chapatis or flat breads which are eaten mainly in a few Northern states of India (Mehta & Dias, 1999) [13] Corn grit is one of the corn products can be used as staple food for rice substitution in order to support food diversification program (Hidayah *et al*., 2019) [15]. In India around 6.5 million tons (roughly 50% of total consumption) goes for feed use, primarily for poultry feed. Another 1 million tons of corn is used by the starch industry and also maize is utilized to make *chapatti* (unleavened Indian bread) at rural level. Maize grains also roasted and ground to prepare a traditional food *sattu* (roasted corn grain flour) which is consumed as breakfast by mixing either water or milk with salt or sugar.Popcorn is the most important, popular commercial snack produced worldwide from corn. It is available in small packs, coated with various ingredients such as hydrogenated oil, sugar syrup, salt, β-carotene, favors, etc. for improving the sensory quality (Kora, 2019) [11]. It is widely used in malting, brewing, baking and the production of feed and alcohol. The abundance of antioxidants in barley aids in food preservation via lipid peroxidation inhibition (Rashid *et al*. 2015; Sharma) [20]. The sand-roasted corn on the cob known as bhutta is one of the most common, favorite, affordable, healthy street side snack in India (Kora, 2019) [11]. It also contains cryptoxanthin, a natural carotenoid pigment which has the potential to reduce lung cancer (Murdia *et al*. 2016) [30]. Corn flour is used in the place of flour of wheat for the making of corn bread in many other baked products. (Elham *et al*. 2019)

Conclusions

1. Various modifications of corn starch can be made to obtain the desired results in foods. Baking powder, prepared mixes, candies, baking goods, and puddings require starch products. Paper and textile industries utilize starch.
2. The greatest use of corn syrup is in confections, followed by bakery and dairy products.
3. High fructose corn syrup is utilized in a wide variety of food systems such as confections, baked foods, table syrup, fountain syrups, sweet beverages, catsup, pickles and other condiments.
4. The largest single food use for dextrose is in baked goods where it serves as a yeast nutrient, provides some sweetness and causes crust browning.
5. Other major uses for dextrose are in confectionery manufacturing, canning and frozen packs, catsup, jams, jellies, soft drinks, wines and malt liquors.
6. Corn oil is consumed as salad or cooking oil and in margarine. Corn oil is also used as a carrier for vitamins and medicine.
7. Grit fractions (0.2-0.6 mm) are used for many foods domestically and commercially. Examples are boiled hominy grits, corn flakes, and Brewer's grits are used in beer production.
8. Maize meal (0.6-0.2 mm) is used for meal mixes, maize bread, maize muffins and some extruded maize snack products.
9. Maize flour (« 0.2 mm) is particularly valuable as an ingredient of pancake mixes, baby foods, cookies, biscuits, ice cream cones, ready-to-eat cereals, batter breading mixes, and binders for loaf-type sandwich meats.

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