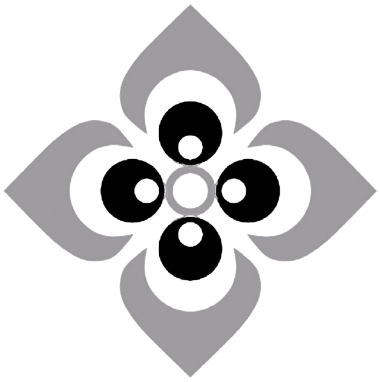

# Consortium for Educational Communication

Module
on

## Maize production, processing and products

**By**

**Dr Anu Appaiah K A**
**Principal Scientist**

**Microbiology and Fermentation Technology**

**CSIR-Central Food Technological Research Institute (CFTRI),**

**Mysuru -570020, Karnataka, India**

## Text

### Introduction:

Maize or corn (Zea mays L.) is the third most important crop worldwide with a total production of 576 million metric tons in 1997-1998. Nearly 41% of the total production is in the United States. Maize is by far the largest component of global coarse-grain trade. Most of the maize that is traded is used for feed; smaller amounts are traded for industrial and food uses. Other major producers include China, Brazil, Mexico, Argentina, Central America and many African countries. Maize is grown well in hot, humid areas of the world and responds to fertilizer and moisture by producing large quantities of grain. However, it does not grow as well in hot, dry areas of the world where sorghum (*Sorghum bicolor*) is grown. Sorghum is similar to Maize in many respects and can also be used for snack food production.

Currently, the United States, Brazil, Mexico, Argentina, India, France, Indonesia, South Africa, and Italy produce 79% of the world's maize production. Between 1990 and 2011, the number of millions of maize hectares harvested ranged from 129.1 to 163.9. During the same period the production of maize in metric tons per hectare increased from 3.7 to 5.1, and total maize production increased from 482.0 to 832.5 million metric tons. Worldwide, 60–70% of maize production is used domestically as livestock feed, and the remaining 30–40% is used for production of items for human consumption. Industries in need of starch include textile, pharmaceuticals, food and beverages, paper and packaging, manufacturing and chemicals.

Japan has negligible maize production and has consistently been the top maize importer in the world. 90 per cent of Japan's maize requirements comes from USA and another 8-9 per cent from Argentina and Brazil. China and Mexico, though being amongst the top maize producing nations, are also top importers.

Maize is processed into a wide variety of products and traditional foods, i.e., porridges, roti, tortillas, are, polenta and many snacks. Utilization of Maize for food and industrial products has increased rapidly using nearly 20% of the annual Maize of 225 million metric tons with the balance going to animal feed. The largest users are wet millers, who produce sweeteners, glucose, starches, starch derivatives, alcohol, oil and other

products, with considerable growth recently in sweeteners and alcohol.

**Types of Maize:**

Flint, dent, floury, sweet or sugary, popcorn, waxy, multi coloured and other types of Maize are grown throughout world. The colour, size, kernel shape and other attributes varying significantly. The production of yellow Maize predominates in the United States, Brazil and China. However, white Maize is preferred in Africa, Central America and Northern South America because of its sweeter, more flavour products. Mexican-type foods (tortilla) in the United States are increasingly made with white Maize.

Maize is grown throughout the year in India. It is predominantly a kharif crop with 85 per cent of the area under cultivation in the season. Maize is the third most important cereal crop in India after rice and wheat. It accounts for approximately 9 per cent of total food grain production in the country. The production of maize has been increasing in the in our county recently (**Table 1 & 2).** These include white, waxy, high-oil, hard-endosperm, nutritionally dense, and low-temperature dried maize. These varieties that have improved properties over commodity maize as in India maize is considered as a food crop. Where as in developed countries maize is commercially grown for industrial use. In India, the yield is half of the global average. Constraints for low productivity include the following reasons:

• Climatic conditions resulting in drought/excess water associated with increased pressure of diseases/ pests

• Cultivation in kharif is mainly under rain-fed conditions on marginal lands with inadequacy in irrigation

• Only about 30 per cent of the area is under SCH. Lack of development of single cross hybrid technology, which is a key to higher productivity gains like USA, China and other countries

• Limited adoption of improved production-protection technology

• Deficiencies in the production and distribution system of quality seed

• Small farm holdings and limited resource availability with farmers

Physical properties and composition of all cereals are shown in **Table 3**. The nutrient compositions indicates that among the cereals maize has the highest fat content. This makes it one of the important cereal for processing. Corn oil is a high value product making this crop economically viable for processing.

**Sorghum utilization in snack foods:**

Sorghum is certified GMO-free and can be used in alkaline-cooked and extruded snacks. It is used alone or in combination with maize for tortillas and tortilla chips in some areas of Honduras, Nicaragua, Guatemala, El Salvador and Mexico. Meal and grits from food sorghum, are easily extruded to produce white or light-colour, bland-tasting products that can easily be coloured and flavoured.

## Structure of maize:

The maize seed is a single fruit called the kernel. It includes an embryo, endosperm, aleurone, and pericarp. The pericarp is a thin outer layer that has a protection role for the endosperm and embryo. Pericarp thickness ranges from 25 to 140 um among genotypes. Pericarp adheres tightly to the outer surface of the aleurone layer and is thought to impart semi permeable properties to the corn kernel. All parts of the pericarp are composed of dead cells that are cellulosic tubes. The innermost tube-cell layer is a row of longitudinal tubes pressed tightly against the aleurone layer. This layer is covered by a thick and rather compact layer, known as the mesocarp, composed of closely packed, empty, elongated cells with numerous pits. A waxy cutin layer that retards moisture exchange covers an outer layer of cells, the epidermis. The endosperm usually comprises 82-84% of the kernel dry weight and 86-89% starch by weight. The outer layer of endosperm or the aleurone layer is a single layer of cells of an entirely different appearance. This layer covers the entire starchy endosperm. The germ is composed of the embryo and the scutellum. The scutellum acts as the nutritive organ for the embryo, and the germ stores nutrients and hormones that are necessary for the initial stage of germination. A typical longitudinal section of a kernel of corn is shown in **Fig 1**.

## Maize Milling:

In many cases milling is a very simple process, involving the use of a simple grinder to create a specific particle size distribution from the bulk raw material. The opposite end of the spectrum is the complex process employed to produce white flour for the baking industry.

Industrially milling is through two methods i.e; wet process and dry processing

**Wet processing**: The wet milling process employed by starch manufacturers is considerably different from other processes due to large quantity of water required for the process, resulting in the liquid product.

The wet milling process consists of the following steps: (a) cleaning, (b) soaking, (c). germ separation and germ recovery (d) milling and fibre recovery and; (e) separation of starch and gluten.

Cleaning: All impurities such as dust; chaff, cobs, stones; insect-infested grain and broken grain, and other foreign materials are removed from corn by screening and aspirating. The clean grains are conveyed to the storage bins.

Steeping/soaking: The major objectives of steeping are 1) soften the kernel for grinding, 2) separation of germ, 3) separation of gluten from the starch granules, 4) remove soluble portion, mainly from the germ. Water impregnated with SO2 (i.e, acidulated water with sulphuric acid) is used for steeping. It helps in arresting fermentation during steeping process. The steeping is carried out at $50^0$C for a period varying from 28 to 48 hours. The steeped corn attains a moisture content of about 45 per cent.

Germ Recovery: The wet and softened corn kernels contains about 45 per cent moisture, when conveyed to the degerminating unit. This machine consisting of a metallic stationary plate and a rotating plate with projecting teeth is employed only for tearing the soft kernels apart and freeing the germs without grinding them. The pulpy mixture containing germs, husk, starch and gluten which is passed through hydroclones. The germ being lighter is separated from other heavier ingredients, by centrifugal force. Only modern starch plants employs hydroclones for germ separation.

Milling and Fibre Recovery: After separation of germ and screening of the coarse particles, the mixture contains starch, gluten and hulls. Mainly horny endosperm and hull are then generally ground by either traditional Burrstone mill or modern entoleter impact mills are used to release the rest of the starch. Material to be ground enters the machine through a spinning rotor and is thrown out with great force against the impactors at the periphery of the rotor and also against a stationary impactors resulting in considerable reduction in particle size. Here, only the starch is readily released, with a very little size reduction of hulls. The milled slurry, containing the ground starch, gluten, and hulls, is passed through a series of hexagonal reels where the coarser hulls and fibres are removed.

Separation of starch and gluten: In the modern process, the slurry containing starch and gluten is concentrated. Further, the lighter gluten particles are separated from the relatively heavier starch particles by the centrifugal force in high speed centrifuges. The centrifuging of starch is carried out in two stages. In many modern plants, the second stage of centrifugation is performed by number of hydroclones type of equipment. The starch obtained from the second stage of separation is filtered and then dried to produce dry starches. The various products from wet processing and its use are listed in **Table 4.**

**Dry Processing**: Maize is dry milled in two ways by:

1. Stone grinding the kernels to produce hominy grits and whole meals rich in bran and germ.
2. Degermination. The latter process produces highly refined grits, meals and flours with longer shelf lives.

Fresh whole maize meals have rich flavour because of their high oil and germ content. Some meals are bolted to remove coarse particles of bran and germ. Whole or bolted meals have a shorter shelf life as the oil becomes rancid quickly. Generally, white maize is preferred for production of whole meals.

The objective of dry milling is to produce the maximum percentage of clean grits, containing minimum fat, fibre and least specks with the maximum percentage of clean germ with maximum oil content and largest particle size. The maize is thoroughly cleaned by combinations of sieving, aspiration, washing in water, electrostatic separation and other methods. All mills carefully examine incoming lots of maize for aflatoxins, fumonisins, grain molds, herbicides and pesticide residues. The clean maize is conditioned to 20 to 23 % moisture and placed in a tempering bin for 1 – 3 hr. The objectives of conditioning are to toughen the germ and bran to facilitate subsequent separations. Tempering hydrates the kernel so maximum grit yields with minimum flour. Modifications of tempering conditions are used depending upon maize attributes.

**Production of starch from maize:** Corn starch, corn flour or maize starch is the starch derived from the maize grain. The starch is obtained from the endosperm of the maize kernel. Corn starch is a popular food ingredient used in the food, textile, pharmaceuticals and paper industries.

The basic unit operations involve in the production of maize starch from raw maize is highlighted below;

Cleaning: The raw material is cleaned to remove foreign matters.

Steeping: Kernels are steeped in large tanks of warm water containing acid and sulphur dioxide. The steeping is for a short period of time.

Milling: Soften kernels are wet milled in a pool of water.

Settling and Decanting: The milled product is allowed to settle under

gravity and thereafter, the water is decanted to obtain a thick slurry of corn mass

Sieving: The slurry is sieved to remove the husks

Centrifuging: The starch with the slurry less germ and husks is separated from the protein

Dewatering: The starch is dewatered to form starch cake

Granulating: The cake is broken to smaller pieces to increase its surface area to effective drying

Drying: The starch is dried using flash dryer

Milling: The dried corn starch is milled into desirable particle size

Packaging: The starch is packaged appropriately in air tight and moisture impermeable packaging material.

**Uses of Maize starch**: Most starch is used for industrial purposes. Starch meets the requirements of a range of speciality products. To meet this requirements three step wet modification in temperature, pH, and additives are done. By applying different reaction conditions and strict process control, speciality products with unique properties are made. These speciality products are named modified starches. They still retain their original granule form and thereby resemble the native (unmodified) starch in appearance, but the modification improves quality in the starch, when cooked. The paste may have improved clarity, viscosity, film-forming ability etc.

Commercial cornstarch is used in the manufacture of sweeteners, sizing of paper and textile and as a food thickener and stabilizer. The by-products are valuable feed ingredients. Being a pure renewable natural polymer starch which has a multitude of applications. Starch finds uses in fast food, sweets, sausages, tablets, paper, corrugated board etc. and plays a prominent part in our everyday life. Almost fifty percent of starch was converted to High Fructose Syrups (HFS). Per capita sweetener consumption is now evenly divided between sucrose and HFS.

Each year, an estimated 60 million tonnes of starch gets extracted from a wide range of cereal, root and tuber crops to be used in variety of products such as stabilizers in soups, frozen foods, as coating on pills and paper, as adhesives on stamps and plywood, as a stiffening agent in textiles, as raw material for making ethanol and even as binder in concrete.

**Byproducts from Maize:**

The by products from maize based industries find various applications:

i. *Maize (Corn) Steep Liquor*: It contains amino acids, proteins and are used by antibiotics drugs manufacturers as source of nitrogen for fermentation industry. Also it is a large source of biogas, which is being used as fuel for driers, boilers etc.

ii. *Maize Gum*: Corn oil is produced by expelling oil from the germs. Corn oil finds applications in food and other chemical industries. Maize oil cake obtained after expelling oil is used as cattle and poultry feeds.

iii. *Maize Gluten*: Maize gluten contains high protein content and used as cattle and poultry feeds.

iv. *Maize Husk:* It contains starch, protein and fat as minor components and mainly consumed as cattle feed.

The major use of maize in developed countries is production of alcohol from the glucose produced from maize starch. This has led to the debate whether, food crop can be used for alcohol production to be used as an alternate fuel to petrol for running cars. Should it not go for the production of food for the poor people in the developing and poor countries?

**Conclusion:** Among the cereal crops maize is the most amazing crop. This crop is used as food and also as an industrial crop. A number of industrially important products are extracted from this grains. The modern methods of agriculture has improved the production of maize. The various milling technique has enabled us to use every part of the grain. The uses may be as varied as production of corn flakes to industrial gum to bioethanol.

**Table 1**. Production of maize in India

| Year | Production in Mn MT tonnes |
|---|---|
| 2004-05 | 14 |
| 2005-06 | 15 |
| 2006-07 | 15 |
| 2007-08 | 19 |
| 2008-09 | 20 |
| 2009-10 | 17 |
| 2010-11 | 22 |
| 2011-12 | 22 |
| 2012-13 | 22 |
| 2013-14 | 23 |

An increased at a CAGR of 5.5 per cent from 14 MnMT in 2004-05 to 23 MnMT in 2013-14

**Table 2.** States production of maize in India

| **State** | **Area under cultivation**Mn Hectares | **Production**Mn tonne | **Yield** Tonnes / Hectare |
|---|---|---|---|
| Karnataka | 1.3 | 4.4 | 3.5 |
| Rajasthan | 1.1 | 2.1 | 1.8 |
| Madhya Pradesh | 0.8 | 1 | 1.2 |
| Maharashtra | 0.9 | 2.6 | 2.9 |
| Andhra Pradesh | 0.7 | 4 | 5.3 |
| Uttar Pradesh | 0.8 | 1.1 | 1.5 |
| Bihar | 0.6 | 1.4 | 2.2 |
| Gujarat | 0.5 | 0.8 | 1.6 |
| Tamil Nadu | 0.2 | 1 | 4.5 |
| Others | 1.7 | 4.3 | 2.1 |

| | | | |
|---|---|---|---|
| India | 8.6 | 22.7 | 2.5 |

India's yield at 2.5 MT/hectare is less than half the global average of 5.5 MT/hectare

**Table 3:** Nutrient composition of sorghum, millets and other cereals (per 100 g)

| Food | | Fat (g) | Ash (g) | | | Energy (kcal) | Ca (mg) | Fe (mg) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rice (brown) | 7.9 | 2.7 | 1.3 | 1.0 | 76.0 | 362 | 33 | 1.8 | 0.41 | 0.04 | 4.3 |
| Wheat | 11.6 | 2.0 | 1.6 | 2.0 | 71.0 | 348 | 30 | 3.5 | 0.41 | 0.10 | 5.1 |
| Maize | 9.2 | 4.6 | 1.2 | 2.8 | 73.0 | 358 | 26 | 2.7 | 0.38 | 0.20 | 3.6 |
| Sorghum | 10.4 | 3.1 | 1.6 | 2.0 | 70.7 | 329 | 25 | 5.4 | 0.38 | 0.15 | 4.3 |

Sources: Hulse, Laing and Pearson, 1980; United States National Research Council/National Academy of Sciences, 1982; USDA/HNIS. 1984; FAO, 1995

**Table 4:** Maize milled through wet processing, its products and their use.

| Product | Feed/food uses | Industrial uses |
|---|---|---|
| Germ oil and meal foods | Livestock | Soap, glycerine, leather dressing |
| Refined oil | Salad and table oils, cooking oils, margarine | Pharmaceuticals |
| Steep water | Yeast food | Phytic acid, inositol |
| Gluten and hulls | Livestock and poultry feed Starch Corn starch, chewing gum, bakeries, baking powder, brewing confectionery | Textiles, laundry, paper and paper boxes, explosives, cosmetics, adhesives |
| Syrup | Bakery products, canned fruits, ice cream, confectionery, soft drinks, chewing gums, mixed syrups and jellies | Textiles, leather tanning, pharmaceuticals, tobacco |
| Sugar | Bakery products, pharmaceuticals, jams and jellies, ice cream, canned foods, confectionery | Rayon, tanning, fermentation, brewing, vinegar, carmel colour, fermentation products, tobacco. |

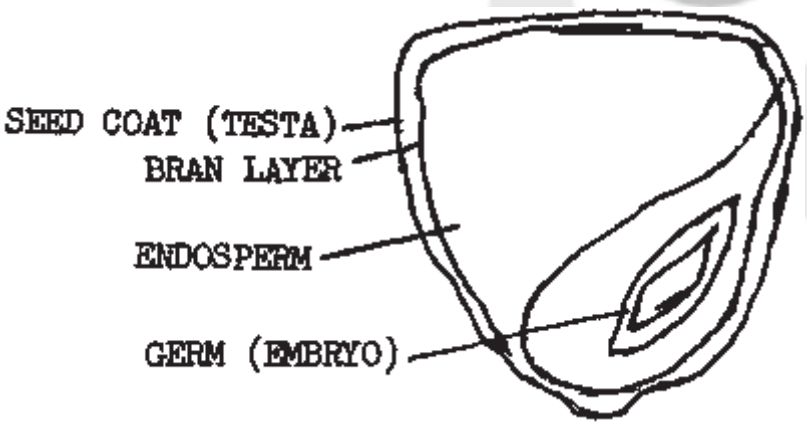


**Fig 1. Structure of maize.**