



COLLECTION  
**PRO-AGRO**

# **Maize**

**production and processing**

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# General

# information

**Maize (*Zea mays*, Poaceae family) is a cereal crop grown in various agro-ecological zones, as a single crop or in mixed cropping. In several countries, maize is the staple food for many people.**

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Maize (*Zea mays*, Poaceae family) is a cereal crop grown in various agro-ecological zones, as a single crop or in mixed cropping. In several countries, maize is the staple food for many people. The maize grain can be prepared for food in many different ways (fried, grilled, in a salad or soup). Processing maize can also produce a wide range of products such as corn flour and corn meal. Maize is also used in livestock feed (poultry, pigs, cattle) in the form of grains, feed milling or as fodder. In addition, it is used a raw material in a range of industries (agri-food, textile, pharmaceutical, etc.) to create biodegradable plastics, biofuel and even alcohol.

Maize is the most heavily cultivated cereal crop globally, with an average annual production of around 817 million tonnes in 2009, and followed by wheat (681 million tonnes) and rice (678 million tonnes).

It can grow to a height of over two metres, and is made up of a single stem from which grow long leaves and both female and male flowers (the latter located on the apex of the stem). Average yields of traditional varieties grown by small-scale farmers are around 0.8 tonnes per hectare, compared with two to five tonnes for improved varieties.

This practical guide describes both the cultivation as well as the agrifood processing of maize. It outlines the steps and processes to produce corn flour, and provides some useful recipes.

# 1

## MAIZE PLANT

**The maize plant is characterized by its anatomy, physiology, development and its natural resistance.**

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### 1.1 Anatomy

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Maize is an annual grass plant ranging in height from 40 cm up to five metres. There are a great number of varieties in terms of size, but the most commonly cultivated range from one to three metres.

#### >>> Root

Maize has shallow, fibrous roots that grow to a maximum depth of only 50 cm. Aerial, adventitious roots also form at the nodes at the base of the stem.

#### >>> Stem

The stem is between 1.5 and 3.5 metres long, with a large diameter of between five and six centimetres. It is woody, and filled with sweet pith, and with nodes and internodes that can commonly be around 20 cm each. At the height of each node, there is a leaf, alternating on each side of the stem.

#### >>> Leaves

Maize leaves are very large (up to 10 cm wide and 1 m long) and sheath-like (at their base they wrap round the stem) with a flat, extended blade in the shape of a strip with parallel veins. Under these leaves and close to the stem grow the ears.



## The anatomy of maize

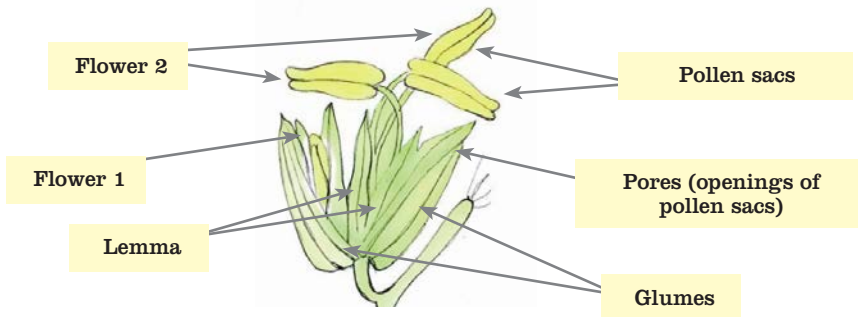


### >>> Inflorescences and flowers

Separate male and female inflorescences are found on a single stem.

- The male inflorescences are on terminal branches. They are small, and enclosed by green, leaf-like bracts. The flowers are in pairs; each pair is called a spikelet, which is enclosed by two bracts. Two smaller bracts enclose three stamens.
- The female inflorescences are lower down, on lateral branches and usually number around one to four per stem. They nestle in between the largest leaves and the stem. These ears are tightly covered over by several layers of leaves, called "spathes", which decay and drop off at maturity. Each ear comprises a "cob" from which grow spirally hundreds of spikelets with two female flowers, only one of which is fertile. During the fertilization period, elongated stigmas appear that look like tufts of hair; at first green, and later red or yellow. The female flower consists of an ovary with a single ovule, and a long style which protrudes from the top of the cob.

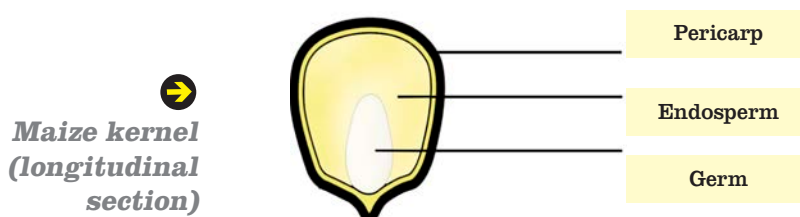
### Flowering spikelet



The male flowers mature before the female; fertilization is therefore out-crossed.

### >>> Fruit

One head produces three to four ears, only one of which will reach full maturity. Depending on the variety, the kernels are arranged in 8 to 20 rows along the length of the cob. They can have different shapes (globular, egg-shaped, dent-shaped, etc.); different colours (white, yellow/red, golden, violet or black); and different textures (smooth or rough). A single ear can contain around 500 to 1 000 kernels, with an average mass at maturity of 150 g to 330 g. The kernel is composed of a germ (embryo + cotyledon), an endosperm and a pericarp, which forms a hard seed coat around the exterior of the kernel, preventing penetration of fungi and bacteria.



The energy reserves represent 80 to 84 percent of the total mass of a fresh kernel and provide energy to the plant during its development. They comprise mainly starch (90 percent) and proteins (7 percent), together with fat, minerals and other elements. The germ at the lower end of the kernel accounts for 9.5 to 12 percent of its total mass. The germ contains a large proportion (35 to 40 percent) of the total fat in the mature kernel. The chemical composition of the various parts of the kernel is presented below.

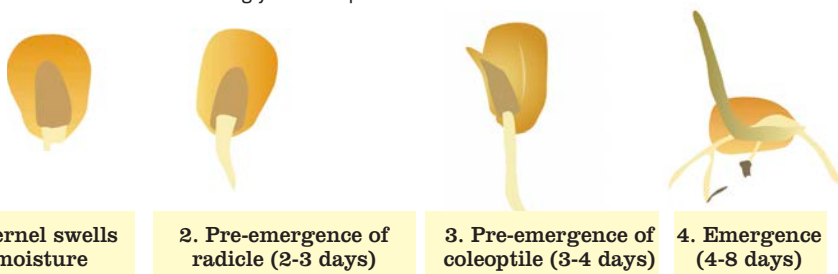
<b>Chemical component</b>	<b>Pericarp (%)</b>	<b>Endosperm (%)</b>	<b>Germ (%)</b>
<b>Protein</b>	3.7	8.0	18.4
<b>Ether extract</b>	1.0	0.8	33.2
<b>Crude fibre</b>	86.7	2.7	8.8
<b>Ash</b>	0.8	0.3	10.5
<b>Starch</b>	7.3	87.6	8.3
<b>Sugar</b>	0.34	0.62	10.8

### Chemical composition of the major parts of maize kernels

The chemical composition of the maize kernel and its nutritional value give it a good position among the group of cereals in the “agrifood” category.

## 1.2 Physiology, development and natural resistance

Germination is triggered by absorption of water through the seed coat and by the development of a radicle root, followed later by lateral seminal roots that elongate towards the dent end of the kernel. A few days after the appearance of the radicle, the coleoptile (also called the “spike”) emerges next from the embryo side of the kernel. The coleoptile initially negotiates its way toward the dent end of the kernel by virtue of the elongation of the mesocotyl. The coleoptile is a rigid piece of plant tissue that completely encloses the four to five embryonic leaves (plumule) that formed during grain development. The plumule leaves slowly enlarge and eventually cause the coleoptile to split open as it nears the soil surface. From this point on, the young maize plant becomes increasingly autotrophic.



### ↑ *Four stages of germination of a maize kernel*

Immature maize shoots accumulate a powerful antibiotic substance, hydroxamic acid, which serves as a natural defense against a wide range of pests, including insects, pathogenic fungi and bacteria.



When maize is attacked by plant-eating larvae such as the European corn borer, it releases a specific blend of volatiles that attract parasitoid insects that are natural enemies of the herbivore, for example, trichogramma wasps, whose female injects her eggs into the eggs of the borer. The wasp larvae consume the embryo and other contents of the egg. Damage to the maize crop can therefore be prevented without requiring chemical products or genetically modified maize.



# 2

## MAIZE PRODUCTION

**Planting is a critical phase in maize cultivation and follows a precise technical itinerary.**

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### 2.1 Getting started

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#### >>> Ecological conditions

Although maize can be cultivated in many different regions (e.g. equatorial forest or savannah), the savannah is the most favourable climatic zone, with an average annual rainfall of between 800 and 1 200 mm and strong sunlight, which will help to reduce parasitism. Maize requires a temperature of between 10 and 19 °C, and should not be cultivated at an altitude above 1 800 m.

#### >>> Selecting the variety and seeds

The choice of variety will depend on the cultivation area, the climate, soil, local technology and the end-use of the harvest.

- Varieties that grow very high and have a short cycle are best suited to high altitude regions. Dwarf varieties are suitable for all agroclimatic conditions. Varieties with a medium-length cycle are suitable for medium-height altitudes.
- Give precedence to good quality seed selected from agronomical research centres or choose the best cobs from the previous harvest. When selecting seed, the best kernels are in the middle of the cob. The kernels should be healthy and come from a pure and improved variety, if possible, which is also suitable for the region. Local varieties can give good yields, but make sure to select the largest and healthiest cobs.

- Select varieties according to their intended market (animal or human consumption, industrial use) and to the cultivation region. For human consumption, give precedence to large-kernel varieties (300 to 400 g per cob); whereas for animal feed, small-kernel varieties are more suitable (100 to 200 g per cob).
- Use seeds with a germination capacity of at least 90 percent.
- Shuck the maize cobs, and then sort the kernels, rejecting the smallest and broken ones, as well as those from the base and tip, which germinate less well.

### **>>> Choice of plot**

Maize prefers particular conditions in terms of soil, water and heat.

- The best soil for maize is deep, loose, fresh, fairly light, well drained, fertile and rich in organic matter. Maize is not suited to soils that are acidic, salty or very wet. The texture should be intermediate: sandy, sandy-loam to sandy-clay loam.
- Maize does not thrive on packed or hollow earth, on soils with too much clay or sand, or those poor in organic matter (less than 1 percent). It does well on soil that has a consistent, well-pressed structure, without areas of other soil types or strata.
- A lack of water during the development of the ears (flowering) can have a disastrous effect on the yield. Make sure that seeding and flowering take place during the rainy season.
- Germination will not occur at temperatures under 10 °C.
- The plot should be easily accessible, with an even surface, with a slope of no more than 12 percent, in order to facilitate low set-up costs.

### **>>> Equipment**

- Hoes and harrows can be used for weeding, and to break up lumps of earth when preparing the seedbeds.
- Machetes are useful for clearing the undergrowth.
- Scales or a spring scale can be used to weigh manure and other fertilizers or pesticides.
- Special manure buckets can be used to spread manure.
- Lines (cords) are useful for taking measurements or marking the spacing when seeding.

### **>>> Previous crops**

The previous crop will depend on the soil texture and its state of deterioration. Maize cultivation is ideal after fallowing, followed by ploughing in organic matter.

The best previous crops are:

- Legumes, such as peanuts, peas, black-eyed peas, to raise the nitrogen content in the soil and add other nutritive elements.
- Roots and tubers, such as potatoes or cassava, to improve root development of the maize.

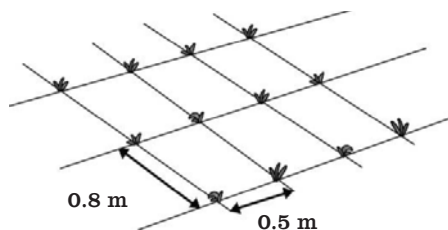
### **>>> Preparing the ground**

- For the best results, cut down any undergrowth (trees, branches) because more light will produce higher yields.
- To facilitate working and tending the crop, weed and clear the plot.
- To discourage rodents (grasscutters, mice), cut down and clear the edges around the plot.
- To facilitate germination, the ground should be well broken up, to a depth of 15 to 30 cm, in ridges or flat.

### **>>> Sowing**

- Calculate 15 to 25 kilos of seed per hectare.
- Keep to the sowing period (start of the rainy season) to ensure the crop gets good rainfall and enough light during development. It should be pointed out that maize can also be sown in the off-season.
- Treat the seeds with a fungicide/insecticide/repellent to protect them from disease and attacks by terrestrial insects, rodents (rats) and predators (crows), and to obtain good seedling growth and optimal density.
- Sow in a line, on ridged or flat ground, at a depth of around three to four centimetres. Use the following spacing guide: 0.8 m between the lines and 0.5 m between the seed holes. Sow three to four grains pretreated with a fungicide/insecticide such as Apron Star or carbofuran (Furadan 5G, for example), to produce a density of 50 000 plants per hectare. Place the kernels at a depth of two to six centimetres.
- To improve germination, the soil should be moist.

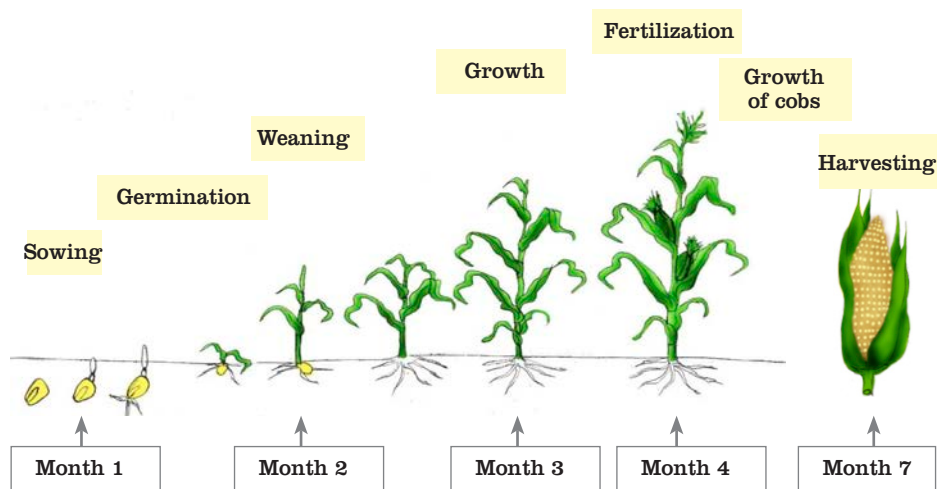
**Seeds should have a germination capacity of at least 90 percents.**



### ⬆ **Spacing in a maize field**

#### >>> **Vegetation**

The germination cycle of maize lasts from 90 to 180 days depending on the variety and the area of cultivation. Maize develops in the following phases: germination, growth, flowering and fertilization.



### ⬆ **Development of late-variety maize**

Maize can reach maturity between 90 and 130 days after the emergence of the seedling, when cultivated in tropical zones at an altitude of between 0 and 1 000 m. At higher altitudes, it may take 200 to 300 days to reach maturity. Furthermore, even at the same altitude and with identical temperatures, certain varieties mature earlier than others because of their early growth pattern. The main difference between an early- and late-variety (90 and 130 days respectively) is the period between the emergence of the seedling and the development of tassels (vegetative period).

This stage can vary from 40 to 70 days. The period of reproduction (from the appearance of tassels up to maturity) for both types is relatively similar and varies between 50 to 58 days.

The appearance of flowers occurs around 40 to 70 days after the seedlings emerge, for the 90-130 day varieties. The flower emerges from the whorl of leaves 1 to 2 days before it begins to shed pollen. Pollen shedding begins 2 to 3 days before the tassel emerges from the tip of the cob, and continues for 5 to 8 days.

Most maize cobs have 14 to 20 rows containing 40 ova or more per row, and produce around 500 to 600 kernels. Any lack of water or nutrients, or excessive exposure to the sun during the first weeks of growth will have an impact on the kernels at the ends of the cob, making them shrivel or die. Maize is very sensitive to humidity stress (lack of water) at this stage, given that it requires significant amounts of water (up to 10 mm per day in very hot and dry conditions).

### ***Germination phase***

- The kernel swells due to moisture.
- The radicle emerges 2 to 3 days after sowing.
- The coleoptile emerges 3 to 4 days after sowing.
- Seedlings should emerge 8 to 10 days after sowing.

### ***Growth phase***

- Maize grows slowly between the emergence of seedlings and the appearance of male inflorescence. The duration of this phase will depend on the variety, the surrounding temperature and the moisture levels of the soil.
- Seedlings should be between 10 and 15 cm high after 4 to 5 weeks.
- 60 days after sowing, the maize plant should be around 50 to 60 cm high.

### ***Flowering phase***

- As soon as growth is completed, the male inflorescence appears, between 70 and 95 days after sowing.
- A few days later, the female inflorescences are ready for fertilization, that is, 5 to 8 days after the appearance of the male inflorescence.

### ***Maturing phase***

- After having formed, the kernels go through three successive stages: milky, mushy and dry.

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## 2.2 Upkeep

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### >>> Fertilization

Fertilization depends on the demands of the variety as well as the conditions in the area of cultivation. Due to their relatively high cost, buying and spreading manure should not swallow up too large a share of the production budget, despite the fact that maize is one of the cereals that respond best to manure and other interventions.

- The introduction of fertilizers is useful in order to produce higher yields and to avoid depleting the soil. It is recommended to combine organic manure with mineral-based fertilizer (with N, P and K mineral elements) to promote effective growth.
- When preparing the soil, introduce – depending on the fertility level of the field – 10 to 20 tonnes of well decomposed manure while working the field. In regions without livestock, plough in the remains of the previous harvest or the products from the fallow period; maize responds very well to organic manure. Fertilizer can also be used, at a ratio of 100 kg to 250 kg/ha, of type N P K S Mg 15-15-15-6-1, or a complete fertilizer of type 20.10.10. Fertilizing can also be done with compost, farm manure or other animal waste, during the working of the soil. Calculate 20 to 50 tonnes (200 to 500 sacks of 100 kg) per hectare every two years; in other terms, 2 to 5 sacks over 100 m<sup>2</sup>.
- Synchronize hoeing/banking up with fertilizer cover 3 to 4 weeks after sowing. Deep fertilization is worked into the soil using a complete 20.10.10 fertilizer at a dosage of 150 kg per hectare, or a fertilizer composed of chicken droppings or other animal waste, at a ratio of 20 to 50 tonnes per hectare (200 to 500 sacks of 100 kg), or a coverage of 2 to 5 sacks over 100m<sup>2</sup>. The second fertilization, still called covering manure, is applied six weeks after the soil was prepared (use 100-150 kg/ha urea, or 1 to 1.5 kg of urea around each seed hole) during the first half of the life cycle. The second application of manure takes place when the male flowers appear.

**When choosing the type of fertilizer, always bear in mind the costs of production. Try to use organic fertilizers whenever possible.**

### >>> Weeding

- Begin thinning out when three to four leaves appear, around 15 days after germination. Remove surplus and weaker plants in order to obtain consistent density (one to two plants per seed hole, after thinning).
- Regular thinning is required to produce a good yield. It can be done manually or chemically, using a selective herbicide.
- Remove any weeds, especially during the vegetative phase of cultivation. Two to three hoeing sessions will be required: the first during thinning; the second when applying the urea; and the third just before the harvest, if the plot has a lot of weeds. If using chemical weedkiller, apply a pre-emergence herbicide such as Primagram Gold 660 SC (S-metolachlor 290 g/l + atrazine 370 g/l) just after sowing and before the emergence of the maize seedlings, calculating 3 l/ha. While the maize plants are developing, treat with Roundup (Glyphosate 360 g/l), using 1 l/ha. Take care to preserve the leaf structure of the crop when using Roundup; it is non-selective and kills any kind of plant.
- The first session of hoeing and banking up should take place 15 to 30 days after emergence, followed by light earthing up, because there is severe competition with weeds during this period. Repeat earthing up forty-five days after the first session.



**Well-tended field**

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## 2.3 Protection

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### >>> Weeds

Weeds such as striga, which attack the roots, can have a devastating effect on maize production. An integrated approach can be effective, using a variety of maize that is tolerant to striga (for example, Acr97TZL Comp1-W, also called Katiola Violet) in association or in rotation with legumes such as soya, black-eyed peas or peanuts.



### *Some harmful weeds for maize*








After harvesting the legumes, sow the striga-tolerant maize, or a legume that is susceptible to striga in between the maize seed holes, three weeks after. The legume will act as a trap crop that will significantly reduce the stock of striga seeds while at the same time improving soil fertility.

As part of good agronomic practice, hoeing can also remove any striga plants, thereby preventing them from flowering and producing large quantities of seeds.









### >>> Harmful insects and pests

Several insects and pests can be harmful to maize yields. The table below describes their appearance, their symptoms and pest control methods.

Insects and pests	Symptoms	Pest control
	European corn borer caterpillars ( <i>Ostrinia nubilalis</i> ) damage the ears of corn, as well as the stalks.	<ul style="list-style-type: none"> <li>• Biological control by the female trichogramma.</li> <li>• Resistant varieties.</li> </ul>
	The caterpillar of the Dark Swordgrass moth ( <i>Agrotis ipsilon</i> ) severs young plants at ground level.	<ul style="list-style-type: none"> <li>• Chemical control by Decis pesticide (15 g/l of deltamethrin) at a dose of 0.5 l/ha.</li> </ul>
	The corn earworm ( <i>Helicoverpa zea</i> ) often causes damage at the tip of the ear.	<ul style="list-style-type: none"> <li>• Biological control of the larva by <i>Bacillus thuringiensis</i> spray.</li> <li>• Mix of molasses and pyrethrin bait, and paint around the base of the maize plants to kill the adults as they emerge from the soil.</li> </ul>
	The larvae of the Western corn rootworm beetle ( <i>Diabrotica virgifera</i> ) attack the roots, leading to wilting plants, which may in turn lead to them collapsing.	<ul style="list-style-type: none"> <li>• Crop rotation: maize/soya.</li> <li>• Use a synthetic insecticide (Tefluthrin) against larvae, during sowing.</li> <li>• Spray with Decis pesticide (15 g/l of deltamethrin).</li> </ul>
	The Corn flea beetle ( <i>Chaetocnema pulicaria</i> ) causes the disease Stewart's Wilt (a bacterial leaf blight).	<ul style="list-style-type: none"> <li>• The toad is a natural predator of the Corn flea beetle.</li> <li>• Apply a mix of ash and lime to young plants.</li> <li>• Liquid fertilizer with garlic or hot peppers.</li> <li>• Pyrethrin can paralyse Corn flea beetles.</li> </ul>
	The Corn leaf aphid ( <i>Rhopalosiphum maidis</i> ) suck sap (nutrients) from the upper leaves and tassels.	<ul style="list-style-type: none"> <li>• Natural control by ladybird larvae, which can eat 100 aphids per day, or insect glue tape with natural pyrethrins, deltamethrin, rotenone or green soap tincture pesticide.</li> <li>• Anti-aphid plants (mint, thyme, absinthe).</li> </ul>
	The larvae and adults of the Maize leafhopper ( <i>Zyginidia scutellaris</i> ) feed on leaf cells, causing white points on the leaves, leading to eventual wilting.	<ul style="list-style-type: none"> <li>• Chemical control with Decis Protech, Pearl Protech or Split Protech (15 g/l of deltamethrin). Dosage: 0.83 l/ha.</li> </ul>

Ensure preventive protection by means of appropriate crop management or by using biological or chemical fungicides or insecticides. However, first make sure that the treatments are cost effective.

## >>> Main diseases

Diseases	Symptoms	Control methods
	<p>Corn smut (<i>Ustilago maydis</i>) or Head smut (<i>Sphaecothea reiliana</i>), due to the pathogen Northern Leaf Blight (<i>Helminthosporium turcicum</i>), are caused by a fungus that attacks the cob, creating large, distorted tumours and giving the cob a scorched appearance.</p>	<ul style="list-style-type: none"> <li>• Avoid physically damaging the plant, or via herbicides.</li> <li>• Respect the balanced fertilization formulas.</li> </ul>
	<p>The symptoms of maize rust (<i>Puccinia maydis</i>) appear as small (1 mm) rusty pustules on the leaves; they initially appear on the lower leaves, before spreading to the upper parts of the plant.</p>	<ul style="list-style-type: none"> <li>• Use disease-tolerant varieties.</li> <li>• Treat the seeds thoroughly with fungicides.</li> <li>• Remove and burn diseased plants.</li> </ul>
	<p>At maturity, the pustules turn black. Maize anthracnose (<i>Colletotrichum graminicola</i>) is produced by a fungus; it causes leaf blight and stalk rot.</p>	<ul style="list-style-type: none"> <li>• Use resistant varieties as the best way to combat anthracnose foliar leaf blight.</li> <li>• Rotate crops.</li> </ul>
	<p>Stalk rot caused by fungi, leading to poor kernel growth, weakened stalk, increased aging and poor circulation of nutrients.</p>	<ul style="list-style-type: none"> <li>• Reduce stress factors (choose varieties with good resistance or tolerance to leaf diseases and stalk rot).</li> <li>• Control of insects and weeds.</li> <li>• Eliminate surplus plants.</li> <li>• Use crop rotation.</li> <li>• Use fertilizers with a sufficient dosage of N (nitrogen) and K (potassium).</li> <li>• Tend the soil according to good farming practice.</li> </ul>
	<p>Fusarium stalk rot (<i>Fusarium sp.</i>), caused by fungi (<i>Fusarium graminearum</i>, <i>Gibberella zeae</i>), causes lesions or dark patches on the lower nodes. Inside the stalk, the rotten marrow tissue turns a salmon-pink colour.</p>	<ul style="list-style-type: none"> <li>• Choose tolerant varieties.</li> <li>• Treating the seed reduces the risk of attack.</li> <li>• Plough under harvest waste (cereals or maize).</li> <li>• Promote crop rotation, avoiding repeated maize cycles.</li> </ul>
	<p>The Maize streak virus (MSV) is an insect-transmitted pathogen that causes white stripes on leaves during the vegetative phase, around 30-50 days after emergence.</p>	<ul style="list-style-type: none"> <li>• Tear up infected plants before they flower.</li> <li>• Sow tolerant varieties such as F8128, DMRESR-Y, EV8766-SR-MRP (depending on the area).</li> </ul>

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## 2.4 Harvesting and post-harvest activities

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The ears of corn are harvested fresh or dry, depending on taste and eventual usage. Harvesting dry ears takes place when the husks have yellowed and the leaves are beginning to wilt, and when the kernels resist scoring with the thumbnail. The ears are harvested fresh or dry 60 to 75 days after sowing for early varieties, and 75 to 85 days for late varieties.

### >>> Drying

- Remove the husks to allow better drying.
- Dry the cobs in open spaces, on cement, drying racks, plastic sheeting or maize cribs. Hang the cobs vertically in the direction of the wind in order to ensure maximal drying out.

**Cobs should hang vertically in the direction of the wind.**



### *Drying maize on a crib*





- Dry until the kernels have a moisture level of 12 %.
- Protect the dried crop from weevils by treating it with a preservative product such as Actellic 2 % DP (pirimiphos-methyl), at a dosage 300 to 500 g per 100 kg of grains.
- Store in a well aired space.

### >>> Make use of harvest waste

Harvest waste can be ploughed into the soil, used as mulch or transformed into manure or compost.

### >>> Stored grain pests

Most stored grain pests belong to two biological orders: Coleoptera and Lepidoptera. The main insects and pests are described in the table below.

Insects and pests	Symptoms	Pest control
	<p>The Maize weevil (<i>Sitophilus zeamais</i>) attacks stored cereal products such as maize, wheat and rice. The female chews through the surface of the grain, creating a hole, before depositing an egg. After a few days, the larva emerges from the egg and begins feeding on the grain.</p>	<ul style="list-style-type: none"> <li>• Spread the maize out in thin layers and expose to sunlight.</li> <li>• Treat or mix the maize with repellent plants such as neem.</li> <li>• Use mechanical control such as silage transfer, shaking or winnowing to eliminate some of the insects.</li> <li>• Coat the maize with a film of insecticide.</li> <li>• Fumigate the maize with insecticide to eliminate all forms of weevil rapidly.</li> </ul>
	<p>The presence of Indian meal moth (<i>Plodia interpunctella</i>) and the European grain moth (<i>Nemapogon granella</i>) can be identified by a webbing of white silk on top of the grain.</p>	<ul style="list-style-type: none"> <li>• Keep the grain stores clean and fill any holes in the walls.</li> <li>• Treat with aluminium phosphide (<i>phostoxin</i>).</li> <li>• Use special winnowing devices to break the infested grains.</li> <li>• Thresh and grind the grain as soon as possible after harvesting, then disinfect the grain store.</li> </ul>
 <p>larva</p>  <p>adult</p>	<p>The Angoumois grain moth (<i>Sitotroga cerealella</i>) infests the grain stock, feeding first on the germ, then the inside of the kernel. Severe attacks reduce seed viability and give the grain a stale odour.</p>	<ul style="list-style-type: none"> <li>• Process with a threshing machine as soon as possible after harvesting.</li> <li>• Turn the grain piles regularly with a shovel.</li> </ul>

# 3

## PROCESSING

## MAIZE INTO FLOUR

**There are more than 400 varieties of maize, which can be distinguished by**

- Kernel colour: yellow, brown, black, bluish-grey, white and yellow, white, pale yellow and dark yellow;
- Taste: more or less sweet, floury;
- Use: human or animal food, industrial.



### *Some maize varieties*

The maize kernels can be eaten raw, cooked, grilled, in a salad or soup, dry (popcorn, etc.), or used in a feed mill or as fresh feed or silage.

Corn flour is one of the most common ingredients in food preparation, and is used as an alternative to wheat flour because of similar calorie content. However, corn flour has a higher percentage of whole grains (4.5 percent) compared with wheat flour. The fibre content is also much higher, as is the amount of vitamin B. As a result, corn flour can provide high nutritional value to food products.

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### 3.1 What you need to make corn flour

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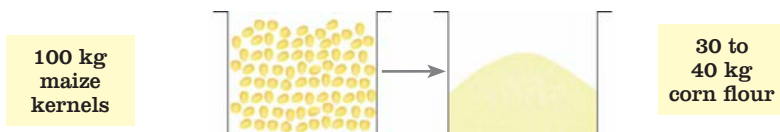
- Silos to store the maize
- A water measure and a lime measure
- A boiler
- A cooking pot
- A dehydrator
- A sieve
- A grinder

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### 3.2 Estimating the volume of maize needed

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The quantity of maize kernels will vary depending on the quantity of flour needed. The amount of corn flour produced is about 30 to 40 percent of the mass of the maize kernels. For example, 100 kg of maize kernels will produce around 38 kg of corn flour.



 **Volume of corn flour produced from 100 kg of maize**

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### 3.3 Types of corn flour

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Corn flour is a fine powder produced by milling or grinding the grains by various methods, depending on the final use or the type of food to be prepared. The degree of coarseness will determine whether the flour can be used for baking bread or other food preparation activities. The most common types of corn flour are

- Precooked corn flour, where the maize is cooked before being ground. This is the most common type sold and also the most practical.
- Masa, where the maize kernels are boiled with lime to remove the husks.
- Cornmeal, where the raw maize is first ground then later cooked.
- Roasted corn flour, where the maize is first roasted then ground.
- "Frangollo", a thick flour used to make the dessert of the same name.

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### 3.4 Corn flour production process

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After harvesting, the maize grains are stored in silos. For effective conservation, the humidity level should be below the “commercial norm” of 15 percent water content. Under these conditions, the maize can be stored for up to a maximum of 18 months.

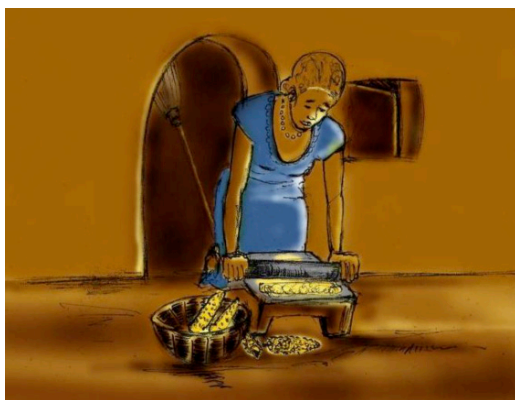
Traditionally, improved conservation required the removal of the germ (an operation that can be carried out by traditional means).

#### **How to make corn flour**

- Add one tablespoon of lime (calcium oxide) to one litre of water to obtain one litre of (approximately) one percent solution of lime water.
- Mix one part of maize kernels for two parts of one percent lime water. This means mixing two litres of water containing two tablespoons of lime per kilo of maize kernels. So for 100 kg of maize kernels, add 200 litres of water containing 200 tablespoons of lime.
- Heat the mix to 80 °C for 20 to 45 minutes. The cooking and soaking time will vary according to local traditions and the type of food preparation envisaged.
- After cooking, leave the maize mixture to cool.
- Mix well, cover, and let the maize soak in the water for a minimum of 24-36 hours, or the time it takes for the kernels to split, separating the grain from the husk. If done correctly, it should now be easy to peel the husks off with your fingers. Cooking changes the kernel's protein matrix, which makes proteins and nutrients from the endosperm of the kernel more available to the human body.
- After soaking, the alkaline liquid, containing dissolved hull, starch, and other corn matter, is decanted and discarded. The remains can also be fed to pigs.

**The soaking time can vary from a few minutes to a whole day, depending on the type of food prepared and local traditions.**

- Then the kernels, now known as nixtamal, are thoroughly washed. The pericarp is then removed, leaving only the germ of the kernel. This hulling process can be performed by hand, in traditional or very small-scale preparation, or mechanically, in larger scale or industrial production.
- The nixtamal is then ground with a mortar or grinder. The result is a corn flour dough.



⬆ ***Grinding nixtamal by hand***

- At this point, the dough can be rolled out into discs of various thicknesses and diameters. The dough can also be dried to make a coarse flour. This flour can then be sieved to separate the lumps, which can be re-ground. The fine flour is now ready for use or for packaging.



# 4

## HOW TO COMMERCIALIZE MAIZE

These days maize can be produced throughout the year, with the result that there is high commercial demand for this food product, from the fresh cob to processed products.

### 4.1 Sale of fresh maize

One hectare of maize can cost 268 925 FCFA (410 euros). Expenses and inputs account for 67 percent of production costs. Labour costs represent around 8.4 percent. A yield of 6.5 tonnes per hectare and a field price of 65 FCFA per kg, the profit will be 153 575 FCFA.

ITEM	EXPENSES			RECEIPTS		
	Quantity	Unit cost	Total cost	Quantity	Unit cost	Total cost
Production sales (kg)				6 500	65	422 500
Seed purchase (kg)						
NPK fertilizer and urea (kg)	150	222	33 300			
Organic manure	5	13 000	65 000			
Spraying (inc. labour)	1	25 000	25 000			
Lubricant and fuel			57 500			
Labour (MD/month)	10	2 250	22 500			
Depreciation provision per ha			15 626			
<b>TOTAL</b>			<b>268 925</b>			<b>422 500</b>
Net profit before taxes			153 575			

Example of a trading account for one hectare of maize

The market price for a kilo of maize is around 0.34 euros (223 FCFA). To ensure good sales, make sure the maize is high quality (good kernel quality and good packaging) and sell during a period when prices are high. Generate regular clients through sales contracts, if possible.

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## 4.2 Sale of corn flour

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Corn flour can be used to make bread and cake products (pancakes, waffles, sweet buns, fritters, tarts, puddings, muffins or biscuits), or as a thickening agent (in sauces, soups, syrups or pastry creams), as well as for non-food uses such as making modelling clay or home-made glue.

The best way is to sell the corn flour in 1 kg packs. One tonne of maize will produce about 380 kg of corn flour. The cost of production depends on the initial investment needed to purchase equipment and maize kernels. To produce 380 kg of flour will cost around 345 euros (226 305 FCFA) to buy the maize kernels, 5 euros (3 279 FCFA) for packaging and the rest for depreciation of equipment and labour costs. One kilo of flour can be sold for a minimum of 1.5 euros (983 FCFA).



 **Corn flour**

# 5

## SOME COOKING SUGGESTIONS FOR CORN FLOUR

**Corn flour is the main culinary use of maize and can be used in several ways.**

### 5.1 Mealie pap (maize porridge)

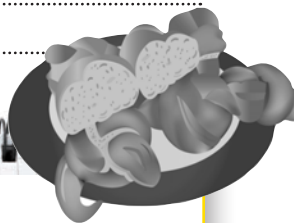
- 1 cup corn flour
- 3 cups water
- 1 cup milk
- ¼ teaspoon nutmeg
- Sugar to taste
- ½ teaspoon salt
- ¼ teaspoon cinnamon
- 1 teaspoon vanilla extract

- Mix one cup of water with the corn flour.
- Combine the remaining water with the milk and bring to the boil, then add the corn flour mix and salt.
- Cook for 10 to 12 minutes.
- Add nutmeg, cinnamon and vanilla extract.
- Sprinkle with sugar and serve hot.

### 5.2 Cornbread

- 225 g corn flour
- 225 g wheat flour
- 15 g baking powder
- 4 teaspoons powdered sugar
- 35 cl milk
- 2 eggs
- 30 g butter
- 1 teaspoon salt

- Mix both flours, sugar, baking powder and salt.
- Melt the butter and set aside.
- Beat the eggs, add them to the melted butter and milk, together with the flour mix.
- Mix well. Grease the baking dish and pour in the mixture.
- Bake at 150 °C (gas mark 5) for 25 minutes.
- Test the bread by using a fork or skewer. Turn out of the baking dish and leave to cool.



# 6

## OTHER

## INFORMATION

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## 6.2 Useful contacts

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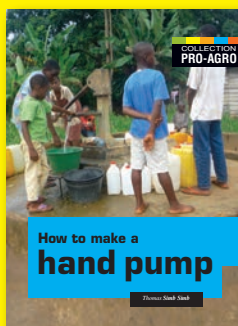
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# Maize

## production and processing

Pro-Agro is a collection of practical, illustrated guides that are jointly published by CTA and ISF Cameroun. They are an ideal source of information for farmers, rural communities and extension workers in tropical and subtropical regions.

This practical guide describes the production of maize and how it can be processed into corn flour. It outlines the different stages from cultivation up to the production of flour, using the method of precooked maize, or nixtamalization. The final section of the guide offers a selection of recipes from Africa, Latin America and Europe.

• **The Technical Centre for Agricultural and Rural Cooperation (CTA)** is a joint international institution of the African, Caribbean and Pacific (ACP) Group of States and the European Union (EU). Its mission is to advance food and nutritional security, increase prosperity and encourage sound natural resource management in ACP countries. It provides access to information and knowledge, facilitates policy dialogue and strengthens the capacity of agricultural and rural development institutions and communities. CTA operates under the framework of the Cotonou Agreement and is funded by the EU.

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