MAIZE

Post-harvest Operations

INPhO - Post-harvest Compendium

Food and Agriculture Organization
of the United Nations

MAIZE: Post-Harvest Operation

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1. Introduction

The maize (*Zea mays* L.) is a monoic annual plant which belongs to maideas tribe and the grass family of gramineae, and their cells have 2n chromosomes. Is the only cereal, which was grown systematically by American Indians. Christopher Colombo encounters that maize was cultivated in Haiti, where it was named "mahiz". He carried the maize from America to Europe and later was carried by Portuguese and others Europeans to Africa and Asia, during 16th and 17th centuries. The maize is the most domesticated and evolutioned plant of the vegetal kingdom, however the origin and evolution of the maize is a mystery, since it has arrived to us highly evolutioned without intermediate forms, while the cereals from the old continent have intermediate wild varieties which are identified and preserved by nature. Notwithstanding, since the 19th century diverse theories have been exposed to explain the origin and evolution of the maize, of which one of the most accepted is that the direct predecessor of the maize is the Teosintle, figure 1.

Fig. 1. Teosintle (Zea mays ssp mexicana)
(Source: Gay J-P., Fabuleux Mais, A.G.P.M. 1984, Kalda, M., MPI Kšln)

The plant of maize has distichous leaves (two ranks of single leaves borne in alternate position). The leaf blades tend to be held at right angles to the sun by stiff mid-ribs. The external surface of the leave blade is adapted for the absorption of solar energy by little hairy structures and the internal surface is shiny and hairless with numerous stomata for breathing. Very often it is said that productivity of maize is due to its large leaf area and to a modification of its photosynthetic pathway. In fact, this modification common in others tropical species resistant to drought periods, is known as the "C4 syndrome", which consists of an efficient mechanism to exchange water vapour for atmospheric carbon dioxide. Under these conditions, C4-species can produce more dry matter per unit of water transpired than normal plants endowed with the conventional (C3) photosynthetic pathway.

The maize plant, exhibits a single predominant stem with some few basal branches (tillers), they serve as feeder for the root system. Longer tillers may compete with the main stem and tillers of intermediate length may have terminals inflorescences which are structurally intermediate between tassels (male inflorescence) and ears (female inflorescences). The male inflorescence terminates on the uppermost spike branched arranged in a loose panicles. On this structure, the flower are organised into paired spikelets into each spikelets and there are two functional florets and each one has three anthers. The anthers are the structure which contains the pollen. Each male tassel may produce around 25 000 000 pollen grains. It means that there are available for each kernel to be fertilised an average of 25 000 pollen grains on an average of 1 000 kernels per ear. Additionally there is also female inflorescence on one or more lateral branches, their terminal ear usually borne on half-way up of the main stem and it remains enclosed into a mantle of many husk leaves. Therefore, the plant is unable to disperse the seeds as a wild plant and instead it requires the intervention of the man to remove the husk, shell and sow its grain to complete the reproductive cycle. The styles (silks) are exposed to pollination as is showed in figure 2 below.

Fig. 2 The maize plant and their parts (C.Geigi)

Maize varies widely in height, some varieties may range from 0.5 to 5 meters standing at flowering and produce 1 to 4 ears per plant. A normal average in height is 2.4 m. Maize is cultivated at latitudes 50 degrees north and south, and even slightly higher from the Equator, also from sea level to 3600 meters elevation (a.i Andean), in cool and hot weathers, and with growing cycles oscillating from 3 up to 13 months. It is a versatile crop, and it has tremendous genetic variability, which enables it to thrive well under lowland tropical, subtropical, and temperate climates. It is grown in more countries than any other cereal. In the middle of 19th and beginning of 20th centuries respectively, U.S. farmers and seeds men develop outstanding open-pollinated varieties, and intensive research in plant breeding offers spectacular improvement in crop yields. Hybrid maize is the greatest practical achievement of plant genetics to date.
Furthermore, the maize exists in different forms in respect to size and colour of plant and ear, type and size of the kernel, as is showed in figure 3.

Fig. 3 Different types of maize cobs.
(Source: Gay J-P., Fabuleux Mais, A.G.P.M. 1984, Kalda, M., MPI Kšln)

Likewise, of relevance for nutritionist, food technologist, and others scientists, is the structural parts which form the mature kernel of maize which are showed in the following figure 4.

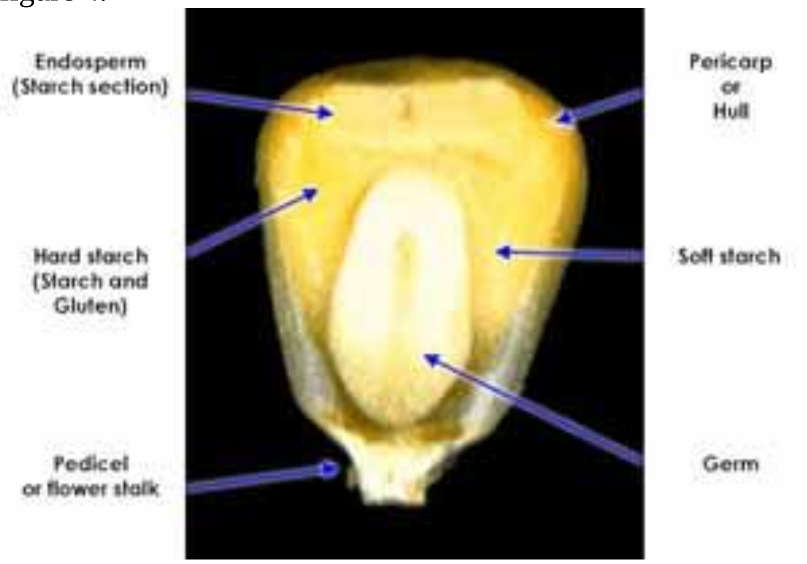

Fig. 4. The maize kernel and their parts.
(Source: maize.agron.iastate.edu)

In line with the figure above, the kernel parts indicated include: The pericarp or hull (thin covering which enclose the kernel). Endosperm (starch section of the kernel both soft and hard starch. The germ (embryo), portion which contain a high proportion of oil, 4.5 percent w/w and it is a large part of the side of the kernel. The endosperm, the largest portion of the kernel represent about 82.3 percent of the weight of the grain and consist largely of the starch along with the gluten the bound protein 9,4 percent. The germ represents 11.5 percent and contains the maize vegetable oil. The hull or pericarp about 5.3 percent and the pedicel or tip cap 0.8 percent. The hardness of the starch in the kernel is associated to gluten. The average caloric content of the whole meal from maize is 3,578 Calories per kilogram.
On the other hand, the main classes of kernel of maize are summarised in the following table 1 according the type of endosperm and others important characteristics.

Table 1: Types and characteristics of the maize kernels.					
Type of endosperm	**Type of pericarp**	**Crown appearance**	**Texture of endosperm (mature)**	**Uses and % as of the total**	**Distribution**
Pop	Very thick	Pointed/Rounded	Hard	Confection (<1%)	USA, Eventually all regions
Flint	Thick medium	Rounded	Mostly hard	General (14%)	Argentina, Southern Europe
Dent	Medium	Dented	Hard & Soft	Livestock feed, industrial process, milground meal (73%)	World wide
Floury	Stretched thin	Slight dented	Soft	Direct human uses as flour, direct at milk stage, parched, beverages (12%)	Latin America and South West
Sweet	Thick medium	Wrinkled	Glassy	Direct at milk stage, 70% moisture, frozen, canned, parched and beverage (~1%)	North America (USA & Canada)

The endosperm composition is the variable feature of maize that relates most closely with its food uses, and a common and useful classification of maize based on endosperm characteristics distinguishes five types:

a. The Pop kernel has almost all starch hard. The kernels contain 12 to 13 percent of moisture and it explode when is heated about 170 o C. This popping effect is caused because the water in the endosperm turn to steam suddenly and exploding.

b. Flinty kernels are almost impossible to grind by hand when it is dry, but may be softened by boiling in lime water and then wet-grinding to prepare the dough named masa. The entire outer portion of the kernel is composed of "hard" starch, which not easily forms a paste with water. The starch composition gives the kernel a shiny surface. It makes a good quality cornmeal (dry milling). It exhibits less risk of spoilage in shipping and storage than dent maize since hard kernel absorbs less moisture. Also this maize is more resistant to fungi and insect damage when is compared with the dent maize. Likewise, flint varieties mature earlier, and its seeds germinate much better in cold and wet soils. It can grow easily to higher latitudes than other forms of maize. This maize can be found in different colours, such as white yellow, red-blue, etc.

c. Floury kernels, is soft when dry and have the advantages for being grind by hand, however a floury kernel called Opaque-2, which is high in lysine, have the disadvantage that may mould on the mature ears in wet areas and therefore, destroy the crop before harvesting. This type is recommended to grown in dry areas.

d. The dented kernel is an intermediate structure between the flinty and the floury types. The surrounded side of the maize dented kernel are flinty, but the central core is floury. Due to this soft structure on the crown it contract more during drying than the hard sides.
e. There is another type of Maize named as waxy due to somewhat waxy appearance of the kernel. China was the original source of the waxy gene (wx), but waxy mutations also happened in USA with dent strains. This Waxy maize is composed entirely of amyl pectin, in contrast with common maize which contains approximately 78 percent of starch and 22 percent of amylose. This type of hybrid maize is used for specialty products of the wet-milling starch industry.
In the case of the sweet maize, the sugary gene retards the normal conversion of sugar within starch during development of the endosperm, causing a dry sugary wrinkled and glassy kernel.
Although there are more than 200 races of maize, in this literature review on maize the idea is to provide a general description of those most relevant species. This document is be more addressed to aspects related to post harvest system of the maize, but is convenient also to give the reader some important issues and details to familiarize with this fabulous food-grain.

1.1 Economic and Social Impact.

The maize represents to all maize-based groups a source of life. Although maize is original from Mesoamerica, it is very adaptable to different weathers, and nowadays its consumption is worldwide. In fact, the maize is the most widely grown cereal crop. In the global production of cereals crops, the maize rank first after rice (paddy) and wheat. Likewise, in countries with developing economies, such as Latin-American and Africa the maize rank first. In Asia rank third after rice and wheat. The table 2 below shows important data about area, yield and production of maize in the world.

Table 2: Area for maize, yield and production from 2000 to 2002 (mean values)

Geographical area	Area (million ha)	yield (t/ha)	Production (million t)
Latin America: México, Central America & Caribbean, South America	27.2 9.7 17.5	3.1 2.2 3.4	81 22.1 58.9
Africa: Developing countries Developed countries	25.7 22.2 3.5	1.8 1.5 2.7	43.2 33.7 9.5
Asia: Developing countries Developed countries	47.2 42.1 5.6	11.1 3.7 15.1	241.9 157.1 84.8
Europe: Western Europe Eastern Europe	11.1 4.4 6.7	7.1 9.2 3.7	65.2 40.4 24.8
USA & Canada Former USSR area	29.8 2.6	7.5 2.8	248.5 7.2
World Industrialised countries	138.6 37.7	4.3 7.9	603.0 299.1

In the period from 2000 to 2002 about six hundred millions tons of maize was produced in the world on 139 millions hectares, of which 70 percent of this area is in developing countries, but only 50 percent of the global maize production is harvested there. The differences on yield are due mainly to environmental, technological, economic and organizational factors. In most developed countries the climate is temperate; likewise they use sufficient inputs and a well mechanised system for the maize production.
As complementary information, the average production in tons per hectares for industrialised countries is 7.9, in contrast in developing countries is only 2.5.
Table 3 shows the 20 larger maize producer countries which accounted for 86 percent of the world production and 77 percent of the total maize area during years 2000 to 2002, as is shown in table 3.

Table 3: The 20 Largest Maize Producers, 2000-2002

Country	**Area (million ha)**	**Yield (t/ha)**	**Production (million t)**
USA	28.6	8.4	240.7
China, Peoples Rep	23.9	4.8	97.2
Brazil	11.9	3.1	36.3
Mexico	7.6	2.5	18.9
France	1.8	8.8	16.2
Argentina	2.8	5.6	15.6
India	6.5	1.9	12.5
Italia	1.1	10.0	10.8
South Africa	3.5	2.7	9.5
Indonesia	3.3	2.7	9.4
Canada	1.2	6.6	7.7
Romania	2.8	2.6	7.5
Egypt	0.9	7.8	6.7
Yugoslavia	1.2	4.0	4.8
Nigeria	4.1	1.1	4.7
Spain	0.5	9.7	4.5
Philippines	2.5	1.8	4.5
Thailand	1.2	3.6	4.2
Ukraine	1.2	3.6	3.9
Germany	0.4	9.0	3.4
Source: FAOSTAT, 2002.			

Due to its worldwide distribution and relative lower price to other cereals, the maize has an ample uses than any other cereals. In many developing countries the maize is a major staple food and the consumption percapita is very high. The maize can be processed in different products at traditional level as well as industrial scale. Moreover, although products derived from maize in developing countries are obtained by traditional methods of processing, the high bulk of demand for industrial process occurs in developed countries. Notwithstanding, currently important changes are happening throughout developing countries in the process of maize for major uses. For example, there is a tendency to adopt simple equipment and processing machines during the phase of post harvest for operations such as shelling, cleaning, grading, dry and wet-milling, etc. These technologies are of especial interest for developing countries where most of the maize is produced by small and medium farmers and it is for direct human consumption.

On the other hand, a large number of maize varieties for direct human consumption are available, including local and new varieties which are grown by commercial and subsistence farmers. The consumers may choice the type of maize to prepare the more acceptable food products in a given area. Traditional or commercial products from maize are based on the properties of the endosperm of the grain and others parameters such as physicochemical, organoleptic and reological properties. By fortune, these properties can could be modified by breeding or applying others agronomic and processing practices.

Some special advantages of the maize beside the broad global distribution, its lower price, the diverse type of grains and the biological and industrial properties which make the maize an adequate product for its utilisation. The maize has a very wide range of uses than any other cereal. It can be used as staple food for human consumption, animal feed and for many industrial uses. The highest rate per caput supply of maize occurs in countries where most of the grain is for feeding animals or where the maize represents the preferred staple food, as is shown in table 4.

Table 4: Countries with Highest Rates of Maize Per caput supply (kg/yr), Average 1998 to 2000.

Africa		**Asia**		**Latin America**		**Europe**	
Lesotho	148.6	Georgia	69.7	Mexico	129.4	Bosnia Her.	115.2
Malawi	134	Nepal	43.5	El Salvador	100	Moldova	93.4
Zambia	131.8	North Korea	42.81	Guatemala	88.3	Romania	37.5
Zimbabwe	123.7	Indonesia	34.2	Honduras	78.5	Macedonia	27.9
Kenya	85.7	Brunei	19.8	Paraguay	51.5	Slovenia	21.5
Swaziland	75.4	China	19.2	Nicaragua	51	Ireland	16.9
Tanzania	68.4	Laos	18.4	Venezuela	48.5	Yugoslavia	14.7
Cape Verde	66.5	South Korea	18	Bolivia	47.7	France	12.7
Namibia	65.7	Turkey	16.1	Colombia	39.1	Austria	11.7
Togo	64.6	Pakistan	7.1	Panama	29.5	Croatia	11.5
Benin	63.6	Thailand	6.4	Haiti	26.1	Ukraine	8.5
Mozambique	54.8	Viet Nam	6.1	Uruguay	25.9	Portugal	7.5

Source: FAOSTAT 2002.

Of the total maize harvested in the world during 2000, about 65 percent is to fed livestock, the 19 percent is for direct human consumption, 8 percent as processed, 4 percent for waste, 3 percent other uses and 1 percent as seed, such as is showed in the following figure 5.

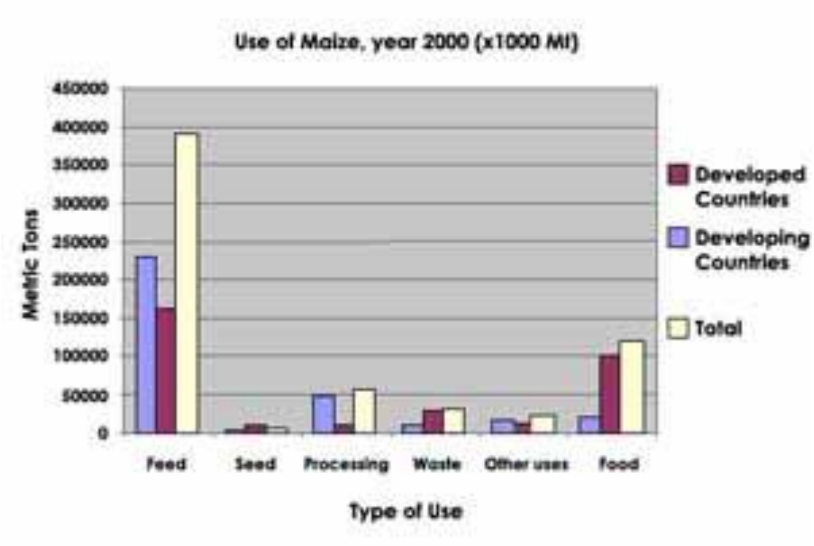

Fig. 5. Estimation on maize use in developed and developing countries.
(Source: FAOSTAT, 2003)

The maize as human food consumed directly in quantities higher than half of its production is found in Andean countries of South America, Mexico, Central America and the Caribbean, Africa and South and Southeast Asia. The maize grain used for human consumption in these regions use mainly varieties of white maize rather than yellow maize. In fact, maize account for at least 15 percent of the total calories daily intake in 28 developing countries, almost all of them in Africa and Latin America, such as showed in the next table 5

Table 5: Countries where Maize Account for over 15 Percent of the Total Calories Intake,
Years from 1999 to 2000.

Country	Calories from Maize in (%) of the Total Diet
Lesotho	56
Malawi	48
Zambia	47
Zimbabwe	40
South Africa	38
Bosnia Herzegovina	33
Mexico	32
Namibia	30
Kenya	29
El Salvador	29
Swaziland	26
Tanzania	26
Guatemala	25
Cape Verde	25
Egypt	23
Cameroon	22
Botswana	22
Honduras	21
Togo	21
Benin	20
B. Faso	18
Moldova	18
Paraguay	17
Mozambique	17
Somalia	17
Nicaragua	15
Nepal	15
Ethiopia	15

Source: FAOSTAT, 2003.

The maize has a big impact in the economies of developed countries as well as developing countries. For example, in USA the maize dominates agriculture with a production more than double that of any other crop. The simple grain of maize in USA finds its way into the life as edible and inedible products such as rubber, plastics, fuel, clothing, food additives and many others. Just to mention an example about the maize utility (most yellow corn of USA), one kernel well sowed may produce a plant with one ear which produce an average of 800 kernels per cob. Likewise, for producing 100 Kg of maize in the form of kernel, 364 cobs are necessary of which may yield approximately what it is described in the next figure 6.

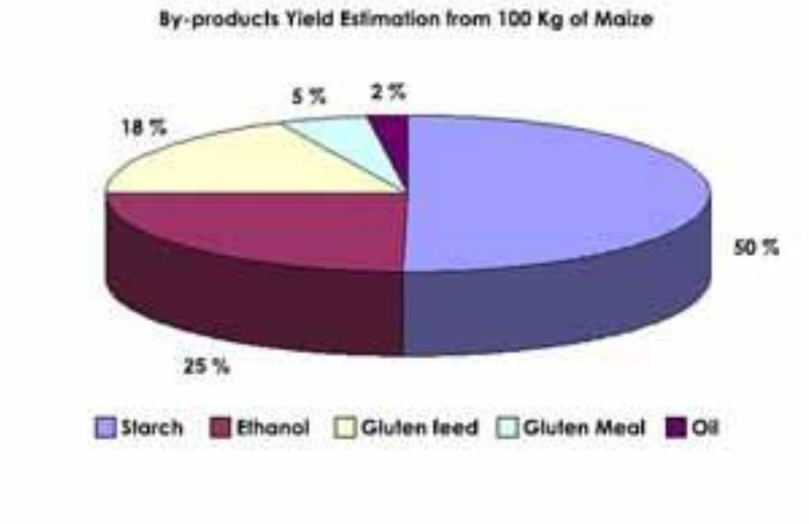

Fig. 6. What is expected from 100 Kgs of maize.

Is convenient highlight that poor and subsistence farmers grow mainly white maize in mixed cropping system which is highly recommended, especially if the complementary crop is legumes like beam. In some areas of Latin-American and even Africa where maize is the main source of caloric intake, mixed of legumes crop with maize is very desirable, since legumes like phaseolus bean and other nitrogen fixer legumes, help to prevent the exhausting of the nitrogen contained in the soil, because the legumes are in general good nitrogen fixer. Therefore, is important to appoint out that due that white maize is an important food in those countries and even, it can supply the minimum daily caloric requirements for a person.
The maize by itself, is a poor source of the essential amino acids such as lysine and tryptophan. A diet where maize is predominant may cause deficiencies diseases such as pellagra and kwashiorkor. However, in some developing countries of Latin-American where the consumption of maize, very often, is complemented with legumes such as phaseolus beam, the protein profile for this mix exhibit a very similar to that of milk. A very common and ancestry practice for the preparation of the maize grain is the cooking in an alkali batch named "Nixtamalizar" or in others parts "Nezquizar", which results in a greater availability for vitamin niacin, which its deficiencies in the diet may cause diseases such as pellagra. Some research indicates that although the lime cooking process to convert maize in tortillas induces some important losses in nutrients, this treatment also causes important and positive changes in nutrients availability, such as increasing of the calcium content (Lime is Calcium hydroxide), better release of aminoacids (histidine, isoleucine, leucine, lysine, methionine, phenylalanine and tryptophan) from tortilla as from maize.

1.2 World trade.

The growth in maize production in the world market has increased considerably particularly in countries with temperate environment where hybrids and high yielding agronomic

practices are used. In 1950 the maize production in the world was about 16 millions of tons and by 1980 it had increased to about 80 millions of tons, after this peak of maize world production and due to rising of production in developing countries and shortage of foreign exchange in many countries, the maize trade tended to diminish.
Since the 1990s the maize trade has fluctuated between 70 to 90 millions of tons. Most of the maize movement for trading is used to fed livestock and poultry. The main maize exporters are: United States, Argentina , France, China P.R., Hungary, Canada, South Africa, such is showed in table 6. China is a relatively new exporter being the main suppliers of Asian neighbor countries.

Table 6: Major Countries exporter of Maize, 1999 to 2002 (mean values)

Country	**Exporter (000 t)**
USA	49,972
Argentina	9.368
France	6,338
China People's Republic	7,385
Hungary	1,357
Canada	581.6
South Africa	518.9
Germany	474.5
Yugoslavia	262.7
Paraguay	193.0
Bulgaria	175.0
Romania	162.6

FAOSTAT, 2003
On the other hand, 28 countries in the world imported an average each during 1999 to 2002, of more than 500,000 tons of maize. All these countries accounted together 75 percent of the world total maize imports, table 7.

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Table 7: Major Importers Countries of Maize Over 500,000 Tons Annually, 1999 to 2002 (mean values)

Country	Imports (000 tons)	Country	Imports (000 tons)
Russian Fed.	769	Venezuela	1,186
United Kingdom	1,387	Saudi Arabia	1,228
China	5,059	Portugal	1,164
Egypt	4,400	Peru	956
Israel	833	Malaysia	2,300
Netherlands	1,935	Italy	929
Indonesia	961	Iran	1,094
Syria	802	D. Republican	947
Spain	3,258	Colombia	1869
Japan	16,369	Chile	1,248
Morocco	814	Canada	1,532
Mexico	5,550	Brazil	1,298
Turkey	1,064	Bel-Lux	587
South Korea	8,431	Algeria	1,300

FAOSTAT: 2003

Of the total maize imported, around 80 per cent corresponded to industrial economies during 1999-2002.

Furthermore, from 1988 to 2002 the world maize supplies expanded slowly compared as was before this period, however developing countries tend to increase their productivity as developed countries does, figure 7. The global maize production currently is around 600 millions of tons and it seems that there is a tendency to increase for the next years due mainly to growth population. However, the increase in productivity owing to the use of improved varieties and agronomic practices has had a big impact in the lowering maize prices. Since United States is the predominant maize trade in the world, the best indicator of world maize prices is the FOB US price.

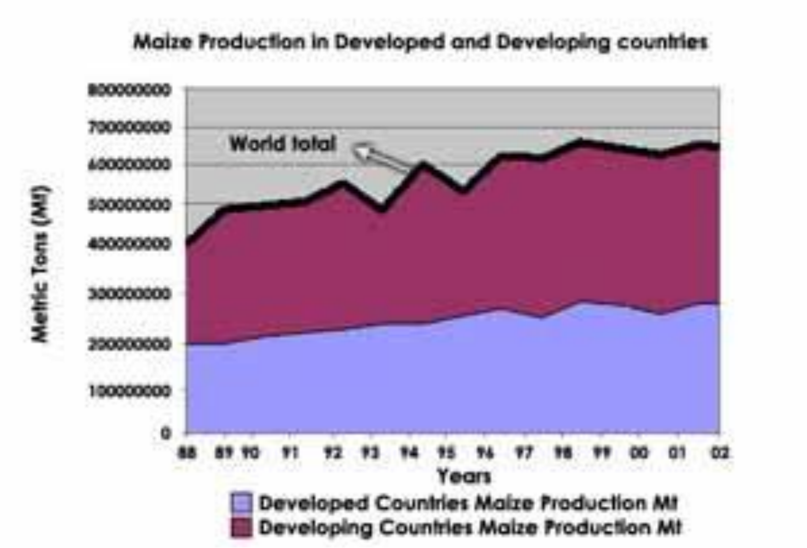


Fig. 7. World Maize Production (1988-2002).
(FAOSTAT, 2003)

The trends in maize prices indicate that maize supply as well demand has changed at about the same rate. In regards, the supply side, cost-reducing technologies, especially in developed countries has doubled the maize production without increase of the real prices. At the same time, the increased demand of maize as animal feed has absorbed the increased production, due mainly to a rising income and growth of the population.
The intervention of governments in the market of maize in producing and consumers maize countries has had (and often adverse) a big influences on international maize prices. In developed countries, the protectionism generally favours agriculture which is paid by taxpayers, consumers and producers of other tradable products in the economy. In contrast, in developing countries and in central planned economies, protectionism penalizes agriculture, in favor of urban consumers and others sector of the economy. The USA and EU with direct and indirect price support have had a significant depressing effect on the international maize price. The governments in most developing countries are removing the discriminatory maize police in response to the pressure from world bank, international monetary fund and others bilateral donors agencies. This lower trend for maize price has worsened the economic situation of maize exporting countries.

1.3 Maize primary products.

Meal is a primary product obtained from maize. The meal from maize can be obtained by manual or mechanically milling. There are different ways to make manually the maize meal, for example in traditional culture of Central America they use traditional tools to ground the grain slowly between two stones figure 8 (molcajete) or piedra de mano (metate) figure 9.

Fig. 8. Manual maize grinder (Molcajete)

Fig. 9. Piedra de mano or metate for grinding maize
(Source: mexico.udg.mx)

In some part of Africa pounding of the maize with a pestle and a mortar is also widely used as traditional method. Likewise, dry milling and wet milling are the most common system to obtain maize meal, for hard varieties like flint-type maize is recommended to use wet milling process. In Africa and in some countries of Latin-American at village level there are small-scale mechanical dry-maize milling. The grain mills hand-operated or engine-powered are available for maize grinding and these equipments can be produced nationally or imported figure 10.

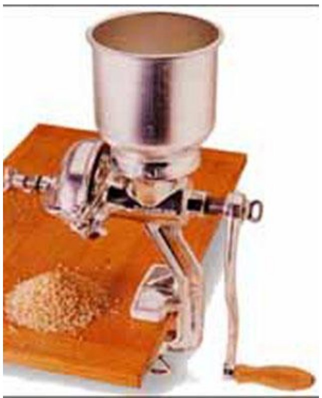


Fig. 10. Hand grain milling

Depending of the use of maize there are some other products of maize which can be considered as primary products. As for example, sweet grain maize grown for green ears, normally this is consumed after boiling or roasting. At the moment of the harvest, the grain has about 70 per cent of water and has not started to harden. These grains have high sugar content and it is sweet in taste. The green ears are generally boiled with or without the husk leaves in water with or without salt or lime. In some part of Africa boiled ears are sun dried and stored for later use after re-boiling and heating. Another manner is to extract the juice from the kernel flavoured, cooked and allowed to become a jelly. This type of product is used in western and eastern Africa. Also fresh kernel removed from green ears are ground into a paste and mashed or slurred without fermentation. Then, this is used to make soup or various porridges or baked products, such as cachapas in Colombia and Venezuela, humita and mingau in others countries of South America and Atole in México and Central America. Likewise, this mashed paste can be allowed to ferment for a few days to make various porridges or pudding dishes. Another type of maize which is popular in some places is the baby ear shot or "baby corn". The young ear shoots are harvested before pollination occurs and it is used as vegetable, popularly known as cooked "Chilote" in Central America. It is also consumed fresh or canned. Tropical environment are suitable for ear baby shoots.

1.3.1 Mature dry grain.

1.3.1.1. Whole grain.

In Africa the grain is usually parched and eaten. Likewise, the hard flint or pop maize grain is popped in hot sand (Africa and Asia) or mostly in a hot plate and eaten hot as popped maize. In Andean regions and even in USA floury grain is roasted and eaten as "corn nuts". In some countries of Africa the grain is boiled and eaten whole or the grain is beaten and pulped to make a product similar to boiled rice, this product is also consumed in Asia. The grain can be cooked in lye or lime water in USA and it is called hominy in Mexico after removing the per carp, it is used to make soup or a traditional dish known as "pozole".
A very popular product named Ogi or Uji is consumed in Africa, this is prepared by steeping and fermenting then milled and made into slurry. Then it is fermented and made into porridge.

1.3.1.2. Dry milled grain.

The maize whole grain can be dry milled to produce a coarse maize meal or fine flour and it is used in a variety of ways. In Africa, for instances, they used to make cooked paste, fermented or unfermented. The flour is used to make a dough adding water. This dough is made for preparing unleaved bread and flat thin called chapattis in Asia. In Ethiopia, the dough is fermented and cooked in a hot plate to prepare the Enjera of maize.
The grain also can be used to make maize meal, biscuits, leavened bread and "corn bread". In Africa and Asia also the maize can be used to make maize grits with or after separating the germ. This grits are boiled and eaten as rice.
In some regions of Central America especially in Nicaragua, dry grains are toasted and then milled. This product it seems like flour and is known as Pinol (in Nicaragua) or Pinole (in Mexico). When cacao seed is added and grinded together with the maize, it is called Pinolillo. These products are used as the base for the preparation of a traditional daily beverage, just by adding water, very often sugar, and shaking. The addition of sugar or others flavour is optional for this product and it is a typical beverage consumed specially in towns and rural areas.

1.3.1.3. Soaked grain

The grain is soaked and cooked in a water or lime solution then the grain is ground to make dough which is used as the base for different preparations. Eventually the grain soaked and cooked is dehulled and the germ removed partially or totally. This product can be pounded to obtain the grit and then cooked and eaten as the rice boiled or can be used to prepare special type of breads such as the arepas in Venezuela or the sopas how is called in Paraguay. Likewise, maize gruel can be transformed into sweet or sour drinks. Fermented drinks are popular in Africa and Latin America. Un example of this product is the chicha and also the pozol, a fermented masa used in Central America used to prepare a typical beverage, just by adding to the portions of fermented masa water, or milk, sugar and shaking. Pozol is made in Nicaragua with maize purple colour grains varieties (called pujagua), although any maize variety can be used.

1.3.1.4. Nixtamalized maize.

This process similar to the previous one described was developed by Native Americans Indians. The kernel are soaked and cooked in lime water (in some parts of Latin America ash is used instead of lime) and then dehulled and ground to form dough called masa. This masa is the base for preparing several traditional products such as tortillas, tamales, etc. Furthermore, the masa can be dried and converted into maize flour by grinding the masa dried, sieving, classifying and blending to obtain dried masa flour. This dry masa flour can be also used to make tortillas (by rehydration), tortillas chips, etc. The dry masa flour can be also used to prepare composite flour.

The nixtamalization consist of mixing one third part of whole maize with two thirds parts of a lime (calcium sulphate) solution between 1 to 2 percent of concentration. In general terms, the cooking time may vary from 15 to 45 minutes and the temperature of cooking is held above of 68 0 C degree. The grinding of the nixtamalized kernels are carry out by simple pounding with a hand operated or electric kitchen grinder-mixer, with a semi commercial grinder for cottage industry or with commercial grinders for mass-scale masa production. The dry masa flour is more stable against rancidity and the shelf life can be until one year, in comparison with the whole dry kernel ground maize flour does. Is important to remark that the nixtamalization treatment has the following advantages: it facilitates the pericarp be removal, controls microbial activity, enhance water uptake, increase gelatinization of starch granules and improve nutritional value through an increased availability of Niacin.

1.3.1.5. Composite flour

The use of composite flours to supplement wheat flour for making bread and biscuits is not a new concept. Due to the increased global wheat production since the green revolution has caused a decrease in the price of wheat and consequently it has boosted wheat consumption in tropical countries where there is no grown of wheat. These countries have depended on imported wheat or wheat flour received as food aid or purchased from countries with surplus of wheat. However, many tropical countries at the present are pressed for foreign exchange and therefore are restricting the import of wheat or wheat flour.

Furthermore, milling and baking research have shown that technically is feasible to substitute in a limited extent flours of crop from maize, sorghum, millet and cassava for wheat flour. Tastes and flavour of such composite flour for making bread is technically feasible.

Some countries in sub-Saharan Africa have little wheat production and the increased demand for wheat create a potential market for composite flour. Notwithstanding, composite flour are only used commercially in Zambia (6 percent maize flour substitution) and in Zimbabwe (10 percent maize flour substitution). In Latin-American only Brazil use composite flour made with cassava and maize. In India when soft wheat imported from Mexico was used, consumers did not like the leathery, chapattis.

According to a FAO publication on precise techniques of composite flour, 25 percent as maize flour can be mixed with 75 percent without appreciable difference in the quality of the composite bread. In other products the substitution could be even higher.

1.3.2 Special types of maize and their use as food

Flint and dent maize type are the most used for human consumption, however there are some special types which are used for specific purpose, as for example:

1.3.2.1. Floury maize.

This type of maize is used in the Andean highland for food. The green ears are roasted and the mature floury kernels toasted becoming partially popped. Some native products from this maize are the kancha and the chicha. Another product is the sopa which is very popular in Paraguay. Corn nut is also popular from floury maize and kernels from the large grain floury race Cuzco Gigante are normally heated in an alkaline solution, washed to remove the pericarp and then blanched in warm water for a few hours. Finally the product is fried to develop texture, colour and flavour. Some floury maize is being used to extract natural food colours from the pericarp.

1.3.2.2. Puffed and popped maize.

The most used kernel is hard flint which is subjected to high temperatures, either in hot sand or in a hot plate in order the kernel puff and pop. This snack is very popular over the world. Some hard flint varieties have been modified and improved by selection in order to obtain a maximum popping expansion up to 30 to 40 fold expansion respect the original volume of the uncooked grains. For an adequate popping of the grain a temperature around 177 0 C is required and at this temperature, the water within the endosperm of the kernel is turned into steam which provides the force and pressure for the endosperm to burst and puff out. The moisture content of the grain is a very important factor to be controlled and it makes the packaging and storage of maize for popping more expensive.

1.3.2.3. Baby ear shoots.

Known also as "baby corn", it was first developed and promoted in Thailand. It is popular in Southeast Asian countries. The immature ear shoots are harvested when the silks have just emerged, but before the silks are pollinated. To ensure that not pollinization take place, the plants are detasselled before pollen sheds. The baby shoots are marketed with husk leaves and the silks. Baby ears shoots cleaned are used fresh in salads, as a vegetable, for making soup or pickled and canned.
The table 8 shows the nutritive value for the baby ears shoots and it is compared with other typical vegetable. After baby ears shoots are harvested, the green maize plant is used as fodder for livestock. In tropical countries there is an advantage, since baby ears shoots can be produced all year round and supplied fresh.

Table 8: Nutritive value of maize baby ear shoots and other salad vegetables per (100g)

Component	Maize baby ear shoots	Cabbage	Cucumber	Tomato
Vitamins A (i.u)	64	75	-	735
Moisture (%)	89	92	96	94
Fat (g)	0.20	0.20	0.20	0.20
Protein (g)	1.90	1.70	0.60	1.00
Carbohydrate (g)	8.20	5.30	2.40	4.10
Ash (g)	0.06	0.70	0.40	1.60
Calcium (mg)	28	64	19	18
Phosphorus (mg)	86	26	12	18
Iron (mg)	0.10	0.70	0.10	0.80
Thiamine (mg)	0.05	0.05	0.02	0.06
Riboflavin (mg)	0.08	0.05	0.02	0.04
Ascorbic acid (mg)	11	62	10	29
Niacin (mg)	0.03	0.30	0.10	0.60

Source: Adapted from Chutkaew and Paroda 1994.

1.3.2.4. Green ear maize.

A favourite snack food in almost every country where maize is grown is green ears roasted or boiled. The grain is eaten on the cob and it is an expanding street snack, especially when a topping like chilli, mayonnaise, butter, etc is added (very common in Mexico and Central America). The most used maize for this purpose is the normal flint maize ears, and it is a good source as food and energy. In some West African countries more than 50 percent of the area planted with maize is harvested for green ears. Among some advantages for this practice are that maize harvested for green ears does not face the problem of ears rots and grain insect damage in the field. Likewise, it makes a very useful source of energy and food between two main crop harvests. The green ear maize once it is cooked is known as "elote" in Central America.

The roasted or boiled green ears are largely consumed by children and women. The grain at the milk stage is more nutritious than rice. Also the fresh kernel separated from the green ears is also used as a vegetable, for preparation of sweet or sour pudding. A traditional tortilla named guirila and an especial tamale called yoltamal is prepared and consumed popularly in Nicaragua, and they are made from the kernel separated from the green ears and then ground. The plants of maize are still green when ears are harvested and it provides better fodder for livestock than dry Stover left over after the harvest of mature maize. Likewise, the green ear maize is a crop with shorter duration and occupies the field for few days allowing more intensive cropping patterns.

1.3.2.5. Quality Protein Maize (QPM).

This type of maize has the opaque-2 gene (o2). The dull appearance of this kernel and others undesirable characters have been overcome with the accumulation of genetic modifiers and extensive selection efforts carried out by scientist at CIMMYT in Mexico. The protein quality in QPM is much better than in normal maize. The zein fraction is reduced between 10 to 13 percent in QPM as against 39 percent in normal maize. In contrast, glutelin and glutelin-like fractions are increased. The nutritional and biological superiority in QPM has been demonstrated in the diets of infants, small children and adults, particularly women. At the present only Brazil, China, Ghana and South Africa are making serious effort to grown QPOM; there is also evidence that this QPM variety may be more suitable for use as greens ears and for production of composite flour.

1.3.2.6. Maize for fodder

The plant of maize is an excellent fodder for milk cattle as well draft cattle. It can be used as fodder at different stages of the plant growth particularly from tasselling onward. The plant does not have problems of prussic acid or hydrocyanic acid; therefore it can be used before flowering or in dry weather. The plant with ears at dough stage of grains development is best for use as fodder. Compared with others fodder it surpasses in dry matter production and digestibility of nutrient per hectare. Even this stage also is the best time for preparing silage. Usually, the grains varieties planted at higher densities have best results as fodder crop.

In some countries of Asia and in Egypt, farmers plant maize a very high density and progressively these are removed for using as fodder. In Mexico and Central America, the stalks above the ears are cut for fodder after ears development is well-advanced. Likewise, the green stalks left after the harvest of baby ear shoots and ear green maize are also used as fodder. Also QPM green ear silage or corn cob mix (CCM) is becoming very popular in Northern European countries, where maize cannot be grown to maturity. The (o2) CCM is equal in yield but superior in nutritional quality than normal maize (CCM) for feeding pigs.

1.3.2.7. Maize as livestock and poultry feed.

The maize grain gives the highest conversion ratio to meat, milk and eggs when is compared with others grains used as livestock feed, this is due its high starch and low fibre content which make it a very concentrated source of energy for livestock production. Although there is not available statistic for maize and livestock use, it is believed that greater portion is used as poultry feed in tropical countries. Yellow maize is preferred for livestock feed and it is used as whole grains, cracked or coarse ground, dry or wet or steamed and generally supplemented with vitamins and others proteins. Is expected that use of maize in formulated feed will increase in the future.
The use of QPM as animal feed promise good potential and it still remains to be exploited particularly for swine production. So far, there is some use of QPM for pig feed and it has been reported that the use of QPM as an ingredient in pig feed could help to reduce costs. However, it is possibly that the unavailability of sizeable quantities of QPM grains in the market, and the fact that cultivation of QPM has not been taken up on a commercial scale.

1.4 Secondary and derived products from maize

There are many products from maize that have been taken over by industry and manufactured and marketed at commercial scale. Several of these products already mentioned are now industrialised on a small or large scale. In the USA over 1 000 different items can be found on the shelves of a typical supermarket and they are derived wholly or partially from maize. These products include: tortillas, maize flours (masa), chips and several types of snack, breakfast cereal, thickness, pastes, syrups, sweeteners, grits, maize oil, soft drinks, beer, whisky, etc.
Basically, there are two milling process used for the maize industry for making various food, feed or industrial products. They are:
1. The wet milling process
2. The dry milling process.
In general, at large scale the wet milling process is more used than dry milling process. The wet milling process apparently allows remove more efficiently aflatoxins and impurities from maize in a more relative manner among other advantages. Normally, these two processes works better at large scale and with high investment, especially the wet milling process. In fact, huge wet milling process for maize by products production works not only for their own intermediate products but also for others plants which supply intermediate processed products, for instances, starch for syrup, germ for separate the oil, etc.
In both process, there are some common operations applicable for the maize to be used, such as the handling system, storage structures, drying and cleaning operations, inspection, etc. Some useful parameters to control in the maize grains are: heaping bulk angle 27 degree, the specific volume 1.2-1.3 m 3 /ton or specific gravity which is 0.72-0.85 grs/cm3. For the maize flour is 0.65 grs/cm3. The moisture content of the grains should be 13 percent and for the maize flour 11.5 percent. The temperature of drying recommendable for the grain is 60 0C and it takes about 12 hours for drying the maize from 35 percent to 15 percent .
According to some experts, a plant for maize flour processing be profitable, the investment for this type of plant is only justified on the basis of processing a minimum of 70 tons/day of maize grains, otherwise it is not profitable.

1.4.1 Wet Milling.

The wet milling process normally produce pure starch, sweeteners (dextrose, fructose, glucose and syrups including high fructose syrups), proteins, industrial starch, fibres, ethanol

and maize oil from the germ. The most important by-products are animal feed and this industry usually uses the flint and dent maize types.
Likewise, some special maize such as the waxy maize and high amylose maize are handled by the wet milling industry to produce tapioca-type high-grade starch and high amylose maize (also called amylomize) starch respectively.
Starch of maize is the most important product of the wet milling process, and it is widely used for food and industrial applications. The starch and oil extraction account for about 70 percent of the product, and the remaining 30 percent is formed principally by proteins and fibres (consisting mainly of cellulose and hemicelluloses) which is converted in animal feed. The flow diagram for this process is described in figure 11.

Fig. 11. Wet-millingProcess flow diagram
(Source: Corn Refining Assoc.)

The process of maize wet milled is to obtain starch, oil, cattle feed (gluten feed, gluten meal, germ cake) and the hydrolysis products of starch, liquid and solid glucose and syrups. The process includes the followings main operations:

1.4.1.1. Cleaning.

The maize received is cleaned before is storage. The selection and cleaning is applied by vacuum and it eliminates undesirable materials or particles such as dust, wastes, and pieces of ears, stone and insects.
Wet milling differs from dry milling in being a maceration process in which physical and chemical changes occurs in the nature of the basic constituents of the endosperm (starch, protein and wall cell material in order to cause a complete dissociation of the endosperm cell contents which release the starch granules from the protein network, where they are enclosed.

1.4.1.2. Drying.

For a safe storage the maize must be dried since the moisture content at harvest is generally higher than the desirable moisture content for storage. The temperature of drying should not exceed 54 0C (130 F), because higher temperatures may cause change in the protein, whereby it swells less during steeping and tend to tie the starch in a stronger manner, than in grain not dried or dried at lower temperatures. Likewise, if is dried above 54 0C, the germ become rubbery and tend to sink in the ground maize slurry (the germ separation depends on the floating of the germ) and the starch tends to retain high oil content.

1.4.1.3. Steeping.

The cleaned maize is steeped at a temperature of about 50 0C (122 F) for 28-48 hrs in water containing 0.02 to 0.03 percent of sulphur dioxide. The steeping is carried out in a series of tank through which the steep water is pumped counter- current. The moisture content in the grain increase rapidly to 35-45 percent , and more slowly to 43-45 percent. The steeping softens the kernel and assist the separation of the hull, germ and fiber from each other. The sulphur dioxide may disrupt the -S-S- bond in the matrix of the protein (Glutelin), facilitating the starch/protein separation. After steeping, the steep water is drained off. It contains around 6 percent of solids of which 35-45 percent is protein. The protein in the steep water is recovered by vacuum evaporation, allowed to settle out of the water in tanks, and dried as "gluten feed" for animal feeding. The water recovered is re-used as steep water or, after concentration, as a medium substrate for the culture of organism from which antibiotics are obtained.

1.4.1.4. De-germing.

The maize grain is coarsely ground freeing the germ from the remainder of the grain without breaking or crushing the germ. A fuss-mill is used for this purpose, it has a bronze-lined chamber housing two upright metal plates studded with metal teeth. One plate rotate at 900 rev/min the other one is stationary. Water and grains are fed which crack and open the grain, releasing the germ. By addition of starch-water suspension (1.06-1.08 sp. gr) the germ floats, whereas the grits and hulls sink.

1.4.1.5. Germ separation.

The ground material flows down separating the hulls and grits settled, while the germ overflows. Modern plants use hydro cyclones which use less space and are less costly to maintain than flotation equipment. Likewise, the germ separated on hydro cyclones is cleaner than the one separated by flotation.
The germ is washed and freed of starch on reels, dewatered and squeeze presses and dried on rotary steam driers. The dry germ is cooked by steam, and the oil extracted by hydraulic presses or by solvent extraction. The oil is screened, filtered and stored. The residual germ cake is used for cattle feed.

1.4.1.6. Milling or grinding.

The de-germed underflow from the germ separators is strained off from the liquor and finely milled on impact mills, such as entoleter or attrition mills like the Bauer mill. After this, the starch and protein of the endosperm are in a very finely divided state and remain in suspension. The hulls and fiber, which are not enough reduced in size, can be separated from protein and starch on reels fitted with 18-20 mesh screens. Fine fibers, which interfere with the subsequent separation of starch from protein, are removed by gravity shakers fitted with fine nylon cloth.

1.4.1.7. Separation of starch from protein.

In the raw grain the starch is embedded in a protein web which swells during steeping and tend to form tiny globules of hydrated protein. The dispersion of the protein, which frees the starch, is accelerated by the sulphur dioxide in the steep water. The suspension of starch and protein from the wet screening is adjusted to a density of 1.04 sp. gr. by de-watering over Grinco or string filters, and the starch separated from the protein in continuous high speed centrifuges, such as the Merco centrifugal separator. The starch is re-centrifuged in hydro cyclones to remove residual gluten protein and is then filtered and dried to 10-12 percent moisture in kiln or ovens, or tunnel or flash driers. The separated proteins is filtered and dried in rotary or fresh driers.
Then the protein is filtered and dried in rotary or flash driers. Further, fractioning to obtain the alcohol-soluble protein (zein), which is 50 percent of the maize gluten by solvent

extraction and precipitation, can be carried out. Zein has ample uses as a water protective coating material for nuts and confectionary, and as a binder for pharmaceutical.

1.4.1.8. Separation of gluten from the starch.

The paste of starch containing between 5 to 8 percent of gluten is passed through high speed centrifugation by using a centrifuge type Merco. Firstly, the good quality of gluten is separated from the starch and then it is concentrated in other centrifuge. The gluten is then filtered and dried in an instant rotatory drier. The gluten out coming is used as one of the major components of many food products.
The starch obtained in the first centrifugation still contains between 2 to 2.5 percent of gluten proteins and is also centrifuged with hydrocyclons. The hiyrocyclons centrifugal equipment used to separate the starch from the gluten is composed of many little tubes within a divided compartment and washing to countercurrent is applied to obtain a good separation of gluten and starch.

1.4.1.9. Zein separation (Optional).

Some companies use to separate from the fraction gluten a portion of the most important protein is the zein. The zein (prolin) is soluble in alcohol and it is contained into the gluten in about 50 percent. The zein is extracted by solvents and then precipitated. The main use of the zein protein is used in the food industry like an especial cover to prevent humidification on the surface of candies. Also it has good glutinous properties in the manufacture of pharmaceutical products.

1.4.1.10. Products derived from starch.

Due to the nature of the starch from it, it is possible to obtain other products by some specific chemical treatment, such as.
1. Syrups and sugars.
Approximately the half of the starch produced is converted into syrups and sugars depending of the extent of the treatment and the degree of purity desired in the final product. The conversion of starch into sugars can be done by enzymatic or acid hydrolysis. The syrups are produced by partial hydrolysis and the sugar dextrose by total hydrolysis. The acid hydrolysis process requires boiling the starch paste with a certain quantity of diluted acid. Generally, the acid most used is hydrochloric acid and the process ends when the degree of hydrolysis is get up. The chemical reaction is stopped by neutralizing agents like sodium carbonate. The impurities and solids particles are removed by filtration, then the syrup is blanched and concentrated until a final specific gravity desired.
The sugar dextrose is obtained by a complete or total hydrolysis of the starch, and then the liquor is neutralized, filtered, clarified and concentrated. Finally, the product is crystallized.
2. Uses for wet-milled maize products.
a. The maize starch.
Include paper manufacture, textile, adhesives and packed foods, and as the starting material for the manufacture of syrups and dextrose sugar by hydrolysis. The starch obtained from the wet milling of waxy maize, also called "amioca", which consist mainly of amyl pectin, is non-jelly and has clear, fluid, adhesive properties. Heated and dried maize starch/water slurries yield pre-gelatinized starch, known as "instant starch" as it thickness upon addition of cold water.
b. Glucose and Dextrose.
Are used in beer, cider, soft drinks, pharmaceuticals, confectionary, baking and jams.

c. Corn Gluten.
Is used mainly as animal feed. Also can be used as cork binding agent, additive for printing dyes, and pharmaceutical.
d. Dextrins.
The dextrins are products obtained by the breakdown of the solid dry starch, which is heated with chemical products like mineral acid almost always hydrochloric acid. The dextrins are used mainly as adhesives, dressing or glutinous agents.

1.4.2 The dry milling process

The process of dry milling is also used to produce a wide variety of food and non food products. In general, the process of maize starts with milling, even the maize which is used at household level. Except the maize eaten as kernel on the cob and popcorn all other products from maize are based on milled maize
A particular problem exist with rodent excreta pellets. Some time because of the maize grain size it overlap with rat's excreta pellets. Removal of this is more difficult than with other cereals, however removal of mouse excreta pellets is less of a problem. The specific gravity table, air separator and wet flotation each remove 50 to 70 percent of rat's pellets with a loss of 0.5 to 1 percent of the maize.
Milling separator, length and width separations and scourer-aspirators were considered less efficient.
There is no doubt that in order to avoid this type of problem, the best solution is storage the grain under rodent-proof conditions.

1.4.2.1 Conditioning.

This step is for a better de-germining. It allows loosen and toughen the germ and bran to mellow the endosperm, so as to obtain maximum yields of grits and a minimum yield of flour in the subsequent milling. This is achieved when the germ is somewhat damper than endosperm. The conditioning involves the addition of 2 to 3 percent of cold or hot water, or of steam for de-germining by rollers or entoleters. A moisture content of 20 to 22 percent is raised if a Beall degerminators is to be used. The conditioned grain stand for 24 hours, but generally it remains for only 1 to 2 hours.

1.4.2.2 De-germining.

This process includes de-germining de-hulling and it is carried out in one of the followings ways:
a) With a Beall de-germinator (d-germer and corn huller)
b) With roller mills and sifters
c) With impact machines, such as an entoleters, and gravity separators.
The Beall de-germinator is a cast iron cone at about 750 rev/min within a conical stationary housing fitted partly with screens and protrusions on the inner surface. The maize with 20 to 22 percent of moisture is fed in at the small end and works along to the large end, between the two elements. The protrusions on the rotors and the housing rub off the hull and germ by abrasive action, and break the endosperm into two o more pieces per grain.
In this method, it produce a maximum yield of large particle size grits (hominy) with low fiber content (about 0.5 percent) and low fat content, suitable for the manufacture of corn flakes. This vitreous part of the endosperm yields the hominy grits which come from the tail end of the machine. The germs are flattened, and cannot be separated from the comminuted mealy endosperm and bran, which pass through the screen mixed. The germ is heavily

damaged and it has 15 to 18 percent of fat. The power consumption is high due to need of drying the hominy grits.
The method using roller mills is the simple one and the germ separation, endosperm and bran is relatively inefficient. The content of fat in the grits and flour is 1.5 to 2 percent and the germ is obtained with a fat content of 15 percent. The roller mills used for de-germining have rolls flutted 15 to 23 cuts per centimeters (6 to 9 cuts per inches) and rotate at a differential speed of 1 1/4:1 or 1 1/2:1.
De-germing by impact machine, for example entoleters or turbo-crushers are used in Europe and it is carried out with the maize with natural moisture content and has lower power consumption than other process. The separation of germ from endosperm on gravity tables is efficient. However, separation of endosperm from bran by aspiration, and of the vitreous endosperm from mealy endosperm is less efficient than with the Beall de-germinator. The following products are obtained from this entoleter process:
Maize germ, 1-4,5 mm, with 18-25 percent of fat
Maize grits, 1-4,5mm, with 1-1.5 percent fat, 0.8-1,2 percent crude fiber: about 60 percent of the original maize
Semolina and flour, which may be made by size reduction of the grits.
The mealy endosperm of higher fat reduces more readily than does the vitreous endosperm, therefore, the flour has a higher fat content (about 3 percent , the semolina of lower fat content) 0.8-1.3 percent than the grits.

1.4.2.3 Drying and cooling.

The product from the Beal degerminators is dried to 15-15.5 percent moisture in a rotary steam tubes at a temperature of 60-710 centigrade degree (140-160 F) and cooled to 32-380 C (90-100 F) by aspiration with air.

1.4.2.4 Grading

The dried stock is sifted to produce a number of particles size fractions (large medium and fine hominy, germ roll stock, and meal). These stocks are fed to the mill, each one entering at a specific point, the large and medium at first break, the fine and germ roll stock at the second roll.

1.4.2.5 Milling.

The milling is carried out on roller mills using fluted rolls. The products are sifted on a plan sifter and are aspirated. The mill is divided into a break station, a series of germ and a series of reduction and quality rolls. The break system releases the rest of the germ as well entire particles and cracks the large grits to produce grits of medium size. The finished grits, meal and flour product are dried to 12-14 percent moisture content on a rotary steam tube driers.

1.4.2.6 Oil extraction.

Solvent extraction and mechanical pressing are used. The germ from the mill is first dried to about 3 percent moisture and then extracted while at a temperature of about 121 0C (250 F). The oil content in the germ is reduced by extraction from 18-25 percent to about 6 percent leftover in the germ cake; the extracted oil is filtered through a cloth using a pressure 552-690 kN/m2 (80-100 lbs/inch.2). The oils have a Specific gravity of 0.922-0.925 and is rich in essential fatty acids. Its high some point make it suitable for use as cooking oil and salad oil. The following table 9 shows particle sizes range and yield of dry-milled maize products obtained by dry-milled process.

Table 9: Particle Size Range and Yield of Dry-Milled Maize Products			
Product	**Mesh***	**mm**	**Yield (%w/w)**
Flaking grits	3 1/2 – 6	3.4-5.8	12
Coarse grits	9 – 12	1.4-2.0	15
Medium grits	12 -16	1-1.4	23
Fine grits	16 – 26	0.65-1.0	
Coarse meal	26 – 48	0.3-0.65	10
Fine meal (Coarse cones)	48-80	0.17-0.30	10
Corn Flour	thro' 80	< 0.17	5
Germ	-	0.5-6.7	14
Hominy feed	-	-	11

* Tyler Standard Screen Scale Size.
Sources: (Stiver, Jr 1955 and Easter 1969.

1.4.2.7. Uses for dry-milled maize products.

1. Flaking grits.
Are used for the manufacture of breakfast cereal corn flakes and grits from yellow maize are preferred.
2. Coarse grits and medium grits.
These are used in the manufacture of cereal products and snack foods.
3. Fine grits.
It is used as a brewing adjunct, providing up to 40 percent of the mash. At domestic level, maize grits or hominy grits are used to prepare porridge by boiling with water. In Italy, the maize porridge, made from fine grits or coarse meal and flavored with cheese is called "Polenta". Also maize grits can be used for the manufacture of wallpaper paste and glucose by chemical hydrolysis.
4. Coarse or granulated maize.
This is used in pancake and muffin mixes, corn snacks, cereals products and other baking products.
5. Fine meal or corn (maize cones).
Used to make maize bread, bakery mixed, infant’s foods and breakfast cereal.
6. Corn (maize) flour.
Is used for make bread and pancake mixed, infants foods, biscuits, wafers, as filler and carriers in meat products, and in breakfast cereals. Dry-milled maize flour it should not be confused with "Corn flour", this term is used in the U.K. for maize starch obtained as a product of wet milling.

Furthermore, dry milling and wet milling process are used for the production of ethanol or gasohol from maize. Approximately one third of gasohol is produced by the dry milling process and two third by the wet milling process. In these two processes only a little over 70 percent of the product is in the form of starch and it is used for ethanol production. The remaining material, which comprises about 11 percent of cellulose, hemicelluloses, leftover starch and sugars, is used to make animal feed supplements. In USA the National Renewable Energy Laboratory has developed a technology using sophisticated biotechnological tools to increase gasohol production. They have selected certain strain of fungi and develop genetically engineered bacteria that can hydrolyse cellulose and hemicelluloses and produce alcohol from these complex carbohydrates. This new technology or biotechnology could increase the ethanol production from maize by about 13 percent and make gasohol more cheap and competitive. Also maize cob and stover, although they do not have starch, however they have cellulose and consequently may become feedstock for ethanol production. These technologies are of special interest in the tropics.

1.5 Requirements for export and quality assurance.

The term quality applied to food material refers to those attributes of the food which make it agreeable to the person who eat it. In a broaden context, attributes of quality involve color, flavor, texture, nutritional value and free of harmful substances such as microorganisms, insects, pest and their products. For these reasons is very important to have and implement a regulatory system to control production and commercialization of food materials in order to protect the public from harmful and poisonous food, prevent the sale of substandard foods containing substances which may not be harmful, but do not describe the food correctly, and eliminate false and fraudulent trade practices. Applications of regulations can be effective only if thoroughly tested standards are set up and implemented.

The quality of food grains is assessed in line to the circumstances prevailing in different part of the world. Usually, they take into considerations attributes like size, color, texture and extraneous materials. Chemical parameters such as oil content, acidity, moisture and presence/absence of toxins may also be considered in quality assessment. Some quality legislation in force in some developing countries was reviewed and detailed analysis of these legislations indicated relevant issues as follows:

• Each country has its own standard of quality, and the quality parameters become more comprehensive for major commodity (ies) than for others.

• The quality standards are seldom based on an objective scientific basis and are often arbitrary.

So that is important to select the most useful indicators of quality and to apply them for minimizing the losses in nutrient available to the population of developing countries. Agreements at the international level on which indicators for using would be most beneficial. In any case, the parameters chosen must be able to be applied uniformly, quickly and cheaply. Likewise, to keep in mind that use of sophisticated equipment and techniques only when their are unavoidable (e.g. pesticides analysis), the indicators chosen should be those which ensure a safe and wholesome supply of grain. Also is recommendable to include factors which affect the market value of the produce. At the present, actions addressed to regulate updating issues like production of cereals genetically improved or modified, etc require regulations. This situation is the great interest for export and import countries and design of parameters on upgrading qualities for trading cereals is required.

A country which deserve be mentioned in this regards is India. It as one of the largest grain producing nations in the developing world, implemented through a coordination of the Food Corporation of India (FCI) and the Prevention of Food Adulteration Act (PFA) a reasonable standard grain system. This system since 1955 has evolved through years and it appears to be working satisfactorily and it applies to purchase, storage and sale of food grains and their products. According to these provisions, food grains meant for human consumption shall fulfill the followings standards of quality:

• Grain shall be free from deleterious material and insecticide residues in excess of the prescribed limits

• >Foreign matter including sand, gravel, dirt, stones, pebbles, straw, stem, chaff, cockles, oilseeds and other non-poisonous seeds, but excluding non-food grains, shall not exceed 4 percent by weight

• Grain that is damaged by fungus, moisture or heating wherein the damage is not superficial, but grain is affected internally, shall not exceed 5 percent by weight
• Uric acid content arising as a result of insect damage shall not exceed 10 mg per 100 g of the sampled grain
• The loss in weight due to moisture content shall not exceed 16 percent .
Other useful and typical standards have been developed by FAO/WHO Codex Alimentarius Commission and may serve as an appropriate reference for trading of maize in developing or developed countries as is showed in the next table 10.

Table 10: Maximum residue Limits for Pesticides in Grains Recommended by the FAO/WHO Code Alimentarius Commission

Commodity	**Pesticide**	**Maximum Residue Limit (mg/Kg)**
Maize	Chlordane	0.05
	Chlorfenvinphos	0.05 (kernels)
	Diquat	0.1
	Paraquat	0.1
	Chlorpyriphos-methyl	10
	Methidathion	0.1
	Monocrothophos	0.05
	Fensulfothion	0.1
	Bromophos-ethyl	0.05
	Ethion	0.05

Likewise, the next table 11 can serve as a model and it also shows some specifications for maize in India.

Table 11: Specifications for maize-general characteristics

Admixture of impurities	**Tolerance limit (percent)**
Foreign matter	1.0
Other food grain	1.0
Admixture of different varieties	10.0
Shriveled and immature grains	3.0
damaged and discolored grains	2.0
Slightly damaged grains	2.0
Weeviled grains	1.0
Moisture	14.0

The next table 12 shows some grades for maize in India as useful reference showing Maximum Tolerance Limit to grains.

Table 12: Specifications for Maize-Schedule showing Maximum Tolerance Limit							
Grade Designation	**Foreign matter (percent)**	**Other food grains (percent)**	**Admixture of different varieties (percent)**	**Shriveled and immature grains (percent)**	**damaged and discolored grains (percent)**	**Slightly damaged and touched grains (percent)**	**Weevilled grains (percent)**
FAQ (fair average quality)	1.0	1.0	10.0	3.0	2.0	2.0	1.0
One grade below	2.0	2.0	15.0	5.0	3.0	4.0	3.0
Two grade below	3.5	5.0	20.0	7.0	4.0	6.0	5.0

1.6 Consumer preferences.

As it was described in previous section 1.3, maize in general is used in more ways than any other cereal. White maize in particular is preferred in developing countries as human food due to the organoleptic properties. In contrast, yellow maize is used in developed countries for feeding livestock and poultry. The yellow maize is desirable, for instances, to increase the yellow colour characteristic of the eggs yolk. In any case, maize is used either home cooked and industrial, as fodder, feed animals and fermentation in various industrial products.

1.6.1 Some nutritional aspects of maize.

Maize nutritionally is superior than others cereals in many ways, except in protein value. The following table 13 shows the nutritive composition of maize, wheat and rice of various parts of the kernels.

Table 13: Maize, Wheat and rice grain nutritional composition (per 100 g)			
Content	**Maize ground meal**	**Wheat flour**	**Rice polished grain**
Calories	362	359	360
(g)			
Water (percent)	12	12	13
Protein	9	12	6.8
Fat	3.4	1.3	0.7
Carbohydrates	74.5	74.1	78.9
Starch fibre	1	0.5	0.2
Ash	1.1	0.65	0.6

(mg)			
Calcium	6	24	6
Iron	1.8	1.3	0.8
Phosphorus	178	191	140
Thiamine	0.30	0.26	0.12
Riboflavin	0.08	0.07	0.03
Niacin	1.9	2.0	1.5

Maize compared with wheat and rice is higher in fat, iron and fibre content. A weak nutritional aspect of maize is the quality of its protein since around a half of its protein is made up of zein, which is low in two essential amino acids, lysine and tryptophan. Fortunately this deficiency nowadays has been corrected with the development of the quality protein maize (QPM), which is nutritionally the most superior cereal grain.

1.6.2. Regional consumption of maize.

In most tropical countries that produce maize on a commercial scale, it is used mainly as food for human consumption, such as is shown in the following table 14.

Table 14: Use of maize by region in tropical countries

Region	**Total Production (000 tonnes)**	**Use (%)**		
		Food	**Feed**	**Other**
Eastern & Southern Africa	11, 523	85	6	9
West & Central Africa	6,172	80	5	15
North Africa Producers (a)	5,378	53	35	12
North African non-producers (b)	-	2	92	6
West Asia producers (c)	2527	49	39	12
West Asia non-producers (d)	-	4	93	3
South Asia	11, 876	75	5	20
Southeast Asia & Pacific producers	16,2	53	40	7
Southeast Asia & Pacific non-producers	-	4	91	5
Southern China	9	35	55	10
Mexico, Central América & Caribbean	17,735	64	22	14

South American Andean Region	3,664	61	32	8
South American Southern Cone	26,879	13	76	11
Producer countries	110, 954	51	37	12
All countries	-	47	42	11

A=Egypt and Morocco
B=Algeria, Libya and Tunisia
C=Afghanistan and Turkey
D=Iran, Irak, Syria, Jordan and Saudi Arabia
E=Malaysia and Singapore
F=Northern Argentina, Brazil and Paraguay are included
Source: extracted from CIMMYT, 1994.
Note: see recipes based on maize in the annex.

1.7 Others.

1.7.1 Maize production and the need for adopting technology.

Technological components are useful if they are used integrated in the production system for sustainable crop or animal production. Most farmers, particularly at the subsistence level, rarely adopt complete production packages, especially for crops such as maize, in zones when it has been produced for many years as a staple food and has become part of their traditional culture. It is deficient for them to afford drastic changes in their traditional technologies, unless they accept the risk of the innovations.
However, there is a need for developing single production components which can be individually adopted by farmers as a mini package of technologies that can secure a noticeable and immediate yield increase (i.e. nitrogen, weed control, mulch, ridging system, manure, intercropping, etc)
The production components varies in specifity such as a nutrients levels, cultivars, tillage system, date of planting, intercropping components or run off and erosion control system.
In the following section, some basic concepts of tropical maize agronomy are presented as a background source of information.

1.7.2 Soil preparation (Basic concepts).

Tillage can be defined as the chemical, physical or biological manipulation of soil to optimize germination, seedling emergence and crop establishment. This definition includes operations involved in producing a crop, such as chopping of residues, planting, applications of pesticides, fertilizers and harvesting.
Although, there are many tillage systems, including zero-tillage, that are undoubtedly play a very important in determining the time-efficiency of a farmer, a system that optimize production and productivity should be chosen depending of the soil and agronomic and climatic conditions.
Since the intervention of the plough, has been justified for many persons that the preparation of the soil is necessary based on reasoning which has not been completely scientifically proven. Some of the main justifications for soil preparation with manual and mechanical implements include: efficient weed control, incorporation of plant residues, soil aeration

improvement, seedbed preparation, disease and/or insect control, improvement of the physical condition of the soil, fertilizer incorporation, plough pan elimination and improvement of root development. However, nowadays is easy to refute these arguments since it is well known that:

• weeds are controlled with herbicides and even with mulch alone

• It is better to leave crop residue on the soil surface than to incorporate them, because crop residue prevent soil erosion. Mulch also protects the soils against excessive water loss caused by evaporation and maintain soil moisture close to the surface and present crusting, which avoid the infiltration of water

• mulch dissipate the kinetic energy of raindrops, which upon impact with the bare soil would otherwise loosen soil particles and cause crusting

• The aeration of the soil not constitutes a problem in untilled soils, except in cases of excess of moisture in the soil.

• An opening made on the soil with a pointed stick or a cut made with a disc of a maize planter is enough to prepare a seed bed. Remotion of 7 000 tones of soil/Ha during seed bed preparation cannot be justified for the only purpose of providing a place to deposit the seeds.

• Soil preparation has a coadjutant effect on maize disease and insect control, however in temperate zones; however the situation in the tropics is controversial. An adequate solution can be found by integrated pest and disease control.

• it is normally accepted that the soils are prepared to improve the physical structure, paradoxically however, in some cases the more the soil is worked, the more pore structure is destroyed. Plough pan and soil compaction are direct consequences of the use of ploughs and harrows.

• Due to compaction of the soil, there is limited water and nutrient availability to plants. Compaction also limits plant growth and yield, by affecting water infiltration, aeration, and plant disease and yield quality.

1.7.3 Conventional and conservation tillage.

Traditional soil preparation methods, almost at the same time, began to change when the mould-board plough was replaced advantageously by the disc plough. This new implement left a good proportion of the crop residue on the soil surface. However, both types of ploughs, and even the offset discs contribute to plough pan formation since they pack the lower furrow-slice. In some cases though, this hard layer may originate from other original causes during the process of soil formation. The advantage of chisel plough, as well as subsoilers, brought the advantage of being able to break the plough pan on naturally well drained-soils, resulting in better root penetration through the cracks, permitting the plants to reach nutrient lying below the arable layer.

During 1950 to 1960, a new generation of herbicides with residual effects and inhibitor effects on photosynthesis, such as triazine, revolutionized maize production. This allowed the implementation of a herbicide-based (atrazine) system known as zero-tillage, which combined various operations into a single pass of machinery, in such a way, that only the planting furrows was opened and the fertilizer incorporated at the same time. The zero-tillage can be performed by smallholders, even without herbicides, through an appropriated management of plant residues, such as mulch cover, which by means of its shading effect checks the development of weeds in the maize field.

This new system, which is a conservation system, includes operations that create an appropriate environment for the development of the plants of maize, while optimizing water and soil conservation. Sometimes, conservation tillage is confounded with minimum or reduced tillage, but the latter simply means that a farmer who normally compresses the soil in eight or even more passes with tilling and other farm equipment reduces a sustainable system that involve growing crops without plowing, harrowing or discing. It is characterized by the least amount of soil disturbance (since tillage is restricted to the minimum necessary for preparing the seedbed) a maximum retention of crop residues o the surface of the soil and at lower costs.

1.7.4 Time of planting.

The time of sowing will be determined by the actual date when appropriated rain is received. For a given cultivar, the exploitation of the best weather conditions in terms of temperature and rainfall, require precise information from experimentation. In some regions, the pre-soaking of the seed in lukewarm water overnight hastens the germination, which is of importance when temperature is low at the time of sowing. For landraces, the traditional dates of planting used by farmers derived from many years of trials and errors and should be highly considered and checked through experimentation. Usually, their planting
Dates avoid periods of excessive rainfall or drought at the time in which maize is most susceptible, such as around flowering.
An important problem in planting maize is the erratic onset of the rains in some regions, where intermittent showers tend to encourage weed growth before rains are in fact established.
If planting is done at the first onset of rainfall and the rain disappear immediately for more than five days or more, germination can be seriously affected. Sometimes the rains take so long to resume that farmers realize, and later there will be the need to replant, which is an expensive exercise.

1.7.5 Planting depth.

Independently of the tillage system used, the seed (treated with fungicides and/or insecticides when deemed necessary) should be placed at the correct depth, generally 5 to 10 cm. It will assure good contact with the moist of the soil to prevent desiccation and secure that the coleoptiles will not have problems in reaching the surface of the soil. Deeper planting is recommendable in areas with high soil temperature and when no mulch is present. Shallow planting in soils with poor moisture must be avoided, since it may not only endanger germination, but may also cause to be very uneven with lagging seedling poorly competing with plants from earlier germinating dates.
Cloddy soils prevent good contact between the soil and seed and are responsible for poor and uneven germination. Soils prone to crust formation should be planted under a zero-tillage system and with a good mulch cover. If planted under conventional tillage, crusting should be disrupted just prior to seedling emergence by means of a very superficial till.

1.7.6 Planting system.

In conventional tillage, maize seeds can be planted by making holes in the soil with a stick, a cutlass or a hoe, or by putting in a furrow opened with a small wooden or mould-board plough. There is several mechanized equipment for planting. They can be operated manually as a planting machine or a planting-fertilizing machine, and it is known in Brazil as "matraca" which has two small containers one for the seed and once for the fertilizer, see figure 12.

Fig. 12. The "Matraca"planter with a seed and a fertilizer deposit (A.D.Violic).

Another model with a zero tillage single planter and with fertilizer attachment is suitable for small and medium farmers , such as is showed in figure 13 below.

Fig. 13. Zero-tillage single planter with fertilizer attachment (A.D.Violic).

Planting machines also apply fertilizers, and some models include adjustable mechanism for the application of pesticides. Zero tillage planting machines must be equipped with additional parts suitable for the type of terrain being planted and for the presence of mulch, since the furrow-opener function is hindered by crop residue on the soil surface. CIMMYT has developed a small, low cost direct-drill planter known as "Chiquita" which can be animal or tractor drawn.

1.7.7 Planting density and spacing.

According to CIMMYT a good density is achieved by using an optimum density (for example, 85 000 plants/Ha.) and suing a simple calculation, where this quantity is reduced by 30 percent. The calculations are as follows:
85 000 - (85 000 x 0.3) = 60 000 plants/Ha.

So that, if 20 percent of the total expected plants are going to be lost between planting and harvesting, the recommended seeding rate should be adjusted upwards:
60 000 x 120 = 72 000 seeds/Ha.
100
Therefore, if 1Kg of maize seed variety contains 3 000 kernels, 25 Kg of seed per hectares will be necessary.

1.7.8 Fertilization.

For the improvement of agricultural sustainability it requires to reduce dependency on external purchase and non-renewable resources and minimizing the environmental harmful. However in order to improve their productivity and profitability, the use of agrochemical nutrients including insecticides, herbicides and fungicides, these may be unavoidable for farmers in tropical and subtropical areas, taking in considerations that the best ones are chosen and for each specific case in the correct way. The following table 15 shows some experimental data from several sources estimating the quantity of nutrients that maize plants extract from the soil to yield different levels.

Table 15: Nutrients removed from the soil

Plant part	**Yield (Tones/Ha)**	**Nutrients Extracted Kg/Ha.**				
		N	**P**	**K**	**Ca**	**Mg**
Grain yield Stover Total	1.0 1.5 2.5	25 15 40	6 3 9	15 18 33	3.0 4.5 7.5	2.0 3.0 5.0
Grain yield Stover Total	4.0 4.0 8.0	63 37 100	12 6 18	30 38 68	8 10 18	6 8 14
Grain yield Stover Total	7 7 14	128 72 200	20 14 34	37 93 130	14 17 31	11 13 24
Source: Sánchez 1976						

These data can be used as a guide in order to estimate how much nutrients are necessary to attain certain yield, but taking into considerations that other biotic and abiotic factors have a minimum interference or influence on the maize crop.

1.7.9 Weed Control.

During maize production weeds, insects and diseases are important factors which can cause loss of maize. Generally the losses due to weed surpass those caused by diseases and insect together. Some studies have demonstrated a negative correlation between weed dry weigh and maize yield, with an actual grain weight reduction of up to 95 percent. Some report of yield losses in maize due to weeds ranging from 20 to 100 percent in Philippines, Brazil, and Gambia, Sierra Leone and Nigeria and 30 to 56 percent in Ethiopia.
Although land area is a constraint to small-scale farmers, the labor is often even more limiting, since it is estimated that weeding may utilize 35 to 70 percent of total agricultural

labor in Africa, except in areas where animal traction is abundant, most weeding during the cropping season is done by hand.
There are three ways which weed affect the maize crop, in terms of light utilization, some weeds grow faster and taller than maize during the first growing stages of the crop, therefore depriving the maize crop from an adequate light supply for photosynthesis. However, early weeding give maize back its natural advantage, which is its tall size.
Likewise, water is a limiting factor in many tropical and subtropical maize growing areas and consequently a few days of water stree may be responsible for severe yield losses. An early drought during the first vegetative growth stage may kill young plants and therefore reduce severely the plant density/Ha. Weeds at this stage will increase water stress during this critical growth period between two weeks before and two weeks after flowering of maize, and consequently the crop will respond with lower yield.
In regards to the competition of nutrients, some weeds absorb up to twice as much nitrogen and phosphorus and up to three times more potash than maize on a plant dry matter basis. Nitrogen is usually the first nutrient to become deficient due to weed competition, and it is recognised by the pale colour of maize seedlings in the heave presence of weeds. In addition to the three types of competition, a biochemical type of competition known as allelopathy is the effect which some weeds have on maize by liberating growth inhibitors structure into the soil and may result in total crop loss.
The weeds which affect maize crop can be controlled by the followings methods:
· Cultural methods, such as crop rotation
· Mechanical methods which could be since hand pulling and hoeing to machine tillage and
· Chemical methods such as herbicides.

1.7.10 Water management.

The maize crop requires from 550 to 650 mm rainfall per unit area for a good growth, and it reduces weed competition for water throughout the growing cycle. However, if the profile of the soil is at field capacity at the time of planting, 350 to 450 mm of well-distributed rain through the growing cycle is enough to produce a good crop.
Good deep soil permitting the roots to grow down to 1.5m deep may have a moisture capacity of 1cm of water per 6cm of soil, i.e. about 250 mm of water. The coefficient of transpiration for maize is 280 to 350 litres of water per Kg. of grain produced. The ratio of evapo-transpiration from the maize field to open pan evaporation is around 0.35 at the seedling stage and increase to 0.80 at the silking stage before declining again. During the early growth stages, most water loss is due to evaporation from the base soil, since only about 2 to 2.5 mm of water per day is needed until the crop reaches the five-to-six-leaves stage. The water requirements also vary with plant density, it means than less water is needed with low stand than with high stand. But, this relationship is not always linear since there is a point at which increasing density will increase water need at a lower rate since the utilization of water in evapo-transpiration does not increase. Considering other losses not related to photosynthesis, and the fact that for every Kg of grain there is about another 1.2 kg of Stover, the total water needed to produce 1kg of maize grain is about 600 litres.
The main sources for the maize crop may come from the moisture retained in the soil before planting, the rainfall during the crop season, from irrigation and in less amounts from dew condensed on the leaves that is funnelled by the leaf bleads and stems to the base of the plant. Most tropical cropping areas are rain fed, which capture and storage of as much water as possible in the soil profile imperative. The solution is irrigation, which although expensive, should be important in the tropics.
When irrigation is available, it should be a priority to provide water during the period two week before to two weeks after silking.

The most common system of irrigation and where water is abundant should consider borders, furrows, level furrows, terraces and sprinklers. Likewise, in order to choose an irrigation system some factors should be taking into account such as the slope, soil texture and depth, topography and costs.
Among the main features of irrigation system are:
· The borders are strips of land surrounded by border which run in the same direction of the slope. The borders guide the water over the field, when it leaves the head ditch.
· Contour furrows are used in steep terrain. The furrows laid out on the contours and the slope of the furrow is less than 3 percent (this is the terrain falls less than 3 m in 100 m).
· Terraces are level beds where maize crop could be irrigated by borders or furrows; it is suitable on soils which do not crack too much and with slopes up to more than 30 percent .
· Sprinklers, which are very used for maize seed production due to its high cost is suitable for uneven fields with slopes even higher than 30 percent .
By using special attachments sprinklers irrigation allow to make fertigation, which is the application of fertilizers and pesticides together with the irrigation water.

2. Post-production Operations

In this section it will be referred to post harvest operations carried out mainly by smallholder and eventually medium farmers in developing countries. Likewise, it will include as much as possible many illustrations, figures, etc in order to describe clearly the post harvest system.

2.1. Pre-harvest operations.

The yield of maize should be optimised once the plant gets the physiological maturity. It is when the kernel has the maximum content of dry matter. So in order to maintain the quantity of maize produced without changes for its commercialization is important to harvest on time. If this considerations is not taken into account the maize could have losses not only in quantity but also in quality.
The period between planting and harvesting for maize depend upon the variety. In general the crop is physiologically mature 7-8 weeks after flowering, at that time the kernel contains 35-40 percent of moisture and has the maximum content of dry matter. This is the time when the crop should be harvested in order to avoid unnecessary losses in the field. Loses may occur when maize crop is harvested at various stages beyond maturity, as is shown in the table 16.

Table 16: Percent of losses when maize crop is harvested at various stages beyond maturity

Percent of moisture at harvesting				
Parameter	30	25	20	15
Missing grain	1.4	2.6	4.7	8.7
Damaged grain	5.5	8.5	12.9	19.7
Source: AGROTEC/UNDP/OPS, 1991.				

The physiological maturity in maize is recognised by the following characteristics:
· Yellowing of most of the leaves
· Some of the leaves start drying up
· Yellowing and drying up of the husks turning papery
· Maize grains acquire a glossy surface
· The grain is too hard and uncomfortable to chew when it is roasted for eating

· Some maize cobs begin to droop (hanging downward) on the stalk. This is in response to the plant shut-off of the supply of nutrients to the shoot system that occur at physiological maturity.
For some varieties of hybrid maize a test known as "Black layer test" has been used to determine the harvesting time. This method consists in collecting randomly 10 maize cobs in an area of one hectare. Then ten maize grains are shelled off from the centre of each maize cob. The 100 shelled grains are thoroughly mixed and a sub sample of ten grains is randomly selected and peeled backwards the tip-caps. Each tip-cap exposed from each peeled grain is observed.
Interpretation: When the colour of the tip-cap scar so exposed is black or dark brown in most of the peeled maize grain, it means that crop maize is mature and ready for harvesting.

2.2. Harvesting

Since the maize crop attains its physiological maturity until it is consumed, a set of activities should be undertaken by farmers. The sequence of such interconnected farm activities forms a post-harvest management system for the crop. Under smallholder maize farming the system take two main alternatives:
· Timely harvesting
· Drying and late harvesting

2.2.1. Description of the timely harvesting system:

1. Monitoring maturity: Physiological maturity style is monitored to ensure timely harvesting. This is aimed at minimising post maturity losses in the field.
2. Harvesting: carried out manually and at physiological maturity. Cobs are detached from the plants, dehusked and placed in pile for transportation to the farm yard.
3. Transport: This implies delivering of maize crop from one point at the farm to the other or to and from the rural or urban market or mill.
4. Drying cobs at the farm yard: The high-moisture content of the cobs in its physiological maturity may get spoiling very fast unless it is quickly and effectively dried. Drying can be carried out through various proven low cost drying methods.
5, 8*. Cobs must be shelled immediately after drying and the grain store in a safe storage place like the small metallic silos. Is recommendable that appropriated technique should take into considerations factors like saving time, reduce drudgery and minimise grain damage shelling.
6. Pest control treatment: Some indigenous methods are used to control insect pests in stored maize cobs or grain, but not always are effective. Where are available appropriated chemicals that effectively contrail infestations and damage caused by storage pests.
7. Storage: Maize crop, either in cobs or shelled, is kept in various storage structure or containers for different lengths of time awaiting use short-term storage(4-5 months), season-long storage (6-9 months), long term storage (>9months).
9. Consumption marketing: The end-uses of maize at the farm level can be for sale, seed or food owners' family and feed for livestock.
*Depending if the cob is shelled immediately of later.
Advantages of the Timely Harvesting System:
· Avert long-term exposure of maize crop in the field. It reduces damage and losses due to birds, insect pests, rodent and wild animals.
· Reduction of damage and losses means better returns to the farmers in terms of quality and quantity crop.
· Less pest field infestation means less problems in storage
· Less risks of crops theft in the field

· Ensure early ploughing and planting of the next crop. This ensures also higher crop yield, better crop rotation and better future harvest.
· Ensure that the plant biomass (leaves, stalks, etc) still have significant levels of nutrients for feeding livestock
· The abundant plant biomass collected under this system can also be used for cooking, heating of water and spaces for lighting in rural areas.
Disadvantages:
· Heavy to handle and transport the bulky high-moisture crop to the farm yard
· Drying the high-moisture content of the crop at the farm yard requires especial equipment.

2.2.2. Description of the Field Drying and Late Harvesting System

1. Field drying: Crop is left to dry in the field for 4-7 weeks beyond maturity, either in stalks, stacks or heaps.
2. Harvesting: This is carried out manually. Cobs are detached from the plants and either dehusked or left in sheaths, ready for transportation to the farm yard.
3. Transport: deliver of crop from one point at the farm to the other or from the farm to and from the rural or urban markets or mills.
5. Drying crop at the farm yard: Field drying does not attain recommended moisture level for safe storage. The crop must therefore be further dried at the farm yard before storage.
4, 6 Shelling cobs, 9 Cleaning grain: Maize crop may be shelled immediately, it is delivered from the field or following on-farm drying and storage.
8. Storage: Maize crop, either in cobs or grains, is kept in various structures or containers for different time awaiting use.
9. Consumption and Marketing: Maize end-uses at the farm level are: sale, seed or as food for owners' family and feed for livestock.
Advantages of the system:
· Less weight of crop transport to the farm yard.
· Less problems of drying due low-moisture crop at the farm yard.
Disadvantages:
· Long-term exposure of the crop to field infestations and damage by birds, rodents, wild animals, insects and fungi beyond maturity
· Infestations and damage that start in the field account for up to 80 percent of insect infestations at the beginning of storage. This becomes a great liability in storage.
· Higher risks of crop theft in the field.
· Maize fields are not released on time for subsequent preparations and planting.
Observations: The advantages of timely harvesting of maize are more and greatly outweigh the problems of handling, transporting and drying and when is compared with the field drying and late harvesting system.

2.3. Transport.

The maize crop harvested requires to be moved from the field to the farm yard. The distance may vary from several hundred meters away but some times can be several kilometers as more than five. The maize is also transported within the farm-site, and to and from the rural or urban mills and markets as is shown in the following figure 14.

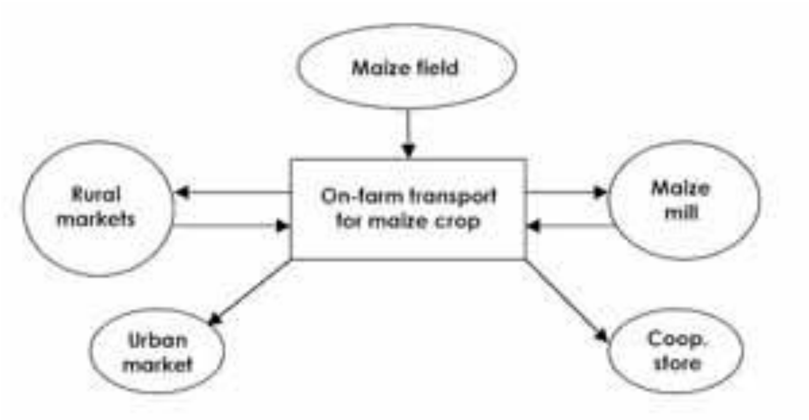


Fig. 14. Transport Diagram for maize
(AGROTEC/UNDP/OPS, 1991)

Most of these movements are handled by women and children, and is common in Africa as well in some Latin American rural areas. Usually the produce is carried either on their heads, on shoulders or backs.

2.3.1. Transport and Technology.

There are different ways to transport harvested crop from the field to its destination. As carrying on head or back of the persons and referred in table 18 below, until modern transportation by using trucks, etc. The destinations could be markets, processing units for grains, storage, etc. The transport system choice will depend of several factors, such as the socioeconomic level of the zone, amount of production of the crop, road of access, distances to be crossed, infrastructures availability, use and availability of animals , ways, roads, railroads, ship for rivers, cars, trucks, etc. to transport the harvested product, etc. So, the selection by the farmer of a method of transport will depend also of the capacity of them. Here it will be refer to technologies of transport very affordable among small and medium farmers of developing countries, which is referred in table below.

Some useful transport technologies recommended for on-farm use include:

· Hand pushed wheel barrows and carts, usually made by women
· Pack-animal, particularly donkey and mules
· Draught animals to carry crop-loads on sledge and on carts.

The criteria for selecting an appropriated on-farm technology must take into considerations biological, technical and socioeconomic feasibility of the technology.

The following table 17 shows comparative data by using a workload (Load x Distance) as a reference factor where for carrying on the head or back is here taken as "base-line ratio" = 1.

Table 17: Comparative guide for selecting on farm transport technology		
Type of transport	**Optimum workload (KgxKm)**	**Ratio by type of transport**
Carrying on head or back	(20-30)x3	1
Using hand-pushed wheel-barrow	(50-75)x5	3-5
Using hand-pushed/pulled cart (2 persons)	(300-400)x2	4-6
Using pack-animals (donkeys)	(40-75)x10	7-9
Using animal drawn sledges (donkey, oxen)	(50-250)x5	12-15
Using animal drawn carts (donkey, oxen)	(500-1000)x8	50-80
Source: AGROTEC/UNDP/OPS, 1991.		

The on-farm transport above indicated includes:

2.3.1.1. Hand-pushed wheel barrow figure 15.

These are often available in the open market although not affordable to smallholder farmers. Notwithstanding, simple wheel barrow can be manufactured at cheap cost in rural carpentry workshop using local materials. The maize can be transported in cobs or grain and either in bulk or bagged. Loads up to 50-80 kg can be carried on simple-wheel wheelbarrow depending upon effort of the operator.

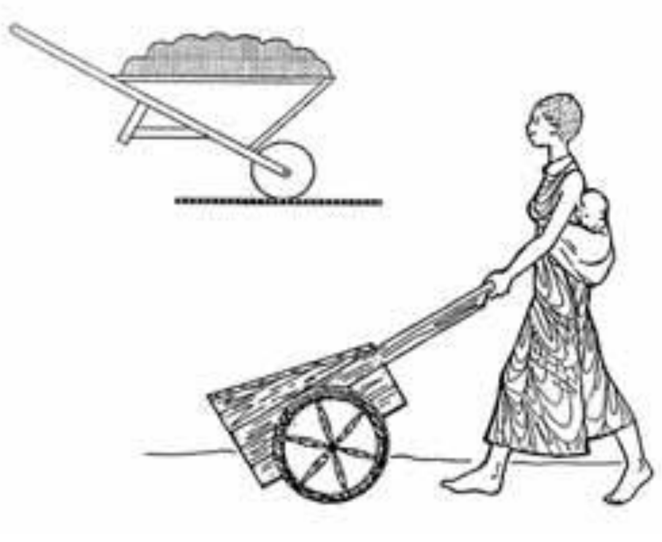


Fig. 15 Hand-Pushed Car
(AGROTEC/UNDP/OPS, 1991)

Advantages:
· Appropriated for low-resources farmers
· Feasible to build in local workshop and local material
· Simple, cheap for making and repair
· Relieve human drudgery and efforts, saving lot of work time
· Can be used on paths and areas with poor roads or no roads

Disadvantages:
· Low carrying capacity
· Difficult to direct when heavily loaded and in poor terrain

2.3.1.2. Hand-pulled/pushed cart fig.16

This an be made in local workshops and entirely with local materials. Is very suitable for medium-size crops loads (up to 300-400 kg) over a short distance. Appropriated for cob maize and other bulky crop from the field to the farm yard.

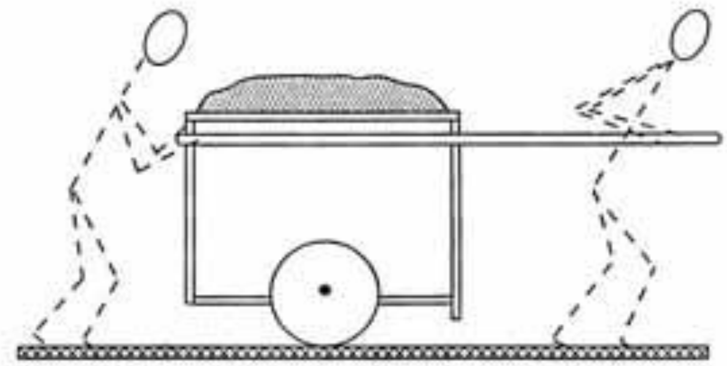
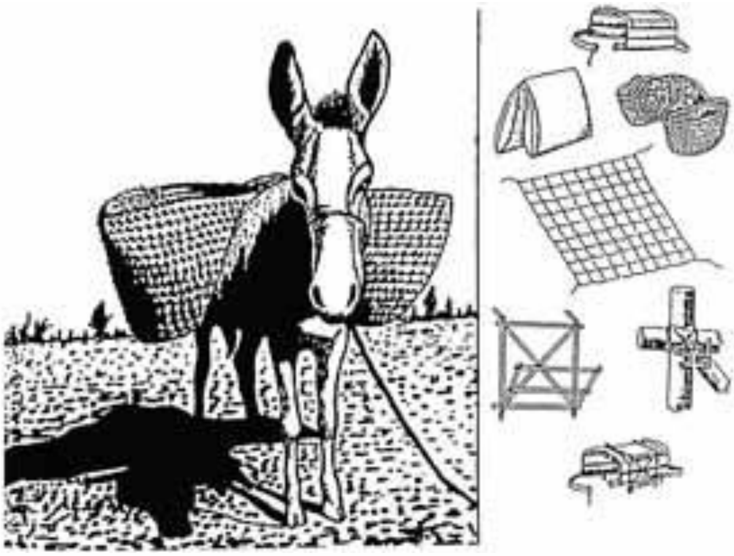


Fig. 16. Hand-Pulled Car
(AGROTEC/UNDP/OPS, 1991)

Advantages:
· Feasibly to make wholly with local materials
· Easy to maintain and repair
· Suitable for bulky crops (cob maize, etc)
Disadvantages:
· Requires enough effort to operate (2 persons preferently)
· Rather sensitive to changes in road terrain.

2.3.1.3. Pack-animals.

The use of pack-animals (donkey, mules, oxen's) is of the most profitable and convenient method, in small scale transport. This method is suitable on plain surface but also feasible in hilly and mountainous areas.
Donkeys are ideal as pack-animals since they are tolerant, patient and require minimum supervision and control. Normally, for transporting some padding must be used over the back of the beast to offer comfort.
A donkey averaging 100-110 kg of weight can carry load of 25-50 over distances up to 20 km. Large donkeys with proper care can carry load 50-75 percent of their own weight over short distances. In average, daily loads of 40-100 kgs (35 percent of body weight) for up to 4 working hours are considered normal, see figure 17.



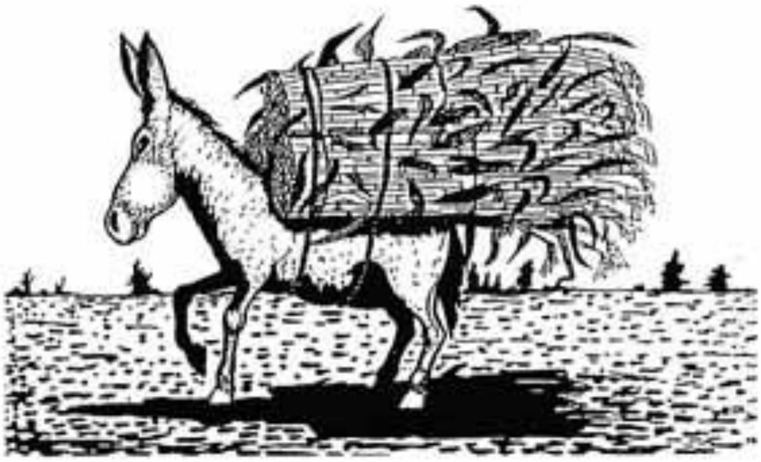


Fig. 17 Packed animal for on-farm transport
(AGROTEC/UNDP/OPS, 1991)

Advantages of pack-animal technology:
· Indigenous technology used for mixed-farming agricultural system
· Relatively cheap technology and easy to maintain and manage
· Saving on the would – be capital investment on motorized transport equipment and on imported fuel
· Other than as "pack-animal" the beast can be also be used for other functions.
· The technology is most restricted only to agricultural support.

2.3.1.4. Draught animal for sledges, figure 18.

Sledges are widely used in southern and east Africa to transport crops at farm level. Sledges can be arranged in parallel pieces or naturally occurring fork of a branch or trunk of a tree. A chain or rope is tied either at the forked apex of the equipment or at a grooved collar-ring made to facilitate traction. A simple platform on the V-arms of the equipment is used to support the crop usually in bags up to 300 kg of crop can be carried on a sledge by a pair of oxens.

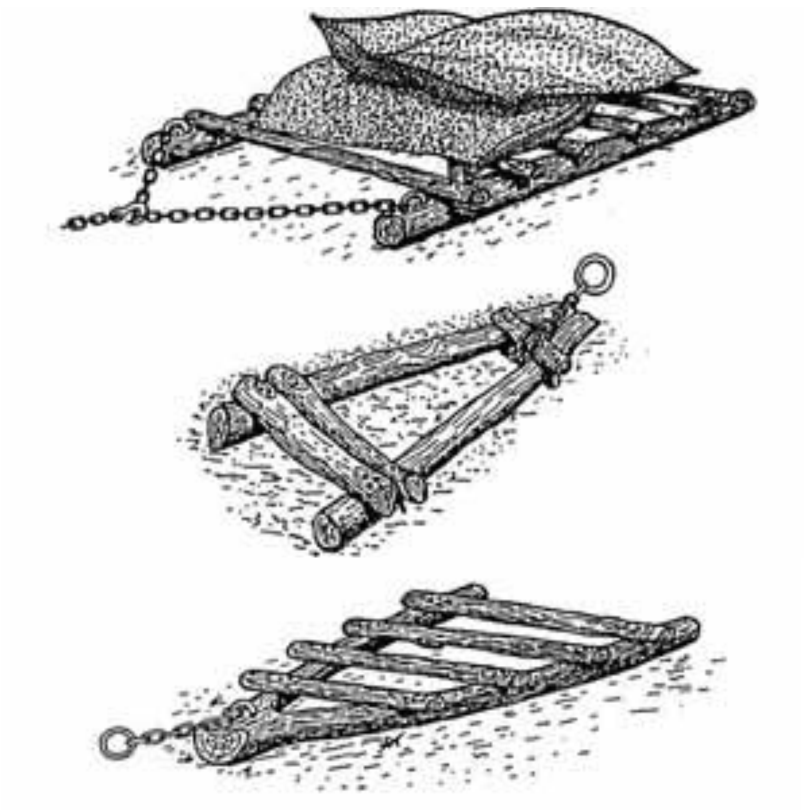
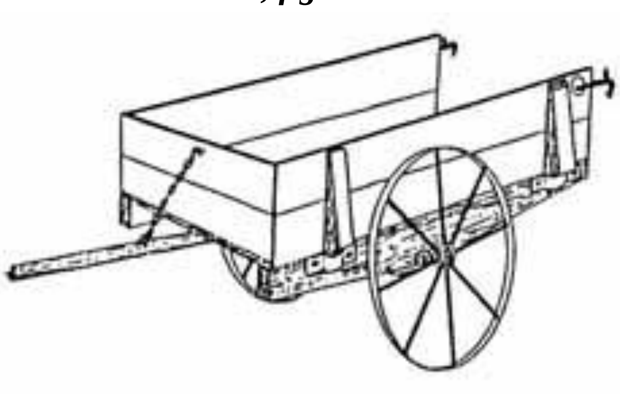


Fig. 18. Draught animal for sledge.
(AGROTEC/UNDP/OPS, 1991)

Advantages:
· Simple and require no special skill to make and repair
· Low-cost may be obtained at no financial cost
· Can operate under various weather and topographic conditions, even on wet ground where sledge’s traction coefficient is best.
· Since it has a low centre of gravity and are narrow can be used on tracks too narrow or steeps for carts
· Can be used to other transport functions other than for carrying agricultural produce
· Indigenous technology for small holder farmers.
Disadvantages:
· The equipment may leaves rutted tracks causing dangerous water courses in heavy rains
· Due to environmental degradation in some southern African have officially discouraged and even banned.

2.3.1.5. Animal drawn carts, figure 19.



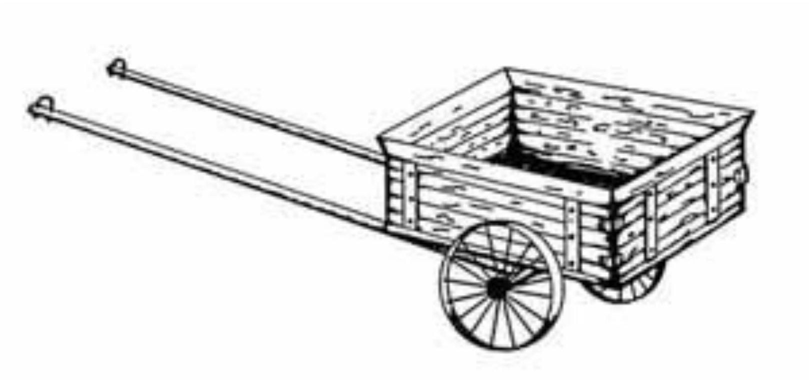


Fig. 19. Animal Drawn Cart
(AGROTEC/UNDP/OPS, 1991)

This on farm transport method is recommendable where agricultural production is significant and topography permitted.

Advantages:

· Draught animals can be used for pulling carts
· Is efficient and may wholly be made of local materials
· It allows to carry variety of crops either bagged or in bulk
· It allows to carry different type of agricultural residues
· May be hired by transport entrepreneurs during agricultural off season, to generate some income for the household and reducing its idle time.
· A single-axle cart drawn by donkeys can carry up to 500 kg load and a pair of well bred oxen can transport 1 000-1500 kgs load

Disadvantage:

· High equipment cost.

2.4. Drying.

The main purpose of drying is preventing germination, prevent the growth of bacteria and fungi and retard considerably the development of mites and insects. One of the main problems in tropical areas is during harvesting time because rain is frequent and in consequence the high relative humidity, poor insulation levels and shortage of household labor heavily constrain drying.

Drying crop in the field by traditional methods fail for attaining safe moisture level for storage. In addition, field drying exposes the crop to field pests. The harvested crop either for any of the two methods previously indicated in harvesting section (timely harvesting, and field drying and late harvesting) must be further dried at the farm yard.

Improvements on traditional methods must consider:

· Facilitate crop moisture levels for safe storage
· Retain maximum quality of the crop
· Give added value to the grain

2.4.1. Traditional drying techniques at the farm yard

2.4.1.1. Maize cob dried dehusked or in sheaths.

A common method involves spreading the crop on bare ground. It take a week for drying late harvested cob but over three weeks to dry timely harvested crop, but it also depend upon weather conditions and the initial moisture content. Dehusked cobs take shorter to dry than in sheaths. Some farmers shell late harvested crop (16-20 percent) for drying in grain form, but still on bare ground.

Advantages:
· Very simple and easy to implement
· It is cost-free in terms of energy for drying.
Disadvantages:
· Is slow, time consuming and labor-intensive, involving lots of crop handling
· Due that rain normally persist at harvesting, is difficult to achieve a safe moisture level for storage
· The crop is exposed to: soil contamination, domestic animals, bad weather, microbiological degradation which reduce quality and quantity
· Excess of heat may cause "case hardening", "bleaching", and "decolouration"of grains affecting viability and storability of the grain.
· The drying crop should be under shelter in case of rain or night fall increasing handling costs and labor inputs.
Some consequences by drying crop on bare ground include:
· Physical losses: animals, lost during gathering up or cleaning, losses may get 2-5 percent
· Quality loss due to: mould infestations with risk from aflatoxins, contamination with extraneous material and animal dropping
· Economic loss: low commercial value of the grain due to reduction on its quality and quantity with risk of rejection by the consumer.

2.4.1.2. Poles or tree-branch to dry:

The maize cob in sheaths may be stringed-up into bunches and then suspended.
Disadvantages:
· In good weather conditions is possible to dry down to 12 percent moisture.
Disadvantages:
· It permits drying only small quantities of crop with no control on environmental effect
· Crop is exposed to insect, rodent infestation and inclement weather
· Physical and quality losses due to pests and bad weather may be significant.

2.4.1.3. Suspended above fire places in kitchen houses in the form of stringed-up cobs.

Advantages:
· The heat and smoke from fire help in drying and scaring off the pests from the crop, keeping the grain intact and safe for future planting.
· Drying below 10-12 percent moisture level is possible without insect infestation
· Loss level either quantitative and qualitative are negligible
Disadvantages:
· Only small quantities can be handled.

2.4.1.4. Round or rectangular slatted wall farm structures.

It is used through the tropics to dry and store maize in cobs. These often have a roof-thatch of grass, papyrus banana or palm leaves. Popular in some part of West Africa.
Advantages:
· These structures can handle realistic quantities of crop to meet farmer’s drying and storage requirements.
Disadvantages:
· They have design deficiencies which neither facilitate proper drying nor protect the crop from damage and infestation by conventional crop loss agents such as rodents, insects and moulds.

2.4.2. Recommended low cost drying techniques.

There are some technique recommended for drying maize which are better to be used rather than pre-harvest drying of the maize in the field.

2.4.2.1. Drying of mats.

Simple mats made of natural leaves or bamboo splits, etc for open sun drying of maize cob or grain. The mat with crop on is spread on the ground or mounted on raised racks. The effect of the heat of the sun and the natural air gradually dries the crop.

Advantages:

· Contamination and moisture diffusion absorption is eliminated

· The quality of the drying crop is improved

· Drying rate of the crop increase

· This technology is easy to use and very affordable.

Disadvantage:

· The crop need to be moved under shelter (inside the house or veranda) when rain threatens or during night fall

· Labour input is significant due to spreading and raking of the crop to facilitate drying and removing.

2.4.2.2. Drying on plastic sheets, figure 20.

Commercial plastic sheets for drying the crop on can be used for maize in cob and shelled. Likewise, heavy-gauge polythene sheeting or sheets made from opened-out nylon sacks can be also used.

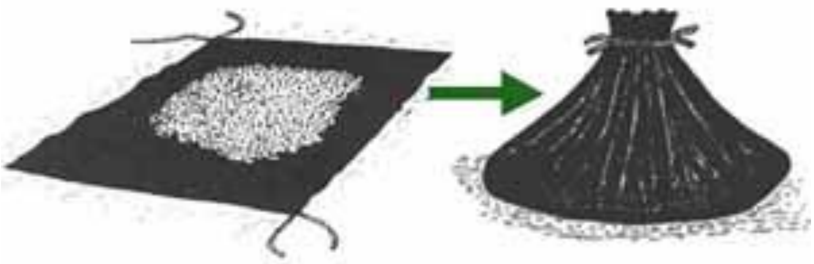


Fig. 20. Plastic sheets for drying
(AGROTEC/UNDP/OPS, 1991)

Advantages:

· Drying crop is protected from ground dampness. It eliminates microbial and soil contamination.

· The air movement about the crop accelerates drying.

· With black plastic sheeting in color, it absorbs readily solar heat with further increase drying rate.

· The sheeting can be easily be spread to dry the crop and rapidly gathered in the sheet when threaten by rain when keeping indoors.

· Performance-wise, drying on plastic sheeting compare very favorably with that on rised trace.

· A sheet 15-20 m2 may hold up to 500 kg of grain at a loading rate of 25-30 kg/m2 .

Disadvantages:

· Cost of the sheets could be rather high.

· Storage of the sheet in the off-season is very difficult, specially for small scale farmers where reliable storage space is limited and protection against rodents and insects, unlikely to be achieved.

2.4.2.3. Drying on wire-mesh or reeds-mesh trays.

In this method maize cobs or grain can be efficiently be dried on simple wire mesh or reed-mesh tray mounted either horizontally or inclined on wooden racks, figure 21.
The frame for the wire mesh tray can be or carpentry timber 25x150mm, with a bottom made of standard 4x4mm mesh-hire sheeting, 90 cm wide.
Likewise, the frame for the reed-mesh tray can be from half-split poles with a bottom made of local reeds nailed to mesh. Both design are approximately 2 mm long. Crop held on the trays dried under the influence of both the sun and the ambient air.

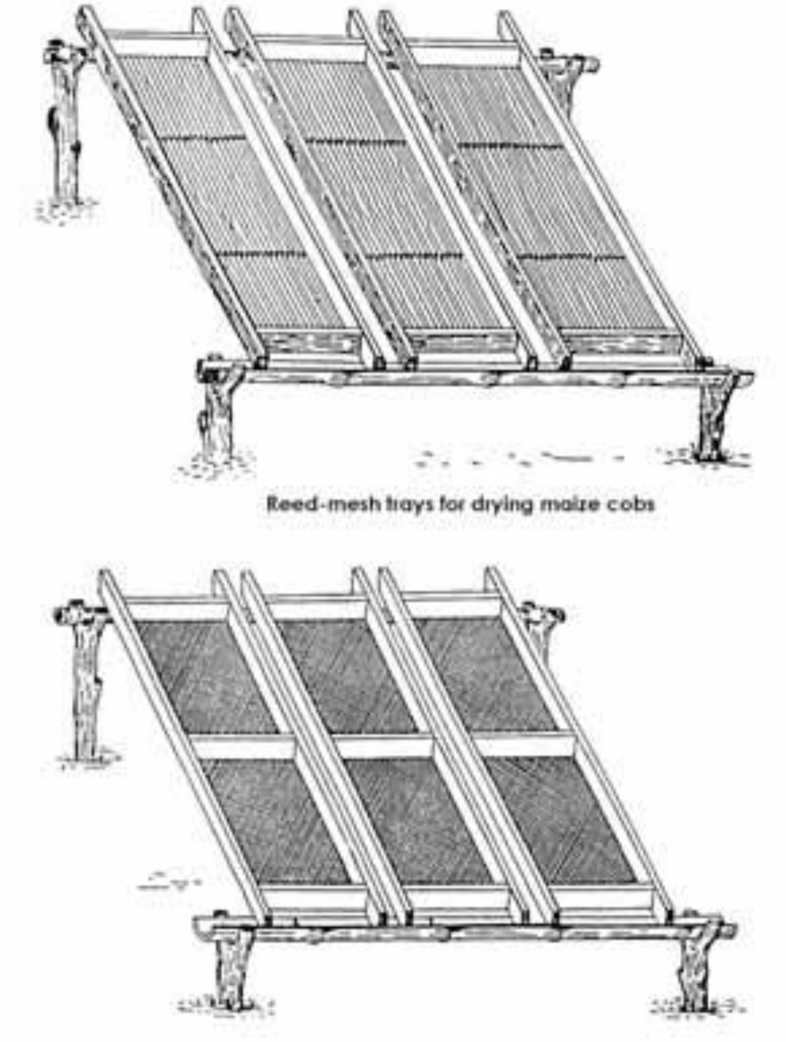


Fig. 21. Wire-mesh or reeds-mesh trays for drying maize cobs or grains (AGROTEC/UNDP/OPS, 1991)

Advantages:
· Simple design and easy to make it
· The reed-mesh design is affordable
· The drying rate increase two time than base ground
· Quality of grain is high since contamination is avoidable

· Final moisture is 11-12 percent therefore is appropriated for seed or long-term store
· Loading rate 20-25 kg/m and 4 cm deep in good weather
· The drying performance of the two design not significant different under most weather conditions
· In case of rain or night fall, trays can be stacked in a heap one on top of the other and using appropriate sheeting, or for delivery indoors.
Disadvantages:
· The metal-mesh sheeting used in the wire mesh tray design, is rather expensive.
Remarks: these structure are highly recommended to be used at all levels of maize farmers.

2.4.2.4. Drying in Improved Natural Ventilate Structure

On-farm drying of maize in a natural ventilate structure, becomes a positive smallholder option, specially when more than one ton of timely harvest maize is to be handled. The circular granary basket is very common in Africa and can be woven from a variety of material and build by local artisans.
Rectangular cribs can have walls of reed-woven or bamboo splits woven panels made to match the dimension of the creep-frame. A more appropriate structure is with walls made parallel strips or slats of timber; Bamboo; or any local poles resistant to insect attacks. In both cases, roof may be of corrugated iron sheets or natural fibers (thatch grass, pal leaves, etc). Circular or rectangular cribs have the same principle of operation, figure 22.

Circular Crib Rectangular Crib

Fig. 22. Circular and Rectangular Crib
(Source: FAO/NRI)

The drying process of maize cob, is achieved by means of the air which blows through the structure walls and through the crop inside; therefore removing the moisture.
Some factors which affect the rate of drying are:
Resistance of air flow by the structure wall and crop inside, air velocity (faster air, faster dry rate), and the percent of the relative humidity of the air.
In order to achieve a fast and uniform drying in a natural ventilated structure, the following design characteristics should be taken into consideration:
· The width (Diameter) of the structure must be selected in accordance with the mean climatic condition at the drying site during three to four months time which maize drying process normally take place. So that, in connection with this, the next table 18 shows a guide line to crib designing.

Table 18: Guideline to crib selection based on mean percent of relative humidity of the locality	
Mean Daily Relative Humidity	**Recommended crib width (m)**
>80%	0.6
75-80 %	1.0
65-75%	1.5
(AGROTEC/UNDP/OPS, 1991)	

· The narrower the structure, the uniform the drying rate, giving less chance for moulding.
· The wall of the structure must ensure a minimum of 50 percent wall opening. This allows effective passage for drying air.
· In windy areas, one of the longest side (facades) most face the direction of the wind.
· This is not applicable for circulated structures.
· The site for the structure most be fully exposed to the effect of wind without obstructing such as trees, bushes or nearby structures.
· Roof with large overhang is necessary to protect drying cob from rain, as is shown in the following figures 23A and 23B.

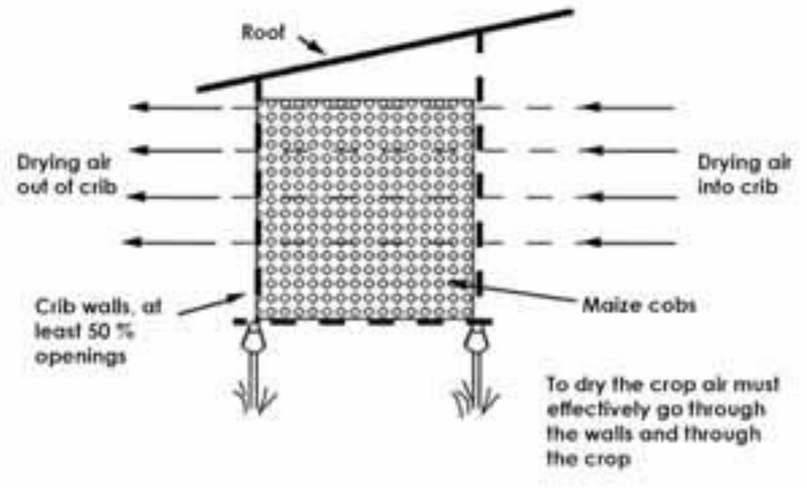


Fig. 23-A. Type of crib for drying crops

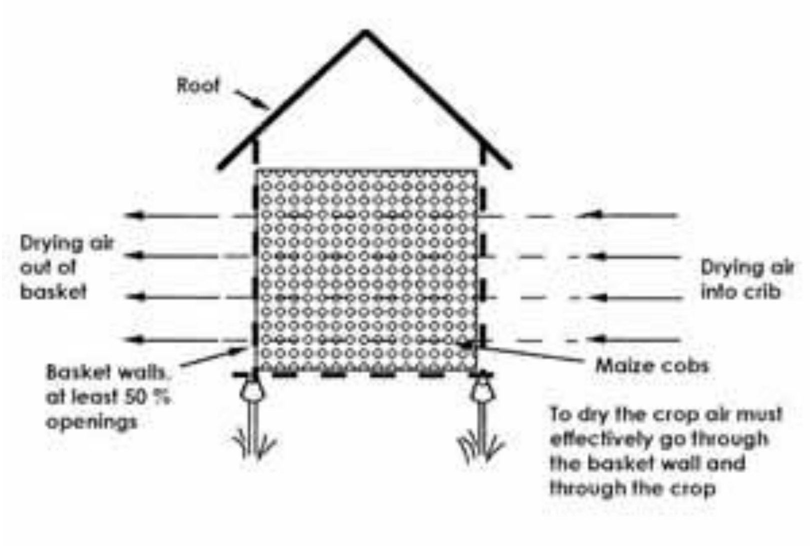


Fig. 23-B. Type of crib for drying crops.
(AGROTEC/UNDP/OPS, 1991)

· The structure must be erected at a site as far as possible from maize field to reduce chance of infestation.
· The constant ventilation keep the crop cool, it limits the rapid infestation by insect pests.
· It takes 50-75 days in this structure to get moisture level of 13-13.50 percent , depending on weather conditions. During this period, the level of infestation of the cob by pest is insignificant, therefore is not necessary chemical treatment for the cob before or they are drying in the structure.
· After cob are dried, they must be removed for shelling, cleaning, and pre-storage treatment to protect the grain from damage by insect pest. Grain is best stored in shelled form, in bulk or bagged.
· Rodent pest are controlled by rat-guard structures (See figure 22 below) which are set up 0.9 m from the ground around the vertical holding pole of the crib.

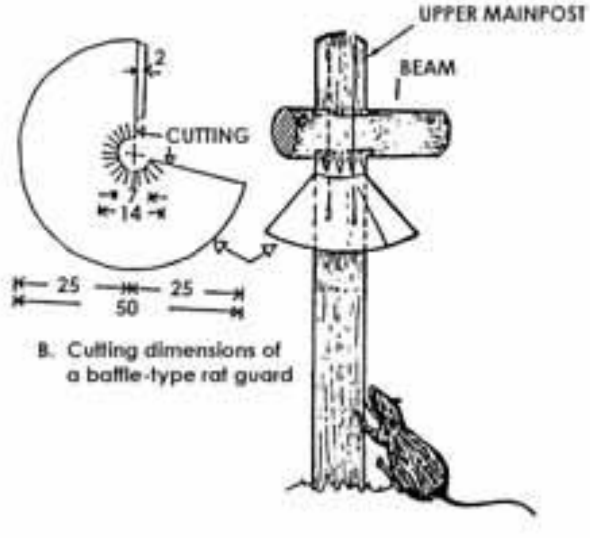


Fig. 24. Rat Guard Structure

The size and capacity for rectangular crib drying structure recommended a width which range 0.6-1.5 m depending on the relative humidity as was shown in previous table 19, however the capacity of the crib can be extended with the extension of the length to accommodate the volume of crop. The following table 21 shows appropriated dimensions of the crib related to the volume of crop as a function of the width of the cribs. Is an Important Remark that for better stability the height of the "box" or basket as part of the crib should not exceed 1.7 m.

Table 19: Dimensions of the crib related to the volume of crop as a function of the width of the cribs.			
Required Parameter	**Width of rectangular crib (m)**		
	0.6	1.0	1.5
Length of one section (m)	1.6	1.6	1.6
Crop loading height from platform (m)	1.5	1.5	1.5
Vol. (per section) available for crop (ms)	1.4	2.4	3.6
Appr. bulk-density of cob maize at 30% MC (kg/rn3)	560	560	560
Weight of husked maize cobs at 30% MC (kg/section)	790	1 350	2 000
Approx. weight of shelled maize grain at 13% MC (kg/section)	470	690	1100
MC= Moisture Content Note: Width of a crib is not rigidly fixed at 0.6, 1.0 and 1.5 meters. Any width between 0.6-1.5 m is appropriated and wider of 1.5 m may result in the drying crop partially rotting inside the structure.			

The following figure 25 also shown recommended dimension of the rectangular crib of various width.

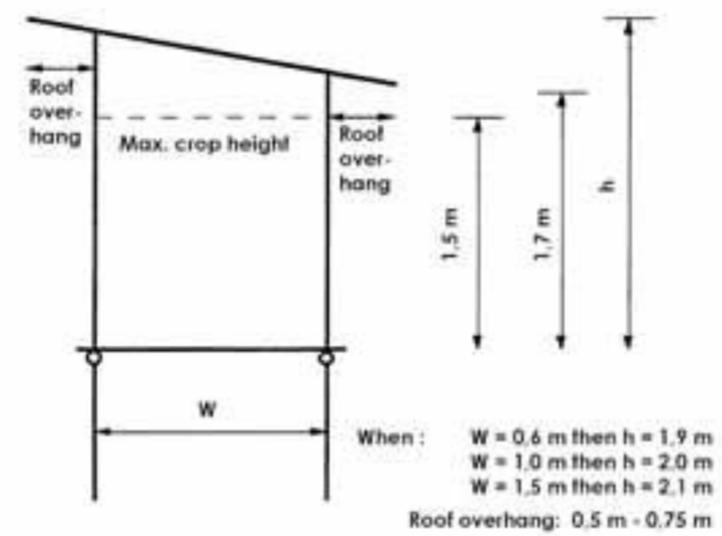


Fig. 25. Main Dimension of crib of various widths (AGROTEC/UNDP/OPS, 1991)

Advantages:

· Its capacity can be extended to meet the production requirement of any level of farmer.
· Durable structure having a lifespan of approximately 10 years
· Is rodent and bird proof
· The open area of the walls is nearly double that of technical cribs. This increase the safety margin for quality drying.
· This structure protect maize from sun, rain and makes non-visible to passing people.
· It is easy to load and unload and can be locked to protect against theft.
· Material required is locally available.
· Can be used for drying and storage of different products, making it engaged almost throughout the year. This reduce pay back period.
· Maintenance is reduced to a minimum.
· It creates a new standard for on-farm structures.
Disadvantages:
· Structure requires more capital investment than traditional structure.
· Construction require more craftsmanship and definitively, some training.

2.4.2.5. Floor of Concrete for crop drying (Piso de Secado)

This is an structure made of concrete-cement on the ground floor and where is possible to dry any type of grain even others like fruits and vegetables. The structure measure are 5x5 m or 10 x 10 m and can be enlarged depending upon the need see figure 26.

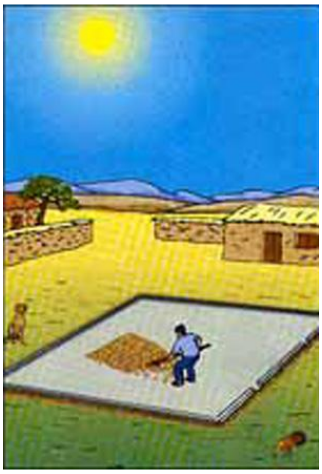


Fig. 26. Floor of concrete-cemented for drying
(Source: FAO/GCP/Bol/032.Net)

The concrete floor for drying has some advantages such as:
· There is no contamination with soils, micro-organisms, etc.
· It is simple and easy to build
· Is versatile since many products can be dried.
· Environmentally adequate because it only uses solar energy for drying.
· On an structure 5 x 5 m, is possible to dry one ton of maize in 8 hours within a sunny day and on a concrete floor of 10 x 10 m is possible to dry 4 tons.
* This structures were successfully used by the FAO project: GCP/BOL/032/NET in rural areas of Bolivia. Prices of these floors of drying of 5 x 5 m and 10 x 10 were approximately $60 and $200 US dollars respectively at this time. They are very useful for small village and communities.

2.5. Shelling Cob and cleaning grain

Shelling/Treshing either removal of maize grain from the cob and winnowing cleaning which involves separating the shaft in broken bits of cob from the grain. Maize Shelling is difficult at a moisture level content above 25 percent . With this moisture content, grain stripping efficiency is very poor with high operational energy and causing mechanical damage to the kernels. A more efficient shelling is achieved when the grain has been suitable dry to 13 percent to 14 percent moisture content.

2.5.1. Shelling the grain.

Traditionally is done by hands (women and child) but it is tedious labour with low productivity 10-25 kg/hour. Some advantages of shelling:
· Reduce required storage capacity
· Facilitate effective application of insecticide.
· Reduce grain susceptibility to large grain borer LGB and other pests.

2.5.2. Cleaning grain.

A simple way is winnowing which consist let to drop grains from certain height and the natural wind eliminates the impurities, however this methods is tedious, inefficient and causes grain losses. Cleaning of grains is useful due to:
· Increase purity and marked value of the grain
· Reduce mould and insect development
· Prevent the propagation of weed seeds in the grain

2.5.3. Improved maize shellers and winnowers recommended.

Low-cost equipment are available and can reduce much of the current high and tedious labor requirement shelling and cleaning maize. These also can yet be within the financial means of the small holder farm household.
This Category Include:
· Hand-held devices of various designs and outputs.
· Small rotary hand sheller
· Free standing manually operating sheller

2.5.3.1. Hand Held shellers

With this sheller, maize cob held on one hand is rotated against a stationary shelling device held on the other hand, or viceversa. In the process, the teeth of the sheller entangle and remove the grain from the cob figure 27 below.

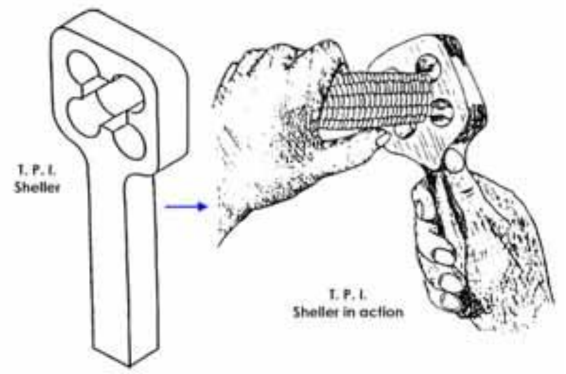


Fig. 27 Hand-held shellers
(AGROTEC/UNDP/OPS, 1991)

Advantage:
· Can be fabricated artesanaly and using local material
· Cheap and suitable for small scale farm
· Minimum damage and loss to the kernels
· More efficient compared to direct hand shelling
· Reduce work tedium and finger soreness
· No required special skills
Disadvantage:
· Low output (8-15 kg/h), 1 cup a time is shelled
· Slow process and required sound dry and uniform size of the cob
· Small, broken or large cob can not be easily handle.
· Winnowing and cleaning of the shelled grain has to be done by traditional methods.

2.5.3.2. Small Rotary Hand Sheller figure 28.

These are made with fixture, facilitating mounting of the equipment on a stationary stand or bench for stability. They have an opening into which single cob are fed for shelling. A hand operated lever rotates a spike disc against the maize cob. This press the cob downward at the same time rotating against the spikes of the disc which removes the grain.

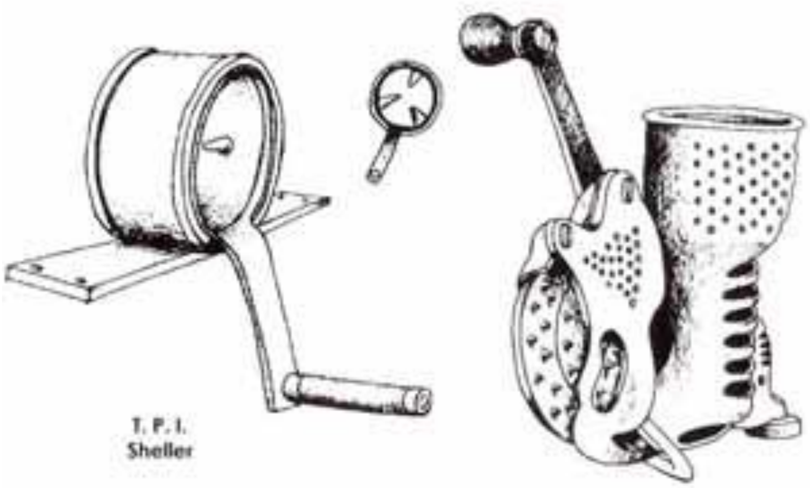


Fig. 28. Chitetze and Atlas types maize rotary shellers respectively.
(Source: ITDG)

Advantage:
· Particularly suitable for small farmers
· Effective and usually quite robust machine with a productivity up to 100 kg/h and above depending of the design
· Operation fairly simple
· These shellers can be made in metal, however is possible to manufacture similar equipment from wooden.
Disadvantages:
· Significant grain damage may result from inadequate use of equipment
· Relatively slow shelling, i.e. Only one cob at a time.

2.5.3.3. Free-Standing manually Operated Shellers

The mode of grain removal in free-standing manually operated maize shellers is similar to that in small rotary hand operated shellers, but include some modification to improve the capacity and efficiency of the machine. Such modification include:
· Use of a Flywheel to maintain momentum required for smooth operation.
· Mechanical cob feed rolls
· Quite often a stripped-cob expeller, a simple grain cleaning screen or winnowing fan.
These equipments may be operated by hand, pedal powered or may be supplied in engine powered form: electrical or fuel, figure 29

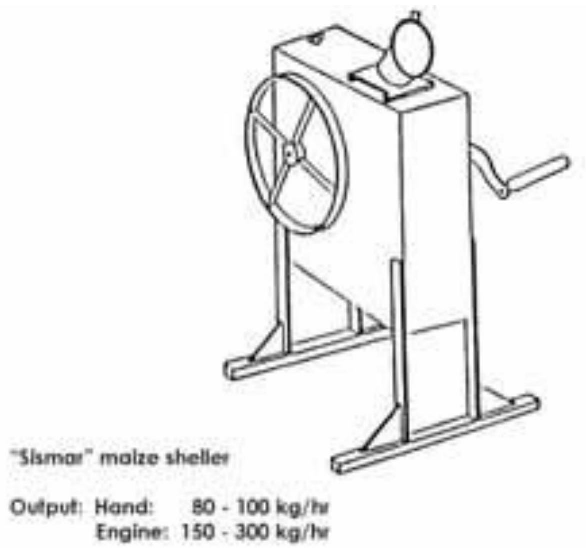


Fig. 29. Example of free-standing manually operated maize sheller. (AGROTEC/UNDP/OPS, 1991)

Advantages:
· More productive and easier to operate than hand powered small shellers.
· Capacity ranging from 80-100 kg/h using a small motor and two operators.
· The small size engine it may require Paraffin, Diesel or Petrol-powered.
· Effective , long lasting and sure to pay off
· Suitable for a group of small holder farmers with a potential to increasing their production, or for rural merchant maize millers.

Disadvantages:
· More expensive than the small hand operated shellers
· Initial Investment beyond financial reach of a single small-holder farmers unless through a loan.

2.5.3.4. Pedal Operated Air Screen Grain Cleaner

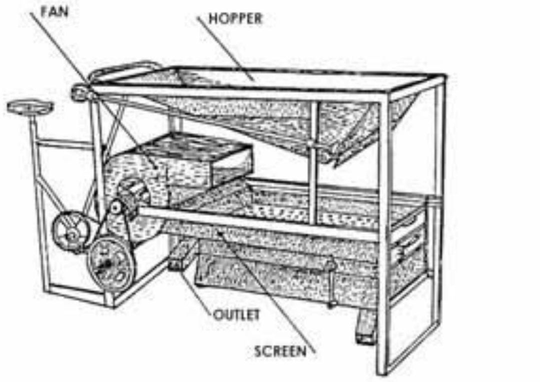


Fig. 30. Pedal-operated air screen grain cleaner.

This pedal operated screen grain cleaner is designed for the separation of dust, dirt, stones, chaff, broken and smaller size grains from granular agricultural materials including shelled maize. Separation take place based on grain size and weight differences. The uncleaned or ungraded grain is kept in the hopper above from where it drops by gravity against an air blast. Different size screens separate the grain into two grades as the chaff gets blown off by the air blast.

Productivity of the equipment is 350-600 kg/h depending on the type of grain.

2.6. Storage.

Here is referred the storage at house hold and village storage systems. This depend of the ability of smallholders farmers, individually or in group to store a significant part of their harvest contributing considerably to attainment the national food security and eliminating consequently hunger spreading.

At small rural farmer level storage start as the crop enters drying, however very often the storage occur after the crop has been dried. It may be in the cob or shelled grain which may or not be chemically treated.

The following figure 31, shows basic operations required before storage either short-term (4-5 months), season-long (6-9 months) and long-term storage (more than 9 storage months) for the <u>timely harvesting</u> method as well for the <u>late harvesting method</u> commonly used for maize in developing countries.

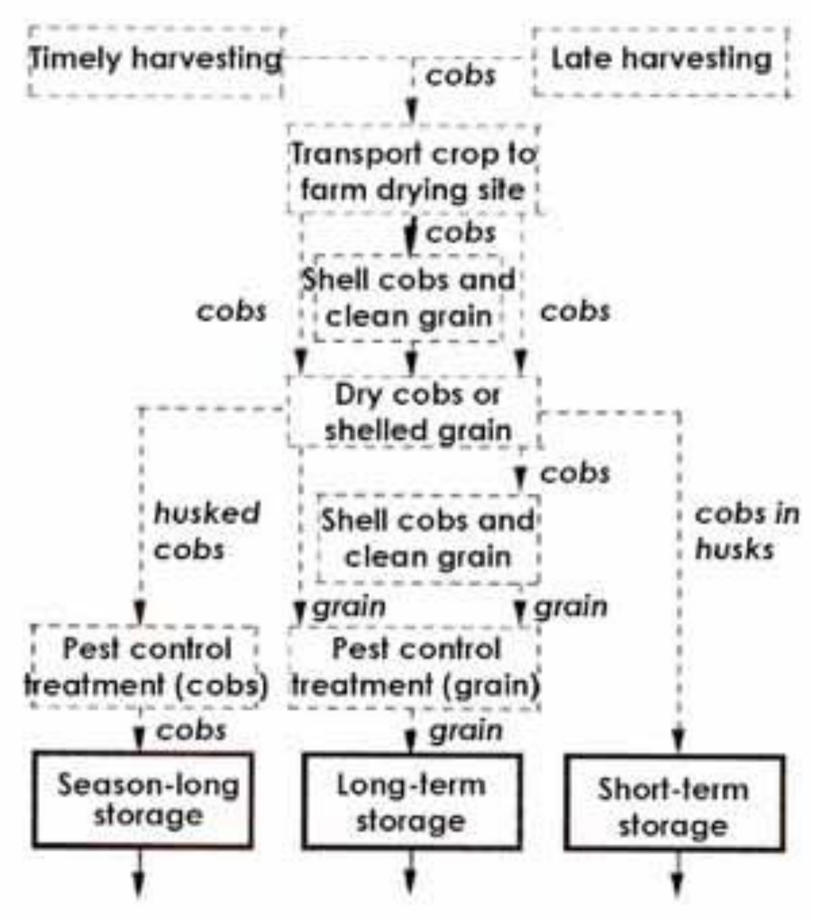


Fig. 31. Short-term, season-long and long-term storage. (AGROTEC/UNDP/OPS, 1991)

2.6.1. Objectives of household storage:

· To provide food to the farm household and where applicable supplement feed for livestock from one harvest season to the next
· To provide carry-over food in case of crop failure and natural disasters
· To service a marketing and trading system right from rural to national level
· To retain seed stock for planting the next crop

2.6.2. Common storage locations and type:

There are different types of structures for storage in many countries and these structures are based on the following:
· The architectural culture of the locality
· Type and availability of local construction materials
· Type and value of the crops to be stored
· Product storage requirements
· Length of storage
· Climatic conditions
· Prevalence of storage-loss agents: birds, insects and rodents
· Prevalence of grain theft at the locality.

2.6.3. Traditional household and village level storage systems and methods in tropical Africa:

2.6.3.1. Outdoor storage

· Unsheathed maize cobs hanged on horizontal cords or creepers or poles
· Maize cobs heaped on traditional barns with or without occasional fire beneath
· Systematic pack of maize cobs on platforms for drying and storage
· Traditional granaries, usually round with a roof thatch of grass, palm leaves or papyrus stems, and raised on stone piles or on yorked poles which include: basket woven, wall of mud clay and cow dung reinforced with straw, and walls of mud and wattle.
Compartmented bin, which may be rectangular, square or round is a common feature in southern Africa. Likewise, in Africa these structures are made using local materials and construction techniques. Anyone interested to look at a gallery of photos on these storage structures, could visit the INPhO web site http://www.fao.org/inpho/ in the photo gallery section. These structures are used for several crops and are widely used.

2.6.3.2. Indoor storage

· Maize cobs in sheaths stringed and hanged above a fire place for seed
· Cob maize bundled in matting or woven straw and hanged above a fire place
· Cobs in sheaths or unsheathed stored in the loft of a dwelling or kitchen house
· Maize grain kept in small indoors containers: gourds, earthen ware clay pots and jars, woven baskets, plastic or metal tins, jars, pails, drums, etc.
· Maize in cobs or shelled kept in nylon, sisal or jute gunny bags heaped or laid on bare ground or leaned against the walls
· In-door bins with walls of mud, mud and cow-dung, mud and straw, mud and wattle, etc.
· Indoor ": granary baskets" woven from local reeds, bamboo splits, etc
· A specific store-room but within a dwelling house.

2.6.3.3. Underground storage

· In the ground dug and lined with straw and thick plastic sheeting

2.6.3.4. Communal village storage

· Large cribs to store maize crop for a group of farmers
· Set of granary silos to store grain for a group of farmers
· Warehouse storage of modern design and capacity 50-500 tons.

2.6.4. Improved and recommended storage systems and methods.

Prices are better for maize when the crop is well stored. Improved storage technologies and methods can be achieved through proper design and construction and through proper management of storage systems.

2.6.4.1. Design requirements.

An improved storage system should have the following design characteristics:
· Maintain an even, cool and dry storage environment
· Provide protection from common storage loss-agents: insect pests, roidents, moulds and bird
· Offer reasonable protection from thieves
· Be simple and inexpensive to construct using locally-obtainable materials where possible
· Be easy to clean and repair and with few cracks and crevices that might harbour and/or facilitate multiplication of storage pests

· Be reasonably long lasting.

2.6.4.2. Management requirements.

A corollary derived of a good store design is: good storage management. This concept include the following three essential features:
· Proper preparation of the crop by: drying, shelling, cleaning and sorting, pest control treatment supervised and at no risk to the user or to the farm household
· Cleaning of the store to remove all traces of previous crop, and where possible disinfecting the structure or container before use
· Having in place all adequate systems of monitoring the condition of the crop throughout the storage period.
In some type of store the design should take into considerations details such as is showed in the following figure 32.

Fig. 32. Barriers to crop pest in storage.
(AGROTEC/UNDP/OPS, 1991)

2.6.5. The household metallic silo for grain storage.

A valuable structure highly recommended by FAO for small and medium rice farmer is the small metallic silo in figure 33. The small metallic silo is a post-harvest storage technology very suitable for getting food security and the fight against hunger in developing countries. It is a proven technology since the 80's for safe store. This technology was introduced by Swiss co-operation for development in Central America and since then, more than 230 000 small metallic silos from a half tonnes to 2 tonnes of capacity were introduced to prevent food losses. It was estimated that more than 2 millions of people are currently being benefited with this technology in Central America. Likewise, a FAO project in Bolivia on the prevention of food losses, GCP/Bol/032/Net, introduced successfully more than 20 000 small metallic silos in the last 5 years.

2.6.5.1. Advantages and characteristics of the silo.

It is a simple storage technology, relatively easy to be implemented and it may provide conservation and good quality grains and cereals. The silo can strengthen the food security of communities through provide daily livelihood and economic support for small and medium scale farmers.
The following are the most important advantages of the metallic silo:

· Hermetic and allows effective fumigation.
· Need little room.
· 0 percent loss of grain stored.
· Sale of surplus grains at better prices.
· High conservable quality.
· House free of rodents and diseases transmitted by them.
· Eliminates use of insecticides, and allows use of non-residual fumigant.
· Simple technology, lasting (15 years) and low cost.
· Adequate capacity for small and medium scales farmers
(180, 360, 540, 810, 1350 and 1810 kg).
· Local technologies; made and serviced by the community.
· Easy to buy and profitable.
· Reduces price fluctuations. Strengthens farmer producer against middlemen trader.
· Helps women with their work.
· Technology transfer is sustainable. Entrepreneurs, craftsmen and others employed in rural areas.
· Decentralised storage.
· Remarkable impact in the fight against poverty.
· Technology already proved in several countries.

2.6.5.2. Requirements for successful adoption of silo

· Qualified people and special tools are required to build the metallic silos.
· Grains should be dried to maximum moisture content of 14 percent before storing.
· If crop drying and storage is not properly done, losses could be as high as 100 percent.

2.6.5.3. Cost of the silo.

Table 20, shows some costs of the silo depending upon sizes and in different developing countries where it has been introduced.

Table 20: Cost of the silo (US$/silo), BOLIVIA (1)						
Size	120kg	250kg	500kg	1800kg		
Cost	20	35	60	92		
Cost of the silo (US$/silo), NICARAGUA (2)						
Size	180kg	360kg	540kg	810kg	1350kg	1800Kg
Cost	22	28	44	51	64	100
Cost of the silo (US$/silo), CAMBODIA (3)						
Size	120kg	250kg	500kg	1800kg		
Cost	10	20	28	45		
1=Mejía, D.J. (1998) Programa Poscosecha en Bolivia: Estudio de Impacto Técnico, Socioeconómico y Perspectivas de desarrollo-AGSI-FAO. 2= Gómez, C. (2002) INTA-COSUDE, Comunicación Personal, Nicaragua, C.A. 3= Kunthy S. (2001) Workshop on Manufacturing of Metallic Silo for Grain Storage, In Cambodia, FAO-AGSI.						

The cost of this technology varies depending upon the size of the silo. It is also noted that there is also differences by countries, for instances, in the most recent workshop prepared by

former Agro-industry and Post-harvest Management Service (AGSI-FAO) in Cambodia, the cost of the silo were lower when they compared with cost in Bolivia or Nicaragua.
In addition, when the silo is implemented it also originates a positive critical mass impact in rural communities, since it increase economic activity and generate employment's, such as village's tinsmith, hardware needs, etc.

2.6.5.4 FAO Strategies for transferring the silo technology.

· Through south-south co-operation by technician from GCP/BOL/032/NET
· Modality: training workshop for trainer
· Time: 2-4 weeks.
· Primary target group: 5-15 post-harvest technician from national agricultural authorities
· Secondary target group: farmers, tinsmith-village, technician from NGOs and others
· Facilities for rotatory credits help farmers to acquire the silo
· Publicity: demonstrations, radio, video films, leaflets and brochures, newsletter, etc
· Highlight that the silo technology implementation involve a critical mass development among agricultural and livestock farmers, trader middlemen, hardware store, tinsmith village, etc.

Fig. 33. The household small metallic silo for storage of grain.

2.6.6. Communal village stores.

2.6.6.1 Reasons for communal village store.

There are some reasons to believe the need for cooperative storage instead of, or in addition to individual household storage:
· Economies of scale allow (higher) investments in: store building material, materials and equipment for pest control and payment and training of a special person or persons directly in charge of the storage enterprise.
· For grains which has been produced for the market, the profits of seasonal price increases can be shared by the (smallholder) producers instead of middlemen or traders.
· Price fluctuations can be reduced if a part of the grain is to be bought back by the farmers from the village store.

2.6.6.2. Communal store types:

These structures could be in the form of large-size storage cribs or granaries, but usually cereal banks are used. These are built regularly with cement or burnt blocks and a roof of corrugated irons sheeting as illustrated in the figure 34 below. The grain is stored in bags and the storage capacity may range from 50-500 tons. Some basic requirements of communal storage include the followings:

· There will be a very dynamic and interested and organised group of farmers with in undertake the venture

· the group must be large enough to make the undertaking economically viable

· a convenient building for grain storage, or credit and qualified technical supervision should be available to build such store.

· there should be revolving fund for the purchase of stocks and for operational expenses.

· tools and storage equipment are necessary for: brooms, brushes, sprayers, containers, insecticides mixing devices, plastic sheets or tarpaulins are necessary for pest control. Likewise, sacks, scoops, dunnage, sampling probes, moisture testers, sieves, scales of weighing, office supply for handling, quality assessment and sale and purchase in the granary.

· The locally recommended pesticides must be easily and regularly available out of fresh stock. The following figure 34, shows a design of a communal village store

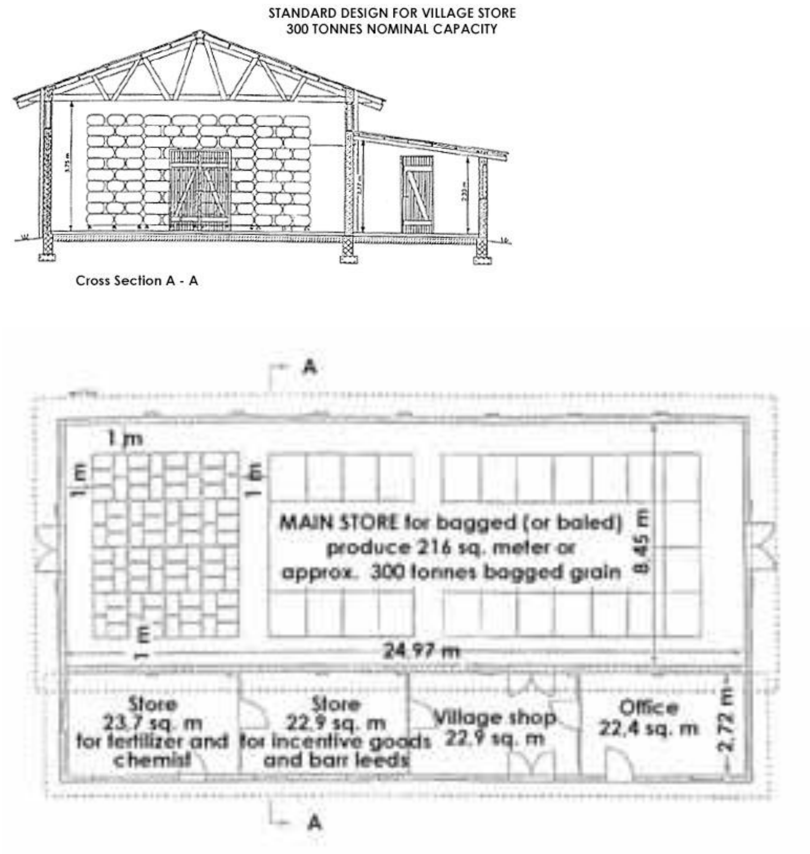


Fig. 34. Typical design of a communal village store.
(AGROTEC/UNDP/OPS, 1991)

2.6.6.3. Common problems in communal storage.

· The quality of building: structurally unsound design, inappropriate for grain storage or unnecessary expensive
· Inadequate pest control: materials, equipment and the basic standards of hygiene are found to be lacking
· High operating costs: such as bags, pest control, transport, building maintenance, training, accounting/audit, depreciation, etc. the cost/ton is often too high if the throughput is not enough
· No training given to the store-keeper: the level of managing required for communal storage is different compared with household storage. Pest management, accounting and building maintenance are essential and important ingredients for such as training.

2.7. Processing.

2.7.1 Processing of whole maize

2.7.1.1. Maize lime cooking in rural areas for tortillas (Nixtamal).

This process is used in rural areas of countries consumer of tortillas mostly in Mexico and Central America. It consists in mixing a part of whole maize kernel with two parts of water lime of a lime solution containing 1 percent of Ca (OH)2 approximately. The mix is heated at 80 0C for 20 to 45 minutes and then it is stand over night. The next day the liquid is decanted and this maize is called nixtamale which it is washed 2 to 3 times with water to eliminate residues of organic materials which can be used for feeding pigs. The cooked and washed maize is ground with a meat mill (plate or discs) and then is re-grounded with stone mill or "piedra de moler" getting a refined masa. Then approximately 50 grams of masa are flattened manually or mechanically and it is toasted on the surface of a heating plate which can metallic or made of earthenware and known as *comal*.
In Guatemala a process for white and yellow maize uses 0.17 and 0.58 percent of Ca(OH)2 with a relation of 1:1.2 of maize grains to water and a cooking time of 46 to 67 minutes at temperature of 94 0C respectively. The rest of the process is the same except that this masa is ground with discs mill.
For new maize (recently harvested maize) is recommendable to use less lime concentration and less time of cooking, and for older maize to inverse the conditions of processing. Is important also to appoint out that during this process of cooking, dry matter is lost between 8.9 to 21.3 percent.

2.7.1.2. Ogi and other fermented maize products

Acid porridges prepared from cereals are eaten in many parts of the world, particularly in developing countries, where they may form part of the basic diet. Some examples of acid porridges include *pozol* in Mexico and Central America, *ogi* in Nigeria, *uji* in Kenya and *kenkey* in Ghana. These porridges are usually made from fermented raw or heat-treated maize, although sorghum and millet are also often used.
a. *Ogi* manufacture
The traditional process of making *ogi* has a number of slight variations described by several authors. *Ogi* is traditionally prepared in batches on a small scale two or three times a week, depending on demand. The clean grain is steeped in water for one to three days to soften. Once soft, it is ground with a grinding stone, pounded in a mortar or ground with a power mill. The bran is sieved and washed away from the endosperm with plenty of water. Part of

the germ is also separated in this operation. The filtrate is allowed to ferment for 24 to 72 hours to produce a slurry which when boiled gives the *ogi* porridge. *Ogi* is usually marketed as a wet cake wrapped in leaves, or it may be diluted to 8 to 10 percent solids in water and boiled into a pap or cooked to a stiff gel.
Some reports indicate that the souring of the maize take place spontaneously without the addition of inoculants or enzymes. Some organisms have been identified and involved in this unaided fermentation process which some effects on the nutritive value of the food. Some microorganism include the moulds as *Epholosporium, Fusarium, Aspergillus and Penicillium species and the aerobic bacteria as Corynebacterium and Aerobacter* species, while the main lactic acid bacterium found was *Lactobacillus plantarum*. There were also yeasts: *Candida mycoderma, Saccharomyces cerevisiae and Rhodotorula sp.*
Although *ogi* is supposed to have an improved B-vitamin content, the results observed are quite variable, at least for thiamine, riboflavin and niacin. Some researchers identified the carboxylic acids of *ogi* fermentation. They also found 11 acids, with lactic, acetic and butyric acids being the most important.
The *ogi*-making process is quite complex, and the porridge can also be prepared from sorghum, rice, millet and maize. Therefore, laboratory procedures have been developed to learn more about the process and introduce changes to convert the grains to food more efficiently. The authors also reported on the yields of *ogi* from whole maize kernels (79.1 percent) and dry milled flour (79.8 percent).
The commercial manufacture of ogi does not differ substantially from the traditional method. Modifications have been introduced, such as the dry milling of maize into a fine meal or flour and subsequent inoculation of the flour-water mixture with a culture of lactobacilli and yeast. In view of the importance of ogi in the Nigerian diet, large-scale production is indicated. The material could be dried and packaged in polythene bags for a good shelf life. There is some problem in achieving a controlled fermentation with pure cultures. Some modifications include spray-drying the slurry or drum drying.
b. Other fermented maize products
Ogi has a number of other names such as *akamu* or *ekogbona, agidi and eko tutu*. These, with the Kenyan *uji* and Ghanaian *koko* , are substantially the same preparation with changes in the grain used or some modification of the basic process. For the Mexican *pozole* , maize is processed with lime as for tortillas. The nixtamal, or cooked maize without the seed-coat, is ground to a coarse dough which is shaped into balls by hand. The balls are then wrapped in banana leaves to avoid drying and are allowed to ferment for two to three days, or more if necessary. The micro-organisms involved are many.

2.7.1.3. Arepas

Another major food made from maize, used daily in Colombia and Venezuela, is arepa. It is defined as a roasted maize bread without yeast, round in shape, prepared from maize that has been degermed. Whole maize is dehulled and degermed using a wooden bowl called a pilon and a double-headed wooden mallet. The moistened maize is pounded until the hulls and part of the germ are released from the endosperm. The hulls and germs are removed by adding water to the mixture containing the endosperm. The endosperm is cooked and then stone-milled to prepare a dough. Small portions of this dough are made into balls, then pressed into flat discs which are cooked rapidly on both sides.
The traditional method of preparing arepas has been substantially modified by the introduction of precooked maize flour, which reduces the time from 7 to 12 hours to 30 minutes. There are two stages in the industrial process. The first is the preparation of maize grits by cleaning, dehulling and degerming the maize; the second is the processing of the grits

to produce precooked flour. Efforts have been made to modify the process even further by extrusion cooking.

2.7.1.4. Other maize preparations

In Latin America there are many maize-based foods besides tortillas and "*arepas*". Some of these are drinks like *colados, pinol* and *macho,* basically suspensions of cooked maize flour. These three products have a very low protein quality. The production of *humitas,* a tamale-like food consumed in Bolivia and Chile have been described. Made from immature common or opaque-2 maize to which is added a number of other ingredients, humitas is produced from precooked maize flour which resembles the lime-treated *masa.* Other products include mote, made from cooked maize and cheese, *pupusas* , made from lime-treated maize and cheese, and *patasca* , which is like a lime-treated maize kernel. From immature maize a sweet, tasty atole of high nutritive value is made. Immature maize, either common or opaque 2, and sweet maize are also extensively consumed. Maize has also been used as a substrate for fermented beverages called *chicha* . Some authors have reported on the microflora of these fermented products, which are made by basically the same process but using a variety of additives.

2.7.2. Milling

The maize kernel is transformed into valuable foods and industrial products by two processes, dry milling and wet milling as was described before. The first yields grits, meal and flours as primary products. The second yields starch and valuable derived products.

2.7.2.1. Dry milling

The dry milling of maize as practiced today has its origins in the technologies used by the native populations who domesticated the plant. The best example is the method used to make arepa flour or hominy grits. The old technology was soon replaced by a grinding stone or stone mill, followed by the grits mill and finally by sophisticated tempering-degerming methods. The products derived are numerous, with their variety depending to a large extent on particle size. They are classified into flaking grits, coarse grits, regular grits, corn meal, cones and corn flour by means of meshes ranging from 3.5 to 60. Their chemical composition has been well established and their uses are extensive, including brewing, manufacturing of snack foods and breakfast cereals and many others.

2.7.2.2. Wet milling

The largest volume of maize in developed countries such as the United States is processed by wet milling to yield starch and other valuable byproducts such as maize gluten meal and feed. The starch is used as a raw material for a wide range of food and non-food products. In this process clean maize is soaked in water under carefully controlled conditions to soften the kernels. This is followed by milling and separation of the components by screening, centrifugation and washing to produce starch from the endosperm, oil from the germ and food products from the residues. The starch has industrial applications as such and is also used to produce alcohol and food sweeteners by either acid or enzymatic hydrolysis. The latter is done with bacterial and fungal alpha-amylase, glucoamylase, beta-amylase and pullulanase. Saccharides of various molecular weights are liberated yielding sweeteners of different functional properties. These include liquid or crystalline dextrose, high-fructose maize syrups, regular maize syrups and maltodextrins, which have many applications in foods.

2.7.3. Small scale milling

As already was mentioned before, there are two main milling technologies: one in which the grain is directly ground without any pre-processing and one in which the grain undergoes a number of pre-processing stages prior to milling. The first one milling technology yields whole meal which contains both the bran and germ, while the latter one yields a large range of products including partly or fully de-germed meals called respectively bolted and super-sifted meals.

The major difference between small scale milling and large scale one is that the kernel does not undergo through the de-germing process before being milled. The resulting milled products differ mainly in the final content of fat, fibre and colour. The product is darker when the whole kernel is grounded, while the fat content of the de-germed product is around 1 percent . Grinding whole kernels yields a product with up to 4 percent oil.

The crude fibre content between the two systems will vary from 0.4 to 1 percent in de-germed products and about 1.5 percent for the whole kernel.

Although the higher oil content in the whole milled product, substantially improves the taste, it is also the main reason for the shorter shelf life of these products. The oxidation of the oil (rancidity) is the major factor in the deterioration of milled product during storage.

2.7.3.1 Equipment for small-scale processing

The production of whole meal is carried out in three types of mills: plate, stone and hammer mills. The output of these mills ranges from 25 kg per hour for plate mills to over 10 000 kg per hour for some large-scale hammer mills. The technical specifications of these mills are given in table 21. Plate, stone and hammer mills may use various sources of energy, including waterpower, diesel and electricity. Some plate mills may use animal or wind power at relatively low outputs. The whole meal produced by these mills may be further sieved for the removal of large pieces of bran and germ. The mills may be equipped with grain cleaning equipment and attached to sieving devices. Water-powered mills are mostly custom mills while the other mechanically powered mills may be either custom or merchant mills, depending on the location and scale of production. The use of plate, stone or hammer mills is usually governed by local preferences, the intended scale of production and the type of output. Plate mills are extensively used in parts of West Africa (e.g. Ghana, Nigeria, Cameroon, Sierra Leone) while hammer mills are more common in East Africa (e.g. Tanzania, Kenya, Malawi). Stone mills for the dry grinding of maize prevail in Central and South America, the Indian sub-continent, North Africa and the Middle East. Hammer mills are predominantly used for the production of ground animal feed, such as in West Africa, Indonesia and Central America.

Table 21: Summarised technical data on mechanically powered, plate, hammer and stone mills			
Characteristics	**Mill Type**		
	Plate	Hammer	Stone
Speed of rotation (rpm) Electric motor capacity (kw) Diameter of grinding plates or stones (cm) Average output per Kg/Kw/hr Average output per hour (kg)	600 0.4-4 25 67 27-270	Up to 3600 2-150 - 74 148-11,100	600-800 0.4-15 20-56(v)* 61-71(h)* 80 (v)* 87-107 (h)* 32-1,200 (v)* 35-1,600 (h)*
*v: vertical millstones *h: horizontal millstones			

2.7.3.2. Plate mills.

Plate mills are made of a cast iron base to which are attached two enclosed vertical grinding plates, figure 35. One plate or disc is fixed while the other is belt-driven from an electric motor (0.4 to 4 kW), or diesel engine (in the range of II to 19 kW). The moving disc rotates at a speed of approximately 600 rpm. Some models may, alternatively, be driven from a tractor engine. The grain is screw-fed from a conical hopper into the gap between the two plates. This gap may be adjusted to vary the fineness of the ground material. The grinding plates, approximately 25 cm in diameter, are made from hardened cast steel. They are grooved to aid the shearing (cutting and crushing) and grinding of the grain. Different plates, with a range of groove sizes, may be used for the production of meals of varying textures.
The hourly output of plate mills depends upon the required fineness of the product and the variety and moisture content of the original grain. Electric plate mills have an output of approximately 67 kg per kW per hour. Thus, a plate mill equipped with a 4 kW electric motor may process approximately 270 kg of grain per hour. In parts of West Africa (e.g. Nigeria) and Central America, plate mills are used for the wet grinding of maize. For this purpose, plates with finer grooves than those used for dry milling are usually recommended by the manufacturer.

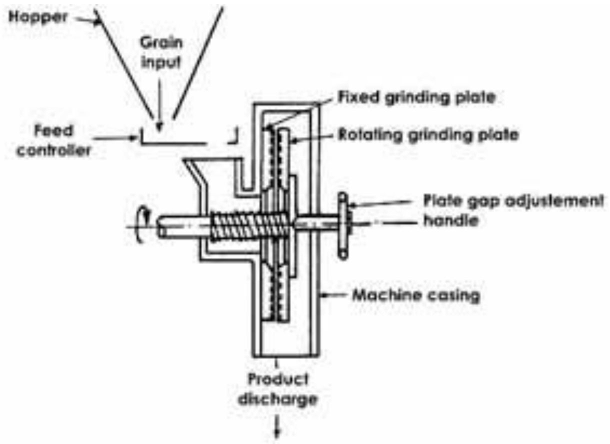


Fig. 35. Scheme representation of a mechanical plate mill.

2.7.3.3. Hammer mills

Hammer mills in developing countries for maize dry milling can be imported, but also many countries have started to manufacturer them. In general, they comprise a cast iron body through which passes a horizontal rotary shaft powered by an external energy source, figure 36 below. The energy source is usually an electric motor or diesel engine. Occasionally a tractor engine can supply the power required. The capacity of the electric motor varies from 2 to 150 kW depending of the size and the model of the mill. A disc or discs, from which project short hammer like plates, are attached to the end of the rotor shaft and enclosed in a metal casing. The speed of the hammer rotates up to 3,600rpm. They may be of the fixed or swinging type, and vary in number from 1 to 32. The fixed hammers are usually in the form of an iron casting whereas the swinging type are made from heat-treated 1 percent chromium steel.

A screen mounted on a fixed circular support, surround the hammer. The maize grain must be reduced in size to pass through the screen before it is discharged from the milling chamber. A range of screens are available for the production of a varieties of grades of ground material. A conical hopper, fixed above the milling chamber, holds the whole grain which is gravity fed into the mill.

Unlike the shearing action in the plate or stone mill, size reduction in a hammer mill occurs principally by impact as the grain hits the hammer, the metal of the screen, and the back wall and front casing of the mill. Impact also occurs between the grain itself. The grain is trapped and sheared between the hammer and the holes of the screen. The broken grain is retained in the chamber of the milling until the size of particle is reduced to allow they pass through the screen perforations. Output of ground final product varies according to the capacity which is the approximately 74 kg for maize with a moisture content of 16 per cent and a screen with 3 mm holes. In the larger models (motor capacity greater than 5 kW), a cyclone discharges the ground material and cools both the mill and the product. In the smaller models (motor capacity less than 5 kW), the ground material is discharged by gravity from the base of the mill.

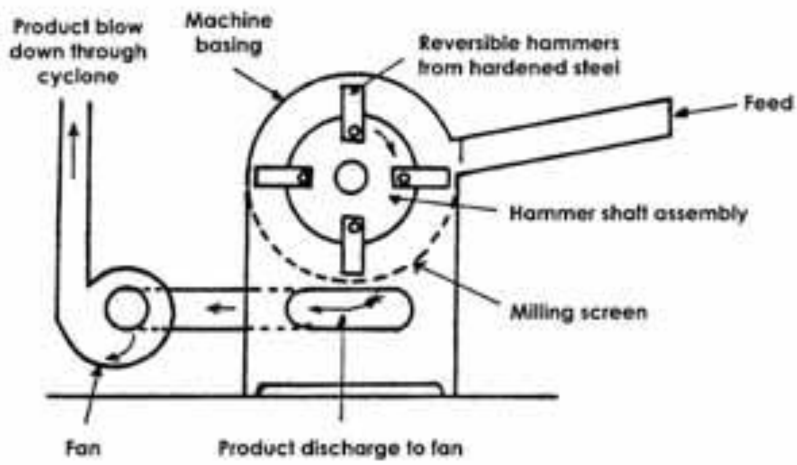


Fig. 36. Schematic representation of a hammer mill.

2.7.3.4.Stone mills.

In a typical stone mill, a conical or pyramid-shaped hopper holds the whole grain which enters to the milling chamber through a feed valve. In some models a shaking device and a screen prevent large impurities from entering the milling chamber. The milling of the grain is achieved by the shearing action of the flat surface of two millstones which are identical in size and construction. One stone is fixed to the milling chamber door, while the other is mounted on a rotating drive shaft connected to an external energy source (e.g. an electric motor, diesel engine, or tractor engine). Figure 37 illustrates the basic design of a stone mill. The grain from the hopper is fed through the central hole in the rotating stone, into the gap between the two stones. As the rotating stone moves against the stationary stone, the grain is ground as it travels from the centre to the periphery of the stones. The two millstones may be set either horizontally with a vertical rotary shaft, or vertically with a horizontal rotary shaft. The vertical type is more common.

The diameter of the millstones varies according to model type and size, the weight of the stones and the relative difficulty in supporting them in an upright position. Vertical millstones are smaller in diameter (20 to 56 cm) than horizontal millstones (61 to 71 cm). However there are exceptions, for instances, some manufacturers produce vertical millstones of 71 cm and 81 cm diameter, while some horizontal millstones are only 30 cm and 41 cm in diameter. In the horizontal type, the crushed grain is moved to the periphery of the stones by centrifugal forces, whereas gravity assists the movement of crushed grain between the vertical millstones.

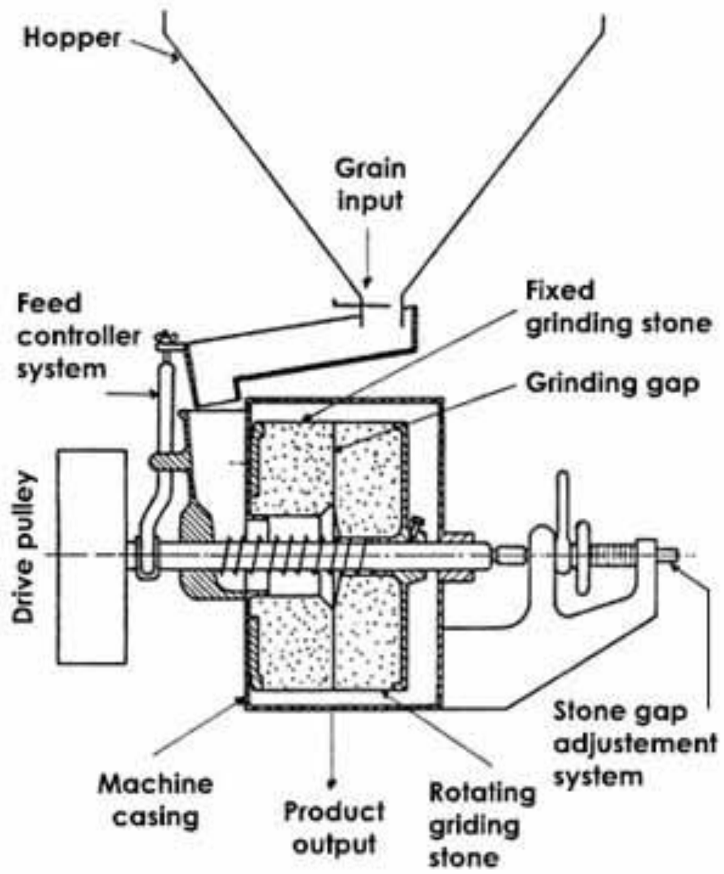


Fig. 37. Schematic representation of a mechanical stone vertical mill.

3. Maize Overall Losses.

Notwithstanding losses is a concept which is difficult to define it, however quantitative losses eventually give a broad picture of where the losses were occurring and their relative scale, and how a specific crop is handled during the post harvest operations. So that, some assessment have been done in order to determine total post-harvest losses for maize. For example, losses are estimated based on post-harvest losses of each stage and assuming that each loss found is a percent age of the amount remaining from the previous stage. Otherwise, if losses are determined on the basis of the original weight of the crop, it can lead to an overestimation of losses.
On the other hand, there are others losses which are difficult to determine and these losses consider include: time, manual labour, agricultural inputs, opportunity cost, illusions and hopes. For these reasons many post harvest specialist agree that the post harvest losses measure concept has changed. However and for practical reasons, still exist some methodologies which give up an idea about the main quantitative and qualitative losses occurring during the postproduction system.

3.1. Definitions of terms.

3.1.1. Loss:

in this context denote a measurable decrease of food grain which may be quantitative, qualitative, nutritive or economic.

3.1.2. Damage:

It mean superficial evidence of deterioration (e.g. holed grain by insects pest, broken grains.
Quantitative loss: denote reduction in weight and can be defined, quantified and valued, For instances, a portion of grain eaten by insects, rodents, or lost during spillage or transportation
· Qualitative loss: damage or contamination of the grain. It is difficult to assess or quantify because is a subjective criteria, but can be described by comparison with quality standards
· Nutritional loss: reduction of the food value of the crop. It can be qualitative and quantitative loss and is also difficult to identify
· Germinative loss: represent a reduction in germination ability. Methods of laboratory exists to measure the degree of viability of a sample of seeds
· Economic loss: reduction in monetary value of the product due a reduction in quality and quantity. Since quality loss is difficult to quantify it is also difficult to quantify economic loss.

3.1.3. factors and causes of grain loss.

The maize post harvest system or pipeline in figure 38, shows several stages at which losses of food can occur. So the main agents or factors responsible for the losses can be grouped as:

3.1.3.1. Physical factors

· Temperature
· Moisture

3.1.3.2. Biological factors

· Produce properties or characteristics
· Insects and mites
· Birds, rodents and other wildlife
· Microorganism: fungi, moulds and bacteria

· Man

3.1.3.3 Mechanical factors

· Type and efficiency of on-farm transport
· Speed and ground conditions of use

3.1.3.4. Engineering factors

· Type and efficiency of harvesting tools, equipment and machines
· Primary processing equipment and machines
· Drying and storage structures

3.1.3.5. Socio-economic factors

· Financial status of the farm household
· Farming system and level
· Storage and marketing system and level

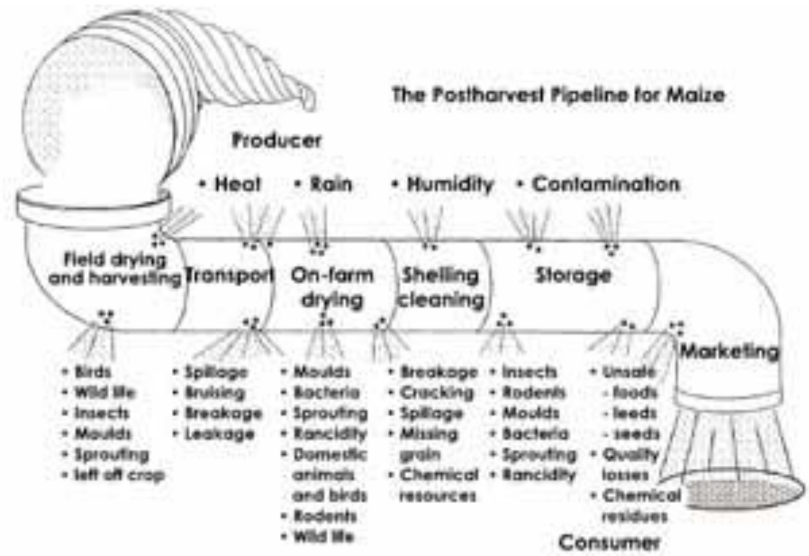


Fig. 38. The post-harvest pipeline for maize.
(AGROTEC/UNDP/OPS, 1991)

3.2. Level of loss during maize post-harvest system.

3.2.1. Field drying and harvesting.

The magnitude of losses at this segment is very likely the highest in the entire post harvest system for maize, and it influenced by:
· The time of harvesting which affects subsequent the storage quality of the grain
· Genetic characteristics of the varieties of maize. Generally traditional varieties are better adapted
· Weather conditions wetting condition from rain and hot sun in the day may result in lodging, sprouting, moulding, decolouration and fissure, and loss of quality and viability, etc.
· Harvesting practices, especially referred to by hand, machine and when
· Long field exposure of the crop may result in heavy infestation by insects pests and damage by rodents, monkey, baboons, bush pigs, elephants, hippos, etc
The effects above indicated occurs normally to the storage phase as the crop is made more vulnerable to infestations in storage by pests. Wildlife is more common in tropical areas and

the savanna belts and less in drier areas. The magnitude of losses in traditional methods of field drying and harvesting varies greatly from country to country. It could be as less as 5 percent for relatively drier areas, to 50 percent or more in places heavily infested by baboons, monkeys or wild pigs. Average loss rank from 7 to 12 percent.

3.2.2. Transport.

Losses due to transport of the crop to, within, and off-farm depend on:
· Type of transport facility used
· Efficiency of transport facility
· Quantity of crop transported
· Ground conditions and surface of the terrain, etc.
Transport losses are generally small, ranking 1 to 2 percent.

3.2.3. On-farm drying.

Depend on how much the maize has been dried in the field. The drying methods and climatic conditions during drying are main factors which affects losses.
Traditional drying methods can cause:
The crop is exposed to proliferation of fungi, moulds and bacteria and soil reducing its quality
The crop is also exposed to attacks of domestic animals and birds causing qualitative and quantitative losses. Some time farmers do not consider crop eaten by livestock as loss.
Estimation of losses in traditional drying and storing in a raised barn for up to 4-5 months has been between 7 to 14 percent. Improved drying technique, as the crib, can reduce losses losses mainly due to fungi and insects in approximately 2 percent. Average on-farm drying losses are 3 -6 percent.

3.2.4. Threshing/shelling and cleaning.

Damage from these operations is proportional to the moisture content of the grain and depend of the method used.
Traditional shelling of maize made by hands causes minimum losses
Use of flails to beat the grain off of the cobs can damage the kernel, and the unseparated grain of the cob can be lost with the chaff
Modern equipment not properly used can also cause damage to kernels
Hand shelling: loss average 1 percent
Machine shelling: considering broken kernels and grain lost with chaff into the soil from 2 to 5 percent.

3.2.5. Storage.

Storage losses depend upon the following:
· Physical factors, e.g. damage during harvesting, transportation and shelling. This make maize susceptible to attacks by insect pests, mites and moulds
· Temperature and humidity may encourage mould formation and create conditions for insect population growth. The losses could be: minimal in cool dry areas, marked in hot dry areas, high in cool damp conditions and very high in hot damp climates.
· Type of storage structures or containers used
· Duration of storage
· The storage management effected prior to and during storage.
Some researchers identify that losses of grain stored at the farm level are in the order of 8 to 10 percent. In some studies done in eastern and southern Africa it indicates that when the

losses are computed considering the actual amount of crop present in the store, at the time of each assessment (other the initial quantity of crop in the store), then the "weighted storage losses" may be in the order of 3 to 8 percent (average 5-6 percent) over a storage season.

3.2.6. Marketing.

Before marketing and consumption, maize is subjected to a whole range of loss-agents discussed above as a result of which the following attributes get affected:

· Reduction in Quantity and quality of the crop
· Reduction in nutritive and germinative attributes
· Reduction in commercial and economic value

The following figures 39 gives some indicators of the post-harvest losses in maize at the small-holder level in eastern and southern Africa.

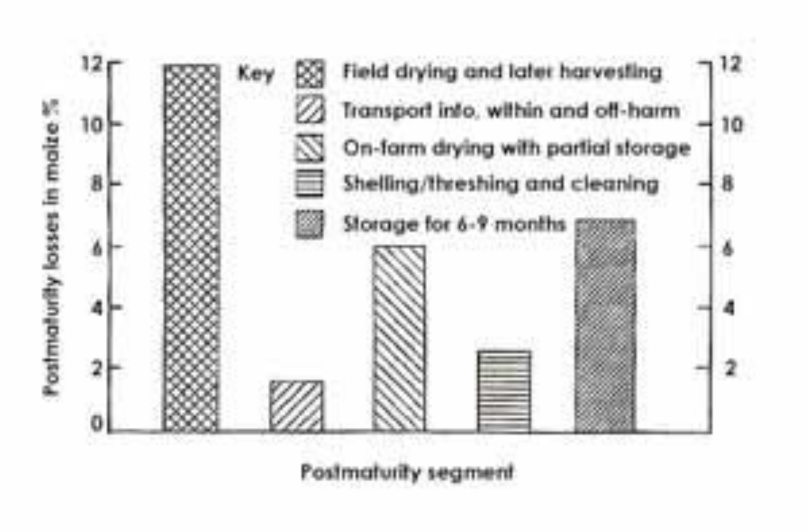


Fig. 39. Indicators of maize post harvest losses by segment at small holder level. (AGROTEC/UNDP/OPS, 1991)

4. Pest control of Storage for Maize:

Insects
Rodents

4.1. Characteristics of Storage Insect Pests

Beetles and moths are the most predominant pests in the tropic causing great loss and deterioration to food grain. These pests typically have a four stage life cycle: egg, larva, pupa and finally adult as shown in the following figure 40:

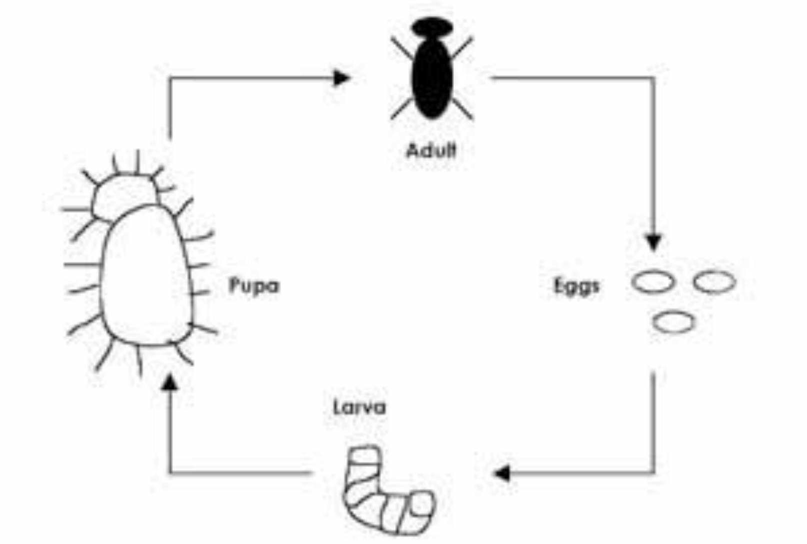


Fig. 40. Cycle of life of a typical storage insect pest.
Adapted from (AGROTEC/UNDP/OPS, 1991)

The eggs are laid either on the surface of grain kernel (normally on physically damaged part of the grain or inside a tiny hole partly bored on the kernel by the parent. The eggs hatch into larvae which voraciously eat their way within the grain, and are responsible for most of the damage on crop. The larvae gradually transform into pupae, a dormant non-feeding stage. These later hatch into adults which eat their way out of the grain kernel and (if beetles) immediately start aggressive feeding on and further destruction of the grain. The *Prostephanus truncatus* or larger grain borer (LGB) losses in the range of 10-35 percent in 5-6 months in household storage and up 60 percent losses over a 9 month storage period. Adult moths are short-lived and do not feed, but their larvae voraciously feed and cause heavy contamination to the stored product through webbing and frass.
Insect pest damage to grain may fold into one of the following categories:
· Bored holes in the grain and disappearance of a large portion of the endosperm.
· Injury to the germ reducing the nutritive value and loss of liability of the grain.
· Heating and condensation and moulding of the grain causing reduction in nutritive value and risk to formation of toxic substances as aflatoxin.
· Contamination of stored grain with excrement and frass.
· Infested grain, specially by *Sitotrogacerealella* figure 41A-3,may have a sickening smell and taste that makes the grain un-palatable.
· Main insect causing significantly damage to cereal, including maize, as shown in the following figure 41A and 41B.

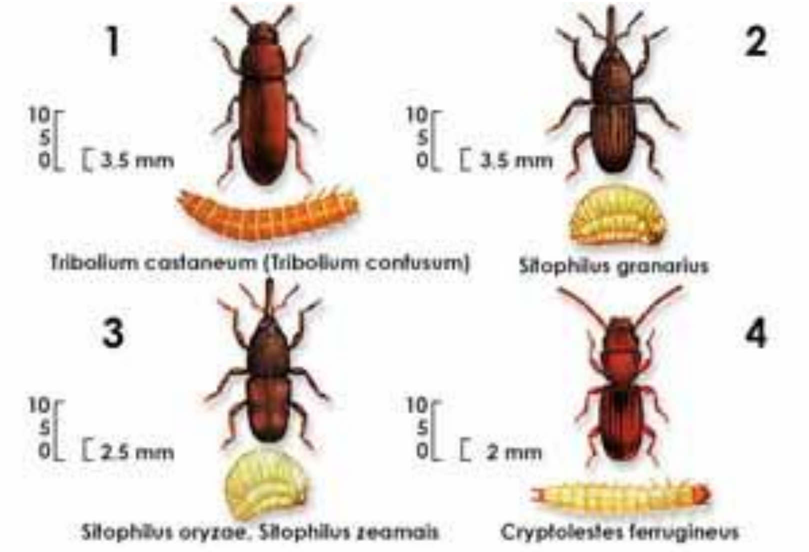


Fig. 41A. Common insect pests of maize.
1). Tribolium casteanum, 2). Sitophilus granaries, 3). Sitophilus oryzae or zeamais, 4). Cryptolestes ferrugineus.
(Source:casa Bernardo Ltda)

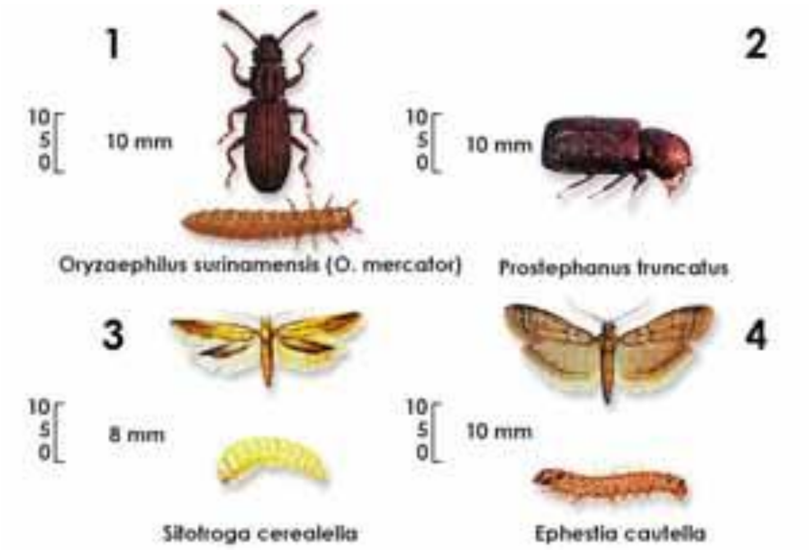


Fig. 41B. Common insect pests of maize.
1. Orizaephilus surinamensis, 2). Prostephanus truncatus (LGB), 3). Sitotroga cerealella, 4).Ephestia cautela.
(Source: casa Bernardo Ltda)

This list include the larger grain borer LGB introduced in Africa in 1981 (figure 41B-2). It causes severe losses on maize grain and even dry cassava in Tanzania, Kenya and Togo and threatening all neighbouring countries. Moreover, the table 24 present some properties of important grain infesting insects with emphasis for maize.

Table 22: Some properties of most important grain infesting insects					
Scientific Name	**Common Name**	**Products infested/ Damaged**	**Type of Damage**	**Temp. for population control (°C)**	**Optimum temp. for reproduction. (°C)**
Sitophilus granarius Sitophilus zeamais *Sitophilus oryzae*	Granary weevil Maize weevil Rice weevil	Maize, sorghum, wheat, rice, paddy.	Larvae develop inside kernel and feed on starchy interior. Adults hatch and eat their way out of the grain and continue to feed voraciously on the grain	17 18 18	28 - 30 29 -31 29 -31
Rhizopertha Dominica Prostephanus truncatus	Lesser grain borer Larger grain borer	Paddy, rice, wheat, maize dried cassava / potatoes Maize, and dry cassava tubers or chips.	Larvae enter grain and feed on starchy interior. Adults bore grain freely and voraciously eat and may destroy entire grain kernels	21 18	30-35 32
ryzaephilus surinamensis Trogoderma granarium Ev.	Saw-grain beetle Khapra beetle	Maize, wheat, sorghum, rice, pulses, oil seeds	Larvae and adults feed on broken and damaged grain. The larva is a very serious stored product pest, the beetle itself does no damage.	19 22	34 33 - 37
Tribolium Confusum Tribolium Constaneum Cryptolestes species	Confused flour beetle Rust-red flour beetle Flat grain beetle	Maize, wheat, sorghum, flour, groundnuts, milled cereal products, dried fruit, legumes, tapioca.	Larvae and adults feed on broken and damaged grain. Larvae free-living on broken and damaged grain. Adults will attack the germ of sound	21 22 20	30 - 33 36 33- 35
Sitotroga cerealella (Oilv) Ephestia cautella Walk Corcyra cepalonica Staint	Angoumois grain moth Tropical warehouse moth Rice moth	Maize, wheat, rice, paddy, sorghum Groundnuts, rice, maize, wheat, sorghum Maize, wheat, rice, millet, sorghum, groundnuts, cocoa	Primary pest, attacks grain in field. Most damage occurs in storage only through larvae. Adults do not feed. Charaterised by heavy webbing and frass on produce. Damage only by larvae. Adult moths are short-lived and do not feed.	16 16 18	28 - 30 28 - 32 30 - 32
SOURCE: AGROTEC/UNDP/OPS, 1991					

4.2. Nature of Insect Pest Infestations

Some of the maize pests have flight ability and often start the infestation in the field several weeks before the crop is harvested or when the maize is being filled dry in stalks or in shocks. The ability of the insects to fly long distances between fields and to and from maize stores as shown below can quickly spread the infestation.
The problem is aggravated by bad practice such as:
· Poorly managed storage structure to maize field
· Careless disposal of all crop or of crop residue swept from infested store
· Leaving fits and pieces of infested cob maize in unplugged fields, or lying all around the farm yard.
The infestation initially in the field often continue an intensifies in storage, reaching high proportion within 2 to 3 months of storage unless efforts are made to control the pest.

4.3. Loss Magnitude by Insects Pests in Traditionally storage

Grain must be guarded against insect infestation in the field by timely harvesting. Protection must also be availed during drying, so as to minimize drying and storage losses.
Weight loss on maize grain varies from region to region, depending on crop variety, storage condition and duration, and on pest combination in storage. Studies conducted on Zambia gave weight losses from insects pests at a small holder storage for different maize varieties to be in the following ranges:

- Local varieties weight loss ranged: 1-3 percent
- Improved varieties weight loos ranges: 5-6 percent
- Hybrid varieties weight loss: 8-9 percent

These cases were obtained in traditionally storage for 6 to 9 months, with similar work done in Kenya, Tanzania and Uganda. The low level of loss in local varieties is attributed to their resistance to insect attack because of hard kernel and to the complete and better coverage by the sheaths which protect considerably the grain in the field, during drying and in storage if in sheaths. In spite of their susceptibility short-coming , improved and hybrid varieties are normally high yielding in fast maturing compared to local varieties. These justifying their production.

4.4. Insect pests control strategy.

The control of insects for maize must start before the harvest and not only when they are detected in storage. For a better control the following point should be taken in considerations:

· The best strategy involve timely harvesting and then proper drying and cleaning of the maize prior to storage.
· Is important also to prepare in advance all storage structure and containers to be used, making them ready and safe to recieve the new crop. Some recommendations depend upon the type of containers of structures, such as:
    - metal, earthware, plastic containers must be washed, desinfected with hot water and well dried before using.
    - Sacks of jute, sisal and nylon should be washed and boiled in hot water to kill off insects pests or theirs eggs and larvae and dried prior to use
    - Reed-woven indoor granary and out-door basket, mud-wall bins or brick-wall silos must be re-plastered using local materials (cow dung, mud, sand, wood, ash, etc) to seal off cracks, holes and crevices which could hide insects pests and their eggs
    - Granaries, cribs, silos and warehouses must be cleanly swept, repaired where possible, desinfected using pests control chemicals, see table 23.

Table 23: Residual spray recommended for store fabrics and their dosage rates (wettable and dispersible powdered)	
Product	**Concentration**
Malathion	1-2 gm/sq meter
Pyrethrin/piperonylbutoxide	0.1-1.0 gm/sq meter
Phoxim	0.25 gm/sq meter
Pytethrins	0.25-0.5 gm/sq meter
Etrimfos	0.25-0.5 gm/sq meter
Mechacrifos	0.25-0.5 gm/sq meter
Pirimiphos methyl	0.25-0.5 gm/sq meter
Bromophos	0.5 gm/sq meter
Fentirothion	0.5 gm/sq meter
Dichloryos	50-70 gm/sq meter

4.5. Traditional insect pest control methods.

Traditional methods used for farmers to reduce infestation of the crop may fall into three groups: 1). Special practices 2). Use of material such as ashes (for its abrasive and letal effect on the insects cuticle), mineral and oil in which physical barrier effects are responsible for the control of insects and 3).The use of whole or parts of the plants where there may be some natural insecticidal, fungicidal or repellent effect (mainly alcohols, alkaloids and terpenes). These methods include as follows:
· Storing very well dried crop or re-drying when infestation is detected
· Storage of maize in sheaths for protection by the husk
· Use of repulsive local herbs and plants to scare off the pests (Nim ground seed, leaves of *acanthaceae*, *acardiaceas*, *annonaceae*, *myrtaceae*, other plants extract, etc,
· Use of dried inert material such as, sand, crushed limestone, wood ash at 1-5 percent w/w filling up in granular space and hindering insect activity, diatomaceous earth, etc
· Use of abrasive ash from paddy husk and mixed with the grain at 0.1-0.5 percent w/w. It cause dehydrates insect pests leading to desiccation and death.

4.6. Chemical control methods.

4.6.1. Chemical methods.

Farmers some time have to turn to use chemical control methods despite some of their short-comings.

4.6.1.1. Fumigants.

Gases or vapours taken into the body of the insect through its respiratory system, resulting in death.
· Fumigants have non residual effect, but can penetrate through stacks or bulk produc killing all stage of insect life
· Fumigants do not protect against re-infestations of the grain
· They are extremely poisonous and if is not properly handled could cause death

· Use of fumigants should be done by well trained persons and they have preferently a license to carry out fumigation

4.6.1.2. Contact insecticide.

Are poisonous able to penetrate through the insect's cuticle entering the body tissue and causing death. The use of contact insecticides by smallhoder farmers will be either in admixtures or as a surface treatment. These insecticides have long term effect, however they are specific in their effect upon insect species.
· Dusting maize cob and grain with insecticides.
· Husking and cleaning of cob maize:
Storage of maize on the cobs with or without the sheathing leaves is still common tradition among smallholder maize growers in Africa and Latin America. In countries with larger grain borer, *Prostephanus truncates*, storage of maize on the cob is strongly discouraged, since it favors development and spread of this pest. Therefore, the sheaths should be taken off the cobs and the dried crop well cleaned before dusting for storage.

4.6.1.3. Layer by layer dusting of maize cobs: sandwich method

The dried and well cleaned maize cobs should treated layer by layer as they are put into the store (granary). This treatment controls most traditional storage insect pests of maize, it may not be effective on the control of LGB. An overdose could be a danger to health. The following table 24 provide some recommended insecticide.

Table 24: Recommended insecticides and application rates on cob maize

Insecticides	Application rat
Actellic 1%	50 grams per 90 kg maize cobs
Malathion 2%	50 grams per 90 kg maize cobs
Malathion 2%	50 grams per 90 kg maize cobs
Etrimfos 1%	50 grams per 90 kg maize cobs
Gardona 3.25%	50 grams per 90 kg maize cobs
Methacrifos 2%	50 grams per 90 kg maize cobs

4.6.1.4. Pest control treatment of shelled maize.

The most recommended way to store maize is in the shelled form. This practice have some advantage:

- Shelled grain is less bulky to handle and to store requiring les space of storage and less handlabour
- Facilitates control of insects and rodents and respond better to chemical treatment than maize cobs
- Reduces losses and storage is easier to manage
- LGB is easier controlled when maize is shelled and admixed with synthetic pyrethroids such as permethrin and deltametrin.

The recommended insecticides are the same as table 31, and can be also recommended actellic at 0.5 percent and bromophos at 2 percent in applications rates of 100 grams per 90 kg grain and 50 grams per 90 kg grain respectively. Is important to remark that application can be made on a surface of concrete sprinkling the insecticide uniformly with a shovel. Another way is to mix in a drum and shake it along with the maize.

4.7. Rodents in storage

4.7.1. Types and general characteristics.

In several tropical countries rodents (rats and mice) cause much more loss and damage to food grain than insect pests. Three species are prevalent: the brown rat (*Rattus norvegicus*), the house mouse (*Mus musculus*) and the roof rat (*Rattus rattus*) figure 42.

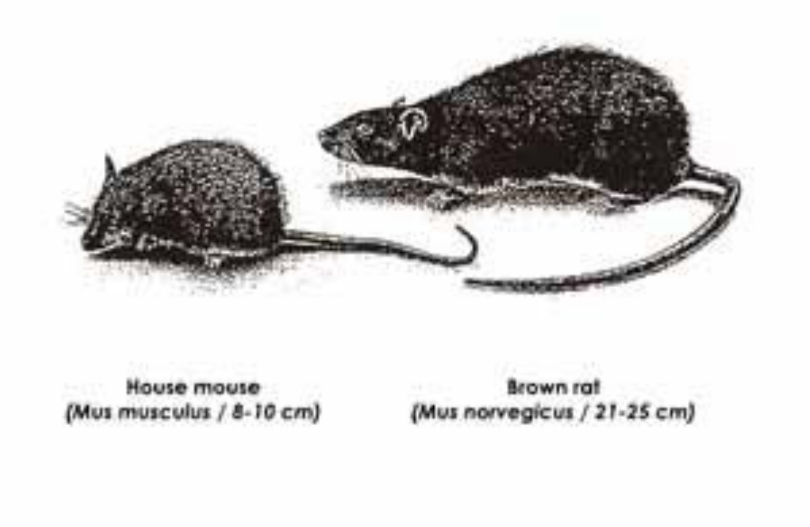


Fig. 42. Common species of rodents in storage.
(AGROTEC/UNDP/OPS, 1991)

4.7.2. Habits and characteristics of rodents:

· Usually they do same activities every day
· The follows same path over and over
· They are away of new things as for example new baits
· They can climb or jump until 60 and 90 cm
· They can swim across pools of water
· They dig and barrow holes through soil, hard structures, containers and objects

4.7.3. Rodents loss and damage to food grain:

· They damage crop in field and storage
· They eat and destroy the grain
· They foul and contaminate grain and cooked food with their feces, urine and hairs
· They can destroy buildings, structures, containers and personal clothings and bedding
· They spillage stacked bagged foods, storage structures and food containers
· They can attack young chicks and may attempt to feed on human feet, causing sores and walking difficulties to their victims
· They may cause disease to man and animals

4.8. Rodents control methods:

· By using various types of rodents traps
· By using domesticated cats

· By hunting rodents in the probably hiding places.

4.8.1. Improved rodents control methods:

· Prevent rodents entering by:
- solid walls structures
- use of metal sheets or chicken wire to structures walls which keep off rodents
- use of rat-guards as been before

· control can be achieved by baiting (poisoning). This requires training to be successful and to prevent accidents and death to humans table 25.

· all these previous methods are strongly supported by a goods standard of hygiene and storage management.

Table 25: Recommended rodenticides

Warfarin Coumatetralyl chlorophacinone	Anti-coagulant for mixing with dry bait or in powder form as a rodenticidal dust, or in soluble form used in drinking water for rodents
Difenacoum Broinadiolone	Anti-coagulant effective to rodent resistant to other anti-coagulant poisons
Brodifacoum	An anti-coagulant most effective to all types of rodents.

4.9. Quality and Economic Loss

Beside weight loss, which may appear small, deterioration in quality of maize due to insect attack or rats damage is also a great concern. The grain that has been damage by the insect and rats are undesirable in the market, causing great economic loss to the producer and quality loss to the consumer.

5. Economic and social considerations.

5.1. Aspects of Improved Post harvest Systems.

5.1.1. Economic considerations.

An economic analysis of investment in an improved post harvest system could be in two ways:
The first involves calculations of new investment, as for example, costs or value of the building materials, labour costs whether hired or self, interest costs, depreciation costs and costs of maintenance.
The second one would calculate the actual cash cost, such as building materials bought, equipment, hired labour, interest cost for borrowed money. Most of the time, farmers would only calculate and taking into consideration the cash expenses used in the investment.
Of high remark is the issue that the farmers should know that if the post harvest system is improved it will pay back the money investment. In case that farmer borrow money to pay, he should be clear that the gain from the improved system has to cover expenses he did as well the interest cost.

5.1.1.1. Analysis used for the cash cost method.

1). Investment cost.
a. Expenses for building materials and equipment
b. Cost for hired labour
c. Total cash investment cost (a+b)
2). Yearly cost.
d. Assuming that farmers want the money back in five years. So that, the yearly costs are:
d (*) = a+b/5
- interest is not indicated in these calculations.
e. Over the years cost for repair and maintenance have to be met. It is difficult to calculate an exact maintenance cost, but this is suggested to consider yearly 10 percent of the cost investment (a+) so, e= (a+b).10/100 = 0.1 (a+b).
f. Operational cost:
It includes labour cost, chemical for pest control treatment, etc. Note that difference in operational cost between old system and the improved system is the accurate difference in cash operations costs.
g. The yearly costs attributed by the improved or renewed post harvest system as compared to the traditional system are the sum of:
- investment.
- (interest cost).
- maintenance costs
- and the difference in operational costs.
- g = d+e+f
h. The yearly extra cost occurred by the introduction of the improved post harvest system should be paid by the gain in saved grain due to the improved methods. One way to calculate this is to estimate how many Kg of grain has to be saved to pay for the total yearly cost and conclude if this is a reasonable figure.
k. The example below demonstrate the method (in US $Dlls).
1. Storage capacity 1500Kgs.
2. cash cost for building materials = $15.00
3. cash cost for labour = $0.00

4. yearly cost during 5 years = 15+0/5 $3.00
5. yearly maintenance cost = (15-0)x0.1 $1.50
6. difference in operational costs = $1.50
7. total yearly costs = 3+1.5+1.5 $6.00
8. sales prices or cost price of one Kg grain = $0.15
9. Kg grain to pay the yearly costs 6/0.15 => 40kgs.
10. percent age of saved grain to pay the cost =>40x100/1500 2.7 percent
This 2.7 percent mean that in order to get profit in this particular example, the improved storage structure must save more than 2.7 percent of grain.

5.1.1.2. Considerations to be aimed to farmers:

· This is an adequate guideline to help farmers to take rationally decisions according to their surrounding, social context and economic resources.
· This guidelines can be used for farmers as an innovative solution depending upon their ambition, motivations and ability to work towards self-defined goals
· Farmers may choose the solutions that they consider suitable for their conditions depending on their capacity, social context, environment and economy.
· This information is addresses to small and medium maize farmers and if it is achieved it will be a good contribution for the improvement of the food security among the beneficiaries.

5.2. Gender Aspects in the Maize Production and Postproduction System.

In developing countries and in different cultures of agricultural farmer’s communities, many members of the family (male, female, and children) make important contributions to agricultural labours. Women play a very essential and important role during the crops production and postproduction systems either in Asia, Africa, Latin America, etc.
In this section it will be presented and discussed some interesting issues compiled in the Andean zones of South America. In this temperate zone, the maize represents the second crop cultivated on the up land until 3250 m above the sea level. In general the maize is planted after the harvesting of potatoes. This crop left good organic material to be used as fertilizer, therefore for these reason farmers traditionally rotates maize and potatoes. This is an ancestry traditions since Incas time.
On decisions taken by farmers about the type or variety of maize to be cultivated, it is normal that men and women (parents) decide. They cultivates in agricultural areas with irrigation and traditional system. They have also access to land, capital and work. When a family do not have any maize production such as land, capital or work, they use to work to others companies, relatives or others.
The agricultural activities of maize are done usually with the participation of the family members. Eventually due to unavailability of work in the community some members move away and therefore hand labour for farmers is scarce, they need and use supplementary hand labour by reciprocal accord (no payable) or interchange of service with others.
The different activities which usually are required for maize production and post harvest operations depend upon the efforts, and these are summarized in the next table 26.

Table 26: Activities distribution during production and post harvest operations for maize			
Activity	**Gender**		
During Production Practices			
Tilling	**M**	W	Ch
Ploughing	**M**	W	Ch
Sowing	M	**W**	Ch
Weeding	**M**	W	Ch
During Post harvest Operations			
Harvesting	M	**W**	Ch
Heaping	M	**W**	Ch
Selection	M	**W**	Ch
Bagging	M	**W**	Ch
Cutting of Plant	**M**	W	Ch
Dehusking	M	**W**	Ch
Shelling	M	**W**	**Ch**
Commercialization	M	**W**	Ch
M=Men; **W**=Women; **Ch**=Children.			

According to table 26 above, the heavy work which require more effort are made by men. In contrast, activities requiring less effort such as weeding, shelling etc are done by women and eventually children. The sowing is done by women because they believe that women are the symbol of fertility and therefore it is expected future good production. Usually children made slight activities such as watering, grain collection, shelling, weeding. Similar behaviour has been found in other developing countries of Africa and Asia. In a general context women have more participation in operations related to post harvest operations and a good example is showed in the following figure 43.

Fig. 43. Sale of maize, main activity done by women in Andean areas.
(Source: BIOSOMA-FAO-IPGRI, 1999)

References

1. CIBA-GEIGY Agrochemicals, Ltd., 1979. Maize a Technical Monograph, Basley, Switzerland.
2. Cooperación Suiza para el Desarrollo COSUDE. 1999. Metal Silos: Manual for manufacturing metal silos for grain storage. Programa Regional de postcosecha/PRP Swiss Agency for development and co-operation/SDC. English edition, 1999.
3. Dowswell, C.R., Paliwal, R.L., Cantrell. R. C., 1996. Maize in the third world. Edited by S.A. Breth series editor and published by Westview press, Inc., A division of HarperCollins Publisher, Inc.,5500 Central avenue, Boulder Colorado 80301-2877, and in the United kingdom , Cumnor Hill, Oxford.
4. Dungan, G.H., Lang, A.L. and Lowery, J.C. 1953. You can grow more corn. The goodheart-willcox Co. Inc, Chicago, U.S.A.
5. Food and Agriculture Organization of the United Nations FAO, 1985. Farines composes: Application des techniques existants. An publication de la commission economique pour lÁfrique des Nations Unies, Africa Hall, Addis-Abeba, Ethiopie.
6. Food and Agriculture of the United nations, FAO. 1999. Small Scale Maize Processing. Unpublished document.
7. Food and Agriculture Organization FAO of the United Nations, 1984. Post harvest Losses in quality of food grains. FAO food and nutrition paper No.29.
8. Food and Agriculture Organization FAO., 1990. Utilización de alimentos tropicales: cereales. Estudio FAO Alimentación y Nutrición. 47/1.
9. Food and Agriculture Organization FAO., 1992. Maize in human nutrition. FAO Food and Nutrition Series, No.25.
10. Food and Agriculture Organization of the United Nations, FAO., 2000. Tropical Maize Improvement and Production. FAO Plant Production and protection series, No.28.
11. Food and Agriculture Organizations of the United nations, FAO. 2000. Piso de secado: Una Buena opción para secar sus productos. Folleto ilustrativo producido por el proyecto GCP/Bol/032/Net.
12. Guzmán, G., López, F., y Alatorre, G. 1982. Los Libros del maiz: como lo usamos. Editorial arbol. S.A. de C.V., 04000, Mexico. D.F.
13. Intermediate Technology Development Group ITDG-Perú and United Nations development Fund for women UNIFEM., 1998. Procesamiento de Cereales. Libro de consulta sobre tecnologias aplicadas al ciclo alimentario, con el auspicio de Asociación para la cooperación internacional al desarrollo (Atelier), Agencia Española de Cooperación Internacional (AECI).
14. Iriarte, L., Lazarte, L., Franco, J. and Fernández, D., 1999. Género y el manejo de los recursos genéticos: El rol del género en la conservación, localización y manejo de la diversidad genética de papa, tarwi y maiz. Una publicación patrocinada conjunta entre el Instituto Internacional de Recursos Filogenéticos (IPGRI), Food and Agriculture Organization of the United Nations (FAO), the Consultative Group on Internacional Agricultura (CGIAR) and BIOSOMA, Cochabamba Bolivia, pg. 60-69. Edited by Imago, Cochabamba, Bolivia.
15. Mazaud, F., 2003. Personal Communication.
16. Mejía, D. J. (2002). Training workshop on: Manufacturing, Handling, Use and Cost Calculations of Small Metallic Silos for Storage of Grains and Cereals in Ondangwa,

Namibia. Back to Office report AGST-FAO, Roma.

17. Odogola, W.R., Henriksson, R. 1991. Technical System for Agriculture: Post harvest Management and Storage of Maize. A publication prepared by AGROTEC Regional, Office Harare, Zimbawe and UNDP/OPS.
18. Rouanet, G., 1984. Le technicien d’agriculture tropicale : Le mais. Edited by Maisonneuve et Larose et A.C.C.T. Paris.
19. The United Nations Development Fund for Women UNIFEM and Intermediate technology development Group, 1988. Cereal processing. Food Cycle technology source No.3.
20. Watson, A.S. and Ramstad, P.E. 1987. Corn: Chemistry and Technology. Published by American Association of Cereal Chemists, Inc., St. Paul, Minessota, USA.
21. http://mexico.udg.mx/cocina/maiz/tortillas.html
22. http://www.mpiz-koeln.mpg.de/pr/garten/schau
23. http://postharvest.ucdavis.edu
24. http://www.mercanet.cnp.go.cr
25. http://farma.qfb.umich.mx/origmaiz.htm
26. http://www.cgiar.org/areas/maize.htm
27. http://www.iita.org/crop/maize.htm
28. http://www.mexconnect.com/mex_/recipes/puebla/kgpastaachiote.html
29. http://www.nju.edu.cn/foode/bei/b95.htm
30. http://www.ann.com.au/herbs/Monographs/zeamays.htm
31. http://www.ag.iastate.edu/departments/agronomy
32. http://maize.agron.iastate.edu/general.html
33. http://www.corn.org/web/processc.htm
34. http://www.usda.gov/nass/aggraphs/cornprod.htm
35. http://southernfood.miningco.com/library/rec00/bl01002i.htm
36. http://www.apc-nicaragua.com/maiz/index.htm
37. http://www.motherlandnigeria.com/recipes.html
38. http://www.cdkitchen.com
39. http://www.kstrom.net/isk/food/r_corn.html
40. http://www.apc-nicaragua.com/maiz/index.htm
41. http://maize.agron.iastate.edu/maizearticle.html
42. http://uk.encarta.msn.com/encyclopedia_761559467/Maize.html#s1

Annex

List of Tables

List of Figures

Recipes

Recipe 1	
Tortillas of maize	
Ingredients.	**Amount.**
Clean grains of white maize Water Lime (Calcium hydroxide**)**	6 kg 12 L 30 gram
Method.	
Mix maize and water Cook the maize at 94 C0for 50 min. Stand (steeped) overnight or 12 hr Decanting supernatant Cooked maize (Nixtamal) Washing of nixtamal for 1 to 2 times with clean potable water Milling of the nixtamal and add water if is necessary Obtaining the masa Hand moulding into flat cakes (120 grs large tortillas or 40 grs for small tortillas Baking on hot griddle (comal) for 1-2 min both side for tortillas of 120 gr	

Recipe 2	
Chicha (Peruvian style)	
Ingredients.	**Amount.**
Yellow Maize dried or jora (sprouting Maize)dried Scent nail/clove Water Brown sugar formed into block Quinoa Whole grains of white maize	1/2 kg 2 tablespoon 18 L 1 1/2 Kg 100 gr. 200 gr.
Method.	
When maize start sprouting (Jora) it is collected, dried by sun and grinded.	

The "Jora" is cooked with soft agitation in a pan with water and the scent nails. Shake smoothly to avoid burning of the product and cook for 8 hours, adding water as much is required to prevent burn. Then strain the cooked product through a gross fabric of straining. Let the product cool Transfer the product into a mud pot Addition of the block of brown sugar, the quinoa and the whole kernels of maize grains Cover the mud pot The liquid is leaved in the pot for 8 days for fermentation Check and shake it once a day. It is tasted to test sweetness and texture, adding water or sugar if it is necessary.

Recipe 3	
Pinolillo	
Ingredients.	**Amount.**
Clean grains of red maize (Pujagua) Cacao Cinnamon Seed sweet pepper	3 kg 1 kg. 15 gr. 250 seeds
Method.	
Heat the maize and water mixed until get boiling Strain the maize by draining the water To toast the maize until it get slightly brown in colour To toast the cacao and remove the peel To mix maize, cacao, cinnamon and seeds of pepper To grind until fine size of particles. The product can be solved in water or milk and sweeten with sugar as much is required, and it is served cold with chips of ice.	

Recipe 4	
Pinol or pinole	
Ingredients.	**Amount.**
White dry maize Water Sal	1 kg 4 litres to the pleasure
Method.	
Toast the cleaned maize in a mud pot of wide mouth until it become golden to slightly brown in colour. To grind the maize until it get fine grains Cooling. Put the grinded grain (pinol) into a container, add the water and shake until it become homogeneous. Add small pieces of ice and it is ready for drinking. Also it may be served adding a little of salt or sugar. It yields about 12 standard glasses.	

Recipe 5	
Nacatamal	
Ingredients.	**Amount.**
White dry maize	7 Lbs.
Back meat of pork	3 Lbs
Lard of pork	1 Lt
Onions of medium size	4
Garlic cloves	4
Tomatoes	2
Potatoes	3
Small sweet pepper	3
Grains of B*ixina orellana* (Achiote)	24
Rice	10 Oz.
Plantain leaves	12
Chilli "congo" or "pikin"	24 units
Salt	at to pleasure
Water	at to pleasure
Method.	
Cooking of the maize kernels until the kernels burst. To separate the cooking water and then wash the burst kernels. To grind the maize grains with the disc mill or stone mill (piedra de moler) until they become a masa of grain fine. While the burst kernels are grinding add to the masa, finely shopped a part of the pork lard, onions and garlic, and the salt to the pleasure. Then pre-cook evenly this mix of ingredients and the masa and let stand before it is used. The pork meat is cut in portions approx. of 4 ounces each and is mixed with the bixina seeds, onions, garlic and salt to the pleasure. The rice is washed with water and it is let it to strain. The plantain leaves are blanched on a fire and should be removed the central vein of each leaf... Packaging and tying of the portions: Over two pieces of plantain leaves approx 35-40 cms length of each sides (square) are set the ingredients in the following order: the maize masa, the pork meat, the rice, the sweet pepper sliced, the slices of onions, slices of tomatoes, slices of potatoes and the chillies (2 whole chillies per portion). Once all the ingredients are portioned above the plantain leaves, these are folded overlapping the extremes and folding inside for forming a rectangular and cylindrical body of masa which is tied with a natural thin cord. Finally, they are put into the pan with a little of water and the nacatamales are cooked for a time of 5 hours. Once cooked then they are ready to be eaten. It yields approximately 12 nacatamales or portions.	

Recipe 6	
Arepas	
Ingredients.	**Amount.**
Pre-cooked white maize flour	2 cups
Salt	1 teaspoon
Water	as is indicated
Oil	as is indicated
Method.	
Put approximately 1 cups of water into a bowl and add the salt and little of oil.	

Then add slowly and progressively the flour solving it in the water and kneading it and avoiding the formation of clumps. The dough knead finalise when the dough is soft and it is not sticky. Formatting small balls of dough and flattens it symmetrically. Heat a hot plate or griddle and put some oils drops, put the arepa over it. Cooke the arepas until they release off from the hot griddle in both side. Put the arepas into the oven previously heated to 350 ºC and let them until become spongy and brown. The arepa can be served with cheese, buttermilk, meats, beans, eggs, etc. in breakfast or dinner. This yields portions for 4 to 6 persons.

Recipe 7	
Tamale pisque	
Ingredients.	**Amount.**
Clean grains of white maize	6 kg
Water	12 L
Lime (Calcium hydroxide**)**	30 gram
Method.	
Cook the maize in water with 15 grs of lime (calcium hydroxide) until the kernels of maize are burst. Eliminate the cooking water by straining the kernels and then wash with clean water until the maize lower tip or pedicel is removed. Grind the maize until a masa of fine grain is obtained by using milling discs. Packaging the portions: Over two overlapping pieces of plantain leaves approx 40 cm length of each side (square) are set a portion of the grinded fine masa of 11 cm of large, 5.5 cm width and 2 cm of height. The portion of masa over the plantains leaves is wrapped by folding the tips or extremes of the remaining leaves very closely. Once the tamales are packed in an appropriate way they must be cooked. Therefore, they are put orderly within a pan and water is added until _ of the capacity of the pan. The tamales will be cooked until they get a solid consistency. Once they are finally cooked, they are let stand to cooling. It yields approx. 16 tamales or units.	

Recipe 8	
Yoltamal	
Ingredients.	**Amount.**
Maize green ears tender	25
Hard cheese	1 Lb
Sugar	1/2 Lb.
Buttermilk	1/2 Lb.
Maize green sheets	20 units
Method.	
Remove the cover sheets of the maize ear and eliminate the silky hairs. To scrape the maize kernels by using a knife. The kernels so obtained are mixed with ground cheese, the sugar and the buttermilk. All the mix is grounded finally. Packaging of the masa: formatting in cylindrical form the maize green ears sheets to be used for wrapping the masa. Fill the masa into the sheets formatted and fold the extremes.	

Then put the small packages of wrapped masa into the pan in vertical position. Add water until the half of the pan and cook to smooth fire for one tour. The final product can be eaten hot or cold. It yields 20 units approximately.

Recipe 9	
Tortillas of maize (millenary recipe)	
Ingredients.	**Amount.**
Clean grains of white maize Water Lime (Calcium hydroxide**)**	6 kg 12 L 60 grams
Method. Washing of maize removing impurities, then separate the water Add 2 litres of water to 1 kg of maize (ratio water:maize;2:1) Cook the maize slowly turning around with a wood spoon until it gets boiling (let 3 min). Stand (steeped) overnight Next day decanting supernatant (nejayote) Cooked maize (Nixtamal, is ready when a cooked kernel can be easily peeled by hands) Washing of nixtamal for 1 to 2 times with clean potable water Milling of the nixtamal with the metate a manual milling with stones or electric milling, adding water if is necessary Obtaining the masa Hand moulding into flat cakes (120 grs large tortillas or 40 grs for small tortillas Baking on hot griddle (comal) for 1-2 min both side for tortillas of 120 grs	

Recipe 10	
Atol duro	
Ingredients.	**Amount.**
Maize dried and cleaned Sugar Milk Anis essence	2 Lbs. 1 1/2 Lbs. 2 L. 1/2 teaspoon
Method. Soaking the Maize 12 hours and then eliminate the water. Grind the maize finely and dilute the masa into water then to strain it through a cotton cloth. Let stand the diluted and strained masa for a while and then decant the supernatant and keep the bottom phase. Add to the solid phase the milk, the sugar and the essence of anis and mix it. Cook with smooth fire and turning around slowly with a large spoon wood until it become thick, once the second boiling come up now it is ready. Put the tick atole within a deep plate of wide mouth and let it to cool. Cut the atole in pieces It yields portions for 15 persons.	

Recipe 11	
Chapattis	
Ingredients.	**Amount.**
Maize flour	1 1/2 cup

Water oil	2/3 cup 1 tbsp
Method. Mix the flour and water together and knead in the oil. Cover with a damp cloth, plastic bag or put underneath an inverted bowl and leave for 2 to 2 1/2 hours. Divide into 3 balls and roll out with the roll pin to 15 cm. Heat a frying pan without any fat or oil in it. Cook each chapatti in the pan for about 30 seconds on each side until it begins to puff. Repeat for all.	

Recipe 12	
Boiled maize cobs	
Ingredients.	**Amount.**
Maize/corn Water Salt	One or two, since this is eaten as a side. Enough to cover 2 teaspoon
Method. Take the husks off the maize, and rinse them if desired. Place the maize in a pot and add enough water to cover it. Add about 2 teaspoons of salt. Cook the maize until it is soft. Drain the maize. Depending on the size, each person will probably want one. Serve as a side to a meal.	

Recipe 13	
KOKORO	
Ingredients.	**Amount.**
Maize flour Gari Sugar Oil Salt Water	500gm (18 ounces) 200gm (7 ounces) 300gm (10 ounces) Enough for frying in a pan 1 teaspoon 4 cups
Method. Boil about 4 cups of water. Add some water to the corn flour, and mix as you add. Should you want a stiff mixture, so don't add too much water. Allow to cool lightly. Add gari (fermented flour from cassava), sugar and salt and mix thoroughly with your hand to get a stiff and smooth mixture. Roll on oiled or floured board. Add oil to a pan, so that it is about 1 inch (2.5 centimetres) or more high. Heat the oil. Place the rolled dough into the oil and deep fry until golden brown. Serve hot or cold.	

Recipe 14	
Aadun	
Ingredients.	**Amount.**
Maize or corn (dried) Salt Palm oil Dried Pepper Green leaf or foil Onion if desirable	2 cups - - - - -
Method.	
Place the maize or corn in a hot pan Heat for about 15-30 or more minutes Allow it to brown Grind on a local stone or a Grinder until powdered (the onion too if desired). Add salt, palm oil, pepper and stir until mixed properly. Serve in foil or local leaf for about 5 people.	

Recipe 15	
Ogi (Nigeria)	
Ingredients.	**Amount.**
Maize Water	2 Kg 4 L
Method.	
Clean well the maize. Soaking into the water (12-72 hours) Wet milling adding water and then sieve it on a fine cloth muslin Let to ferment (1 to 3 days) Decant the water supernatant The remaining sediment is the Ogi slurry It ready to be boiled and served in the form of porridge. The porridge contains approximately 90 percent of moisture content.	

Recipe 16	
Kenkey (Ghana)	
Ingredients.	**Amount.**
Maize Water	2 Kg 4 L.
Method.	
Clean well the maize. Soaking into the water (24-48 hours) Decant the water Then, grind Add water in the ratio 1:2, milling maize to water Let to ferment (1 to 4 days) Divide the fermented dough in 1/3 and 2/3 parts. The 1/3 parts of dough is added with 2 parts of water and salted then mixed and cooked. The 2/3 parts of dough previously prepared now should be mixed with the 1/3 cooked dough prepared as above.	

Now it is ready the Kenkey mass This mass is wrapped in maize or plantains leaves and then boiled This is called Kenkey

Recipe 17	
Basic Maize Bread	
Ingredients.	**Amount.**
Cornmeal Eggs beaten Buttermilk Bacon drippings, melted, or veg. oil	2 cups 2 2 cups 2 Tablespoons
Method.	
Heat oven to 450 degrees. Grease your 9-inch skillet with about 2 tablespoon of shortening or oil (Use bacon drippings instead if available). Leave oil in bottom of pan... Place pan in oven to heat.... Combine cornmeal, 2 eggs, buttermilk, and the melted bacon drippings. Mix well. A whisk does this nicely. Pour into hot skillet. Batter will sizzle. Bake at 450 degrees for 35 minutes or until golden brown. Serves 6 to 8. Hint: Sprinkle a little cornmeal in the hot pan before adding the batter. It will brown and add a crispier texture. If using plain cornmeal, add 2 teaspoons of baking powder and 1/2 teaspoon of salt for each cup of regular meal.	

Recipe 18	
Sweet Maize Bread	
Ingredients.	**Amount.**
All-purpose flour Corn flour Sugar Baking powder Salt Egg, beaten Sour cream (can use non-fat) Milk Butter or margarine, softened	1 cup 1 cup 1/4 cup 1/2 tsp. 1/2 tsp. 1 1 cup (8 oz.) 1/3 cup 1/4 cup
Method.	
In a bowl, combine the dry ingredients. In another bowl, combine egg, sour cream, milk, and butter. Stir into dry ingredients just until moistened; pour into greased 8" square baking pan. Bake at 400 degrees for 20 to 30 minutes or until a toothpick comes out clean. Serve warm (8 to 10 serves/makes	

Recipe 19	
Cususa (distilled)	
Ingredients.	**Amount.**
Dry and clean maize Brown sugar formed into blocks Water	13 lbs 5 Lbs. 5 L

Method.
Put the maize grains on a layer of sand or bags made with natural fibre and watering every day for 4 days. The fourth day emerge the little plant from each grain. Wash the germinated maize and put it then into a big mud pot together with the grinded brown sugar adding the water Let stand for 4 days the mixed taking care of covering the pot After 4 days the fermented process should finish. Now is obtained the final fermented product (called "chicha muerta") is ready to be distilled Distillation consists of boiling the fermented liquid product previously obtained by condensing the vapours (alcohols) through a refrigerated coil tube which are finally collected in transparent glass recipient. 3 qualities of distilled can be obtained, a, b and c and 4 litres of distilled can be expected.

Recipe 20	
Enchiladas	
Ingredients.	**Amount.**
Masa of tortilla	1 Lb.
Vinegar of fruits	1/4 L.
Vegetal oil	1/2 L.
Chilli pikin or Congo (small red chilli)	1 Oz.
Achiote (Bixa orellana)	10 Seeds
Salt	At pleasure
Plastic fibre	A piece
Method.	
Mix well the masa with salt and the ground seed of achiote. To separate portions of 1/2 Oz of the mix. Flattening the masa on a flan surface like the press tool to make tortillas using a plastic sheet to avoid sticky of the masa. Otherwise use a pin roller. Then fry the pieces flattened in boiling oil until it get crispy texture Once fried, let cool and then dressing with a hot sausage The sausage can be prepared grinding the chilies and mixing with the Vinegar. Then the cooked enchiladas are dressed with this sauce and now there are ready to be served. It gives 32 serves	