**MAIZE IN LATIN AMERICA COUNTRIES**

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4. **INTRODUCTION**

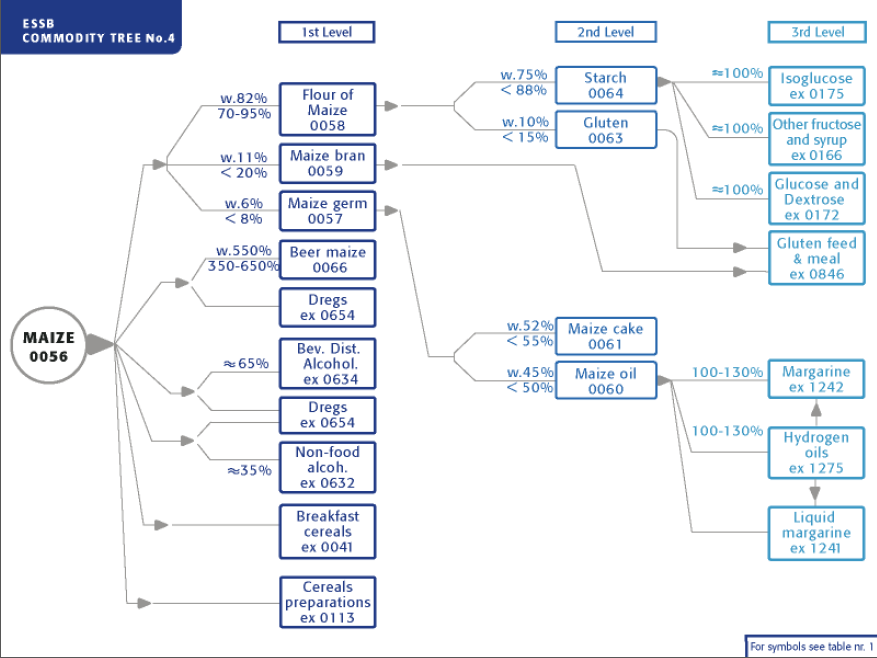
Beyond the production level, little is known about **what**, **where** and **how** key commodities are transformed and - more importantly - how much is being made available for food consumption and in what form.

The **scope of this research is to study selected staple food commodities in particular regions to develop guidelines for monitoring food security at country level**. The idea is to survey agents in value chains for staples who are present at the farmgate at the time of harvest and are engaged in buying the crops for particular markets, e.g. retail, feed, food processing and alcohol, and how much of the staple is retained by the farmer for seed and storage. The survey can also be implemented in conjunction with other surveys, namely on production, to ensure low cost and sustainability.

The analysis is based on physical characteristics, ways of utilization and storage, and traditional vs industrial methods to transform raw commodities into processed food. This should provide us with more detailed information on nutritional characteristics of staple food in relevant regions and what should be targeted.

In order to proceed in this research, information has been collected on major staple foods, and notes have been drafted on crops and their transformation process. Starting from the structure of FAO Commodity Trees[[1]](#footnote-1), research has been conducted on (i) crop characteristics, plant anatomy and nutritive factors, for which different nutrition sources have been compared (e.g. West African Food Composition Tables, United States Department of Agriculture Agricultural Research Service Database[[2]](#footnote-2), ESS Nutritive Factors list[[3]](#footnote-3), etc.); and (ii) processed product transformation: how these primary commodities are transformed into processed food, nutritional characteristics, local recipes, etc.

In order to identify the importance of the commodities in diets and in key countries, data on *food supply* (kcal/capita/day), *protein supply quantity* (g/capita/day) and *fat supply quantity* (g/capita/day) have been downloaded from the FAOSTAT for the following crops: cassava, maize, maize, oats, rice milled, rice paddy, sorghum, soybean and wheat. For each country, the commodity supply on total food supply has been calculated, and the average for the last three available years (2007-2009) has been considered to rank results and identify where single commodities have a higher impact on total food supply. Based on that information, countries and commodities have been selected, and what came to light is that **maize** is one of the most important staple foods in Latin America. dMaize is in the family of cereals, it is particularly relevant in diet for population in **Guatemala**, **Mexico** and **Honduras**.

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The *maize supply* in Guatemala is around the **36%** of the *total food supply* share (average 2007-2009).

The *total* *maize production* for the same country amounts at **1,570,882** tonnes (average 2007-2009), around **13.52%** of total crop food production in Guatemala (Table 1).

**Table A: Maize production and maize supply in Guatemala (FAOSTAT DATA)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Maize Supply, Guatemala (kcal/capita/day)** | | |  | **Total Food Supply, Guatemala (kcal/capita/day)** | | |  |  |
| **2007** | **2008** | **2009** | **Maize average supply (2007-2009)** | **2007** | **2008** | **2009** | **Total food average supply (2007-2009)** | **Maize supply/ Total supply (2007-2009)** |
| 791 | 800 | 810 | **800.33** | 2,199 | 2,226 | 2,224 | **2,223** | **36%** |
| **Maize Production, Guatemala (Tonnes)** | | |  | **Total Food Production, Guatemala (Tonnes)** | | |  |  |
| **2007** | **2008** | **2009** | **Maize average production (2007-2009)** | **2007** | **2008** | **2009** | **Total food average production (2007-2009)** | **Maize production/ Total production (2007-2009)** |
| 1,459,562 | 1,566,196 | 1,686,888 | **1,570,882** | 11,153,807 | 11,623,018 | 12,074,561 | **11,617,128.66** | **13.52%** |

The *maize supply* in Mexico is around the **32.45%** of the *total food supply* share (average 2007-2009).

The *total* *maize production* for the same country amounts at **22,658,556** tonnes (average 2007-2009), around **19.64%** of total crop food production in Mexico (Table 2).

**Table B: Maize production and maize supply in Mexico (FAOSTAT DATA)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Maize Supply, Mexico (kcal/capita/day)** | | |  | **Total Food Supply, Mexico (kcal/capita/day)** | | |  |  |
| **2007** | **2008** | **2009** | **Maize average supply (2007-2009)** | **2007** | **2008** | **2009** | **Total food average supply (2007-2009)** | **Maize supply/ Total supply (2007-2009)** |
| 1,026 | 1,051 | 1,022 | **1,033** | 3,215 | 3,188 | 3,146 | **3,183** | **32.45%** |
| **Maize Production, Mexico (Tonnes)** | | |  | **Total Food Production, Mexico (Tonnes)** | | |  |  |
| **2007** | **2008** | **2009** | **Maize average production (2007-2009)** | **2007** | **2008** | **2009** | **Total food average production (2007-2009)** | **Maize production/ Total production (2007-2009)** |
| 23,512,752 | 24,320,100 | 20,142,816 | **22,658,556** | 116,345,017 | 120,884,717 | 108,850,566 | **22,658,556** | **19.64%** |

The *maize supply* in Honduras is around the **27.12%** of the *total food supply* share (average 2007-2009).

The *total* *maize production* for the same country amounts at **586,131** tonnes (average 2007-2009), around **12.07%** of total crop food production in Honduras (Table 3).

**Table C: Maize production and maize supply in Honduras (FAOSTAT DATA)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Maize Supply, Honduras (kcal/capita/day)** | | |  | **Total Food Supply, Honduras (kcal/capita/day)** | | |  |  |
| **2007** | **2008** | **2009** | **Maize average supply (2007-2009)** | **2007** | **2008** | **2009** | **Total food average supply (2007-2009)** | **Maize supply / Total supply (2007-2009)** |
| 723 | 712 | 739 | **724.67** | 2,634 | 2,687 | 2,649 | **2,672** | **27.12%** |
| **Maize Production, Honduras (Tonnes)** | | |  | **Total Food Production, Honduras (Tonnes)** | | |  |  |
| **2007** | **2008** | **2009** | **Maize average production (2007-2009)** | **2007** | **2008** | **2009** | **Total food average production (2007-2009)** | **Maize production/ Total production (2007-2009)** |
| 634,881 | 536,277 | 587,235 | **586,131** | 4,918,882 | 4,848,337 | 4,798,347 | **4,855,189** | **12.07%** |

1. **COMMODITY CHARACTERISTICS[[4]](#footnote-4)**

Botanically, maize (**Zea mays**) belongs to the grass family (**Gramineae**) and is a tall annual plant with an extensive fibrous root system. It is a cross pollinating species, with the female (ear) and male (tassel) flowers in separate places on the plant. The grain develops in the ears, or cobs, often one on each stalk; each ear has about 300 to 1 000 kernels, weighing between 190 and 300 g per 1000 kernels, in a variable number of rows (12 to 16). Weight depends on genetic, environmental and cultural practices. Grain makes up about 42% of the dry weight of the plant. The kernels are often white or yellow in colour, although black, red and a mixture of colours are also found. There are a number of grain types, distinguished by differences in the chemical compounds deposited or stored in the kernel.

Special crops grown primarily for food include sweet corn and popcorn, although dent, starchy or floury and flint maize are also widely used as food. Flint maize is also used as feed. Immature ordinary corn on the cob either boiled or roasted is widely consumed. Floury maize is a grain with a soft endosperm much used as food in Mexico, Guatemala and the Andean countries. The dent type of maize has a vitreous horny endosperm at the sides and back of the kernel, while the central core is soft. Flint kernels have a thick, hard and vitreous endosperm surrounding a small, granular, starchy centre.

**The origin of maize**

The cultivation of maize or Indian corn most probably **originated in Central America**, particularly in **Mexico**, from whence it spread northward to Canada and southward to Argentina. The oldest maize, about 7000 years old, was found by archaeologists in Teotihuacan, a valley near Puebla in Mexico, but it is possible that there were other secondary centres of origin in the Americas. Maize was an essential item in Mayan and Aztec civilizations and had an important role in their religious beliefs, festivities and nutrition. They claimed that flesh and blood were made from maize. The survival of the oldest maize and its distribution depended on humans who harvested the seed for the following planting. At the end of the fifteenth century, after the discovery of the American continent by Christopher Columbus, maize was introduced into Europe through Spain. It then spread through the warmer climates of the Mediterranean and later to northern Europe. Mangelsdorf and Reeves (1939) have shown that maize is grown in every suitable agricultural region of the world and that a crop of maize is being harvested somewhere around the globe every month of the year. Maize grows from latitude 58° in Canada and the former Union of Soviet Socialist Republics to latitude 40° in the Southern Hemisphere. **Maize crops are harvested in regions below sea-level in the Caspian Plain and at altitudes of more than 4 000 m in the Peruvian Andes**.

In spite of its great diversity of form, all main types of maize known today were apparently already being produced by the native populations when the American continent was discovered. **All maize is classified as Zea mays**. Furthermore, evidence from botany, genetics and cytology has pointed to a common origin for every existing type of maize. Most researchers believe that maize developed from teosinte, Euchlaena mexicana Schrod, an annual crop that is possibly its closest relative. Others, however, believe that maize originated in a wild maize that is now extinct. The closeness of teosinte to maize is suggested by the fact that both have ten chromosomes and are homologous or partially homologous.

Introgression between teosinte and maize has taken place in the past and still does today in areas of Mexico and Guatemala where teosinte grows among the maize crop. Galinat (1977) indicated that of the various hypotheses on the origin of maize, essentially two alternatives remain viable: first, that present-day teosinte is the wild ancestor of maize and/or that a primitive teosinte is the common wild ancestor of both maize and teosinte or, second, that an extinct form of pod maize was the ancestor of maize, with teosinte being a mutant form of this pod maize.

In any case, most of the modern varieties of maize have been derived from materials developed in the southern United States of America, Mexico and Central and South America.

**2.1 MAIZE PHISICAL DESCRIPTION AND SPECIES**

**The maize plant**

The **maize plant** may be defined as a **metabolic system** whose **end product is mainly starch deposited in specialized organs, the maize kernels**.

The development of the plant may be divided into two physiological stages. In the first or the vegetative stage, different tissues develop and differentiate until the flower structures appear. The **(i)** **vegetative stage** is made up of **two cycles**. In the **first cycle** the **first leaves are formed and development is upward**. **Dry matter production** in this cycle is **slow**. It ends with the tissue differentiation of the reproductive organs. In the **second cycle** the **leaves and reproductive organs develop**. This cycle **ends** with the **emission of the stigmas**.

The **(ii) second stage**, also known as the **reproductive stage**, **begins** with the **fertilization of the female structures**, which will **develop into ears and grains**. The **initial phase** of this stage is characterized by an **increase in the weight of leaves and other flower parts**. During the **second phase**, the **weight of the kernels rapidly increases** (Tanaka and Yamaguchi, 1972).

The **plant develops morphological characteristics and differences** in the vegetative and reproductive stages as evolutionary consequences of natural selection and domestication. **Some genotypes** have **adapted to specific ecological zones** and so have developed such barriers as day-length sensitivity and temperature sensitivity, which limit their adaptability to specific areas of latitude and altitude. Thus improvement programmes must be conducted within the areas where the improved varieties are to be grown. This does not mean, however, that specific genetic characteristics can be attained by backcrossing.

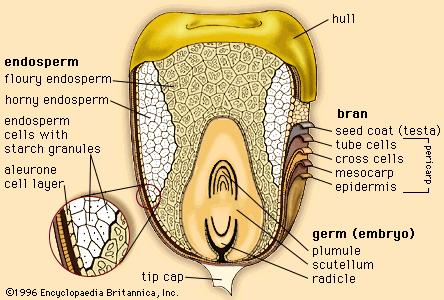
The morphology or architecture of the plant has also suffered evolutionary pressures that have resulted in great variability in the number, length and width of leaves, plant height, positions of ears, number of ears per plant, maturation cycles, grain types and number of rows of grain, among many other characteristics.

This **variability is of great value in improving the productivity of the plant and specific organic components of the grain**. The main yield components include the number and weight of grains. These yield components are determined by quantitative genetic effects that can be selected relatively easily. The **number of grains depends** on the **ear** and is **determined by the number of rows and the number of kernels per row**. The size and shape of the kernel determine its weight in the presence of other constant factors such as grain texture and grain density. The ratio of grain weight to total plant weight for most maize lines is about 0.52. From 100 kg of cobs, about 18 kg of grain is obtained. One ha of maize yields about 1.55 tonnes of stalk residue. In field-dried maize plants from three locations in Guatemala, plant dry weight varied from 220 to 314 g. This weight comprised 1.8% dried flowers, 14.7 to 27.8% stalks, 7.4 to 15.9% leaves, 11.7 to 13% husks, and 9.7 to 11.5% cobs. The field-dried grain represented 30 to 55.9% of the whole plant dry weight. These data show the significant yield of plant residues that are often left in the field. The distribution may change, however, since it is accepted that about half of the dry matter is grain and the other half is made up of plant residues excluding roots (Barber, 1979).

**Anatomy**

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

**Grains and their structure**



**Structure of the maize kernel**

Maize kernels develop through accumulation of the products of photosynthesis, root absorption and metabolism of the maize plant on the female inflorescence called the ear. This structure may hold from 300 to 1 000 single kernels depending on the number of rows, diameter and length of the cob. Kernel weight may be quite variable, ranging from about 19 to 40 g per 100 kernels. **During harvest the ears of maize are removed from the maize plant either by hand or mechanically**. The **husks** covering the ear are first **stripped off**, then the **kernels are separated by hand or, more often, by machine**.

**TABLE 1 - Weight distribution of main parts of the kernel**

|  |  |
| --- | --- |
| **Structure** | **% weight distribution** |
| Pericarp | 5-6 |
| Aleurone | 2-3 |
| Endosperm | 80-85 |
| Germ | 10-12 |

The **maize kernel** is known **botanically** as a **caryopsis**; a single grain contains the seed coat and the seed. The **four major physical structures of the kernel** are (i) the **pericarp**, **hull or bran**; (ii) the **germ or embryo**; (iii) the **endosperm**; and (iv) **the tip cap** (dead tissue found where the kernel joins the cob).

The **endosperm**, the largest structure, provides about **83% of the kernel weight**, while the **germ** averages **11%** and the **pericarp 5%**. The remainder is the tip cap, a conical structure that together with the pedicel attaches the kernel to the ear of maize.

**Root**

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

**Stem**

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

**Leaves**

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

**2.2 MAIZE PRODUCTION**

**HARVESTING AND PREPARATION[[5]](#footnote-5)**

Maize is taken from the field by removing the long grainy head from the rest of the stock Before it can be used for food it must be processed to remove the uneatable portion of the husk. The maize is first threshed to remove the usable grain from the hard husk and break-up the grain into smaller more manageable pieces. Further separation is then done by manual pounding . Grain is normally pounded with a wooden pestle in a wooden or stone mortar. It is common for the maize to first be moistened with about 10% water or soaked overnight to make the pounding easier. A woman working were hard can at best pound only 1.5 kg of grain per hour. After the usable portion of the grain has been separated by pounding the edible portion is removed winnowing or sieving. Winnowing is a process to separate grains from chaff by blowing air. The whole content is thrown up in the air, and the grain and chaff get separated out by gravity. The lighter chafe is blow away leaving behind the heavier usable grain. The final step in processing maize is making flour. Traditional grinding stones used to grind grain to flour usually consist of a small stone which is held in the hand and a larger flat stone which is placed on the ground. Grain is crushed by the backward and forward movement of the hand-held stone on the lower stone. The work is very laborious, and it is hard work for anyone to grind more than 2 kg of flour in an hour.

**MAIZE POST-HARVEST TECHNOLOGY: PRE-PROCESSING[[6]](#footnote-6)**

The **chemical components and nutritive value of maize do not lose their susceptibility to change when the grain is harvested**. Subsequent links in the food chain, such as storage and processing, may also cause the nutritional quality of maize to decrease significantly or, even worse, **make it unfit for either human and animal consumption or industrial use**.

**Drying**

**Maize harvesting is highly mechanized in developed countries** of the world, **while it is still done manually in developing countries**. The **mechanized system removes** not only the **ear from the plant** but **also the grain from the cob**, while **manual harvesting** requires **initial removal of the ear**, which is **shelled at a later stage**. In both situations, **maize is usually harvested when its moisture content is in the range of 18% to 24%**. **Damage to the kernel** (usually during the shelling operation) is **related** to **moisture content at harvest**; the lower the moisture content, the less the damage.

**Changes in the physical quality** of the **grain** are often a **result of mechanical harvesting**, **shelling** and **drying**. The first two processes sometimes result in external damage, such as the breaking of the pericarp and parts around the germ, facilitating attack by insects and fungi. **Drying**, on the other hand, **does not cause marked physical damage**.

**Significant maize losses have been reported in tropical countries**. Losses of **up to 10%** have been found, **not including those losses caused by fungi, insects or rodents**. **If these were included, losses could go up to 30% in tropical humid areas or 10 to 15% in temperate areas**.

**Drying Methods**

**Layer drying**

In this method, **the harvested grain is placed in a bin one layer at a time**. **Each layer of grain is partially dried**, before the next is added, **by forcing air through a perforated floor or through a duct in the bottom of the bin**. To improve efficiency, the partially dried grain is stirred and mixed with the new layer. An alternative is to remove the partially dried grain and dry it completely in batches. **One of the problems** with this and other methods of drying is in **finding a way to mix low-moisture grain with high-moisture grain to get the desired equilibrium in the final product**. Spoilage often occurs in this attempt. Methods have been developed to detect highmoisture maize in mixtures with artificially dried maize.

**Portable batch dryers**

Since **drying installations are costly**, few maize producers, particularly small farmers, can afford to have their own. **Portable batch dryers are useful since they can be moved from farm to farm**. These dryers operate with air heated to 140 to 180°F (60 to 82°C).

**Continuous flow dryers**

The principle behind these dryers is the **continuous flow of grain through heated and unheated sections so that it is discharged dry and cool**. The equipment is the central point in grain storage depots.

**STORAGE**

**Biotic and non-biotic factors**

The **efficient conservation of maize**, like that of other cereal grains and food legumes, **depends basically on (i) the ecological conditions of storage**; the physical, chemical and biological characteristics of the grain; **(ii) the storage period**; and **(iii) the type and functional characteristics of the storage facility**. Two important categories of factors have been identified. **First** are those of **biotic origin**, which include **all elements or living agents that, under conditions favourable for their development, will use the grain as a source of nutrients and so induce its deterioration**. These are mainly **insects, microorganisms, rodents and birds**. **Second** are **non-biotic factors**, which include **relative humidity, temperature and time**. The **effects of both biotic and nonbiotic factors** are **influenced by the physical and biochemical characteristics of the grain**. Changes during storage are influenced by the low thermal conductivity of the grain, its water absorption capacity, its structure, its chemical composition, its rate of respiration and spontaneous heating, the texture and consistency of the pericarp and the method and conditions of drying.

**Nutrient losses** have been **reported in maize stored under unfavourable conditions** (e.g. carotene losses in maize stored under different temperature and moisture conditions).

Although **damage caused by insects and birds is of importance**, a **great deal of attention** has been paid to the **problems caused by micro-organisms**, not only because of the losses they induce in the grain, but more importantly, **because of the toxic effects of their metabolic by-products on human and animal health**.

**Classification of grain quality**

**To facilitate marketing and to identify the best uses for the various types of maize produced throughout the world, measures of grain quality have been identified**, although they **may not be accepted by all maize-producing countries**.

Although the **moisture content** of maize, an important part of its chemical composition, is **not considered a quality factor**, it **has much influence on composition, quality changes during storage and processing and economics**. High-moisture maize with a soft texture is easily damaged in storage, while maize with low levels of moisture becomes brittle. The most commonly accepted moisture level for marketing purposes is 15.5%. Density of maize - weight per unit volume - is important in storage and transportation since it establishes the size of container for either purpose. Moisture content and density or test weight are related; the higher the moisture level the lower the specific density test weight. This characteristic of maize is also important for milling.

**Another important quality characteristic of maize is its hardness**, since this **influences grinding power** **requirements, dust formation, nutritional properties, processing for food products and the yield of products from dry and wet milling operations**. Hardness of maize **is genetically controlled**, **but** it **can be modified by both cultural practices and post-harvest handling conditions**.

Finally, **freedom of the kernel from fungi is recognized as a quality characteristic**.

**POST-HARVEST TECHNOLOGY: COMMODITY PROCESSING METHODS**

**Forms of maize consumption**

**Maize is consumed in many forms in different parts of the world**, from **maize grits**, **polenta** and **corn bread** to **popcorn** and products such as **maize flakes** ~~(Rooney and Serna-Saldivar, 1987)~~. The grain is **fermented to give ogi in Nigeria** (Oke, 1967) and other countries in Africa (Hesseltine, 1979) and is **decorticated, degermed and precooked to be made into arepas in Colombia and Venezuela** (Instituto de Investigaciones Tecnológicas, 1971; Rodriguez, 1972).

In **Egypt** a **maize flat bread**, aish **merahra**, is widely produced. Maize flour is used to make a soft dough spiced with 5% ground fenugreek seeds, which is **believed to increase the protein content**, improve digestibility and extend the storage life of the bread. The dough is fermented all night with a sourdough starter. In the morning the dough is shaped into small, soft, round loaves, which are left for 30 minutes to "prove". Before baking the loaves are made into wide, flat discs. Aish merahra keeps fresh for seven to ten days if it is stored in airtight containers. A **similar product** called **markouk** is **eaten in Lebanon**.

Maize is also widely used to make **beer**. In **Benin**, for example, malt is obtained by germinating the grain for about five days. The malt is then exposed to the sun to stop germination. The grains are lightly crushed in a mortar or on a grinding stone. The malt is cooked and the extract is strained off, cooled and allowed to stand. After three days of fermentation it is ready to be drunk as beer (FAO, 1989).

The **lime-cooking process for maize is particular to Mexico and Central America** (Bressani, 1990), although **today the technology has been exported** to other countries such as the United States. A **dough prepared from limecooked maize** is the **main ingredient** for many popular dishes such as **atole**, a beverage with a great variety of flavours, and **tamalitos**, made by wrapping the dough in maize husks and steam-cooking it for 20 to 30 minutes to gelatinize the starch. This form is usually prepared with young chipilín leaves (Crotalaria longirostrata), the flowers of loroco (Fernaldia pandurata) or cooked beans mixed with the dough, thus improving the nutritional quality of the product and its flavour (Bressani, 1983). The dough is also used for **tamales**, a more complex preparation because of the number of ingredients it contains, **in most cases with chicken or pork meat added** to the gelatinized dough. It is also used to provide support for **enchiladas**, **tacos** (folded tortillas containing meat, etc.) and **pupusas**, the latter made with fresh cheese placed between two layers of dough and baked like tortillas. When the dough is **fried and flavoured**, it yields foods such as **chips** and **chilaquiles**. If the dough is allowed to ferment for two days, wrapped in banana or plantain leaves, it provides a food named **pozol** from which a number of drinks can be made. It has been claimed that **this preparation is of high nutritional quality**.

**Lime-cooking in rural areas**

A number of researchers have described how maize is cooked in rural areas of countries where tortillas are eaten. Illescas (1943) first described the process as carried out in **Mexico**. It involves the **addition of one part whole maize to two parts of approximately 1% lime solution**. The mixture is heated to 80°C for 20 to 45 minutes and then allowed to stand overnight. The following day the **cooking liquor is decanted and the maize, now referred to as nixtamal, is washed two or three times with water to remove the seed-coats, the tip caps, excess lime and any impurities in the grain. The addition of lime at the cooking and steeping stages helps to remove the seed-coats.**

The **by-products are either thrown away or fed to pigs**. Originally, the maize was converted into dough by grinding it a number of times with a flat stone until the coarse particles were fine enough. Today the initial grinding is done with a meat grinder or disc mills and the dough is then refined with the stone. A portion of about 50 g of the dough is patted flat and cooked on both sides on a hot iron or clay plate.

In Guatemala a **similar process** (described by Bressani, Paz y Paz and Scrimshaw, 1958) uses **either white or yellow maize**, but the lime concentration varies from 0.17% to 0.58% based on the weight of maize, with a grain-to-water ratio of 1:1.2, and the maize cooking time varies from 46 to 67 minutes at a temperature of 94°C. The rest of the **process is essentially the same**, **except** that the **dough is prepared with a disc mill and is cooked for about 5 minutes at a temperature of about 170°C at the edges and 212°C in the centre**.

**Tamalitos**, for which the **dough is steamed**, are **softer and keep longer**. For recently harvested maize less lime is used and cooking time is decreased; the procedure is modified conversely when the grain is old and dry. The dry matter losses are about 15%, but they can vary between 8.9% and 21.3%.

**Industrial lime-cooking**

Factors such as the **migration of people from rural to urban areas** created a **demand for ready-cooked or pre-cooked tortillas**. Equipment for processing raw maize into lime-treated maize and then into a dough and tortillas was developed and industrial production of tortilla flour began in Mexico and other countries. Mechanized production in **Mexico** became important soon after the Second World War. **Two types of industry** are found in **urban areas**. One is the **(i) small family-owned home tortilla industry**, where **the process** is **as described above** but **with larger and mechanical equipment** used **to supply a larger market**. This development became possible through the introduction of rotary mills and the tortilla maker designed by Romero in 1908. This equipment was later replaced by a more efficient type in which the dough is passed through a rotating metal drum where it is cut into tortilla shapes. These fall onto a moving belt or continuous cooking griddle, dropping into a receptacle at the end of the belt. This small industry may use whole maize, in which case the dough is cooked in large receptacles, or it may start with industrial tortilla flour.

The second type of industry is **(ii) the large industrial conversion of maize into an instant precooked tortilla flour**. The process has been described by various workers (e.g. Deschamps, 1985). It is **based** for all practical purposes **on the traditional method used in rural areas**. More recently, the **process of producing the flour has been expanded to produce tortillas**.

Maize is bought after the buyer has inspected its quality and sampled it. Batches of maize with a high percentage of defective grains are rejected. Those that are accepted are paid for according to the defects found in the raw material. Maize is also selected according to its moisture content, since very high moisture will result in storage problems. During the cleaning stage, all impurities such as dirt, cobs and leaves are removed. The cleaned maize is sent to silos and warehouses for storage.

From there it is conveyed to treatment units for lime-cooking. There it is converted into nixtamal, using either a batch or a continuous process. After cooking and steeping, the lime-treated maize is washed with pressurized water or by spraying. It is ground into a dough (masa) which is then transferred to a dryer and made into a rough flour. This flour, consisting of particles of all sizes, is forced through a sifter where the coarse particles are separated from the fine ones. The coarse particles are returned to the mill for regrinding and the fine ones, which constitute the final product, are sent to the packing units. Here the flour is packed into lined paper bags.

One complete unit must have equipment for lime treatment, milling, drying and sifting and a daily production capacity of 30 to 80 tonnes of flour. These figures are the minimum and the maximum; to increase its production capacity, a commercial enterprise must install several parallel units. The use of such units seems to be more a tradition than a technical necessity, since it would be perfectly feasible to design plants with a capacity lower than 30 tonnes or higher than 80 tonnes per day. Plants that are very large or very small are apparently not considered viable.

The industrial yield of alkali-cooked maize flour fluctuates between 86% and 95% depending on the type of maize, the quality of the whole kernels and the lime-treatment conditions. Industrial yields have been reported to be higher than those at the rural and semi-industrial levels, possibly because of the quality of the grain processed.

Tortilla flour is a fine, dry, white or yellowish powder with the characteristic odour of maize dough. This flour when mixed with water gives a suitable dough for the preparation of tortillas, tamales, atoles (thick gruels) and other foods. All maize flours made in Mexico must conform to the specifications of the government's Department of Standards and Regulations.

When the flour has a moisture content of 10% to 12% it is stable against microbial contamination. If the moisture content is over 12% it is easily attacked by moulds and yeast. The problem of bacterial attack is almost nonexistent since the minimum of moisture required for bacterial growth is so high that flour with this moisture content would already be transformed into masa. Another matter related to the stability of flour is rancidity, which is normally not a problem unless the flour is packed at high temperatures. The minimum time required for the flour to spoil in Mexico is four to six months during the winter and three months during the summer. Nevertheless, it is usually sold to the consumer within 15 days of being sold to retailers and wholesalers, while its shelf-life is one month (Delvalle, 1972).

Tortillas made from lime-treated maize flour can be made at home or in factories. Such flour has been a great advantage for households and for factories both large and small, although its use in rural areas is not widespread.

In Guatemala, about 3000 metric tons of maize are produced yearly for tortilla flour production. This amount is significantly lower than that in Mexico; the population is smaller and there are few small tortilla factories. About 90% of the production is sold in urban areas and 75% goes into tortilla making. Other countries where lime-treated maize flour is produced are Costa Rica and the United States. In Costa Rica tortilla consumption per person is about 25.6 kg per annum. Approximately 62% of the production is commercial, 30.6% is home-made from commercial flour and 7.4% is home-made from grain.

**Modifications of lime-cooking**

The traditional method of cooking maize with lime to make tortillas at the rural level is both time-consuming (about 14 to 15 hours) and hard work. The cooking and soaking operations take up 70% to 80% of the time, which in a sense may be acceptable to the rural housewife. Nevertheless, the availability of an instant tortilla flour offers many advantages such as convenience, less labour and lower use of energy, for a safe, stable and nutritious product. At the industrial or commercial level, grinding and dehydration are large factors in the cost. Lime-cooked maize contains about 56% moisture, which must be decreased to 10% to 12% in the flour. Therefore, any method that would decrease both time and cost and still yield acceptable tortillas would be advantageous.

Efforts in this respect have been made by a number of workers. Bressani, Castillo and Guzmán (1962) evaluated a process based on pressure cooking at 5 and 15 lb pressure per square inch (0.35 and 1.05 kg per cm²) under dry and moist conditions for 15, 30 and 60 minutes, without the use of lime. None of the treatments had any effect on chemical composition and true protein digestibility, but all reduced the solubility of the nitrogen. Pressure cooking at 15 lb per square inch (1.05 kg per cm²) under dry conditions reduced the nutritional quality of the product, particularly when carried out for 60 minutes. The pressure cooking method without lime did not reduce crude fibre content, which is one of the particular effects of lime, and the calcium content was significantly lower than in dry dough (masa) prepared by the traditional method.

Khan et al. (1982) conducted a comparative study of three lime-cooking methods: the traditional way, a commercial method and a laboratory pressurecooking procedure. For each process maize was undercooked, optimally cooked and overcooked to measure some of the physical and chemical changes that might occur. Although the traditional method caused the greatest loss of dry matter from the grain, it gave the best tortillas in terms of texture, colour and acceptability. The pressure-cooking procedure yielded a sticky dough and undesirable tortillas. The commercial method was the least desirable. This study allowed the authors to propose a method to evaluate the completeness of cooking.

Bedolla et al. (1983) tested various methods of cooking maize and sorghum as well as mixtures of the two grains. The methods tested included the traditional one, steam cooking as tested by Khan et al. (1982) and a method using a reflux (condensing) system. They found that the methods of cooking affected the total dry matter lost during processing into tortillas.

Variation of cooking conditions can result in lower processing times. For example, Norad et al. (1986) found that a 40% reduction in cooking time could be achieved by pre-soaking the grain before alkali cooking. In these studies dry matter losses, water uptake, calcium content and enzyme susceptible starch increased, whereas amylograph maximum viscosity decreased in both presoaked and raw maize upon cooking. The decrease in viscosity and increase in the other parameters was faster in the pre-soaked maize.

Dry-heat processes have also been studied. Johnson, Rooney and Khan (1980) tested the micronizing process to produce sorghum and maize flours. Micronizing is a dry-heat process using gas-fired infrared generators. Rapid internal heating takes place, cooking the product from the inside out. The authors used this process to produce tortilla flour, claiming that it would be quicker and more economical than the traditional method.

Molina, Letona and Bressani (1977) tested production of instant tortilla flour by drum drying at the pilot plant level. Maize flour was mixed with water at a ratio of 3: I with 0.3% lime added on the basis of maize weight. After mixing, the dough was passed through a double-drum dryer heated with steam at 15, 20 or 25 lb per square inch (1.05, 1.40 or 1.75 kg per cm2), 93, 99 and 104°C surface temperature and 2, 3 or 4 rpm. The process produced an instant tortilla flour with physico-chemical and organoleptic characteristics identical to those of the reference sample prepared by the traditional method but different from those of a commercial product.

Extrusion cooking has also been evaluated as an additional technology for producing tortilla flour. Bazua, Guerra and Sterner (1979), using a Wenger X-5 extruder, processed ground maize mixed with various lime concentrations (0.1% to 1.0%). The dough and tortillas made by extrusion were compared with those made by the traditional process for their organoleptic properties as well as lysine tryptophan and protein content. No appreciable differences were noted at comparable use levels of calcium hydroxide. Both the traditional process and the extrusion modification induced losses of tryptophan related to the amount of lime added. With a 0.2% addition 8% of the tryptophan was lost, while with 1% lime more than 25% was lost. Some lysine losses were also observed. The organoleptic results suggested that it is possible to make culturally acceptable tortillas using extrusion as an alternative to the lime-heat treatment.

**Maize for tortillas**

Grain quality is a concept now growing in importance in breeding programmes aimed at increasing acceptance of genetically improved seeds by farmers as well as by consumers and food processors. The grain quality characteristics include yield, technological properties and, when possible, nutritional elements as well. Technological properties include stability during storage, efficiency of conversion into products under given processing conditions and acceptability to the consumer. The technological aspect of maize quality for tortilla preparation is of little importance to small farmers in the least developed countries, who seldom use seed other than that kept from harvest to harvest. Furthermore, the rural housewife knows how to adjust cooking conditions to the type of maize she will process for consumption. But maize is now being converted into a tortilla flour using industrial processes, where the grain being used may be of different varieties from various producers and different environments. It may have a variety of structures or may have been poorly handled after harvest, factors which influence the yield and physico-chemical and organoleptic as well as culinary properties of the product. This would appear to be of growing importance in countries such as the United States where the maize tortilla is becoming a very popular food.

That physical characteristics of maize are important became clear some time ago, when Bressani, Paz y Paz and Scrimshaw (1958) showed that the yield of dry matter in the form of dried-maize dough or flour was affected by the maize cultivar. In their rural home studies dry matter losses from white maize averaged 17.2% with a variability of 9.5% to 21.3%. Dry matter losses from yellow maize averaged 14.1%, with a range from 8.9% to 16.7%.

Cortez and Wild-Altamirano (1972) conducted a series of measurements on 18 cultivars of maize produced in Mexico. These included kernel weight, colour and lime-cooking time using a standard cooking procedure with 1.5% lime at 80°C and a steeping time of 12 hours. Cooking efficiency and time were measured by the ease with which the seed coat could be removed. Evaluations of the cooked maize included measurement of the volume of I kg of maize, the yield of dough from I kg of grain and the moisture content of the dough. The dough was further evaluated by measuring its strength and water absorption. The dehydrated dough was then ground to 60-mesh size and evaluated for moisture, colour, specific volume and other physical characteristics using a mixograph. The tortillas made from the dough of each maize sample were further evaluated for extensibility, volume, plasticity, softness and roughness of the surface.

From this extensive study, the authors reached several conclusions. Maize varieties or cultivars of higher weight per volume, a harder endosperm, more moisture and a high protein content produced the best tortillas. Two cultivars of popcorn maize were among the best types for tortillas. The Swanson mixograph was useful in establishing differences in maize types. The time required to cook the samples ranged from 30 to 75 minutes, and dry matter losses ranged from 10% to 34%. Rooney and Serna-Saldivar (1987) found that maize with hard or corneous endosperm required a longer cooking time. Bedolla and Rooney (1984) stated that the texture of the dough was affected by the endosperm texture and type, drying, storage and soundness of the maize kernel. MartínezHerrera and Lachance (1979) established a relationship between kernel hardness and the time needed for cooking. They reported that within a maize variety, higher calcium hydroxide concentration slightly decreased cooking time. Furthermore, knowing the initial hardness of a variety made it possible to predict the time required to cook it. Khan et al. (1982) and Bedolla and Rooney (1982) measured a parameter termed nixtamal shear force (NSF), an indication of kernel hardness. The measurement was related to both cooking time and processing method. These authors showed that the NSF measurement could reveal small differences in maize with similar endosperm texture and could be used to predict optimum cooking time.

Dry matter losses resulting from lime-cooking constitute a good index of maize quality for tortilla preparation. Jackson et al. (1988) reported that greater losses resulted from stress-cracked and broken kernels than from sound kernels. Therefore they concluded that any system for assessing maize for alkaline cooking should include measures of broken kernels, the potential for breakage and ease of pericarp removal. Specific studies on the effects of drying and storage on quality of maize for tortilla making are not readily available. Bressani et al. (1982) reported on QPM storage as related to tortilla quality. The Nutricta QPM variety was stored under a number of field or rural conditions. Containers made of cloth not treated with insecticides allowed insect infestation and therefore higher dry-matter losses during cooking; but the protein quality was not affected.

Possibly the most interesting feature of the process of converting maize into tortillas is the use of an alkaline medium, and particularly calcium hydroxide. The most obvious effect of adding lime is the facilitation of seed coat removal during cooking and steeping. According to Trejo-González, Feria-Morales and Wild-Altamirano (1982), added lime maintains an alkaline pH, which is needed to hydrolyse the hemicelluloses of the pericarp. Lime uptake by the kernel follows that of water, but the rate is lower than that of water. Norad et al. (1986) showed that soaking the kernels before cooking led to a higher calcium content in the grain. Calcium content of masa was affected by lime levels and also by cooking-steeping temperatures. Several other authors (e.g. Pflugfelder, Rooney and Waniska, 1988a) have shown in one way or another that lime uptake during alkaline cooking is affected by physical and chemical characteristics of maize dough.

Martínez-Herrera and Lachance (1979) found that higher calcium hydroxide concentrations slightly decreased cooking time, but the differences were not statistically significant. These authors also reported an interaction between maize variety and calcium hydroxide concentration. However, the coefficient of variation was high (29.1%); this was attributed to inherent variability in the kernels of the different varieties.

**2.3 MAIZE UTILIZATION[[7]](#footnote-7)**

Maize has **three possible uses**: as **food**, as **feed for livestock** and as **raw material for industry**.

**Human food**

As a food, the whole grain, either mature or immature, may be used; or the maize may be processed by dry milling techniques to give a relatively large number of intermediary products, such as maize grits of different particle size, maize meal, maize flour and flaking grits. These materials in turn have a great number of applications in a large variety of foods. Maize grown in subsistence agriculture continues to be used as a basic food crop.

**Animal feed**

In developed countries more than 60% of the production is used in compounded feeds for poultry, pigs and ruminant animals. In recent years, even in developing countries in which maize is a staple food, more of it has been used as an animal feed ingredient. "High moisture" maize has been paid much attention recently as an animal feed because of its lower cost and its capacity to improve efficiency in feed conversion. The by-products of dry milling include the germ and the seed-coat. The former is used as a source of edible oil of high quality. The seed-coat or pericarp is used mainly as a feed, although in recent years interest has developed in it as a source of dietary fibre[[8]](#footnote-8).

**Industrial use**

Wet milling is a process applicable mainly in the industrial use of maize, although the alkaline cooking process used in manufacturing tortillas (the thin, flat bread of Mexico and other Central American countries) is also a wet milling operation that removes only the pericarp[[9]](#footnote-9) (). Wet milling yields maize starch and by-products such as maize gluten, used as a feed ingredient. The maize germ processed to produce oil gives as a by-product maize germ meal, used as an animal feedstuff. Some attempts have been made to use these by-products for humans in food mixes and formulations.

Although the technology has been available for a long time, the increase in fuel oil prices has resulted in much research on the fermentation of maize to produce alcohol, popular in some states of North America. Fermentation also provides some alcoholic beverages.

Finally, maize plant residues also have important uses, including animal feeds as well as a number of chemicals produced from the cobs, such as furfural and xylose. These residues are also important as soil conditioners.

* + 1. **Maize in human nutrition**

There are important differences in the chemical composition of the main parts of the maize kernel as shown in Table 2. The seed-coat or pericarp is characterized by a high crude fibre content of about 87%, which is constituted mainly of hemicellulose (67%), cellulose (23%) and lignin (0.1%)[[10]](#footnote-10). On the other hand, the endosperm contains a high level of starch (87.6%) and protein levels of about 8%. Crude fat content in the endosperm is relatively low. Finally, the germ is characterized by a high crude fat content, averaging about 33%. The germ also contains a relatively high level of protein (18.4%) and minerals. Some information is available on the chemical composition of the aleurone layer (see Figure 1), which is relatively high in protein content (about 19%) as well as in crude fibre. Tables 2 and 3 provide some additional details on nitrogen distribution in the maize kernel. The endosperm contributes the largest amount, followed by the germ, with only small amounts from the seed-coat. About 92% of the protein in teosinte comes from the endosperm. Protein in the maize kernel has been reported on by a number of researchers[[11]](#footnote-11).

**TABLE 2 – Proximate chemical composition of main parts of maize kernels (%)**

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

The **carbohydrate** and **protein contents** of **maize kernels** **depend** to a very large extent **on the endosperm**, and crude fat and to a lesser extent protein and minerals on the germ. Crude fibre in the kernel comes mainly from the seed-coat. **The weight distribution among parts of the maize kernel and their particular chemical composition and nutritive value are of great importance when maize is processed for consumption**. In this regard there are two important matters from the nutritive point of view. Germ oil provides relatively high levels of fatty acids[[12]](#footnote-12). Where there are high intakes of maize, as in certain populations, **those who consume the degermed grain will obtain less fatty acids than those who eat processed whole maize**. **This difference is probably equally important with respect to protein**, since the **amino acid content of germ proteins is quite different from that of endosperm protein**. This is indicated in Table 3, in which essential amino acids are expressed as mg% by weight and as mg per g N. The **endosperm represents between 70% and 86% of the kernel weight and the germ between 7% and 22%**. It follows that, in considering the whole kernel, **the essential amino acid content is a reflection of the amino acid content in the protein of the endosperm, in spite of the fact that the amino acid pattern in the germ protein is higher and better balanced**. **Germ proteins** nevertheless **contribute a relatively high amount of certain amino acids, although not enough to provide a higher quality of protein in the whole k ernel**. The **germ provides some lysine and tryptophan**, the two limiting essential amino acids in maize protein. **Endosperm proteins are low in lysine and tryptophan, as is the whole grain protein**.

**TABLE 3 - Essential amino acid content of germ protein and endosperm protein**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Amino acid** | **Endosperma** | | **Germb** | | **FAD/WHO pattern** |
|  | **mg %** | **mg/g N** | **mg %** | **mg/g N** |  |
| Tryptophan | 48 | 38 | 144 | 62 | 60 |
| Threonine | 315 | 249 | 622 | 268 | 250 |
| Isoleucine | 365 | 289 | 578 | 249 | 250 |
| Leucine | 1 024 | 810 | 1 030 | 444 | 440 |
| Lysine | 228 | 180 | 791 | 341 | 340 |
| Total sulphur amino acids | 249 | 197 | 362 | 156 | 220 |
| Phenylaianine | 359 | 284 | 483 | 208 | 380 |
| Tyrosine | 483 | 382 | 343 | 148 | 380 |
| Valine | 403 | 319 | 789 | 340 | 310 |

**Notes:**

a1.16% N   
b2.32% N

**TABLE 4 - Net protein of whole grain, germ and endosperm of Guatemalan maize varietiesa**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sample** | **Yellow** | **Azotea** | **Cuarenteño** | **Opaque-2** |
| Whole grain | 42.5 | 44.3 | 65.4 | 81.4 |
| Germ | 65.7 | 80.4 | 90.6 | 85.0 |
| Endosperm | 40.9 | 42.0 | 46.4 | 77.0 |

**Notes:**

aExpressed as%age of case in (100%)

The maize varieties include three of common maize and one of **quality protein maize (QPM)**. In all cases **the quality of germ proteins is much higher than that of endosperm proteins and is obviously superior to the quality of whole kernel protein**. Endosperm protein quality is lower than that of the whole kernel because of the higher contribution of germ protein. The data also show less difference in the quality of germ and endosperm proteins in the QPM variety. Furthermore, the QPM endosperm and whole grain quality are significantly superior to the endosperm and whole grain quality of the other samples. These data, again, are important in regard to how maize is processed for consumption and in its impact on the nutritional status of people. They also clearly show that the quality of QPM is better than that of common maize. The higher quality of QPM endosperm is also of significance for populations that consume maize without the germ.

Information on the gross chemical composition of maize is abundant. The **variability of each major nutrient component is great**. The variability observed is both genetic and environmental. It may influence the weight distribution and individual chemical composition of the endosperm, germ and hull of the kernels.

**TABLE 5 - Gross chemical composition of different types of maize (%)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Maize type** | **Moisture** | **Ash** | **Protein** | **Crude fibre** | **Ether extract** | **Carbohydrate** |
| Salpor | 12.2 | 1.2 | 5.8 | 0.8 | 4.1 | 75.9 |
| Crystalline | 10.5 | 1.7 | 10.3 | 2.2 | 5.0 | 70.3 |
| Floury | 9.6 | 1.7 | 10.7 | 2.2 | 5.4 | 70.4 |
| Starchy | 11.2 | 2.9 | 9.1 | 1.8 | 2 2 | 72 8 |
| Sweet | 9 5 | 1 5 | 12.9 | 2.9 | 3.9 | 69.3 |
| Pop | 10.4 | 1.7 | 13.7 | 2.5 | 5.7 | 66.0 |
| Black | 12.3 | 1.2 | 5.2 | 1.0 | 4.4 | 75.9 |

**Starch**

The **major chemical component of the maize kernel is starch**, which provides **up to 72 to 73% of the kernel weight**. **Other carbohydrates are simple sugars** present as **glucose**, **sucrose** and **fructose** in amounts that vary **from 1 to 3% of the kernel**. The starch in maize is made up of two glucose polymers: amylose, an essentially linear molecule, and amylopectin, a branched form. The **composition of maize starch is genetically controlled**. In common maize, with either the dent or flint type of endosperm, amylose makes up 25 to 30% of the starch and amylopectin makes up 70 to 75%. Waxy maize contains a starch that is 100% amylopectin. An endosperm mutant called amylose-extender (ae) induces an increase in the amylose proportion of the starch to 50% and higher. Other genes, alone or in combination, may also modify the amylose-to-amylopectin ratio in maize starch[[13]](#footnote-13).

**Protein**

**After starch**, the **next largest chemical component of the kernel is protein**. Protein content varies in common varieties **from about 8 to 11% of the kernel weight**. **Most** of it is found **in the endosperm**. The **protein in maize kernels** has been studied extensively. It is **made up of at least five different fractions[[14]](#footnote-14)**: albumins, globulins and non-protein nitrogen amount to about 18% of total nitrogen, in a distribution of 7%, 5% and 6%, respectively. The prolamine fraction soluble in 55% isopropanol and isopropanol with mercaptoethanol (ME) contributes 52% of the nitrogen in the kernel. Prolamine 1 or zein 1 soluble in 55% isopropanol is found in the largest concentration, about 42%, with 10% provided by prolamine 2 or zein 2. An alkaline solution, pH 10 with 0.6% ME, extracts the glutelin fraction 2, in amounts of about 8%, while glutelin 3 is extracted with the same buffer as above with 0.5% sodium dodecyl sulphate in amounts of 17% for a total globulin content of 25% of the protein in the kernel. Usually a small amount, about 5%, is residual nitrogen.

Table 6 summarizes data[[15]](#footnote-15) on the **protein fractionation of a common maize (Tuxpeño-1) and a QPM (Blanco Dentado-1)**. Fractions II and III are zein I and zein II, of which zein I (Fraction II) is significantly higher in the Tuxpeño-1 variety than in the QPM. **Amounts of the alcohol-soluble proteins are low in immature maize. They increase as the grain matures**. When these fractions were analysed for their amino acid content, the zein fraction was shown to be very low in lysine content and lacking in tryptophan. Since these **zein fractions make up more than 50% of the kernel protein, it follows that the protein is also low in these two amino acids**. The albumin, globulin and glutelin fractions, on the other hand, contain relatively high levels of lysine and tryptophan. Another important feature of the zein fractions is their very high content of leucine, an amino acid implicated in isoleucine deficiency[[16]](#footnote-16)

Quality protein maize differs from common maize in the weight distribution of the five protein fractions mentioned above. The extent of the change is variable and affected by genotype and cultural conditions. It has been found, however, that the opaque-2 gene reduces the concentration of zein by some 30%. As a result, **lysine and tryptophan content is higher in QPM varieties than in common maize**.

**TABLE 6 - Protein fraction distribution of Tuxpeño-1 and Blanco Dentado-1 QPM (whole grain)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fraction** | **Blanco Dentado-1 QPM** | | **Tuxpeño-1** | |
|  | Protein (mg) | Percent protein | Protein (mg) | Percent total protein |
| I | 6.7 | 31.5 | 3.2 | 16.0 |
| II | 1.3 | 5.9 | 6.2 | 30.8 |
| III | 2.0 | 9.4 | 2.7 | 13.7 |
| IV | 3.7 | 17.6 | 2.4 | 12.0 |
| V | 5.7 | 27.2 | 4.1 | 20.4 |
| Residue | 1.8 | 8.3 | 1.4 | 7.1 |

The **nutritional quality of maize as a food is determined by the amino acid make-up of its protein**. To establish the adequacy of the essential amino acid content the table also includes the FAD/WHO essential amino acid pattern. In common maize, deficiencies in lysine and tryptophan are evident as compared with QPM. **An additional important feature is the high leucine content in common maize and the lower value of this amino acid in QPM**.

**Oil and fatty acids**

The **oil content of the maize kernel comes mainly from the germ**. Oil content is **genetically controlled**, with **values** ranging from **3% to 18%**. These values differ to some extent; it may be expected that oils from different varieties have different compositions. Maize oil has a low level of saturated fatty acids, i.e. on average 11% palmitic and 2% stearic acid. On the other hand, it contains relatively high levels of polyunsaturated fatty acids, mainly linoleic acid with an average value of about 24%. Only very small amounts of linoleic and arachidonic acids have been reported. Furthermore, maize oil is relatively stable since it contains only small amounts of linoleic acid (0.7%) and high levels of natural antioxidants. Maize oil is highly regarded because of its fatty acid distribution, mainly oleic and linoleic acids. In this respect, populations that consume degermed maize benefit less in terms of oil and fatty acids than populations that consume whole-kernel products.

**TABLE 7 – Amino acid content of maize and teostine (%)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Guatemala maize** | | | | **US maize** | | | |  |  |  |  |
| **Amino acid** | **Cuyuta (white)** | **SSD (white)** | **TGY (yellow)** | **142-48 (yellow)** | **4251 (hybrid)** | **HO  (high-oil white)** | **H5 (high-protein yellow)** | **HO (high-protein white)** | **Teosinte** | **Hard QPM** | **Soft QPM** | **FAO/WCO pattern** |
| (Nitrogen) | 1.28 | 1.37 | 1.57 | 1.83 | 1.31 | 1.99 | 2.24 | 2.91 | 3.81b | 1.74c | 1.71d | - |
| Alanine | 7.5a | 12.5 | 10.3 | 8.6 | 8.9 | 6.4 | 10.8 | 9.9 | 8.5 | - | - | - |
| Arginine | 3.5 | 3.6 | 4.1 | 2.9 | 3.9 | 4.6 | 3.60 | 3.9 | 2.9 | 6.3 | 6.7 | - |
| Aspartic acid | 6.5 | 5.8 | 6.1 | 6.0 | 6.2 | 6.0 | 6.80 | 6.1 | 5.3 | 8.7 | 8.9 | - |
| Cystine | 1.4 | 1.4 | 1.4 | 1.6 | 1.6 | 1.5 | 1.20 | 1.4 | 1.1 | 2.2 | 1.9 | - |
| Glutamic acid | 15.4 | 14.0 | 13.5 | 15.0 | 14.6 | 13.9 | 12.40 | 12.8 | 19.9 | 19.8 | 19.2 | - |
| Glycine | 3.1 | 2.8 | 2.9 | 2.6 | 3.3 | 3.4 | 2.60 | 2.8 | 2.2 | 4.6 | 4.6 | - |
| Histidine | 2.1 | 2.0 | 2.2 | 2.1 | 2.8 | 2.3 | 2.00 | 2.2 | 1.9 | 3.7 | 3.6 | - |
| Isoleucine | 2.6 | 2.7 | 3.4 | 3.0 | 3.3 | 3.5 | 3.70 | 4.0 | 4.7 | 3.5 | 3.5 | 4.0 |
| Leucine | 10.5 | 12.0 | 12.2 | 13.4 | 12.2 | 7.8 | 13.60 | 15.2 | 16.8 | 9.1 | 8.7 | 7.0 |
| Lysine | 2.8 | 2.1 | 2.6 | 2.3 | 2.9 | 3.2 | 2.10 | 2.0 | 1.3 | 4.5 | 4.4 | 5.4 |
| Methionine | 1.3 | 1.2 | 1.0 | 1.0 | 1.6 | 1.2 | 1.70 | 1.1 | 1.2 | 1.7 | 1.8 | 3.5c |
| Phenylalanine | 4.4 | 4.6 | 4.4 | 5.4 | 4.5 | 2.9 | 5.30 | 5.7 | 5.7 | 5.2 | 4.1 | 6.0d |
| Proline | 8.1 | 7.4 | 6.6 | 9.6 | 10.3 | 9.3 | 8.30 | 6.8 | 9.6 | 8.4 | 8.1 | - |
| Serine | 4.5 | 4.2 | 4.6 | 4.5 | 4.6 | 4.8 | 5.00 | 5.5 | 5.2 | 4.3 | 4.5 | - |
| Threonine | 3.1 | 2.9 | 3.1 | 3.0 | 3.3 | 3.2 | 3.10 | 3.3 | 3.0 | 3.6 | 3.7 | 4.0 |
| Tryptophan | 0.63 | 0.47 | 0.51 | 0.44 | 0.5 | 0.56 | 0.43 | 0.44 | 0.38 | 0.9 | 1.0 | 1.4 |
| Tyrosine | 2.9 | 3.0 | 3.0 | 3.3 | 3.4 | 3.5 | 3.60 | 4.1 | 4.4 | 3.7 | 3.7 | - |
| Valine | 4.1 | 4.1 | 4.3 | 4.0 | 4.6 | 2.1 | 4.30 | 4.6 | 4.8 | 5.4 | 5.3 | 5.0 |

**Notes:**

**a**% of crude protein (Nx6.25), g/16 g N

**b**Dehulled

**c**Total sulphur amino acids

**d**Total aromatic amino acids

**TABLE 8 - Fatty acid content of Guatemalan maize varieties and Nutricta QPM (%)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Maize variety** | **C16:0 Palmitic** | **C18:0 Stearic** | **C18:1 Oleic** | **C18:2 Linoleic** | **C18:3 Linolenic** |
| QPM Nutricta | 15.71 | 3.12 | 36.45 | 43.83 | 0.42 |
| Azotea | 12.89 | 2.62 | 35.63 | 48.85 | - |
| Xetzoc | 11.75 | 3.54 | 40.07 | 44.65 | - |
| Tropical White | 15.49 | 2.4 | 34.64 | 47.47 | - |
| Santa Apolonia | 11.45 | 3.12 | 38.02 | 47.44 | - |

**Dietary fibre**

**After carbohydrates, proteins and fats**, **dietary fibre is the chemical component found in the greatest amounts**. The complex carbohydrate content of the maize kernel comes from the pericarp and the tip cap, although it is also provided by the endosperm cell walls and to a smaller extent the germ cell walls. **Differences in soluble and insoluble dietary fibre are small between samples**, even though QPM Nutricta has higher levels of total dietary fibre than common maize, mainly because of a higher level of insoluble fibre. Table 10 shows values of fibre expressed as acid and neutral detergent fibre, hemicellulose and lignin in whole maize. The values shown in the table are similar to those reported by Sandstead et al. (1978) and Van Soest, Fadel and Sniffen (1979). Sandstead et al. found that maize bran was composed of 75% hemicellulose, 25% cellulose and 0.1% lignin on a dry-weight basis. Dietary fibre content in dehulled kernels would obviously be lower than that of whole kernels.

**TABLE 9 - Soluble and insoluble dietary fibre in common and quality protein maize (%)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Maize type** | **Dietary fibre** | | |
|  | **Insoluble** | **Soluble** | **Total** |
| Highland | 10.94 ± 1.26 | 1.25 ± 0.41 | 12.19 ± 1.30 |
| Lowland | 11.15 ± 1.08 | 1.64 ± 0.73 | 12.80 ± 1.47 |
| QPM Nutricta | 13.77 | 1.14 | 14.91 |

**TABLE 10 - Neutral and acid detergent fibre, hemicellulose and lignin in five maize varieties (%)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Maize No.** | **Neutral detergent fibre** | **Acid detergent fibre** | **Hemicellulose** | **Lignin** | **Cellular walls** |
| 1 | 8.21 | 3.23 | 4.98 | 0.14 | 9.1 |
| 2 | 10.84 | 2.79 | 8.05 | 0.12 | 10.8 |
| 3 | 9.33 | 3.08 | 6.25 | 0.13 | 12 |
| 4 | 11.4 | 2.17 | 9.23 | 0.12 | 13.1 |
| 5 | 14.17 | 2.68 | 11.44 | 0.14 | 14.2 |
| Average | 10.79 ± 2.27 | 2.79 ± 0.44 | 8.00 ± 2.54 | 0.13 ± 0.01 | 11.8 ± 2.0 |

**Other carbohydrates**

**When mature, the maize kernel contains carbohydrates other than starch** in **small amounts**. Total sugars in the kernel range between 1 and 3%, with sucrose, the major component, found mostly in the germ. **Higher levels** of **monosaccharides**, **disaccharides** and **trisaccharides** are **present in maturing kernels**. At **12 days after pollination** the **sugar content** is relatively **high**, while **starch is low**. **As the kernel matures**, the **sugars decline and starch increases**. For example, sugars were found to have reached a level of 9.4% of kernel dry weight in 16-day-old kernels, but the level decreased significantly with age. Sucrose concentration at 15 to 18 days after pollination was between 4 and 8% of kernel dry weight. **These relatively high levels of reducing sugar and sucrose are possibly the reason why immature common maize and, even more, sweet maize are so well liked by people**.

**Minerals**

The **concentration of ash** in the maize kernel is about **1.3%**, only **slightly lower than the crude fibre** content. The **average mineral content of some samples from Guatemala** is shown in Table 11. **Environmental factors probably influence the mineral content**. The **germ is relatively rich in minerals**, with an **average value of 11%** as compared with **less than 1% in the endosperm**. The **germ provides** about **78% of the whole kernel minerals**. The **most abundant mineral is phosphorus**, found as phytate of potassium and magnesium. All of the phosphorus is found in the embryo, with values in common maize of about 0.90% and about 0.92% in opaque-2 maize. As with most cereal grains, **maize is low in calcium content and also low in trace minerals**.

**Fat-soluble vitamins**

The **maize kernel contains two fat-soluble vitamins**: **provitamin A**, or ***carotenoids***, and **vitamin E**. **Carotenoids** are found **mainly in yellow maize**, in amounts that may be genetically controlled, while **white maize has little or no carotenoid content**. Most of the carotenoids are found in the hard endosperm of the kernel and only small amounts in the germ. The **betacarotene** content is an **important source of vitamin A**, but **unfortunately yellow maize is not consumed by humans as much as white maize**. Squibb, Bressani and Scrimshaw (1957) found **beta-carotene** to be about **22% of total carotenoids** (6.4 to 11.3 µg per gram) **in three yellow maize samples**. Cryptoxanthin accounted for 51% of total carotenoids. Vitamin A activity varied from 1.5 to 2.6 µg per gram. The carotenoids in yellow maize are susceptible to destruction after storage. Watson (1962) reported values of 4.8 mg per kg in maize at harvest, which decreased to 1.0 mg per kg after 36 months of storage. The same loss took place with xanthophylls. Recent studies have shown that **the conversion of beta-carotene to vitamin A is increased by improving the protein quality of maize**.

**TABLE 11 - Mineral content of maize (Average of five samples)**

|  |  |
| --- | --- |
| **Mineral** | **Concentration (mg/100 g)** |
| P | 299.6 ± 57.8 |
| K | 324.8 ± 33.9 |
| Ca | 48.3 ± 12.3 |
| Mg | 107.9 ± 9.4 |
| Na | 59.2 ± 4.1 |
| Fe | 4.8 ± 1.9 |
| Cu | 1.3 ± 0.2 |
| Mn | 1.0 ± 0.2 |
| Zn | 4.6 ± 1.2 |

The other fat-soluble vitamin, **vitamin E**, which is subject to some genetic control, is found **mainly in the germ**. The source of vitamin E is four tocopherols, of which alpha-tocopherol is the most biologically active. Gamma-tocopherol is probably more active as an antioxidant than alphatocopherol, however.

**Water-soluble vitamins**

**Water-soluble vitamins** are found **mainly in the aleurone layer of the maize kernel**, followed by the germ and endosperm. This **distribution is important in processing**, which, as will be shown later, induces **significant losses of the vitamins**. Variable amounts of thiamine and riboflavin have been reported. The **content is affected by the environment and cultural practices rather than by genetic make-up**. Variability between varieties has, however, been reported for both vitamins. The water-soluble vitamin nicotinic acid has attracted much research because of its association with niacin deficiency or pellagra, which is prevalent in populations consuming high amounts of maize (Christianson et al., 1968). As with other vitamins, niacin content varies among varieties, with average values of about 20 µg per gram. A feature peculiar to niacin is that it is bound and therefore not available to the animal organism. **Some processing techniques hydrolyze niacin, thereby making it available**. The association of maize intake and pellagra is a result of the low levels of niacin in the grain, although experimental evidence has shown that amino acid imbalances, such as the ratio of leucine to isoleucine, and the availability of tryptophan are also important[[17]](#footnote-17).

**Maize has no vitamin B12**, and the mature kernel contains only small amounts of ascorbic acid, if any. Yen, Jensen and Baker (1976) reported a content of about 2.69 mg per kg of available pyridoxine. Other vitamins such as choline, folic acid and pantothenic acid are found in very low concentrations.

**Changes in chemical composition and nutritive value during grain development**

In many countries, **immature maize is often used as a food**, **either cooked whole as corn on the cob** or **ground to remove the seed-coat**, **with the pulp used to make thick gruels or foods** like tamalitos. The **changes in chemical composition that take place upon maturation are important**. All relevant studies have shown a **decrease in nitrogen**, **crude fibre and ash** on a dry-weight basis and **an increase in starch and ether extract** (e.g. Ingle, Bietz and Hageman, 1965). The **alcohol-soluble proteins increase rapidly** as the **kernel matures**, while **acid- and alkali-soluble proteins decrease**. During this biochemical process **arginine, isoleucine, leucine and phenylalanine** (expressed as mg per g N) **increase**, while **lysine methionine and tryptophan decrease** with **maturation**. Gómez-Brenes, Elías and Bressani (1968) further showed a decrease in protein quality (expressed as protein efficiency ratio). Thus, **immature maize should be promoted during weaning or for infant nutrition**.

**Nutritional value of maize**

The **importance of cereal grains to the nutrition of millions of people around the world is widely recognized**. Because they make up such a large part of diets in developing countries, cereal grains **cannot be considered only as a source of energy**, as **they provide significant amounts of protein as well**. It is also recognized that **cereal grains have a low protein concentration and that protein quality is limited** by deficiencies in some essential amino acids, mainly lysine. Much less appreciated, however, is the fact that **some cereal grains contain an excess of certain essential amino acids that influence the efficiency of protein utilization**. The classic example is maize. Other cereal grains have the same constraints but less obviously.

A **comparison of the nutritional value of maize protein with the protein quality of eight other cereals** is given in Table 12, expressed as percentages of casein. The **protein quality of common maize is similar to that of the other cereals except rice**. Both opaque-2 maize and the hard-endosperm QPM (Nutricta) have a protein quality not only higher than that of common maize, but also significantly higher than that of other cereal grains.

**TABLE 12 - Protein quality of maize and other cereal grains**

|  |  |
| --- | --- |
| **Cereal** | **Protein quality (% casein)** |
| Common maize | 32.1 |
| Opaque-2 maize | 96.8 |
| QPM | 82.1 |
| Rice | 79.3 |
| Wheat | 38.7 |
| Oats | 59 |
| Sorghum | 32.5 |
| Barley | 58 |
| Pearl maize | 46.4 |
| Finger maize | 35.7 |
| Teff | 56.2 |
| Rye | 64.8 |

Some researchers[[18]](#footnote-18) have reported that tryptophan rather than lysine is the first limiting amino acid in maize, which may be true for some varieties with a high lysine concentration or for maize products modified by some kind of processing. All researchers have agreed that the **simultaneous addition of both lysine and tryptophan improves the protein quality of maize significantly**; this has been demonstrated in experimental work with animals.

The improvement in quality obtained after the addition of lysine and tryptophan has been small in some studies and higher in others when other amino acids have been added. Apparently, the limiting amino acid after lysine and tryptophan is isoleucine, as detected from animal feeding studies[[19]](#footnote-19). Most researchers who reported such findings indicated that the effect of isoleucine addition resulted from an excess of leucine which interfered with the absorption and utilization of isoleucine[[20]](#footnote-20). It has been reported that **high consumption of leucine along with the protein in maize increases niacin requirements, and this amino acid could be partly responsible for pellagra**.

When a response to threonine addition has been observed, it has been attributed to this amino acid's correction of amino acid imbalances caused by the addition of methionine. A similar role can be ascribed to added isoleucine resulting in improved performance. Similarly, the addition of valine, which results in a decrease in protein quality, could be counteracted by the addition of either isoleucine or threonine.

In any case, isoleucine seems to be more effective than threonine, producing more consistent results. A possible explanation for these findings is that maize is not deficient in either isoleucine or threonine. However, some samples of maize may contain larger amounts of leucine, methionine and valine, end these require the addition of isoleucine and threonine besides lysine and tryptophan to improve protein quality. In any case, the addition of 0.30% L-lysine and 0.10% L-tryptophan easily increases the protein quality of maize by 150% (Bressani, Elías and graham, 1968). Many of the results of the limiting amino acids in maize protein are influenced by the level of protein in the maize. As was indicated previously, protein content in maize is a genetic trait that is affected by nitrogen fertilization. The observed increase in protein content is highly correlated with zein, or the alcohol-soluble protein, which is low in lysine and tryptophan and contains excessive amounts of leucine. Frey (1951) found a high correlation between protein content and zein in maize, a finding that has been confirmed by others. Using different animal species, various authors have concluded that the protein quality of low-protein maize is higher than that of high-protein maize when the protein in the diets used is the same. However, weight for weight, high-protein maize is slightly higher in quality than low-protein maize. The levels of dietary protein, then, affect the response observed upon amino acid supplementation with lysine and tryptophan in particular but with other amino acids as well, such as isoleucine and threonine.

**2.4 MAIZE STORAGE[[21]](#footnote-21)**

**Storage and loss risk**

**Storage of flour**

**Flour** is **usually produced as it is needed and is not often stored** for long periods because it tends to turn rancid. This is **particularly evident with pearl maize flour**, because of its very high tat content. Maizes, particularly pearl maize, are therefore best stored as whole grain.

**METHODOLOGICAL APPROACH**

In order to analyze the life circle of maize products in Latin America, a survey will be designed asking the producer and consumers for relevant information on production, consumption, utilization and market of maize.

As said above, maize is an important cereal crop for farmers in semi-arid areas in Latin America.

It has been traditionally cultivated for home consumption, but in recent years market demand has increased. This offers new opportunities for smallholders to commercialize production, which is seen as a pathway for prosperity in the dry lands. Understanding production, consumption and utilization patterns for maize is important to study diet habits and food security of populations, and to develop strategies and awareness campaigns to promote and increase maize consumption: obtaining more information about utilization is one of the most important pre-condition for starting to consume it. Information about utilization is also the most important requirement to increase the consumption.

One strategy for the promotion of maize consumption is to point out the high nutritional value of this crop: maize crop would benefit from information campaigns about its nutritional value.

The survey is designed to interview consumers at three different market outlets to find out where consumers buy the cereal: supermarkets, small retail shops and open-air markets, in order to understand how the urbanization processes change the shopping behavior and highlights the importance of making maize available.

In addition, households are grouped into three different classes: low, middle and high income, to capture consumption habits of different income levels in rural and urban areas, for production and non-production zones.

To understand if maize is bought as grain and/or flour, it is important in order to comprehend the final utilization of the crop and its consumption.

It can also be useful to understand the reasons why some respondents may not consume maize (availability, price issues, etc.).

**SURVEY CONSTRUCTION AND INFORMATION NEEDED**

**EXAMPLE OF IMPACT ON COMMODITY EXTRACTION RATES**

Farmers = Sellers; Traders = Buyers; Households = Final consumer

QP = Quantity Produced

QS = Quantity Sold (Commercial Sale) = A1+B1+C1+…+N1 = 100% = Total quantity available to be processed

QP - QS > 0 = Stored, kind payments, seed, etc…

Total Quantity Processed = A2+B2+C2+…+N2 = 100% = Total quantity for final consumption

**Extraction Rates =**

**PROCESSED PRODUCTS 1ST LEVEL**

MAIZE **SOLD** QUANTITY

FEED

FOOD INDUSTRY

**A1%**

**B1%**

**C1%**

NON-FOOD INDUSTRY

MAIZE **PRODUCED**QUANTITY

**QP**

**QS**

OTHER PROCESSED PRODUCTS\*…

**N2%**

OTHER BUYERS

**N1%**

WHOLE GRAINS

MAIZE BRAN

**B2%**

**C2%**

MAIZE GERM

**A2%**

MAIZE BEV. DIST. ALCOHOL.

NON-FOOD ALCOHOL.

**D2%**

**E2%**

**F2%**

**G2%**

FLOUR OF MAIZE

**I2%**

BREAKFAST CEREALS

**H2%**

CEREALS PREPARATION

MAIZE BEER MAIZE

\* e.g. Fermented beverages, infant food, etc.

**PROCESSED PRODUCTS 1ST LEVEL**

MARGARINE

LIQUID MARGARINE

HYDROGEN OILS

ISOGLUCOSE

OTHER FRUCTOSE AND SYRUP

GLUCOSE AND DEXTROSE

GLUTEN FEED AND MEAL

**PROCESSED PRODUCTS 3RD LEVEL**

**PROCESSED PRODUCTS 2ND LEVEL**

MAIZE CAKE

MAIZE BRAN

CEREALS PREPARATION

MAIZE OIL

GLUTEN

STARCH

WHOLE GRAINS

BREAKFAST CEREALS

NON-FOOD ALCOHOL.

MAIZE BEV. DIST. ALCOHOL.

MAIZE GERM

OTHER PROCESSED PRODUCTS\*…

MAIZE BEER MAIZE

FLOUR OF MAIZE

**INFORMATION NEEDED FROM SELLERS, BUYERS AND CONSUMERS**

* Respondent details
* Maize physical characteristics + details
* Maize production and utilization + details
* Percentage of maize sold
* Main purpose of production of the holding + details
* Other economic production activities of the holding + details
* Use of good agricultural practices + details
* Use of organic agricultural practices + details
* Maize consumption (market) + details
* Land use land tenure + details
* Household food security + details
* …….

**PILOT DRAFT**

**Legend**:

Green cells: confirmed

Yellow cells: optional

The survey contains a list of information needed to update the extraction rates in staple food commodity trees.

It has to be better designed; information should be revised, adjusted and additional information might be needed.

The same survey can be used for all commodities in all countries, paying attention to local recipes.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 1. **SECTION TO BE FILLED IN BY FARMERS**   **(maize sellers)** | | | |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **Respondent details:** |  |  |  |
|  |  | Name/Title: |  |  |
|  |  | Age (years) |  |  |
|  |  | Male/Female |  |  |
|  |  | Complete address |  |  |
|  |  | Tel: |  |  |
|  |  | Email: |  |  |
|  | **MAIZE PHYSICAL CHARACTERISTICS** | | | |
|  | Type of maize produced per typology: |  |  |  |
|  | *Zea mays indenata* (Dent) |  |  |  |
|  | *Zea mays indurate*  (Flint) |  |  |  |
|  |  | Sweet  (*Zea saccharata or Zea rugosa*) |  |
|  |  | Flour  *(Zea mays amylacea)* |  |
|  |  | Popcorn  *(Zea mays everta)* |  |
|  | **MAIZE PRODUCTION** | | | |
|  | **Primary maize production** |  |  |  |
|  |  | Area Harvested (Ha) | FAO Prod. Quest. |  |
|  |  | Production (MT) | FAO Prod. Quest. |  |
|  | **Producing maize mainly:** |  |  |  |
|  |  | For home consumption | WCA |  |
|  |  | For sale | WCA |  |
|  |  | Forms of in-kind payment | WCA |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **Sold maize for:** |  |  | Utilization data refer to the use of crops in the country during the reference period.  On the utilization side a distinction is made between the quantitites used for food, seed, feed, liquid biofuels and industrial utilization. The general utilizations concept further include waste and imported/ exported quantities, which are not part of this survey.  Please provide the utilization in metric tonnes (MT) for the primary crops produced in your country. |
|  |  | Feed | FAO Prod. Quest. | Feed refers to quantities fed to animals, wether direct or used to produce compound feed. |
|  |  | Food industry | FAO Prod. Quest. | Food refers all quantities available for human consumption, either direct by the producers, available for human consumption at the retail level or processed for food use. |
|  |  | Non-food industry (Maize manufacturing) | WCA | Includes a whole range of activities associated with transforming raw materials into new products. For households, the most common manufacturing activities are f**ood processing**, making clothes and other textile materials, tanning, and making wood products. |
|  |  | Storage |  |  |
|  |  | Seed | FAO Prod. Quest. | Seed covers quantities used for reproductive purposes |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 1. **SECTION TO BE FILLED IN BY TRADERS**   **(maize buyers/industry)** | | | |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **PROCESSING METHODS** |  |  |  |
|  | **Maize to be processed** |  |  |  |
|  |  | Total quantity of maize available to be processed |  |  |
|  | **Producer industry structure** |  |  |  |
|  |  | High tech production | MOA, NSO |  |
|  |  | Low tech production | MOA, NSO |  |
|  | **Traditional processing methods** |  |  |  |
|  |  | Quantity of maize processed by grinding whole grain |  |  |
|  |  | Quantity of maize processed into malted grains |  |  |
|  |  | Quantity of maize processed into parboiled grains |  |  |
|  | **Industrial processing methods** |  |  |  |
|  |  | Quantity of maize grains milled semi-wet |  |  |
|  |  | Quantity of maize grains milled wet |  |  |
|  | **Maize milled on a commercial scale** |  |  |  |
|  |  | Quantity of maize processed by abrasive decortication |  |  |
|  |  | Quantity of maize processed by rubbing techniques |  |  |
|  |  | Quantity of maize processed by roller mills |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **PROCESSED FOOD - MAIZE TREE** | |  |  |
|  | **Selected derived maize commodities from FAO Maize Commodity Tree** |  |  |  |
|  | **Flour1** |  |  |  |
|  |  | Quantity of flour of maize produced |  |  |
|  |  | Quantity of starch of maize produced |  |  |
|  |  | Quantity of gluten of maize produced |  |  |
|  |  | Quantity of isoglucose of maize produced |  |  |
|  |  | Quantity of other fructose and syrup produced |  |  |
|  |  | Quantity of glucose and dextrose produced |  |  |
|  |  | Quantity of gluten feed and meal produced |  |  |
|  | **Bran2** |  |  |  |
|  |  | Quantity of bran of maize produced |  |  |
|  | **Maize germ** |  |  |  |
|  |  | Quantity of germ of maize produced |  |  |
|  |  | Quantity of maize cake produced |  |  |
|  |  | Quantity of maize oil produced |  |  |
|  |  | Quantity of margarine produced |  |  |
|  |  | Quantity of hydrogen oils produced |  |  |
|  |  | Quantity of liquid margarineproduced |  |  |
|  |  |  |  |  |
|  | **Breakfast cereals** |  |  |  |
|  |  | Quantity of breakfast cereals produced |  |  |
|  | **Cereal preparation** |  |  |  |
|  |  | Quantity of maize based preparation produced |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Beverages** |  |  |  |
|  |  | Quantity of maize malted to produce fermented beverages |  |  |
|  |  | Quantity of maize malted to produce unfermented beverages |  |  |
|  |  | Quantity of beer of maize produced |  |  |
|  | **Infant food** |  |  |  |
|  |  | Quantity of maize malted to be incorporated into infant cereals |  |  |
|  | **Other processed products** | Any other processed products (please specify) |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 1. **SECTION TO BE FILLED IN BY HOUSEHOLDS**   **(maize buyers/industry)** | | | |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **MAIZE CONSUMER MARKET** |  |  | <http://oar.icrisat.org/7245/1/C_Schipmann_Schwarze_et_al_2013_ISEDPS_10.pdf> |
|  | **Type of household consuming maize on a monthly basis** |  |  |  |
|  |  | Urban |  |  |
|  |  | Rural |  |  |
|  |  | Non-producer |  |  |
|  |  | Producer |  |  |
|  |  | Low income |  |  |
|  |  | Middle income |  |  |
|  |  | High income |  |  |
|  | **Monthly consumption of maize on a household level, quantity** |  |  |  |
|  |  | Bought as grain |  |  |
|  |  | Bought as pure flour |  |  |
|  |  | Bought as blended flour |  |  |
|  |  | Mean amount bought (kg) |  |  |
|  |  | Amount bought as grain (kg) |  |  |
|  |  | Amount bought as pure flour (kg) |  |  |
|  |  | Amount bought as blended flour |  |  |
|  | **Utilization of maize by consumers** | e.g.: |  | A deeper research on regional recipe to be conducted |
|  |  | Hot Corn with Chimichurri Butter |  | Chile |
|  |  | Corn-Flour Patties (Sopes) |  | Mexico |
|  |  | … |  | … |
|  |  | … |  | … |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **Future demand for maize and reasons for changing demand** |  |  |  |
|  | **Demand** |  |  |  |
|  |  | Increasing |  |  |
|  |  | Decreasing |  |  |
|  |  | Constant |  |  |
|  | **Reasons if increasing** |  |  |  |
|  |  | Family size |  |  |
|  |  | Availability |  |  |
|  |  | Taste |  |  |
|  |  | Cheap |  |  |
|  |  | Healthy |  |  |
|  |  | Own cultivation |  |  |
|  |  | Easy to blend |  |  |
|  |  | Habit |  |  |
|  |  | Learned utilization |  |  |
|  |  | Increased income |  |  |
|  | **Reasons if decreasing** |  |  |  |
|  |  | Family size |  |  |
|  |  | Expensive |  |  |
|  |  | Taste |  |  |
|  |  | Not available |  |  |
|  |  | Decreased income |  |  |
|  | **Reasons if constant** |  |  |  |
|  |  | Family size |  |  |
|  |  | Consume enough |  |  |
|  |  | Dificult to prepare |  |  |
|  |  | Taste |  |  |
|  |  | Expensive |  |  |
|  |  | Constant income |  |  |
|  |  | Not available |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **Demand for maize flour of consumers who buy maize flour** |  |  |  |
|  | **Bought** |  |  |  |
|  |  | Loose |  |  |
|  |  | Packed |  |  |
|  | **Reasons if packed** |  |  |  |
|  |  | Quality |  |  |
|  |  | Convenience |  |  |
|  |  | Availability |  |  |
|  |  | Other, please specify |  |  |
|  | **Reasons if loose** |  |  |  |
|  |  | Quality |  |  |
|  |  | Price |  |  |
|  |  | Blend to own taste |  |  |
|  |  | Availability |  |  |
|  |  | Other, please specify |  |  |
|  | **Buying same brand if packed** |  |  |  |
|  |  | No |  |  |
|  |  | Yes |  |  |
|  | **Consumption experiences of maize of non-consumers** |  |  |  |
|  | **Maize** |  |  |  |
|  |  | No |  |  |
|  |  | Yes |  |  |
|  | **Frequency** |  |  |  |
|  |  | Few times |  |  |
|  |  | Regularly |  |  |
|  | **Utilization and Preparation knowing** |  |  |  |
|  | Regional recipes maize based: please indicate any additional ingredient |  |  | *Additional ingredients:* |
|  |  | 1 |  |  |
|  |  | 2 |  |  |
|  |  | 3 |  |  |
|  |  | 4 |  |  |
|  |  | 5 |  |  |
|  |  | 6 |  |  |
|  |  | Etc… |  |  |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **Awareness about the nutritional value of maize** |  |  |  |
|  | **Awareness of consumer** |  |  |  |
|  |  | No |  |  |
|  |  | Yes |  |  |
|  | **Awareness non-consumers** |  |  |  |
|  |  | No |  |  |
|  |  | Yes |  |  |
|  | **Knowledge consumers** |  |  |  |
|  |  | Provides energy |  |  |
|  |  | Is nutritious |  |  |
|  |  | Increases appetite |  |  |
|  |  | Has proteins |  |  |
|  |  | Strengthening |  |  |
|  |  | Good for diabetic |  |  |
|  |  | Good for blood |  |  |
|  |  | Good for children |  |  |
|  |  | Other, please specify |  |  |
|  | **Knowledge non-consumers** |  |  |  |
|  |  | Provides energy |  |  |
|  |  | Is nutritious |  |  |
|  |  | Increases appetite |  |  |
|  |  | Has proteins |  |  |
|  |  | Strengthening |  |  |
|  |  | Good for diabetic |  |  |
|  |  | Good for blood |  |  |
|  |  | Good for children |  |  |
|  |  | Other, please specify |  |  |

1. FAO commodity list is tailored on commodity trees so that the primary crop and its derived products are traceable all along the value chain of agricultural production. [↑](#footnote-ref-1)
2. <http://www.ars.usda.gov/main/site_main.htm?modecode=12-35-45-00> [↑](#footnote-ref-2)
3. <http://www.fao.org/economic/the-statistics-division-ess/publications-studies/publications/nutritive-factors/en/> [↑](#footnote-ref-3)
4. <http://www.fao.org/docrep/t0395e/T0395E01.htm#Types%20of%20maize> [↑](#footnote-ref-4)
5. http://forest.mtu.edu/pcforestry/resources/studentprojects/jon/Maize.html [↑](#footnote-ref-5)
6. <http://www.fao.org/docrep/t0395e/T0395E04.htm#Chapter%203%20-%20Post-harvest%20technology:%20pre-processing> [↑](#footnote-ref-6)
7. <http://www.fao.org/docrep/t0395e/T0395E02.htm#World%20production> [↑](#footnote-ref-7)
8. Earll et al., 1988; Burge and Duensing, 1989 [↑](#footnote-ref-8)
9. Bressani, 1990 [↑](#footnote-ref-9)
10. Burge and Duensing, 1989 [↑](#footnote-ref-10)
11. e.g. Bressani and Mertz, 1958 [↑](#footnote-ref-11)
12. Bressani et al., 1990; Weber, 1987 [↑](#footnote-ref-12)
13. Boyer and Shannon, 1987 [↑](#footnote-ref-13)
14. Landry and Moureaux (1970, 1982) [↑](#footnote-ref-14)
15. by Ortega, Villegas and Vasal (1986) [↑](#footnote-ref-15)
16. (Patterson et al., 1980) [↑](#footnote-ref-16)
17. Gopalan and Rao, 1975; Patterson et al., 1980 [↑](#footnote-ref-17)
18. Hogan et al., 1955 [↑](#footnote-ref-18)
19. Benson, Harper and Elvehjem, 1955 [↑](#footnote-ref-19)
20. Harper, Benton and Elvehjem, 1955; Benton et al., 1956 [↑](#footnote-ref-20)
21. <http://www.fao.org/docrep/t0818e/T0818E08.htm#Chapter%203%20-%20Storage%20and%20processing> [↑](#footnote-ref-21)