CULTIVARS AND CHARACTERISTICS OF CORN GRAIN

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ABSTRACT

Maize (*Zea mays L*) is of global importance as a commodity because it is the main source of energy used in animal feed. The anatomy of corn is divided into endosperm (83%), pericarp (5%), germ (11%) and tip (2%). The starch granules and the protein matrix of the endosperm classifies corn into two types: farinaceous and vitreous. The relationship between hard endosperm (*Flint*) and floury (*Dent*) defines the vitreousness of a corn grain. Thus, the greater the vitreousness, the greater the amount of hard endosperm present in the grain. Today on the market there are specific corn cultivars for the production of grain, green corn, sweet corn, white corn (hominy), silage, popcorn, among others. The cultivars varieties are highly heterozygous, with greater productive stability, having greater genetic variability, less uniformity in the product and low productivity, caused by low heterosis, have great rusticity and adaptability, being indicated for low technology systems. Commercial hybrids are the result of the crossing between genetically distinct and homozygous individuals, for maximum heterosis response. Simple hybrids are potentially productive and suitable for systems that employ high technology. Transgenic hybrid corn is obtained by Genetic Engineering from the modification of DNA by introducing genes from other species through recombinant DNA techniques. Transgenics aims at three main targets, which can be classified as: herbicide tolerance; insertion of insect and disease resistance genes; and quality of products. White corn is a special cultivar that is characterized by having toothed

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and floury grain, it is widely used for the production of hominy, starch (cornstarch), flour and etc. Popcorn is a special cultivar of low productivity with rounded grains, fully vitreous endosperm, and thin film which allows spacing when the grain is heated. Green corn is an alternative to family horticulture because it adds more income, it refers to corn harvested while still in the milky stage, with 70 to 80% moisture. Sweet corn and super sweet corn are also included as green corn, differs from conventional corn in that it is intended for the canning industry and by the presence of mutant alleles that block the conversion of sugars into starch in the endosperm, giving it a sweet character, making sweet corn wrinkled and translucent when dry. Man has selected and developed several maize cultivars with distinct and special characteristics for each cropping system and purpose of use. The present study aims to address through a literature review the anatomical and nutritional characteristics of the maize grain and to address the different cultivars used in Brazilian agriculture.

Keywords: Cultivars. Maize Crop. Endosperm. *Zea Mays* L.

INTRODUCTION

Corn (*Zea mays* L.) has a great contribution to the economic scenario, as it has several uses from animal feed to the high-tech industry. Most of the corn grown in the world, about 70%, is destined for animal feed and in some regions it represents a basic ingredient of cooking for human consumption (MÔRO; FRITSCHE-NETO, 2017).

It was probably domesticated between 7,000 and 10,000 years ago, in the region called Mesoamerica, which comprises the region that, in the north, runs from Tampico, in the Gulf of Mexico, to the southern part of Sinaloa, in the Pacific, and is limited to the south by Honduras and Nicaragua (MACHADO; MACHADO, 2009).

It had already been distributed throughout the American continent, even before the arrival of Europeans in America, however, when Portuguese explorers arrived in Brazil in the sixteenth century they did not make great references to corn. Possibly because the low-altitude lands with which the Portuguese first made contact and settled, were more conducive to the cultivation of sweet potatoes and cassava and corn would assume a secondary role because it was a culture of high-altitude lands and a cooler climate (FERRÃO, 2013).

Today corn is one of the main agricultural crops cultivated in Brazil, being cultivated from family farming systems, with low technology, low investment and with a predominance of crops of up to 10 ha; to business systems with high technology, high investment that aim at productions above 6 t.ha-1. In industrial agriculture, the cultivation of improved seeds, single and triple hybrids, prevails, and in family farming, about 50% of producers use improved seeds (MIRANDA; GALVÃO; SANTOS, 2007).

The present work aims to address through a literature review the anatomical and nutritional characteristics of corn grain and to address the different cultivars used in Brazilian agriculture.

STRUCTURAL AND NUTRITIONAL CHARACTERISTICS OF THE CORN GRAIN

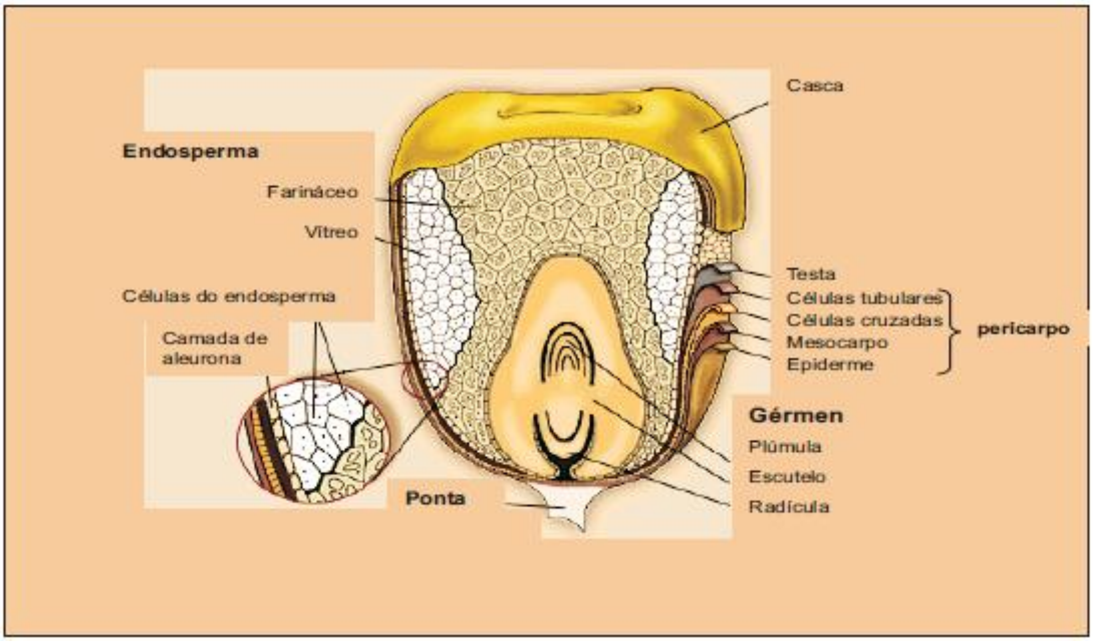
Maize is of global importance as a commodity because it is the main source of energy used in animal feed, especially in the intensive breeding of poultry, pigs and cattle (MÔRO; FRITSCHE-NETO, 2017). According to the main Brazilian tables of animal nutrition requirements (VALADARES FILHO *et al*., 2016; ROSTAGNO *et al*., 2017), corn has about 9% crude protein (CP), 13% neutral detergent fiber (NDF), 66% starch, 72% non-fiber carbohydrates (NFC) and 3,936 kcal/kg of gross energy (GE).

The anatomy of maize is divided into pericarp, endosperm, germ and tip (Figure 1), which differ in chemical composition (Table 1) and in the organization within the grain. The

Endosperm and represents up to 83% of the grain, and is organized into starch granules (88%), reserve proteins (8%) of the prolamin type, called zeins, and lipid substances and carotenoids that give the color to corn grains (zeaxanthin, lutein, betacryptoxanthin, alpha and beta carotenes). The germ represents 11% of the corn grain and concentrates almost all the lipids (oil and vitamin E) (83%) and minerals (78%) of the grain, in addition to containing important amounts of proteins (26%) and sugars (70%).

The pericarp and the protective layer of corn can represent up to 5%, and a more fribrous layer and its cells are made up of hemicellulose (67%) and cellulose (23%) polysaccharides, in addition to lignin (0.1%) in its composition. The tip and the region of the grain ligament with sabuco, and represents about 2%, is not covered by the pericarp and is basically formed by lignocellulosic compounds (PAES, 2006).

Figure 1. Anatomy of the corn grain and its parts.



Source: Adapted from Britannica (2006); cited by Paes (2006).

Based on the distribution of starch granules and protein matrix, the endosperm of corn is classified into two types: floury and vitreous. In the first, the starch granules are rounded and dispersed, with no protein matrix surrounding these structures, which results in vacant spaces during the grain drying process, from the spaces where it was previously occupied by water, during the development of the grain. On the other hand, in the vitreous endosperm, the protein matrix is dense, with structured protein bodies, which surround the polygonal-shaped starch granules, not allowing spaces between these structures (PAES, 2006).

The main corn hybrids sold in Brazil are of the duct type (*Flint*) that has a vitreous endosperm and starch of lower digestibility, which reduces the action of digestive and microbial enzymes. The relationship between hard endosperm (*Flint*) and floury (*Dent*) defines the vitreousness of a corn grain. Thus, the greater the vitreousness, the greater the amount of hard endosperm present in the grain (CORREA *et al*., 2002).

Table 1. Average chemical composition of the ripe corn grain and its components, in percentage (%).

Fraction	Grain	Starch	Proteins	Lipids	Sugars	Ashes
Whole grain	100,0	73,5	9,0	4,3	1,9	1,5
Endosperm	82,6	87,6	7,9	0,83	0,62	0,33
Embryo	11,1	8,0	18,3	33,5	10,5	10,6
Pericarp	5,4	7,2	3,6	1,03	0,36	0,85
Tip	0,8	5,3	9,1	3,8	1,61	1,59

Source: Fornacieri Filho (2007); quoted by Môro; Fritsche-Neto (2017).

In the Brazilian seed market, there is a predominance of semi-hard and hard grain cultivars, with about 54% and 25% respectively, and dented corn has only about 6%. Hard corn is more resistant to pest attack, such as the weevil or corn weevil (*Sitophilus zeamais*), being more valued by the industry, even having a better price than farinaceous corn (FRITSSCHE-NETO; MÔRO, 2017), since storage for a long time in public and private warehouses is typical of the Brazilian market.

In the structure of dentate corn (Figure 1), the farinaceous endosperm is in the central part of the grain, between the tip and the upper end (where the dentition characteristic is formed after the grain is dried); On the sides of this band on the back of the grain is the vitreous endosperm. And in the structure of hard corn, the grain has a continuous volume of vitreous endosperm, which results in smooth and rounder grains, with a hard and glassy appearance (FRITSSCHE-NETO; MÔRO, 2017).

However, the durum corn grain ends up having low digestibility, however, there are processing techniques such as milling, pelleting, rolling and flocculation, which improve the digestibility of the grain and starch.

MAIZE CULTIVARS

The migration of maize from Mesoamerica to the rest of America gave rise to a great diversity of breeds, as well as making it possible for them to adapt to different ecological conditions. It has adapted well to the various regions of the American continent, being cultivated in climates ranging from equatorial regions to subarctic regions, as well as in extremely arid areas (MACHADO; MACHADO, 2009).

The wild form of corn has not yet been found and the current existing plants are the result of successive hybridizations with local plants, as the plant multiplied throughout

America, even before the arrival of Europeans (FERRÃO, 2013). It became the plant species with the highest degree of domestication, being so high that today this species does not survive without the care of man (NASS; PATERNIANI, 2005).

Maize is a monoecious plant, with pollen production on the tassel anthers and stigma style on the ears, characterizing male and female organs, separated on the same plant. There are no male and female corn plants. Only, when it is intended to make a certain specific crossing, it was agreed to call the plant that kept the tassel to provide pollen a male, and the one that had the tassel torn off a female, because it will receive pollen from another plant (MACHADO; MACHADO, 2009).

Today in the market there are specific corn cultivars for the production of grain, green corn, sweet corn, white corn (hominy), silage, popcorn and etc., which increases the chances of success of the enterprise due to the optimization of specific advantages (MIRANDA; GALVÃO; SANTOS, 2007b).

VARIETIES

They are known as variety or open pollination, due to this name because they are obtained through random mating, through free pollination. Becoming highly heterozygous, with greater productive stability, having greater genetic variability, less uniformity in the product and low productivity, caused by low heterosis (FRITSSCHE-NETO; MÔRO, 2017).

The maize varieties have improved populations, having great rusticity and adaptability. Generally, varieties are more adapted to cropping systems that employ low to medium amounts of inputs and their seeds can be multiplied (MIRANDA; GALVÃO; SANTOS, 2007b).

According to MACHADO; MACHADO (2009) corn varieties can be classified into five types:

Traditional varieties: these are varieties that have been managed by natural human selection processes, in the same agroecosystem for at least three family generations (grandfather, father and son), in which historical values are incorporated that become part of local traditions. They are adapted to the environments where they are grown and also to the cultivation systems adopted by farmers who incorporate social and cultural values from their perception.

Old traditional varieties: same definition as above; but in this case they are varieties, chiefly, from primary and secondary centers of origin, which are being selected for a long time over ten family generations.

Local varieties: are varieties or populations that are under continuous management by farmers based on dynamic cycles of cultivation and selection (not necessarily) within specific agroecological and socioeconomic environments. It takes at least five growing cycles for a variety to become local.

Modern and/or improved varieties: these are varieties that have been improved or selected using scientific methods for aspects such as high production, short stature, response to fertilizers, among others. Selection methods can be conventional and centralized, and or participatory and decentralized. Traditional, creole or local varieties can become modern and/or improved and the reverse can also occur, as long as there is no insertion of genes from other species.

Creole varieties: Spanish term used mainly for traditional varieties, but which can be adopted for local varieties in certain situations, such as, for example, for those varieties introduced in communities for less than 20 years.

MACHADO *et al*. (2002) evaluated local varieties and improved varieties that would best adapt to family farming systems in the states of Rio de Janeiro and Espírito Santo. These authors observed very high yields in the different trials for improved and local varieties. And they also report the importance of local varieties in the adaptive processes of maize germplasm and that participatory breeding with agricultural communities can contribute to the selection of varieties tolerant to abiotic stresses.

SCALLOP; WAR; BARBOSA. (2016) characterizing native varieties of corn collected in the state of Santa Catarina so that it can contribute to genetic improvement programs, observed that the vast majority were dented and semidentate corns (53.4 and 33.3%, respectively). And that the average productivity of the native varieties was much lower than the improved varieties Catarina and Fortuna (2,709, 6,171 and 5,896 kg/ha, respectively).

These authors suggest that the use of native varieties in breeding programs should be carried out with caution, since there is a risk of drastic reduction in grain yield in segregating populations. And that these native varieties have potential in pre-breeding programs that include hybridizations between traditional maize with added value, contributing to adaptability to local conditions.

HYBRIDS

As it is a monoecious species, it becomes easy for humans to manipulate the hybridization of corn. By planting in male rows (pollinator) and in female rows (emasculated or artificially peeled) in variable proportions (1:2, 1:3, 1:4, 2:4, etc.) in isolated fields to avoid contamination by foreign pollen (MACHADO; MACHADO, 2009).

Commercial hybrids are the result of the crossing between genetically distinct and homozygous individuals, for maximum heterosis response (BORÉM; MIRANDA, 2013). Different types of hybrids can be obtained, depending on the number of parents employed, highly heterezygotic and homogeneous (FRITCHE-NETO; MÔRO, 2017). Hybrids, depending on the genetic basis, can be classified as (MIRANDA; GALVÃO; SANTOS, 2007b):

Intervarietal hybrid: cross between two varieties;

Simple hybrid: cross between two strains;

Double hybrid: crossing of two single hybrids;

Triple hybrid: crossing a simple hybrid with a lineage.

Hybrids are developed for systems that use high technology, which justifies the high investment in seeds, fertilizers, pesticides and, in some cases, irrigation (MIRANDA; GALVÃO; SANTOS, 2007b). Simple hybrids are potentially productive, even exceeding the mark of 15,000 kg $^{ha-1}$, have greater uniformity of plants and ears, making their seed bag very expensive. However, it only has high vigor and productivity in the first generation (F1), if the second generation (F2) is used for planting, there may be a reduction of 15% to 40% in productivity (FRITCHE-NETO; MÔRO, 2017).

FUMAGALLI *et al*. (2017) evaluating the productive performance of the simple corn hybrid Pioneer 30S31 in three row spacings (0.5, 0.7 and 0.9 m) and four plant populations per hectare (50,000, 60,000, 70,000 and 80,000) in the second harvest, after soybean harvest. These authors saw that the maximum optimal plant populations at row spacings of 0.5; 0.7 and 0.9 m were 80,000, 64,500 and 66,860 plants $^{ha-1}$, respectively. And that the row spacing of 0.5 m with a population of 80,000 plants $^{ha-1}$ promoted higher grain yield (11,250 kg $^{ha-1}$).

KLEIN *et al*. (2018) evaluating the agronomic and productive characteristics of Agroeste corn hybrids: AS 1551 Conventional, AS 1551 PRO 2, AS 1656 PRO 3 and AS 1596 PROX. The authors observed that corn hybrids with larger size and longer cycles (AS 1596 PROX) tend to produce silage with a higher participation of fibrous material, while earlier and smaller hybrids (AS 1656 PRO 3) have the potential to produce silage with a higher percentage of ear and grain. In addition, the authors report that corn hybrids with a lower proportion of senescent material (AS 1656 PRO 3) at the time of harvest simplify the management of the ensiling process, by facilitating and improving the compaction of the material to be ensiled, and providing better lactic fermentation to maintain the nutritive value of the silage.

The nutritional quality of the plant and the corn grain reflects directly on the animal performance, a predominant characteristic of corn hybrids for silage is that they have toothed grains.

NEUMANN *et al*. (2017) evaluating the performance of feedlot 1/2 Angus steers with 50% of corn silage inclusion, the authors observed that the corn silage of the hybrid LG6030 PRO, compared to the hybrid P30B39 H, was more digestible (72.92% against 70.52%), generating better feed conversion (6.11 against 7.81 kg of DM kg of weight $^{gain-1}$).

According to the authors, the two materials were harvested and ensiled at the same stage (reproductive R5), and higher dry matter content was observed in the hybrid LG6030 PRO in relation to the hybrid LG6030 PRO (40.19% against 37.66%, respectively), given the higher precocity of the first material and that the silage of the hybrid LG6030 PRO had higher levels of TDN and CP (71.07 and 5.83%, respectively) in relation to the silage of the hybrid P30B39 H (70.56 and 4.96%, respectively).

GMOs

Transgenic hybrid corn is obtained by Genetic Engineering from the modification of DNA by introducing genes from other species through recombinant DNA techniques. Currently, these transgenic techniques aim at three main targets, which can be classified as: herbicide tolerance; insertion of insect and disease resistance genes; and quality of products. In addition to these objectives, these techniques can also be used for the formation of raw material for non-edible uses, such as for the production of plastics, spermicides, among others (MACHADO; MACHADO, 2009).

The elaboration of a transgenic plant requires the isolation of the genes of interest, through the development of a genomic library and the use of probes to collect these genes. This process is based on recombinant DNA technology, which was developed after the discovery of restriction enzymes, DNA ligase, cloning vectors, and bacterial transformation methods (ALMEIDA; SALTY; BORÉM 2011). Subsequently, the stage of transferring genes of interest to the plant species is carried out, which has been possible by two methods (MORAIS; BORÉM, 2017):

Indirect method: which is the transformation by biological vector via *Agrobacterium*, which includes three steps. The first step is to obtain disarmed bloodlines through a recombination process. In the second step, it is necessary to build a vector that contains the genes of interest in its T-DNA. In the third stage, the binary vector should be transferred to the disarmed *Agrobacterium lineage*, through the method of three-parent conjugation, electroporation or thermal shock.

Direct method: it is performed by bioballistics, which is a physical method that consists of the acceleration of gold or tungsten microparticles that cross the cell wall and the plasma membrane, carrying the DNA to the interior of the cell. The process takes place under vacuum, to avoid damage to the cell and to maintain the speed of the microparticles (1,500 km/h). Thus, the DNA impregnated under the particles is dissociated from the microparticles by the action of the cellular liquid and integrates into the organism's genome in a random way.

For both the direct and indirect methods, *in vitro* regeneration of genetically modified plants is required. Selection markers are used, which are genes that bind to the gene of interest, allowing the growth of only transformed cells (MORAIS; BORÉM, 2017).

For the development of transgenic cultivars, single and triple hybrids are usually used, and a high technological level must be used in the crop. In addition, the recommendation of refuge area should be used for *Bt* corn, with common hybrids that can vary from 5 to 20% of the planted area, so that there is no selection of caterpillars resistant to the genetic material. And in the case of herbicide-resistant corn, crop rotation so that there is no selection of herbicide-resistant weeds (FRITCHE-NETO; MÔRO, 2017).

The main hybrids available in the Brazilian market are related to resistance caterpillars (TC 1502, Hercules I® brand; MON 810, registered trademark YieldGard VT PRO;® Bt11 Agrisusure TL;® and MIR 162, TL VIP®) and herbicide tolerance (Roundup Ready®, GA 21-TG and TC 1502, Hercules I® brand) (FRITCHE-NETO; MÔRO, 2017). The first transgenic corn hybrid (MON810, YieldGard) was approved for cultivation in Brazil in 2007, and had already been approved in the USA in 1996 (MORAIS; BORÉM, 2017). In the 2008/2009 Brazilian harvest, it represented about 1.2% (170,000 ha) of the total corn planted area in that period and, in the 2015/2016 harvest, transgenic hybrids accounted for 95.2% (18.5 million ha) (CÉLERES, 2016).

WAQUIL; VILLELA; FOSTER. (2002) evaluated Bt corn hybrids, available in the American market, for resistance to fall armyworm (*Spodoptera frugiperda* Smith), of which nine express the toxins Cry 1F, Cry 1A(b), Cry 1 A(c) and Cry 9C, in addition to one hybrid (MP 704 X 707) expressing natural resistance to *S. frugiperda*. All evaluated in plots and subplots were compared to common hybrids, and all were subjected to infestation at 33 days after planting.

The authors observed that most Bt hybrids were more resistant to *S. frugiperda* than common hybrids, and, consequently, had higher grain yield. Among the *Bt* hybrids, the authors observed that those with the Cry 1F toxin stood out as highly resistant, Cry 1Ab stood out as resistant, Cry 1Ac stood out as moderately resistant, and Cry 9C stood out as susceptible.

VARGAS; MORAIS, R.M.; REDAELLI. (2017) evaluated the infestation, egg parasitism and damage of fall armyworm, *Spodoptera frugiperda* (J. E. Smith), and fall armyworm, *Helicoverpa zea* (Boddie), in maize cultivars: Criollo variety (Lombo Baio), conventional hybrid (Semilha S395) and genetically modified hybrid (*Bt*) (TC1507 Herculex I®, Cry1F).

The authors observed that damage caused by fall armyworm was similar between Creole and conventional corn, which was higher than in genetically modified Bt corn. Greater leaf injuries in the Creole variety (7.34) and in the conventional hybrid (7.05), in relation to the transgenic hybrid (2.15). The laying of fall armyworm and larvae did not differ between Creole, conventional and *Bt* corn. And the average number of earworms per plant was higher in Creole corn (0.19) than in conventional corn (0.12) and Bt corn (0.05).

SPECIAL CULTIVARS

WHITE CORN

White corn is widely used in Brazil for the production of hominy, corn starch (cornstarch), silage and grain. Most varieties and hybrids of white corn are toothed and have a great characteristic of farinaceous endosperm. Of the six creole varieties of white corn found by VIEIRA; WAR; BARBOSA NETO. (2016) in the interior of the State of Santa Catarina, three were dentate corn, two were semidentate corn, and one was opaque corn.

In Mexico, white corn is more cultivated than yellow corn, due to the fact that the focus of corn production is aimed at producing food for the human population. Mexican cuisine has several dishes that have corn as an ingredient such as: tortillas, corn flakes, corn flour, etc. In the USA, the production of corn for human consumption is about 3%, less than 1%, and white corn, but the planted area of white corn has grown due to the growing increase of the Latino population, especially the Mexican population (AGMRC, 2018).

White corn is little cultivated in Brazil, the planted areas occur in isolation, with Paraná being the main producing state, followed by Minas Gerais and Santa Catarina (SOUZA *et al*., 2009). The production is mainly intended for the production of hominy and its commercialization is more concentrated in the months of June festivities and with greater emphasis on the Northeast Region. Hominy is obtained by removing the germ, used in the extraction of the oil, and the outer film of the grain. After these operations, the beans are polished to remove the dust, washed, dried and packaged (PEREIRA FILHO; CRUZ, 2011).

In the region around the municipality of Barbacena, Minas Gerais, it is the tradition of family farmers to plant a variety of white corn called *Barbacena white corn* or horsetooth *corn*. This white corn is traditionally used by farmers, either in their own food such as corn flour, cornmeal, cornstarch and hominy, or to obtain silage and feed for poultry and pigs (SOUZA *et al*., 2009).

In the south of the state of Mato Grosso do Sul, the Indians of the Guarani-Kaiowá ethnic group cultivate an ancient natural variety called *white corn* or *avatí moroti* (in Guarani). In Kaiowá mythology, *corn-flavored* is considered a sacred food, being used in the food and production of chicha, an alcoholic beverage used in religious rituals. This indigenous corn variety is at great risk of extinction, as the Guarani-Kaiowás have lost much of their ancestral land. Those who are in demarcated territories and those under demarcation still have the risk of crossing with transgenic hybrids planted on large estates around the villages, in addition to the loss of their tradition by the Indians who move to urban centers (HOFFMANN, 2017).

Embrapa Temperate Climate has developed a variety of white corn called BRS 015 Farináceo Branco, which comes from access collected in São José do Norte, still in the 1990s, from the original population, called *Branco Açorianos*. Between 2003 and 2008, Embrapa Temperate Climate selected more than one hundred progenies (descendants) that, combined, gave rise to the variety (EMBRAPA. 2019).

According to EICHOLZ *et al*. (2018) the BRS 015 cultivar of white and farinaceous grains has a higher mill yield, the starch (cornstarch) has a white color like wheat, has a fully floury endosperm giving higher starch yield (40%) than conventional ones, being indicated for the production of cakes and breads intended for intolerant and allergic people to gluten.

The IAPAR (Agronomic Institute of Paraná) developed the white corn IPR 127, which is a simple hybrid, with high productivity (up to 9,000 kg $^{ha-1}$), with well-stuffed ears and an early cycle. IPR 127 white corn produces hard grains, with a low rate of burnt and high industrial yield in the production of hominy, cornmeal, flour and starch (IAPAR, 2019).

POPCORN

The popcorn crop has great potential in Brazilian agriculture, its cultivation has grown and the price of the grain is higher than that of the conventional one, however, its productivity is less than half of the conventional one. The Brazilian demand for popcorn is 65,000 to 70,000 tons, about 15,000 to 20,000 tons are imported, mainly from Argentina and the USA (MIRANDA; GALVÃO; SANTOS, 2007c).

Popcorn is planted in small areas and mainly by small producers, with the exception of a few large corporate producers who use irrigation to have the product always on offer, meeting the demands of cerealists who package and make the product available in the market (PEREIRA FILHO *et al*., 2020b). Most small producers use their own seeds of local varieties or advanced generations of American hybrids. And industrial farmers use seeds of improved national cultivars or imported hybrids (MIRANDA; GALVÃO; SANTOS, 2007c).

Popcorn kernels differ from conventional corns (toothed and hard) in that they have a thicker pericarp, with a predominantly glassy endosperm, are smaller in size and round in shape (FRISTSCHE-NETO; MÔRO, 2017). The grain still has the capacity to expand, because its capsule that surrounds the endosperm is thin.

The popcorn film works as a kind of rigid wall, which breaks with the internal pressure because of the heat that is transferred to the interior of the grain. This film is three times more efficient in popcorn than in conventional corn, due to the rectangular distribution, forming a typical crystal arrangement, of the cellulose fibers that form popcorn corn. While in conventional corn they are organized in an amorphous way (MIRANDA; GALVÃO; SANTOS, 2007c).

The hardness of the popcorn pericarp is so intense that the pressure required to burst the grain is on the order of 9 $^{kg.cm^{-2}}$, while to burst an automobile tire is 6 $^{kg.cm^{-2}}$. The expansion capacity ends up being the most important characteristic than the productivity of popcorn compared to conventional corn (MÔRO; FRISTSCHE-NETO, 2017).

GREEN CORN

Green corn refers to corn harvested while still in the milky stage, with 70 to 80% moisture, approximately 90 days after seedling emergence. The milky stage can be identified by pressing the grain with the tip of the nail, the grain bursts exposing the liquid and milky content (MIRANDA; GALVÃO; SANTOS, 2007a).

It is a viable alternative for small producers, as it achieves better prices than grain corn, especially in the between harvests (June and September), since the supply is lower and the demand for the product is higher (PEREIRA FILHO; CRUZ, 2011). In addition, the plants can be sold *in natura* or as silage for cattle ranchers near the plantation.

There are hybrids and specialized varieties for the production of green corn, with desired characteristics such as: uniform, well-stuffed, long and cylindrical ears, with light and thin sabucos; Long, uniform, light yellow, toothed grains, with a fine pericarp and with a balance in sugar and starch levels – for making tamale, curau, cake, etc. In addition, cultivars must be tolerant to the main diseases that attack the ear and impair the quality and aesthetics of the ear (MIRANDA; GALVÃO; SANTOS, 2007a).

SWEET CORN

Sweet and super sweet corn are also included as green corn, but unlike conventional green corn that is planted by farmers or horticulturists and sold directly to merchants and marketers. Sweet corn is planted and destined for the canning industry and, on a smaller scale, the production of canned corn (MIRANDA; GALVÃO; SANTOS, 2007c; ASCHERI, 2020).

The main difference between sweet corn and conventional corn is the presence of mutant alleles that block the conversion of sugars into starch in the endosperm, conferring the sweet character, making sweet corn wrinkled and translucent when dried (ASCHERI, 2020). While conventional corn has 3% sugar and 60 to 70% starch, sweet corn has 9 to 14% sugar and 30 to 35% starch, and super-sweet corn has 25% sugar and 15 to 25% starch (MIRANDA; GALVÃO; SANTOS, 2007a).

The genes that confer this mutation are the *sugary* gene in sweet corn and the *brittle gene* in supersweet corn. The mutation that gave rise to sweet corn is believed to have occurred in pre-Columbian South America, and indigenous populations began to use it as a source of sugar. Today, the world's largest producers are the USA, where production is concentrated in the northern middle of the United States and extends to southern Canada (PEREIRA-FILHO; CROSS; COSTA, 2020a).

In Brazil, the production of sweet corn is concentrated in the State of Goiás, due to the possibility of cultivation all year round, and almost all of the production is destined to the canning industry (BARBIERI *et al*., 2005). Another product of sweet corn is the mini-corn, which is the female inflorescence of corn, without fertilization (the male inflorescence is peeled), which has a very sweet flavor (MÔRO; FRITSCHE-NETO, 2017).

LUZ *et al*. (2014) evaluated yield and grain yield of six sweet corn hybrids (SWC03, SWC04, SWC05, SWC06, SWC07 and SWC08) and two green corn hybrids (SWC01 and SWC02) at four harvest intervals (26, 28, 30 and 32 days after flowering).

The authors observed that the hybrids SWC04 and SWC08 of sweet corn had the highest yields of ears with straw, yield and grain yield when harvested at 30 days before flowering (24.38 and 22.18 t $^{ha-1}$; 11.70 and 10.95 t $^{ha-1}$ and 47.96 and 49.30%, respectively).

CONCLUSION

The corn crop (*Zea mays* L.) has undergone several selections by man from its domestication in Pre-Columbian Mesoamerica to the advent of Genetic Engineering in the twentieth century. The has distinct and special characteristics for each cultivation system and purpose of use.

The grain as one of the most common foods on the Brazilian table, its generation of employment and income is the prominent place in Brazilian agribusiness.

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