Faculty of Tropical AgriSciences

Czech University of Life Sciences Prague
Faculty of Tropical AgriSciences

Mapping of Postharvest Losses of Maize in Latin America

Bachelor thesis

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Author:
Petr Malík

Supervisor:
Helga Johana Hernandez Ph.D.

Declaration

I hereby declare that I have done this thesis entitled “Mapping of Post-harvest Losses of Maize in Latin America” independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 19th April 2019

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Petr Malík

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Abstract

Agriculture creates an important part in economy of developing countries and the region of Latin America is not an exception. This sector has to face many challenges, post-harvest losses belong to these issues. The post-harvest losses, which measure qualitative and quantitative loss of a particular product, can occur at any stage of the post-harvest management activities. The importance of mapping of the losses is essential for further improvement of particular techniques involved in these activities.

This bachelor thesis “Mapping of Post-harvest Losses of Maize in Latin America” was written in form of literature review based on scientific articles. The thesis aims to summarize the available data about post-harvest losses of maize in countries of Latin America.

Key words: post-harvest losses, post-harvest management, maize, Latin America

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List of abbreviations

CFS	Committee on World Food Security
CGIAR	Consultative Group for International Agricultural Research
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GRDC	Grains Research and Development Corporation
NAFTA	North American Free Trade Agreement
OEC	Observatory of Economic Complexity
OXFAM GB	Oxford Committee for Famine Relief Great Britain
USD	United States Dollar
USDA	United States Department of Agriculture

1. Introduction

Post-harvest losses are a negative but essential part of the post-harvest management and part of the agricultural production itself. Post-harvest technologies are set up in order to minimize the losses of agricultural production, enhance the nutrition and bring a value to the final product which afterwards reflects in reduction of poverty and supporting the growth and development of the agricultural sector (Grolleaud 2002). Agricultural production is closely connected with the food security which is considered to be one of the oldest and most important issues, not only of Latin America but the whole world. The problem of food security is discussed very frequently these days. Moreover, it is also connected with other socio-economic problems such as hunger. The importance of an appropriate post-harvest management is essential in order to decrease or even eliminate the post-harvest losses and thus ensure more stable food security itself (FAO 2011).

Maize belongs to the group of three most important crops for human consumption. Along with wheat and rice it ensures around 30% of food calories of almost 2/3 of total world population. It is considered to be the most important food crop in Africa and Latin America. As the total world population is still increasing, there is a higher demand for food that will presumably result in the rise in demand for corn. It is also expected that maize will peak the most significant crop in 2025, speaking about developing countries. In the developing world, the number of demanded maize is supposed to be doubled in the year 2050. Moreover, maize is considered the most valuable feed grain for livestock and it is relatively easy to grow (CGIAR 2016). Latin America covers a very huge region, therefore its agriculture plays an integral role in the global market, too. Especially big countries, such as Brazil and Argentina belong to the group of major actors in global agriculture production (Duff & Padilla 2015).

The importance of maize is undisputable, therefore there is also big importance of appropriate post-harvest practices that begin with the moment of harvesting and end with delivering the final goods to the consumer. The post-harvest losses include every loss of maize during the post-harvest chain: harvesting, thrashing, drying, storing and transporting (Chegere 2018).

2. Objectives

The main objective of this bachelor thesis is to map the post-harvest management practices of maize in Latin America region and at the same time to provide an overview of main post-harvest losses during different phases of maize management.

3. Methodology

The literature research is written according to secondary data that were retrieved from scientific articles and journals. The search has been carried out using keywords: “post-harvest losses, post-harvest management, maize, Latin America. “

The literature review, the main core of the bachelor thesis, will be divided into various subsections with the main focus on post-harvest practices of maize and the losses occurring during them.

4. Literature review

4.1. Agriculture in Latin America

Latin America is globally an important region in the sense of export of agriculture commodities. The majority of goods from this region are exported to the United States and the greatest exporters are, not surprisingly, the largest countries, such as Brazil and Argentina, which are producing the most. In terms of the world total export, Latin America's export was four times higher than import. Duff and Padilla (2015) reported that export of agricultural production was by 16% covered by this region in 2015. While only 4% of total agriculture goods distributed worldwide are imported into the countries of Latin America (Duff & Padilla 2015).

As the region of Latin America is very huge in terms of area, thus it is incontestable that there is also a wide range of agricultural commodities. Regarding the largest countries of the region of Latin America, Brazil is one of the countries that contribute the most to the agricultural production where one of the most important agricultural commodities is sugar cane - being the 1st world producer, with more than 3/4 billion of tons in 2016. Followed by soybeans and concerning cereals mainly corn and wheat (FAOSTAT 2016). It is necessary to mention the other major players of Latin America agricultural production, such as Argentina and Mexico. The Latin America region is considerably widespread and therefore different conditions occur in individual countries. For instance, weather conditions may be the factor that affects the agricultural production in different regions (Gavier-Pizarro 2011). Observatory of Economic Complexity (2017) reported Argentina to be a large exporter of soybeans and maize, also sugar cane and wheat play an essential role in the production regarding exports. According to the statistics of OEC (2017) Mexico's export peaked 26 billion USD, which makes Mexico the third greatest country in terms of agricultural production in Latin America and the first one in Central America region. Mexico's production activities are mainly focused on sugar cane but in the top ten

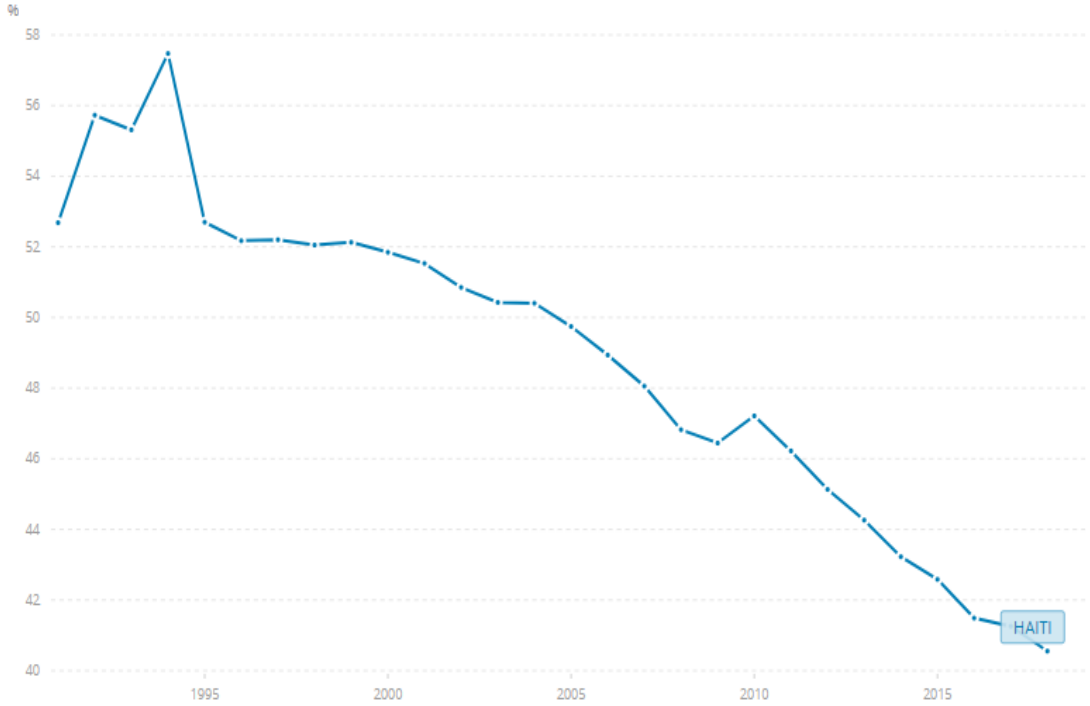
most produced commodities it also has fresh vegetables, such as avocados (where it is the 1st producer in the world) (FAOSTAT 2016).

The region of Latin America also plays a significant role in terms of undiscovered agricultural land. For Brazil and Argentina, this fact shows that the importance of the unexploited land will keep on playing a very significant role in world production of agricultural goods and also in terms of export of food products in the future. On the other hand, the world population is still increasing, and it could bring the issues of making a profit by exporting agriculture products, rather than achieving required needs of people living in this region. The countries of Latin America should keep in mind that one of the most important goals is sustainability, which is really challenging to pursue, along with achieving economic growth of the region, or a relevant country (Duff & Padilla 2015).

4.2. Economic role of agriculture in Latin America

Generally, developing countries are becoming more developed and the importance of agriculture has decreased in the last decades. In terms of economic growth, the share of GDP and the employment in agriculture have declined. The big share of agriculture in terms of GDP of the countries has been replaced by services and the industrial sector. However, Latin America covers a huge region and that is why it may differ from one country to another, and thus it is necessary to mention that in some countries, agricultural sector still employs a considerable part of the population. Figure 1 shows the data of the World Bank from 2018, where the country with the biggest employment in agriculture sector is represented by Haiti (in the Caribbean region) where over 40% of the work force is employed in agriculture (World Bank 2018).

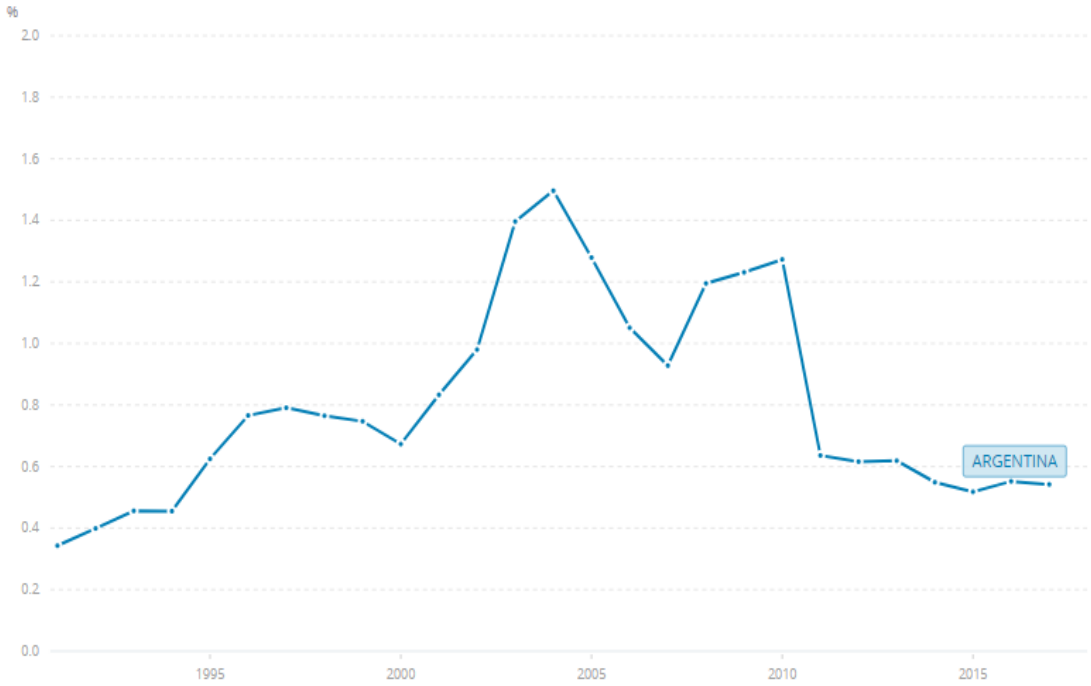
Figure 1: Employment in agriculture in Haiti (% of total employment)



Source: World Bank (2018)

On the opposite side of the rankings stands Argentina where less than 1% of population works in the agriculture sector. The employment in the agriculture sector has not peaked 2% in Argentina, as it is clearly visible in Figure 2. However, the export of agricultural goods is one of the highest in Latin America (World Bank 2018).

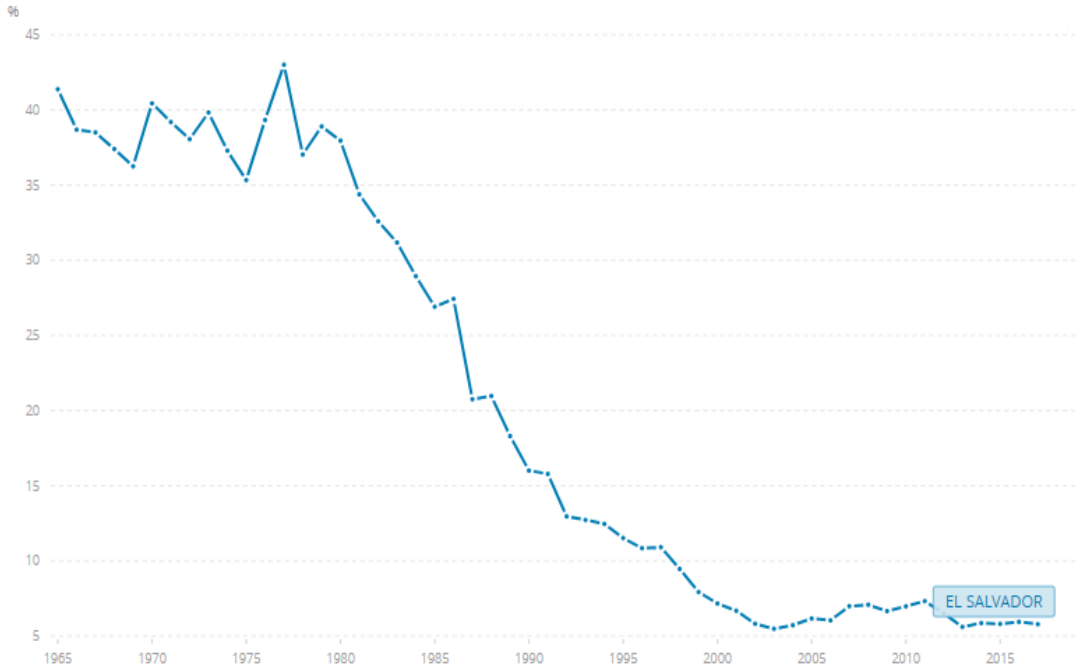
Figure 2: Employment in agriculture in Argentina (% of total employment)



Source: World Bank (2018)

As it was mentioned in the first paragraph of this chapter, the share of agriculture in the GDP has decreased in Latin America. With respect to the numbers, nowadays, between 4-5% of the GDP is covered by the agriculture sector in Latin America and the Caribbean region according to the latest data of the World Bank (2018). However, the employment in agriculture may differ in different regions of Latin America and therefore, the share of agriculture in the GDP may be different as well. Nevertheless, it could be considered not so relevant to compare the countries with completely different numbers in terms of population and their agricultural production. For better imagination of the situation, in El Salvador the decrease in share of agriculture in the GDP has been the most dramatic recently (Figure 3). In the last 40 years the share of agriculture in the GDP has decreased almost by 40% which gives us approximately 1% decrease every year.

Figure 3: Agriculture, forestry and fishing, value added (% of GDP) in El Salvador



Source: World Bank (2018)

Nowadays, according to FAOSTAT (2016), the total production of maize in Latin America was around 151 million tons on approximately 34 million hectares harvested in year 2016. The top three producers of Maize in Latin America are Mexico, Argentina and Brazil, while the two South American countries exported corn of the value of almost 8.5 billion USD in 2016. In Mexico the value of exported corn was "only" 0.5 billion USD (OEC 2016), which means that this country keeps a high amount of corn production for their own domestic consumption and utilization. Moreover, according to the statistics of FAOSTAT (2016), Mexico imported more than 14 million tons of maize in 2016, and thus became the second biggest importer of corn worldwide. Maize is the major food crop in a lot of countries in the world in terms of traditional and cultural background. In addition, with increasing meat demand, maize creates a significant part in livestock feeding (Lardy et al. 2016).

4.3. The role of Post-harvest practices

Post-harvest management, in other words, the complex of all activities considered as post-production practices involve many stages. Starting with harvesting, threshing and cleaning, drying, followed by packaging, storing and transporting. The stages may differ according to several practices (Chegere 2018).

All people in the world need to consume nutritionally balanced food in order to meet their dietary needs (FAO 1996). Moreover, people, as consumers, require the products as fresh as possible and without any considerable damage or any kind of contamination. Therefore, it is important to analyse and control each step of the post-harvest management in order to ensure that harvested products will reach the consumers without any deterioration in quality and any losses in quantity (Godfray et al. 2010).

4.4. Post-harvest loss and Food security

According to World Food Summit in 1996, food security exists “When all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO 1996). Food security is based on four principles, sometimes called pillars of food security. The four principles are: availability, access to food, utilization and stability. All these aspects must be achieved so that the food security could be ensured (CFS 2009).

There are two terms that need to be discussed when speaking about food - its wastage or loss. Food loss can be defined as the decrease in quality and quantity of food, i.e. the food that was produced for human consumption but not eaten. Food waste can be considered a component of a food loss (FAO 2019). Food can be lost during each stage of the supply chain, from the first step, i.e. production, to the ultimate stage, which is the consumption level. According to the statistics of FAO,

each year 1/3 of all food produced for human consumption is lost or wasted globally (FAO 2011).

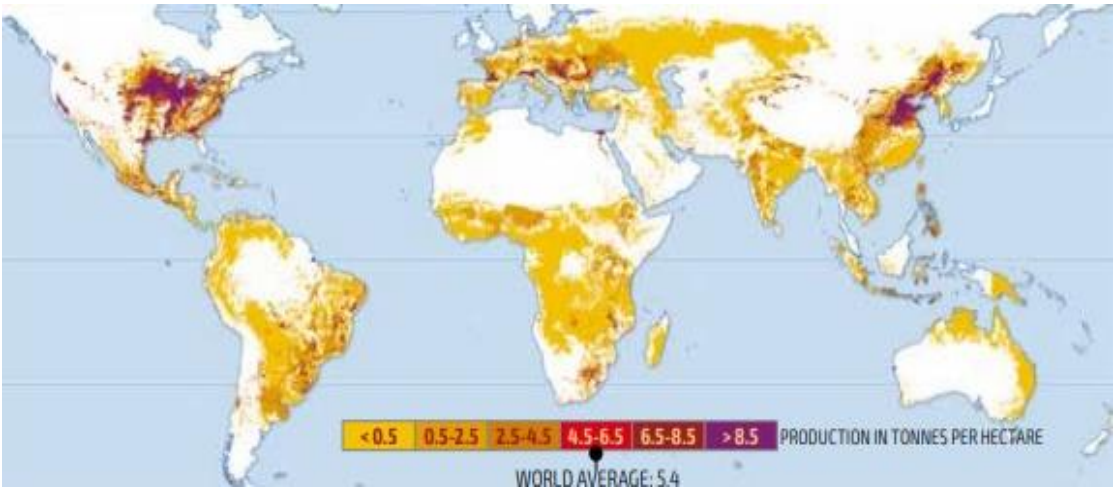
4.5. General information about Maize

Maize (*Zea Mays*) also known as corn, originally from the region of Central America is considered to be one of the most important crops, not only for human but also for animal consumption. Maize belongs to the group of annual grasses and it has two major species, *Zea Mays* and *Zea diploperennis*. *Zea Mays* could be further classified into different subspecies according to its taste or utilization, such as Sweet Corn or Popcorn (Wang et al. 2005).

Figure 4 represents the world production in tonnes per hectare (2010) where it is clearly visible that corn is cultivated in many parts all around the globe, and therefore in different climatic conditions. In colder areas, meaning temperate zones, the corn needs to be planted in a particular part of the year, when the weather conditions allow a proper development of the plant. The plant must be cultivated in suitable conditions together with sufficient amount of water available. It is obvious that there are many factors which can influence the growth of the plant during each stage of its development. The negative or also the positive circumstances differ according to the location where the corn is cultivated. For instance, in the African region, where the temperatures are relatively high and the supply of water could be sometimes very challenging, the soil is very dry and the plant itself could slow or even stop its development because of the shortage of nutrients. On the other hand, the low temperatures could also affect the growth of corn in a drastic way (FAO 2016). The weather extremes, i.e. a very high or a very low temperature, definitely affect the development and the growth of the plant in a negative way. Generally, the temperature response differs according to the life cycle in which the extreme weather hits the crop (Hatfield & Prueger 2014). One of the main environmental circumstances that affect the development and growth of the plant is a very low temperature. Moreover, the cold also causes the losses in productivity which definitely has a negative impact on the profit. The cold stress undoubtedly causes

diseases on the leaves and deteriorates the development of the grains (Meena et al. 2015).

Figure 4: World production of maize in tonnes per hectare in 2010



Source: FAO (2016)

The plant itself usually grows up to 3 meters of height, even though the development of the plant depends on the species types and other conditions, which could influence the differences in each species. The ear of maize is the main part of the plant which is further used for different purposes such as animal feeding or, for instance, for industrial use (Wang et al 2005).

The importance of corn worldwide is not only related to its utilization in terms of a food product but, it is also a type of crop exploited for industrial purposes, such as biofuel, which actually makes it a well-known topic for discussion. Moreover, a great diversity of maize hybrids brings the possibility of alternative usage (Pajić et al 2010).

There is not a very significant difference in nutrition values of maize compared to other grains, and that is why maize is easily comparable with the most consumed grains in the world, i.e. wheat and rice (FAO 1992). However, corn and the products from it do not provide a very high nutrition value. For instance, its protein is not of a very high quality, it is rather low in *niacin* (a form of vitamin B). Dietary habits, in

which maize plays a major role, could result in diseases such as *pellagra* or corn allergy (Hampl & Hampl 1997). The best prevention for the diseases caused by overconsumption of maize is to consume the products from maize along with food that contains the appropriate amount of proteins. The nutritional data of three main cereal grains: rice, wheat and corn, consumed by people are presented in Table 1 the data were retrieved from USDA Food Composition Databases.

Table 1: Content of nutrients in three major grain crops

Nutrients (In 100 grams)	*Zea mays* (Maize)	*Triticum aestivum* (Common wheat)	*Oryza sativa* (Asian rice)
Sugars (g)	**0.64**	1.02	0.12
Total lipid (fat) (g)	**4.74**	1.95	1.42
Protein (g)	**9.42**	9.61	5.95
Water (g)	**10.37**	12.42	11.89
Energy (kcal)	**365**	332	366
Fiber (g)	**7.3**	13.1	2.4

Source: USDA (2018)

Maize plays an essential role in human food in many parts of the world. For instance, in Mexican cuisine it is used very often in their traditional dishes and it is the main ingredient of tacos and tortillas. As another example of its use we can also mention cornflakes, which is a frequent breakfast meal well-known in countries all over the world. Maize harvested in an earlier state of growing could be also eaten after some kind of boiling or heat treatment (FAO 1992).

4.6. Utilization of Maize

Maize plays an essential role in terms of feed for livestock. There are different options of how the corn could be used as feed for animals. It could be used in form of grain feed, just the kernel part, kept in the dry form in order to decrease the risk of spoilage (Ferraretto & Shaver 2015). Another possibility is to use the whole plant. The whole plant is cut down and later on kept in the form of silage to ensure better digestibility. In tropical regions it is very common to gather the corn during the whole year and then bring it to the livestock as a fresh forage (Brewbaker 2003).

Generally, industrial purposes are an integral part of agriculture production and with increasing demand for energy, the world has to find new solutions how to use agriculture production in the most effective way. Therefore, there are still new technologies how to work with the part of the plant that is not used for feeding or any other type of consumption (Pajić et al. 2010).

In recent years, maize has been used in wide range for the production of ethanol, which furthermore is used as fuel. Petrol mixed with ethanol gives us an alternative biofuel for running cars and any other types of vehicles. With no stable prices of gasoline on the market, the share of ethanol has increased and nowadays, it is a very good alternative to gasoline. However, the demand for maize, from which the ethanol is fabricated and then used as an alternative fuel for cars, is also affected by the fact that gasoline powered cars can only handle the ratio of 10% ethanol and 90% gasoline. Moreover, the effect of ethanol on the metal parts of the engine is questionable and according to some studies it could be harmful if the ratio overcomes the 10% and it could have a negative impact on the power of the engine. Nevertheless, it has also brought some drawbacks in the form of affecting the price of food by usage of maize for biofuel production (Torres et al. 2016).

Another alternative use of maize is the utilization of maize for heating and the use of biomass to manufacture the maize into so called corn pellets. However, as it was mentioned before, without any doubt, it has also brought some disadvantages. According to the study by Oxfam GB (2000), when NAFTA opened the borders for

importing corn, the small-scale farmers were the ones who suffered the most because the prices went dramatically down. Therefore, the lower demand for maize on the local market caused eventually the loss of job opportunities for farmers (Nadal 2001).

4.7. Post-harvest management of Maize

After spending hours of working in the fields to make appropriate quality yield of maize, the farmers need to keep in mind that the post-harvest management of the crops is undoubtedly not less important than the production itself. Sometimes it might be very challenging to produce quality products because there are a lot of factors that could affect the production negatively, such as changing weather conditions, pests etc. It is very important to harvest the crops at the proper stage of growth because it could also affect the future, post-harvest losses. Maize harvested in an early stage of growth, immature stage, may react differently and for instance its quality could deteriorate (Bachmann & Earles 2000).

Maize belongs to the group of grain crops, due to this fact, the essential steps or features of postharvest system are generally the following: harvesting, threshing and cleaning, drying, the phase of packaging, storing and the final one - transporting. Each of these steps has its own specific features that need to be properly done in order to prevent the deterioration of the product (Lardy et al. 2016).

4.7.1. Harvesting

In general, every stage of the post-harvest system has its own rules or steps that must be taken. Speaking about the harvesting period, maize demands usually around 17 weeks to reach its full maturity. Nevertheless, the maturity may differ according to species and also according to the area in which the corn is

cultivated. There are some varieties that require only 11 weeks. These species belong to the group of early maturing varieties (Chegere 2018).

There are basically two main types of harvesting. The first one is called timely harvesting and the second one is called drying and late harvesting. To provide the main difference between these two types of harvesting it is necessary to go little further into let say next stages of post-harvest because, while during the first one, called timely harvesting, the ears are separated from the rest of the plant, the husk is removed from the cob, gathered up together and then ready to be transported to the hall where other post-harvest stages are happening. The second type, called drying and late harvesting, is done in a different way. During this late harvesting system, the plant is left for around 30 up to 45 days over the maturity and dried in the field, depending on the weather and species. After that, the process is comparable with the timely harvesting - the cobs are separated, gathered together and transported to the hall or farm. However, it is necessary to mention that even if the plants are left in the field for longer time to decrease the water content in it, the process of drying afterwards is needed to be taken because the so called field drying does not reach required moisture level for future storage (Mejía 2003).

The process of harvesting itself is mainly done mechanically by machines. However, in case of small-scale farmers, where the yield is no very large, the harvesting could be also done manually. The whole plant is cut down and left in the pile, when the matter is dry the maize cob is separated and thrashed. Another possibility is to use the whole plant as fresh hay (Plessis 2003). Based on the surveys that have been held among small scale farmers, in Guatemala in year 2016, 88% of the questioned farmers rather prefer to let the corn ears, after cutting down, in the field under the direct sunlight to extract as much water content as possible directly after cutting (Mendoza et al. 2016).

4.7.2. Cleaning and Drying

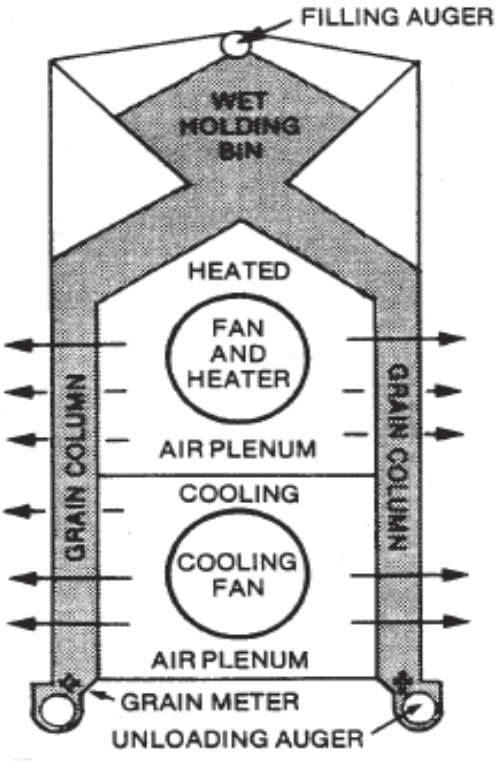
First of all, it is necessary to mention that the phases of post-harvest chain of maize may differ in their order because there are several methods how to carry out this process and there are alternative opinions about it, which means that in some studies available the thrashing may be held before cleaning and drying. To summarize this idea by at least one reason why the phases may differ could be also the fact that there are many different uses of the final processed maize. For instance, the maize intended for consumption by animals is not similar to the one that is afterwards used in human consumption. Moreover, wide range of species intended for discrepant future usage may also require its own particular treatment (Arahón & Aquiles 2007).

The survey retrieved from scientific articles showed that there are several uses of maize and therefore, several methods what needs to be done first. For better imagination one concrete example could be taken. In the process of wet-milling the most important product is the starch used in the future for industrial purposes or as feed for livestock. In this particular process the first operation that needs to be taken is cleaning. The corn must be cleaned before storing even before drying. The process of cleaning itself is done by blowing the wind in the matter in order to get rid of unwanted particles such as pieces of ear, soil bits, small stones and also the insects (Mejía 2003). There is also one almost natural possibility how to clean the grains, called winnowing. The grains are falling down from the line and during that the impurities are extracted by the blow of natural wind. Another nearly similar process is called sifting. While during winnowing the grains are cleaned only by natural wind, during sifting the grains are falling into a big colander which keeps the larger and unwanted particles out of the cleaned corn grains. The maize cleaning has a lot of advantages such as reduction of the possibility of appearance of mould, increased market value etc. However, it is very important to say that during all these processes the losses are undisputable (Hellevang & Wilcke 2013).

During particular practices the drying takes place directly after the cutting of the plant. However, as is was discussed before the water content after the field drying is not sufficient for the safe storage. Therefore, another drying needs to be taken to reach the required moisture of the grains (Lardy et al. 2016).

It is necessary to modify the drying stage according the period of time for which afterwards the maize is stored. For short-term storing the maize should be dried to 15.5%, for around one year storing the moisture content should not overcome 14% and for long term storing it must be 13.5%. Generally, there are different types of dryers such as a batch dryer or cross-flow dryer but the most used is the cross-flow (Figure 5). The grains are inserted on the top into the filling auger then they fall down through the grain's column. In the middle, there is a heater which blows hot air through the grains in the upper parts of the column. The temperature of the air in this part moves around 60 °C. In the lower sections there comes the cooling which cools down the grains right after. It is desirable not to exceed the temperature in order to avoid damages in grains structure. Higher than recommended temperatures may cause denaturation of proteins (disintegration of native structure). The initial moisture content usually varies from 26-28% and after the process of drying the average water content is around 14% (Hellevang & Wilcke 2013).

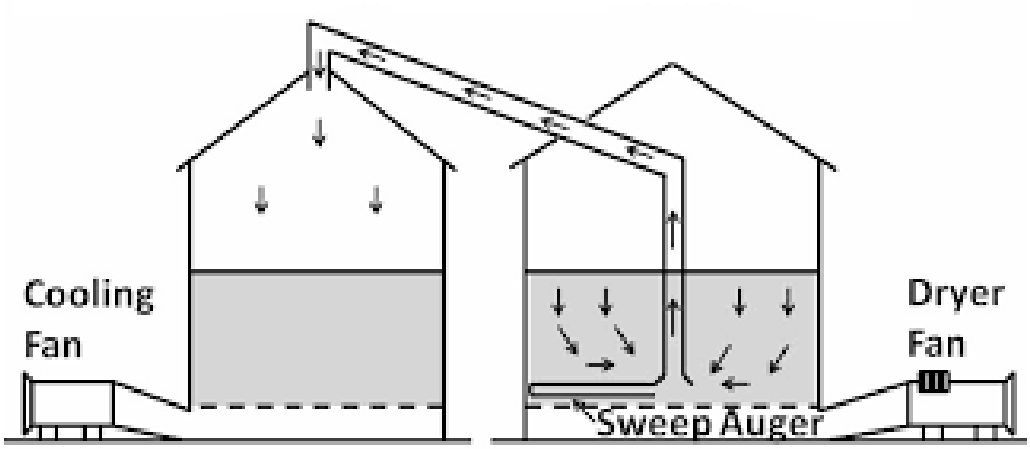
Figure 5: Column cross-flow dryer



Source: Hellevang & Wilcke (2013)

Another type can be named, such as bin dryer that operate on different principles. It is clearly visible from the Figure 6 in contrast to the column dryer, that a certain amount of grain is placed in the bin and the drying fan is located on the bottom. The drying temperature is comparable with the column dryer – it is around 60°C. This system is more complicated because it is necessary to have two bins. In the first one, the grains are heated by the warm air blowing from the bottom and the other one goes through the chimney where the process of cooling takes place. It is based on the same basis with the only difference that on the bottom of the second bin there is the cooling fan (Hellevang & Wilcke 2013).

Figure 6: (Continuous-flow) bin dryer



Source: McNeill (2013)

Every stage of the post-harvest system is important because every step is followed by another. The drying phase is very important for future safe storage. In other words, if the maize is properly dried there are lower chances of mould occurrence and the storage time without deterioration of the quality is longer. To mention also the negative side, some percentage of loss is unavoidable. Nevertheless, the new techniques occur, and the process is getting better in order to minimize the losses (Ballestero 2012).

4.7.3. Storing and packaging

Once the grains are properly dried the next step in the chain that needs to be done is storage. It is very important to store the maize in appropriate conditions, otherwise the entire harvest could be damaged or even completely wasted (Valdes et al. 2016).

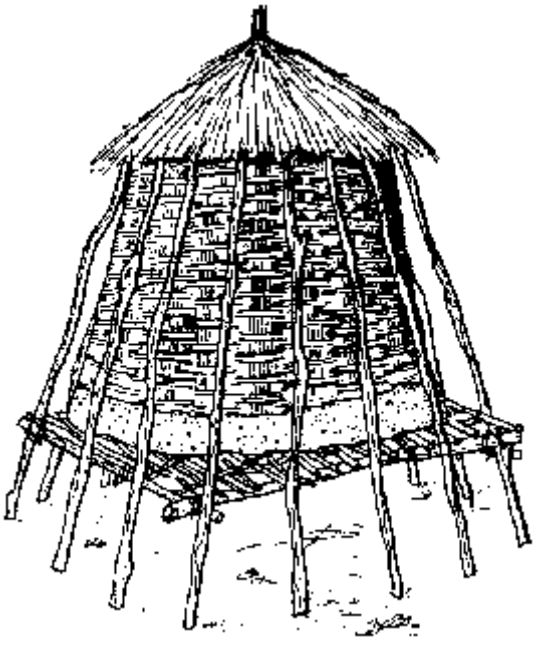
The old traditional type of storing cannot preserve and protect the harvest sufficiently. The method of keeping the harvest on the ground could be only temporary because once the maize is kept on the group, it starts to be very vulnerable to pest and diseases caused by changing weather conditions (Mejía 2003).

On the other hand, nowadays, with all the changes and technological innovations that have been made during the last decades the situation has changed dramatically. In other words, the possibility of storing the harvest in proper conditions in order to avoid losses has increased (Valdes et al. 2016).

There are several methods of storing the maize, from primitive storing on the ground to well-developed storing facilities where the loss of grains is supposed to be the lowest. Generally, the area where the maize is stored must be cool and dry in order to achieve the best storing conditions. According to the studies the optimal temperature for mould and insect activities is around 25°C. When the temperature is kept approximately at 4-5°C the activities of insects and moulds are undoubtedly lower or even limited (Martínez 2009).

People have always tended to store the grains and food in general since very past. However, logically in the past the storing possibilities, demonstrated in Figure 7, were not comparable with those that could be seen nowadays. What remains the same is that storage systems are modified according to the environmental conditions, storage time, grain types etc. (Valdes et al. 2016).

Figure 7: Traditional ventilated structure



Source: Greig & Reeves (1985)

One of the most traditional ways of storing is a wooden chest, which can be a box of any size depending on the amount of grains that need to be stored. It is one of the most primitive versions of storage facility which can be furthermore reflected in the relatively high possibility of loss. Another type is called Tapanco, which is the name of a simple wooden construction in Central America. Tapanco is built over the fire place, in sufficient distance from the stored grains, there are two main reasons why to keep the production over the fire. The smoke from the fire should work like a repellent against insects and it helps to keep the storage dry. However, according to the studies some insects have become resistant to that fume and, therefore it is not as useful as it should be (Martínez 2009).

In order to achieve safe storage for grains, the storing facilities have been developing since the very beginning. However, similar to other stages of the post-harvest, the new technologies and innovations depend on the development and economic possibilities of the particular country. That is why there can be incomparable storage facilities in rural areas of developing countries on one side and the modern storage with proper cooling on the other. According to the studies by GRDC (Grain Research and Development Corporation 2013) metal silos represent the most common type of grain storage worldwide. Some benefits and drawbacks of different types of storage, commonly used nowadays, will be discussed later.

A gas-tight silo, which has the biggest advantage in controlling the ratio of gases in the silo, therefore allows the pest control, and also the cooling systems are essential components to ensure the required temperature for storing. It has a wide range of dimensions usually from 15 up to 3000 tons of the total capacity. Some drawbacks to be provided: relatively high initial investment, the gas-tightness must be checked regularly which means very probable future expenditures. The usual option for short-term storage is the usage of grain storage bags. When the maize is stored in the bags one advantage could be the skipped step of packaging because once the production is packed, it is ready to be transported. Another advantage of this storing type is low initial cost. On the

other hand, the bags are not very resistant to pests such as rats, mice and any kind of insects, the bags could be used only once to ensure the proper hygiene and last but not least, there is just limited control of moisture content (GRDC 2013). The process of packaging is also an integral part of the post-harvest management especially nowadays when the reduction of plastics is an up-to-date topic. With the increasing effort to use more sustainable technologies, the new techniques of packaging and using the recyclable and reusable packages have become a commonly discussed topic nowadays. It is important to mention that the types of package systems may differ according to which state the final product is transported to. Typical packaging facilities used are made from different materials such as plastic, wood, fibre (Kitinoja & Gorny 1999).

One of the issues mentioned above is the overusing of plastics worldwide, which causes many problems to the whole world but in developing countries, where the economic situation is not comparable to the developed countries, the usage of plastics is still running mainly because of economic reasons (Hopewell et al. 2009).

4.7.4. Transportation

Transportation is phase of delivering the processed maize to the final user or consumer. There are several methods used varying from using the animal labour by small-scale farmers in developing countries and modern vehicles used by big agricultural companies. The way of transport may also differ according to the state to which the maize is transported. The process of transportation also requires attention because inappropriate transportation system could lead to the losses of the final product. The main aim of the maize transport is to deliver it to the desired destination with the smallest possible losses and damage (Mendoza et al. 2016).

During the transport, maize must be kept properly in order to minimize damage. Small-scale farmers in developing countries very frequently use animal labour as

a beast of burden to transport the maize to the local market. Donkeys and cows are the most used animals for these purposes. The method of using the animal for transport is also appropriate in mountainous areas because the modern trucks are not able to deliver it from these areas. That is why this method still remains the most common one (Kitinoja & Gorny 1999). The other possibility, the modern one, using the vehicles, requires steps that need to be taken in order to prevent deterioration or damage. One of the most important things is to keep the loading area as clean as possible to prevent disease and mould occurrence. That is why the vehicles are usually designed in a way that the loading area can be cleaned easily. The vehicles should be equipped with waterproof material on the top and the air flow should be also secured to prevent damages. Using the open air truck has a disadvantage in the possibility of rain damages during transport. However, on the other hand, the issue of air flow is solved (Mejía 2003).

4.7.5. Importance of post-harvest losses

Post-harvest loss is the unfavourable reduction and deterioration in the quality and quantity of food grain from the stage of harvesting to the final one, i.e. consumption. The losses at the post-harvest stage play also an essential role from economic, social or nutritive point of view (Mejía 2003). It is necessary to mention, that every single step of the post-harvest is connected to the next one, therefore, it is obvious that inappropriate techniques during one stage may affect the future ones. There are many factors contributing to the post-harvest losses which are divided into individual groups (Table 2).

Table 2: Factors contributing to the post-harvest losses

Physical	**Biological**	**Mechanical**	**Engineering**	**Socio-economic**
Temperature	Insects	Speed and a ground condition	Equipment and type of tools	Financial status
Moisture content	Birds and other wildlife	Efficiency and effectiveness	Primary processing equipment	Farming system
	Microorganisms: Fungi, moulds and bacteria		Drying and storage techniques	Storage system

Source: FAO (2003)

The economic impact of the post-harvest losses is represented by the value of products that cannot be eaten or sold, its value is decreasing in terms of quantity and quality. The economic importance, rather to say the loss, is estimated in percentages according to the commercial value of the product during the period of transaction (FAO 2012).

Social impact of post-harvest losses is represented by the amount of food that could be delivered to the consumers, therefore it helps to resolve the issue of hunger in the world. According to the research by FAO, around 40% of the food is wasted at retail market and during consumption. While in developing countries, approximately the same amount of food is lost due to the bad post-harvest handling practices (FAO 2012).

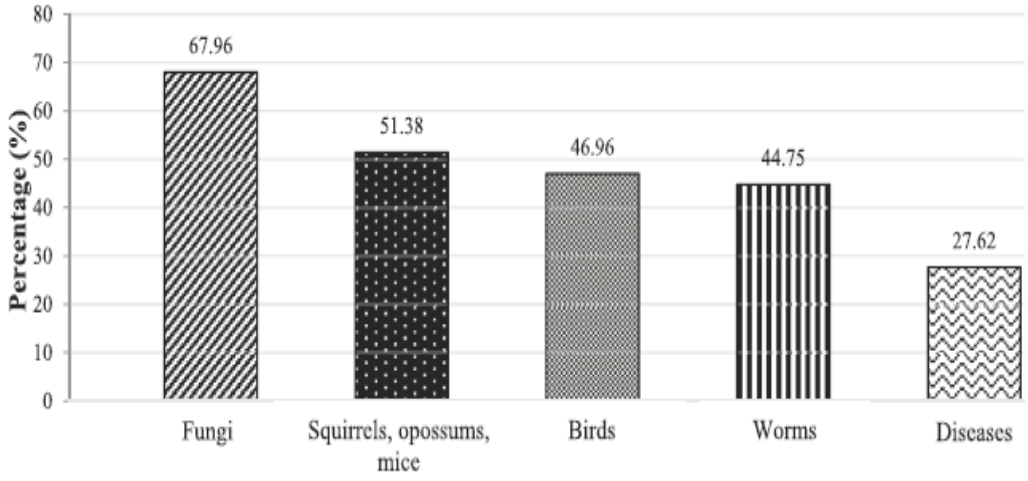
4.7.6. Factors associated with post-harvest losses – Harvesting

Generally, there are many factors contributing to the post-harvest losses. Starting with inappropriate handling practices during the harvesting. Post-harvest losses of maize are also caused by mechanical damage during harvesting due to inappropriate practices. Some studies were held in the countries of Latin America in order to gain more knowledge in this field and to improve these techniques and thus to reduce the losses (Mendoza et al. 2016).

The study of reduction of losses during the harvesting stage was held in Argentina between the years 2007 – 2008. During the mechanical process of harvesting by the combine, 28% of losses are caused by the thrashing, separation and cleaning. However, the most crucial part for reducing the losses during harvesting is to improve the efficiency of cob harvesting. The poor crop conditions may also contribute to high extent of damage. Due to this fact, new technologies have been implemented in order to improve the collection efficiency. According to the study held in Argentina, during the last year the efficiency of harvesting has been improved. Speaking in figures, there was a decrease in losses by 35% during harvesting which also brings a higher income balance. To reduce harvesting losses a few suggestions have been implemented. During harvesting, the crop itself should have the same mean of spike and stem which is very challenging to aim. If possible, the objective is to ensure uniform maturation and improve the pest control before harvesting in order to keep the crop in appropriate conditions for harvesting (Bragachini & Peiretti 2009). The issue of losses, due to harvesting in immature state of the maize, was also studied in Peru where maize was harvested at different points of humidity level in order to find out what the most appropriate humidity for harvesting is. According to the statistics of this study, the optimum humidity for harvesting was estimated at 22-24%. At this humidity level, the crop is the least vulnerable to be damaged. On the other hand, when the maize is harvested in different humidity levels, the deterioration may occur during future post-harvest processes as well (Hernández

et al. 2009). Another example the case of small-scale farmers in Guatemala, where 98% of the interviewed farmers responded that some losses during harvest period occur. From the Figure 8, it is clearly visible that in most cases the damage was caused by fungi, almost 68%, followed by small animals, approximately 51%, birds 47%, worms between 44-45% and around 28% are represented by diseases (Mendoza et al. 2016).

Figure 8: Damage during harvesting period



Source: Mendoza et al. (2016)

As is it clearly visible from Figure 8 there are many factors contributing to the post-harvest losses during the harvest phase. Harvesting of maize requires properly carried out techniques which include monitoring and mathematical calculation in order to achieve data for the most successful harvest. Nevertheless, even though there has been visible progress in improving the harvesting technologies, there are still losses that are undisputed. Another example that can be documented is the case of El Salvador where the post-harvest losses in the phase of harvesting reached 19% (Deras 2012).

Generally, there are many obstacles during the harvesting stage and these are the main issues that the farmers need to face during harvest. Insufficient tools for harvesting, inappropriate methods due to lack of knowledge, low level of treatment during cultivation, therefore future pest control is limited etc. All

these factors may lead to immediate or future damage (Bragachini & Peiretti 2009).

4.7.7. Factors associated with post-harvest losses – Drying

Drying is another integral part of post-harvest chain and it is very important to realize this process properly in order to prevent future deterioration or damage of maize. There are different techniques and different types, therefore the losses may differ according each phase (Mendoza et al. 2016).

Firstly, during the field drying, which is one of the first steps of post-harvest management, significant losses may occur. Weather conditions are one of the crucial parts in this section and it could be said that it has significant importance for the steps to follow (Mejía 2003). The weather conditions, such as rain, may result in moulding, loss of quality or even irretrievable damage. That is why it is impossible to use sun-drying in some tropical regions when the harvesting needs to be done during rainy conditions. Another possible damage of maize during the field drying may be caused by the wildlife animals and insects. The range of losses during the field drying may differ from 5 up to 30 % it all depends on the particular aspects but generally, according to the study of small-scale farmers of maize in Guatemala the average loss rank from 6-13% (Mendoza et al. 2016).

Along with another possibility of drying another possible loss of grains appears. The moisture level that needs to be achieved depends on the future length of storage. For instance, according to the study in Peru, where the best moisture content was studied for future metal silo storing, it was estimated at 14% of moisture level (Hernández et al. 2009). Another example from another study based in Guatemala, where 9 out of 10 farmers reported that they use drying before storage. While 3,5% of the farmers dry the whole plant, the rest remove the cob. The small-scale farmers in Guatemala also responded that they use both, sun-drying and also drying in Tapanco but none of them use the mechanical dryers (Mendoza et al. 2016). Generally, the factors that may affect the harvest

during drying phase are not so different from the drying directly at the field. However, the losses may differ according to what type of secure and improved techniques are used. In “on-farm” drying the harvest may be eaten by livestock for instance. Speaking in figures, the estimated percentage ranges from 7 to 14 % of losses during traditional post-harvest drying, while, during the more improved techniques, keeping the harvest in the shelter, the losses may decrease. The average losses during “on-farm” drying were estimated at around 5% (Mejía 2003).

4.7.8. Factors associated with post-harvest losses – Storage

Generally, the maize losses during storage depend on different factors. Starting with physical factors such as mechanical damage during harvesting or inappropriate drying which makes corn more vulnerable to be attacked by moulds and pests in the process of storing. The humidity level of previously dried maize is an important factor that contributes to the future losses during the storage. Together with the temperature it affects the losses in an essential way (Mejía 2003). Another important fact to mention is that the losses are increasing proportionally to storage time therefore, for long-period storing the maize must be kept in the most appropriate conditions in order to avoid deterioration or damage of the grains (Martínez 2009). The post-harvest losses of maize during storage period also vary according to the storage facility and structure used. According to the FAO the losses of grains during storage may reach as much as 50%, which is rather a high number. However, the amount of losses may differ again according to the particular conditions in particular countries (Lara & Bergvinson 2007).

Starting with the example of Honduras where the post-harvest losses of maize were also studied in different zones of the country. As it was previously mentioned, it all starts with the proper drying of maize grains and the case of Honduras is not an exception. For the most appropriate storing the humidity

level must be kept around 13%. Small-scale farmers that produce only for their own consumption but also the ones who produce for the future selling have to struggle with losses during storing. According to the statistics of this particular study, the average losses during storage reach 10% (Valdes et al. 2016).

As another example of the same case a study from Mexico can be provided. According to this study 63% of losses during harvest is caused by different types of pests. This particular example is comparable with the case of Honduras because in Mexico the biggest issues also occur during the phase of storing where the losses rise up to 12%. The study in Mexico was also focused on the different types of pest that are causing the damage. Different pests occur in different conditions and also the fact that some pests are nourished on the endosperm, the interior part of the grain, while other parasites attack the other parts of the grain that are more suitable for them (Baéz 2017).

Another study focusing on the types of losses during storage was held in El Salvador where the case study was based on the research of different types of insects. From the 75 interviewed farmers almost a half responded that their losses were caused by rodents, 24% by insects and the rest has not been specified (Deras 2012). As it was previously discussed there are many types of insect species that are very adaptable for living in stored maize grains. Moreover, according to the studies made not only in Latin America they play a major role in post-harvest losses of grains stored in the conditions of rural areas but also the maize stored for commercial purposes in more advanced facilities. The studies were also focused on the practices how to reduce these losses and different direct and indirect damage.

Direct damage is characterized as destruction of grains by insects, its excrements or by the dead insects that contaminate the grains, further on they turn the grains into inedible state. On the other hand, by indirect damage it is meant - the process of heating the grains by the metabolism of insects and development of microorganisms, which causes undesirable smell (Deras 2012). It is statistically approved that using the chemical treatment reduces the damages and losses in

higher extent. However, there is also the dark side of the chemical treatment, such as harmful effects on the soil etc. According to the study in Mexico, which was focused on the reduction of post-harvest losses of maize, the efficiency varies from 10% to 90%. The range is so wide because it is affected by a lot of factors such as appropriate utilization of pest control, weather conditions, humidity of the product etc. (Lara & Bergvinson 2007).

4.7.9. Factors associated with post-harvest losses – Transport

Transport, as the final step of post-harvest chain, also participates in the group of possible losses during post-harvest. However, in order to determine this parameter, the information would have to be obtained from the surveys done among the population which will state the quality of delivered product. Nevertheless, according to the study available the losses during transport are nearly negligible in comparison with for instance the storage phase. Since the sacks, used for transport, are previously cleaned and inspected before the grain is packed, so there is very small probability of transport losses but as previously mentioned it mainly relies on the prior treatment (Mejía 2003).

On the other hand, an analysis was made with small-scale farmers of maize in El Salvador and small amount of losses occurred in some cases. The research was based on the same group of farmers as in case of storage losses. 91% of farmers responded that they do not record any losses during the transportation. The rest had reported that during the transport they recorded losses due to the damage of bags (Deras 2012). The study of FAO also confirmed the fact that post-harvest losses during transportation are generally small, the figures vary from 1 to 2 %. The main factors contributing to the losses during transport are - the type of transport, effectiveness of the transport used, the quantity of grains and also the level of infrastructure (Mejía 2003).

5. Conclusion

The bachelor thesis was focused on post-harvest management of maize and post-harvest losses that are a negative but integral part of the post-harvest activities.

To great extent, the economic situation of Latin America is based on historical development, political situation and natural resources. The economic situation affects the agriculture production and the economy of the country and the agriculture sector are also closely connected. The main source of income still belongs to the agriculture sector, where a very significant part of the products are exported, mainly to the United States. In many cases inappropriate mechanization or even no mechanization exists, therefore, maize is exported in a raw form, not a mechanized form. The improvement of post-harvest handling practices of maize is essential for sustaining the independence of living of the farmers.

The appropriate post-harvest practices could prolong the shelf life and also the quality of maize in general terms. The post-harvest activities comprise harvesting, drying, processing, storing, packaging, transporting, post-harvest pest and disease control. The post-harvest losses occur in each of these phases with varied intensity depending on the particular conditions. The appropriate post-harvest activities would bring benefits i.e. the possibility to provide goods in better quality with longer shelf life and thus higher income for the producers.

However, due to lack of knowledge and insufficient technologies the losses occur in the post-harvest management. The loss of maize during the post-harvest chain may cause some future issues connected with food insecurity. Mainly, in terms of small-scale farmers, the post-harvest losses may be crucial because the farmers are dependent on their own production. The production of maize is a source of their income and also an essential source of food for them. If their production is not in sufficient quality and quantity, it increases the poverty and food insecurity. This issue may be called a vicious circle because poor public awareness of appropriate post-harvest practices causes production of poor quality, which further on results in low incomes, and low incomes mean a lack of money for food and it causes food insecurity.

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