FOOD LOSSES IN PRIMARY CEREAL PRODUCTION. A REVIEW
/
RISIPA ALIMENTARA LA NIVELUL PRODUCTIEI AGRICOLE PRIMARE. REVIEW

Oana-Mihaela Dumitru[1)], Sorin Iorga[*1)], Nicolae-Valentin Vlădut [2)], Carmen Brăcăcescu[*2)] [1]
[1)] National Research and Development Institute for Food Bioresources -IBA Bucharest / Romania;
[2)] National Institute for Research-Development of Machines and Installations Designed for Agriculture and Food Industry - INMA Bucharest / Romania
Tel: +0743046536, e-mail: soriniorga@gmail.com
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ABSTRACT
The food waste and losses (FW) became one of the most impacting aspects in modern society. This review article presents an overview of various aspects linked to the phenomenon of food losses in primary cereal production and its consequences. From the analysis of reviewed specific literature, it resulted that the losses are found both in the harvesting process and in the post-harvest processes (conditioning, separation, sorting, chemical treatment, transport etc.) these representing the primary processing of agricultural products, especially seeds. The review focuses on the new technologies' influence in reducing FW in harvesting and post-harvesting process, highlighting the contribution of agricultural engineering studies on this specific topic.

REZUMAT
Deșeurile și pierderile alimentare (PA) au devenit una dintre problemele de mare impact din societatea modernă. Acest articol de revizuire prezintă o imagine de ansamblu a diferitelor aspecte legate de fenomenul pierderilor de alimente în producția primară de cereale și consecințele acestuia. Din analiza literaturii specifice revizuite a rezultat că pierderile se găsesc atât în procesul de recoltare, cât și în procesele post-recoltare (condiționare, separare, sortare, tratare chimică, transport etc.) acestea reprezentând prelucrarea primară a produselor agricole, în special semințe. Revizuirea se concentrează asupra influenței noilor tehnologii în reducerea pierderilor alimentare în procesul de recoltare și post-recoltare, subliniind contribuția studiilor de inginerie agricolă pe acest subiect specific.

INTRODUCTION
The technical progress, social awareness campaigns and dietary evolution, the need of assessing and quantifying the food waste and losses (FW) remain of main interest for the scientific community (*Bräutigam et al., 2014; Mesterhazy et al., 2020; Mirzaadeh et al., 2015*). There are a lot of efforts of specialists around the world on developing FW reduction methods on the entire food chain, starting from seed to fork. According to a recent definition food waste is the difference between the amount of food produced and the sum of all food employed in any kind of productive use, whether food or nonfood (*Bendinelli et al., 2020)*.

In the acreage structure of world agriculture, cereal crops occupy more than half. Their main areas are in Asia, North America, Europe, Australia and Africa. Of these, rice and wheat are the most important food crops in the world. Likewise, wheat is food crop with the highest yield and ranks first among cereals (*Fu et al., 2018*).

On the other hand, grains are the main food items in agriculture. Grains like maize, wheat and rice account for 43% of all food calories and 87% of all grain production worldwide. Maize is the most consumed food in the world. Over 42% of the world's population depends on maize to fulfill its food requirements. About 87% of the whole maize output is consumed and produced in developing countries (*Khan et al., 2018*).

Mar'in and Vereshchagin (2016) considers that adverse effects on the grain may occur during cultivation, harvesting and post-harvesting handling or storage. During grain cultivation problems may be caused by edaphoclimatic conditions, affected grains, dead-ripe stage or overwintering in the field. During the harvest problems may be caused by mechanical damage, prolonged storage in heaps and waiting for post-harvest treatment. During post-harvest handling or storage problems may be caused by pests and microorganisms. High values of humidity and impurities can lower grain value by affecting their technological advantages.

[1] *Dumitru O.M., Eng.SR III, Ph.D.Eng; Iorga C.S., Ph.D.Eng.; Vlădut V., Ph.D.Eng.; Brăcăcescu C., Ph.D.Eng.*

Wheat sowing mechanization technologies were also analyzed in detail by *Creț et al. (2018).*

The Postharvest Losses (PHL) through deterioration of the grain quantity and quality that occurs in the time interval between harvesting and marketing or when it reaches the consumer, lead to loss of nutritional and monetary values as well as limited access to particular market segments. In many developed countries, postharvest losses of cereals account to 10-15%. Qualitative and quantitative post-harvest losses are mainly due to insect infestation. In search of food and shelter, they contaminate the grains with their by-products, making them unfit for consumption. Tropical and wetlands are most prone to pest infestation of stored grain (*Gach and Chlebowski, 2016; Mostafavand and Kamgar, 2014; Nkurunziza et al., 2015*).

Minimizing post-harvest losses through efficient post-harvest handling, primary processing, storage and marketing can contribute substantially to reducing production volumes needed to feed a growing population, resulting in improved food and nutrition security (*Odendo et al., 2017*).

One of the underestimated aspects of capacity building to reduce post-harvest losses is the personnel level of knowledge and their ability to manage grain stocks throughout their value chain. In general, the emphasis is on the introduction of state-of-the-art technologies and a little on the training of operating personnel *(Ileleji et al., 2017).*

Nowadays, the introduction of new technologies into the agricultural production requires constant upgrades of the machines. So, the present article is a part of the research that assesses the FW impact on primary production, by focusing on the technological influence in reducing FW in harvesting and post-harvesting process.

MATERIAL AND METHOD

The selection of articles was made by Elsevier search which included criteria related to the grain primary production, harvesting techniques' efficiency, food waste reduction. An initial 300 articles addressed some of the criteria. The final assessment selected 69 articles that considered food waste reduction in grain primary production process. The selection includes researches conducted in some of the main agricultural areas: SE Europe, France, sub-Saharan Area, China, India and South America. Manny of them are international cooperation projects that reunite researchers from USA, UE together with colleagues from Africa, or SE Asia.

From the analysis of reviewed specific literature, it resulted that in agriculture sector the losses are found both in the harvesting process and in the post-harvest processes (conditioning, separation, sorting, chemical treatment, transport etc.) these representing the primary processing of agricultural products, especially seeds.

The dynamics of mechanization and automation of agriculture is constantly growing: the current focus is on increasing the number of agricultural machinery and equipment and improving their performance.

1. Harvesting

Cereal harvesting is the final part of the agricultural production process and represents it's fulfilment. Nowadays, the demand for food is constantly increasing and because of this fact it is important to use proper technology that not only increases production on the same land area, but also preserves the biodiversity and the environment *(Ilea et al., 2013).*

The main problem about harvesting is to ensure timely collection and obtain minimum loss of grain production. In the same time, harvesting is also the process that requires the greatest weight in terms of resources (labour consumption and material costs), others than the mechanization technology.

Taking into account these aspects, the cereal harvesting combines are among the most complex machines, which are used in agriculture, as they are made up of different gears and specialised operating parts, but also of a lot of auxiliary technical and checking systems. Due to the reduction of the existing combine harvester park, physical depreciation of the machines, their obsolescence, increase in number of the broken machines, as well as an increase in the average load on the machine, it is important to choose the combine harvester that meets the conditions in the sector best. Upgrading the machines brings long-term positive results in technical and economic areas, so when choosing a combine harvester, one needs to analyse both the technical characteristics and the results of field trials *(Popa et al., 2010; Prístavková et al., 2016; Redlingshöfer et al., 2017; Shvedyk, 2015; Mahmoodi et al., 2007).*

A performant combine harvester needs to be a high-tech one in order to deliver high productivity with minimal crop losses, damage and minimal expenses on maintenance (*Zubkoet al., 2018*).

It is known that the combine productivity depends both on the technical parameters of the machine, and on the logistics factors. Such a factor is the place of unloading the full grain tanks (*Delchev et al., 2016*).

1.1. Straw harvesting combines

Straw grain harvesting is a very important operation that must be performed at the optimal time and with the lowest possible losses. On the other hand, the maintenance of combine harvesters is considered by the specialist as the main condition for a successful harvesting campaign (*Popa et al., 2010; Zubko et al., 2018*).

The evolution in the field of construction of agricultural machines has led to the emergence of *self-propelled straw harvesting combines* much better in terms of productivity, reliability, with a high degree of automation, ensuring an increased quality of harvested crop and increased operating comfort. To determine losses upon harvesting straw cereals operation, it is necessary to evaluate yield before harvesting. In straw grain harvesting the main losses depend on field state, on the flow of the thresher, on self-propelled combine components tightness, etc. Losses are presented quantitatively and as percentage depending on the yield evaluated being determined for each case apart. A higher power flow than optimal for straw harvesting combines can cause higher losses. Optimum feeding flow is established in accordance with the type of the harvesting combine and the field state, so that grain losses range within admitted limits. So, using straw grain harvesting combines rationally and at the optimum time ensures minimum loss and low expenses (*Duma-Copcea et al., 2017*).

In modern agriculture, combine harvester is a crucial farm machine which it is mainly used for the harvest of cereal crops (wheat, corn, oat, barley, etc.), soybean and sunflower.

Current modern combine harvester is a fully automated self-propelled farm machine that carries out multiples task s during its operation (Figure 1). The operation starts with gathering and cutting the crop by the header unit, then material is conveyed into threshing unit which processes it. Finally, the mixture of grain and chaff goes to the cleaning unit and the straws are sent to the separation unit (straw walker).

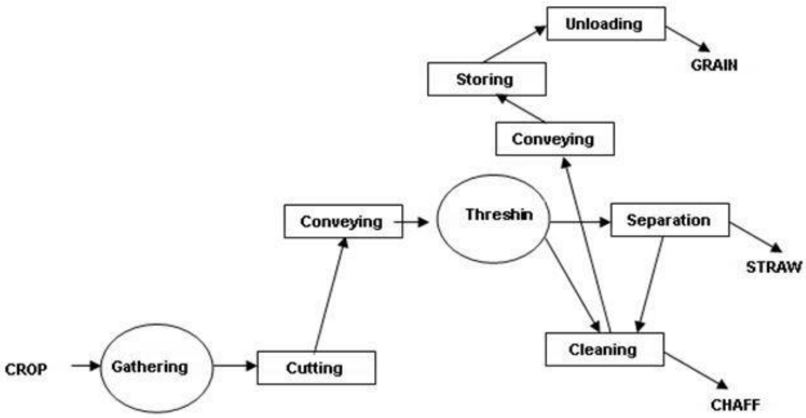

Fig. 1 - A simplified flow chart of the internal tasks of a combine harvester (*Keskin and Şekerli, 2018*)

The straw and chaff are dumped out of the harvester onto the field ground while the clean grain material is conveyed to the storage tank. When the tank is full, the grain is unloaded to a trailer through the unloading auger (*Keskin and Şekerli, 2018*).

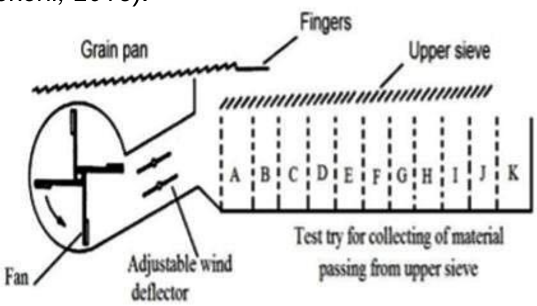

Fig. 2 - A schematic diagram of a cleaning mechanism (*Mirzazadeh et al., 2015*)

Bumbar et al (2018) consider as the most effective way to improve the harvesting process in general and increase the efficiency necessary for obtaining agricultural products to use a rational adjustment of the parameters of the threshing-separating device of a combine harvester and an optimization of the operation of the crop-harvesting equipment fleet, depending on the physical and mechanical properties of the harvested crops and the calendar time of harvesting.

The most important function of grain harvester is threshing, so grain damage and loss are significantly related to threshing theory and harvesting technology. Many researchers put their efforts to study grain-threshing devices, the results of these research have been the developing of different kinds of grain threshers or threshing components (*Alatürk and Şal, 2018; Tihanov, 2017; Tihanov 2019; Tang et al., 2015; Upadhayay et al., 2018)*.

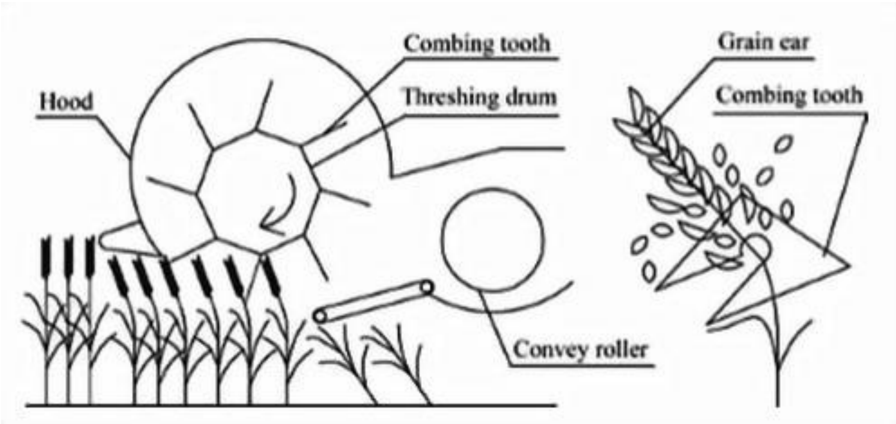

Fig. 3 - Pre-cut combing threshing harvester (*Fu et al., 2018*)

There are four kinds of threshing principles (impact, rubbing, combing and grinding) which led to the construction of four correspondently types of contact models between grain and threshing components. Grain damage can be regarded as a function of peripheral velocity and contact pattern of impacting, while grain loss can be regarded as a function of contact pattern of rasp bars. Grain loss coming in the subsequent process (cleaning and separation) of combing threshing was significantly decreased. Tangential and axial threshing technologies have been widely applied in modern grain threshing system. Research has shown that in the combined application, tangential rolls accelerate grain flow, and axial rolls increase threshing quality especially lower loss and damage. Also, conical concave may take the place of the traditional cylindrical one. With the development of sensor, digital technology and artificial intelligence, harvesting robot and automatic threshing system will be integrated together to improve grain quality, productivity and operator comfort (*Fu et al., 2018*).

In harvesting grain loss and damage are significantly affected by threshing performances so, higher level of threshing theory and technology are still the unswerving pursuit. A major parameter to evaluate the performance of grain threshing is loss rate. To improve quality of grain threshing, reducing the mechanical loss become a more practicable means. Another direct index of grain threshing which negatively affects the market value and storage is damage rate. Typical kinds of grain damage are mechanical and chemical damage. Mechanical grain damage comes from the impact of grain kernels and rigid surface of threshing unit of high relative speed (*Tang et al., 2017*). To find the morphological and textural characteristics of three views of grain when grain kernels free fall and impact, the method of high-speed digital imaging has been used. When grain is harvested during the rainy season, chemical damage is due to a complex of fungi. Previous research indicates that the grain chemical damage could decrease to the minimum level if grain crops are harvested at physiological maturity and then dried artificially.

In terms of harvesting machine performance in grain threshing system are widely applied tangential and axial threshing technologies. T-series of John Deere, four drums of New Holland and Fendt of Agco apply tangential threshing technology on threshing drum independently, while S-series of John Deere, Twin rotor of New Holland, APS of CLAAS, Axial-Flow of CASE IH, Challenger and Gleaner of AGCO apply tangential and axial threshing technologies together. Experimental research shows that in the combined application, tangential rolls accelerate grain flow, and axial rolls raise threshing quality indicators.

Fu et al., (2018), conclude that grain loss and damage are the result of mechanical action of threshing, so, the best solution for threshing quality is an intelligent threshing system. Manual intervention of farmers is difficult to be efficient during the grain harvesting process.

Because of the fact that material properties (moisture content, planting density, etc.) are diverse, the threshing system' s of speed and clearance should be controlled intelligently.

The development of sensors and hydromatic system contributed to the development of intelligent control system and mechanical threshing system to ensure improvement of grain quality and operator comfort.

1.2. Grain maize harvesting combines

Maize harvesting is a most important field operations on which maize production largely depends. The accelerating development of maize industry determined that mechanized maize harvesting to be widely accepted and used by farmers all over the world. The shortening of the harvesting period and the increasing of labour productivity depends of the scientific organisation of harvesting grain maize. Also, to obtain high yields per area unit with low expenses, it is necessary to strictly observe the cultivation technologies corroborated with the use of innovative aggregates with the highest efficiency possible (*Petrovska and Valkova, 2018; Li et al., 2016*).

Self-propelled combines for the harvesting of grain maize are made up of two main components: maize cob cropper and maize stem thrasher. The maize cob cropper has the role of detaching the maize cobs from the stems, carrying the leafless maize cobs to the thrasher and chopping the stems. The chopped stems can be loaded into a means of transport or they can be spread over the soil to be later incorporated into the soil. The maize stem thrasher thrashes the maize cobs, separates the grains from impurities, and carries the grains to the bunker (*Duma-Copcea et al., 2018*).

As the mechanized maize harvesting works have become more widespread worldwide lately, the choice of the optimal operating parameters of the harvesting aggregates are determining factors in increasing the productivity and quality of the harvested material and in reducing costs. Analysis of literature leads to highlighting of scientific research regarding the improvement of self-propelled grain maize harvesting combines and cob collectors parameters to meet increasing qualitative and quantitative requirements in work. Besides choosing the most efficiency variants of mechanisation technology in harvesting grain maize, for reducing costs other factors are important (periodical technical maintenance, optimum feeding flow of the thrasher, working speed correlating with field yield, movements of the combine during the day from one plot to another, daily working norm for each combine, the equipment adjusting depending on the maize cultivar being harvested, etc.). In order to obtain high yields per unit area with low costs, complex aggregates with high production capacity must be used (*Creț et al., 2018; He et al., 2017*).

According to the harvesting methods, maize harvesters could be classified into two types: maize-for-grain harvesters (including pickers and grain harvesters) and whole plant harvesters (including forage harvesters and combined grain-stover harvesters). Large size farms require big horsepower engines with working efficiency, automation and intelligence devices. Grain combine harvesters will take a large scale in the future with maize breeding development and with implementation of great varieties that are suitable for grain harvesting.

The purpose of mechanized maize harvesting is to replace manual labour to harvest maize from fields in time with minimum loss while maintaining high quality. The harvesting method and equipment depend upon planting pattern, agronomy and climate conditions. The entire harvesting operation may be divided into gathering, snapping, husking, cutting, threshing and cleaning (Figure 1). These functions are performed by different equipment, or can be performed by one equipment in a single pass depending on the method employed for harvesting, Among the biggest advantages of mechanized maize harvesting are increasing of productivity and reducing of human drudgery. The development of maize harvesting machinery can be traced back to the successful development of field operation machine of snapping, husking and stalk cutting. The emerging of new maize varieties with the ability of dense planting and high yield will cause the change of cultivation modes, especially plant row spacing. It is required to study new harvesting technologies and harvesters with higher adaptability; and at the same time, maize dense planting puts forward a higher request for picking ears and threshing technology. The research and development of new efficient picking ears, threshing and separation device will become the emphasis for improving the production efficiency and reducing the yield loss (*Milkias et al., 2018*).

Marek et al. (2019), performed experimental measurement during maize harvesting, cleaning and drying with grain moisture 23 - 35%. The purpose of coarse and light trash analysis was the next step to find out the losses of grain quality. The analysis of the internal grain quality from the starch, fats and proteins was then conducted.

1.3. Soybean harvesting and threshing

In soybean production, harvesting and threshing are the most important operations and for their optimization the knowledge of the physical- mechanical properties of soybean stem and seeds are therefore particularly important, as it is reflected into minimization of losses and mechanical damage (*Faggion et al., 2017)*. As it is known, soybean is usually harvested in the autumn season with high air relative humidity and possibility of rainfall. Because of this, the moisture content of soybean pods and stems are high, so during the harvesting and threshing operations, can occur some problems such that the conventional combine harvester can`t harvest the stem, thresh and separate the bean from its pod properly. For a proper designing and manufacturing pre-threshing dryer on combine harvester, determination of physical and mechanical properties of soybean pod is needed. Due to the distribution of pods along the plants, it is necessary to cut the entire crop using existing combine harvesters before threshing, separating and cleaning. About 40% of the combine engine power is used by the threshing cylinder who is located at a high level because it processes the stem in addition to the pods. As the moisture content of soybeans decreases, so does the amount of energy needed to shatter soybeans. To open soybean pods at impact velocities similar to those imported by the reel and cutter-bar of a combine a small amount of energy is necessary. So, the energy required to shatter soybean pod is correlated with moisture content and impact velocity. More information on the physical and mechanical properties of soybean is necessary for the efficient use of energy in soybean harvesting and threshing. To reduce harvesting losses, mainly due to pod shattering, especially designed equipment was developed. Also, to reduce impact on soybean pods and to reduce the cutting height, header components were modified. Shear force and shear strength of stems are important data in the design of harvesting and threshing machine (*Öztürk et al., 2017*).

1.4. Canola harvesting

Asoodar and Izadinia, (2012,) considers that in canola harvesting with common combine platforms, considerable losses is due by some mechanized harvesting systems. The amount of losses in combine harvester could decrease with the header extension through the increasing of the distance between platform auger and cutter bar. Also, it could be able to reduce grain loss by improving the conditions before harvesting and by using the hydraulic system instead of mechanical system and double knife cutter bar instead of the single cutter bar.

1.5. Rice harvesting

Harvesting techniques have a significant economic input. Results demonstrated that a harvester cutting and straw chopping combination was the harvesting method with the lowest operating cost, high yield, time savings and high net income (*Latif et al., 2018).* The rice crop harvesting time is an important parameter in respect of yield as well as in economic terms. A suitable time of rice harvesting and a suitable storage after harvesting allow to obtain a production with 10-15% higher. An early harvest can lead to a low yield and a long delayed harvest can lead to an increased percentage of broken grains and a decrease in yield (*Jewel et al., 2016*).

Rice with pericarp in various colours began to gain popular interest and increased consumption *(Promsomboon, 2018). Promsomboon, (2019)* considers that Kum Bangpra variety had greater yield than Riceberry under the same cultivation conditions. It was found that in lowland condition Kum Bangpra variety had straw-coloured husk, round grain with a dark purple color, a gelatinization temperature at 67°C which causes the cooked rice to become soft and sticky.

Present trend in the field of rice combine harvester is to increase harvesting capacity, reducing harvester losses, resulting in large combines with a high level of automation with high cost which is also resulting in soil compaction problem with modern farming system. *Adisa et al., (2016),* determined optimal operating parameters of a self-propelled stripper harvester prototype developed for Nigeria’s small farm size and intercropping farming pattern.

Postharvest losses to “stacks” of harvested rice in the rice-pulse systems are a major concern. The harvested rice is stacked before threshing for 2-5 weeks. Drying of grain and seed typically relies on sun drying. *Gummert et al., in 2016,* considers that late threshing and poor postharvest management practices by stacking rice in improper conditions can reduce both the quantity and quality of rice grain.

1.6. Hemp harvesting

A simple technological hemp harvesting solutions with practical applications in Latvia is harvesting of the hemp stalks in spring. The disadvantages of this technology are that there is a significant loss of product mass and a decrease in its quality. The possible solution for reducing these losses is raising the cutting height of the stalks when the seedy part of the yield is harvested (*Ivanov et al., 2015).*

1.7. Paddy harvesting

During production of paddy crop, harvesting is one of the major operations among all other operations which plays significant role in realizing the full benefit of raised crop.

Bhanage et al., (2016) conclude that in the range of field operations, the most important operations are paddy harvesting and threshing. These operations are laborious, involving human effort, requiring approximately 150-200 man-h / ha to harvest paddy alone. The main advantages of the paddy stripper harvester are: increased harvesting capacity, reduced power requirement and more time available for harvest. However, most of the straw is un-harvested and left in the field.

Stripper harvesting technology, which strips only seeds and keeps straw high in the field, has the bright prospects for mechanizing the harvesting operation in small and fragmented land. Specialists believe that for mechanization of the harvesting operation on small and fragmented lands is appropriate the technology of harvesting the stripper, which only strips the seeds and keeps the straw high in the field. This technology has the advantage of reducing the time required for threshing operation with the light mechanism and with a lesser power compared to conventional cutter bar combine harvester (*Bhanage et al., 2017).*

1.8. Lupinus albus harvesting

Of particular interest is the possibility of harvesting large grains of Lupinus albus by harvesters with axial rotary threshing and separating device. Their constructive peculiarity consists in the fact that the gaps between the rotor and a concave are large and allowing to work on light modes providing low damage of seed. So, the area of grain separation has improved more than the classic combines harvesters ensuring the allocation of grain from the heap. Experimental results has shown that the use of axial rotary combines or Lupinus albus harvesting allow reducing the seeds loss and damage *(Aldoshin and Didmanidze, 2018)*. Another advantage is that the casing in the threshing and separating parts can rotate in the passing or counter direction with the rotor. The locking elements provides the possibility of using the system with a fixed casing.

2. Postharvest

Postharvest cereal loss is the loss of grains between harvest and consumption. A poor post-harvest storage management can lead to postharvest cereal losses due to rodents, grain weevils and microorganisms (*Agwang and Okiki-Lating, 2017*; *Stathers et al., 2017; Westerman and Werf, 2007; Zaica et al., 2018)*. Adoption of improved postharvest storage modern facilities (e.g. open drums, metal silo, hermetic bags/ drums, etc.) or various preservation methods are major approaches towards loss reduction (*Ndiritu and Ruhinduka, 2019; Egessa et al., 2017; Ahmed, 1983; Njoroge et al., 2017*).

In Africa the level of knowledge of the operating personnel and their capacity to manage grain stocks through the grain value-chain is one of the understated aspects of capacity building to reduce postharvest losses. Most of the time, emphasis is placed on the provision of modern technologies that aid in improving grain quality and reducing losses during grain handling and storage, with little emphasis on training of personnel *(Ileleji et al., 2017).*

2.1. Storage

Efficient design for long term storage is impose by seasonal fluctuations in the harvesting of grains because the grains quality will be retained by proper storage. The qualitative and quantitative losses of grains in postharvest processing and storage at a particular geographical location are influenced by a lot of factors such as temperature, humidity, aeration, insect infestation, rodents, fungus etc. (*Loganathan et al., 2018; Jatkauskas and Vrotniakiene, 2006)*.

Cereals proper storage must not be neglected because of the importance and high demand of cereals for consumption. The postharvest grains damage caused during storage is mainly due to infestation by storage pest which causes huge quality losses in food grains and last but not least financial losses. This damage may be due to microbiological agents like fungi and bacteria or to direct feeding of grains by insects and pests.

The above storage losses can be minimized through use of proper pest management practices. Moulds and insects are different causative agents which cause economic and quality losses during storage.

The main reasons of fungal infection are humidity and non-aerated storage space. The only solution to avoid the infection is a proper drying of the stored product because due to their strong viability even a high aeration at the place of storage do not completely kill the spores *(Katagi and Malashetti, 2014).*

Postharvest losses (PHLs) are crop/product specific and occur at many stages in the supply chain (harvesting, drying, storage, market, transport, etc.). They are evident as loss of weight and loss of quality and are compounded by subsequent losses of market opportunity and lost production resources such as land, water, labour, agricultural inputs and soil fertility. By improving PHL estimates it will be possible to target loss-reduction interventions at the most affected areas (geographically), the most affected links in the postharvest chain or those links that would be most cost effective to address.

Suitable initiatives underpinned by modern rapid approaches to loss assessment are required to strengthen the ability of developing countries to collect relevant data, in the format needed by the system *(Hodges et al., 2010).*

The main physical factors that affect grain in storage are climate variables such as temperature, moisture content and relative. They influence insect and mould development, which lead to deterioration and loss of quality of stored grain. Higher or very low temperatures and low level of humidity are less likely to support the development of most of the pests and insects (*Ndiritu and Ruhinduka, 2019*).

The lack of centralized storage and the non-performance of grain conditioning leads to the fact that producers cannot perform a proper post-harvest handling and storage, not having grain drying units, pre-cleaning equipment and the required number of granaries. In addition, a proper grain storage requires higher financial costs, so not every producer can meet the necessary technological requirements of grain receiving and post-harvest primary processing. Also, the processing of the incoming grain mixture with another moisture content, hard-separable impurities and content of germinated grains using standard practice is costly or this grain is used for animal feeding purposes *(Mar'in and Vereshchagin, 2016).*

Because infection spread through the spores, which are present in the atmosphere everywhere and move by insect and wind it is very difficult in stored grains to identify the stage of fungal infection. Some of the obvious indicators of fungi infestation are blackening of grains and pungent smell. Improper storage spaces lead to fungal infection who completely altered grain quality, texture, and taste. Also food items acquire bad taste and have decreased nutritious quality. The main reasons of fungal infection are humidity and non-aerated storage space. The only solution to avoid the infection is a proper drying of the stored product because even high temperature at the place of storage does not completely kill the spores due to their strong resistance (*Katagi and Malashetti, 2014*).

Chen et al., (2018) considers that to ensure grain security in China reducing post-harvest grain loss represents one of the most realistic and effective ways. The results of their survey show that grain storage conditions followed by transportation have the greatest impact on post-harvest grain loss. To analyse the main factors affecting post-harvest grain loss during sales was used the Tobit regression model. The findings suggest that the seller's education level, experince of working as a seller, the conditions of grain storage, and the supply and management level of public facilities in the market were negatively correlated with grain loss in the sales process, whereas the seller's age, the separation of sales shops and storage warehouses, and the fall season were positively correlated with grain loss.

2.2 Seed treatment technology

Within primary processing and post-harvest technologies, cereal and seed treatment technology represents an area of great interest with high impact on environmental and food industry. Establishing a suitable seed and grain crops coating technology involves a thorough analysis of all the factors involved in the coating seed process (seed quality, special characteristics depending on the variety of seed, destination, etc.). “Seed treatment” means any process that seed have undergone before sowing in order to obtain high and stable yields.

Success in growing cereal seed starts with efficient treatment, so one of the criteria for seed quality assessing is chemical treatment with major implications for future crop development. Achieving a proper seed treatment technology of cereals requires a thorough analysis of all the factors involved in the process of seed coating.

To perform a proper seed treatment operation are used complex machines which are composed of rotating disc system for the spreading of the substance to treat and screw conveyor brush for better uniformity of coating substance on the surface of seeds. For the determination of the degree of coverage, speed rotating disc and screw conveyor speed are two basic parameters (*Zaica et al., 2016*).

Fusarium graminearum is the major causal agent of Fusarium Head Blight (FHB) of wheat and other cereals, a devastating disease responsible of yield and quality losses worldwide. It is actually able to produce a wide range of mycotoxins highly resistant to thermal and chemical treatments. Consequently, they cannot be removed from the crops and therefore, efforts to control FHB should be made before harvesting.

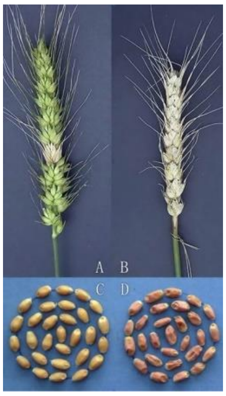

Fig. 4 - Wheat reaction to Fusarium graminearum A, PI 672538 spike, B, L661 spike, C, PI672538 seed, and D, L661 seed *(Li et al., 2017)*

Various studies demonstrated the importance of cultural practices and fungicides in the management of FHB but these methods are not sufficient enough to ensure high quality grains at harvest. Thus, it is important to find effective alternatives and the use of antagonistic microorganisms against *Fusarium graminearum* could become one of them (*Legrand et al., 2015*).

It is reckoned that a sizeable quantity of world's food production is lost due to damage caused by bacteria, mould, insects and other pests. One of the major cause of postharvest loss encountered in stored grains is the presence of larvae and adults of several insects.

Many of the postharvest chemical fumigants currently in use for control of insect infestation, such as methyl bromide (MB), ethylene dibromide (EDB) and ethylene oxide (ETO) are either banned or to be phased out because of their danger and adverse impact on human health and environment. There are also reports of development by major grain pests of higher levels of resistance to phosphine, the other major grain fumigant used worldwide.

Therefore, a long-term proper storage of agricultural products may be at risk as the traditional fumigants are phased out and/or due to development of increased insect resistance. Practical control of insect pests, regardless of species or stage of development is possible by low dose irradiation in the dose range of 0.2 to 0.5 kGy. The advantages include short treatment time, no undesirable chemical residues in the food, no resistance developed by the insects and no significant changes in the physicochemical and functional properties or the nutritive value of the product (*Thomas, 2001*).

2.3. Drying

Specialists believe that by taking away of water contents from agricultural product, drying provides extended period of shelf life. Solar energy is used by the solar air heaters to heat air and it can be engaged in many applications, for example heating of spaces and drying of crop material. The drying is carried out in two processes. In the first process, the vaporization of moisture hooked on the atmosphere from surface of the substance at stable rate of drying takes place. In the second process, drying rate decreases because it decreases with moisture content or decreases with increase in air humidity.

Fig. 5 - Comparative test of multipurpose solar dryer (left), drying tray in open-air (centre), and tarp in open-air (right) *(Ileleji et al., 2017)*

Solar dryers are the machines that organize the drying practice and prevent the agriculture product from being destroyed by insect pest, rain and dust. *Khan et al., 2018*, designed and developed the solar collector for air heating and evaluated the energy requirements for the drying of grains. Blower was used to scatter the air that strike the grains. A solar collector was joined with the bin in which grains were kept. The solar collector was 6m long, 4 m wide and 0.3 m deep. The material used for absorber plate was steel metal sheet. For glazing, a single glass with 6 mm thickness was used. They used plywood as an insulating material for the body of the solar collector. They tested the performance at seven different convective air flow rates. They found that the drying efficiency of the solar collector was 10% higher than all previous conventional methods. Statistical analysis was also done to check the performance of the solar collector and showed that the flow rate of hot air increased its performance (*Khan et al., 2018*).

Cardoso et al., (2015) evaluates the influence of the moisture and type of drying applied to grains on the level of carotenoids in yellow maize. Based on the results, they recommended that the harvest be done preferably when the grains present 22% humidity, followed by drying in a dryer or in shade.

CONCLUSIONS

Considering the system or the agro-food chain as a whole, harvesting can be seen as the connecting operation or binder between the pre-harvest operation, corresponding to production activity and the post-harvest operation, extending from harvesting to marketing and consumption.

For the purpose of business development, producers of agricultural products from all countries focus on determining the ways to increase the gross harvesting of products, and improve its quality indicators. In order to deliver high productivity with minimal crop losses, damage and minimal expenses on maintenance, the combine harvester needs to be a high-tech one.

Postharvest loss is a complex problem and it vary for different crops, climatic conditions, agriculture practices, and the degree of industrialization and economic development of each country. Therefore, reducing food losses contributes to global food demand satisfaction and to continuously improving food security and increasing resource use efficiency.

In postharvest operations more than one-third of agriculture production is lost or wasted while fulfilling the food demand of an increasing population remains a major global concern. In developing countries, especially, reducing the postharvest losses, could become a reliable solution to increase food availability, eliminate hunger, reduce pressure on natural resources and last but not least to improve farmers’ livelihoods. Modern technologies and improved storage structures can successfully reduce postharvest losses and increase farmers’ revenues in the same time. Using the sealed waterproof bags or structures (hermetic storage creates an automatic modified atmosphere of high carbon dioxide concentration) lead to significant reduction of losses due to insect infestations. With the help of properly sealed hermetic storage structures storage losses reduced by 98%, maintaining the quality and long-term viability of stored seeds.

Using the latest agricultural practices and adequate innovative technologies on primary cereal production farmers all over the world can significantly reduce the losses, help strengthening food security and at the same time to increase their profit.

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