QUALITY INDICATORS FOR COMBINES WITH DIFFERENT THRESHING SYSTEMS

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Abstract

The operation of cereal and oilseed crop combines is based on several key factors: increased reliability, prolonged mechanical endurance, accessible maintenance for every farmer, timely and cost-effective harvesting to reduce expenses, and meeting quality, energy, and operational standards. The manner in which combines are used, operated, and maintained is of utmost importance in achieving higher productivity and maximum economic efficiency. Knowledge of the operational potential of these machines can significantly influence productivity and result in peak production performance. The cereal harvesting process involves several complex stages, including cutting the plants, threshing (separating the seeds from the rest of the plant), collecting, and transporting the resulting products (grains, chaff, plant residue). Self-propelled combines offer several advantages, including higher maneuverability, greater working width, increased working speed, and the ability to be adapted for harvesting different crops.

Key words: harvester, threshing systems

Harvesting cereal crops with combines is a crucial task among agricultural activities. Therefore, combine harvesters must meet certain technological aspects, requirements related to the type of crop, field conditions, weather, post-harvest technologies, as well as quality performance indicators for cereal processing. The importance of combine harvesting stems from several considerations:

- It is the primary method of cereal harvesting worldwide;

- It is seasonal, requiring timely completion within a short period (e.g., 4-6 days for wheat harvesting) with minimal grain losses.

Ideally, harvesting a crop begins when the content of valuable organic substances (proteins, lipids, amino acids, etc.) in cereals reaches its peak. When the weather is uncooperative, plants may fall to the ground. The combine machine is capable of picking up and cutting these plants and processing them correctly inside the machine. Failure to introduce cereals into the combine can lead to significant losses (Matthias N., 2020).

For better quality and quantity of grains, sometimes it is better to modify the harvesting and storage technology, for example, by initially cutting the plants and placing them in rows, followed by later threshing, separating, drying, and so on.

The combine should have a modular design that allows for the connection of various equipment or subassemblies, such as different headers and more, to be equipped and operated flexibly for a variety of cereal crops. Consequently, the combine and the appropriate equipment are adaptable and flexible, meaning they are versatile.

The parameters of the combine process are adjustable within relatively wide ranges to meet technological requirements for processing a variety of cereals and residues that vary in terms of shape, size, moisture, mechanical strength, aerodynamic properties, and more (Marcal D., 2020).

The machine's speed varies depending on harvesting conditions, while the parameters are maintained at optimal values.

Proper operation of the machine results in efficient harvesting. This can be significantly improved through machine monitoring and control.

The combine also provides operator comfort (less dust, noise, and vibration, coupled with suitable temperature and humidity control) in an optimally controlled cabin, which is of great importance for the design, manufacture, and operation of the machines (Liang X., 2021).

Increasing the combine's forward speed is determined by two fundamental requirements: increasing cereal production and the need to

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harvest cereals under optimal conditions in optimal time periods. Self-propelled combines have already reached the road width limit, so continuous and cost-effective improvement of combine performance will undoubtedly be achieved through modeling, simulation, and optimization of both processes and component design, along with the implementation of a high level of process automation, control, and improved grain transportation and storage logistics.

The combine's operating rate can be further improved by working continuously in the field until the entire harvest is completed (avoiding transitions between different fields), providing sufficient trailers for unloading harvested grains on the go and for transportation, scheduling operators in shifts with adequate breaks, and maintaining good performance through preventive maintenance. Adequate capacity for grain storage, drying, or post-harvest processing is highly desirable (Ivan G., 2021)

The threshing unit/system of the combine is the most critical assembly in terms of the working processes and power requirements. A tangential threshing unit primarily consists of a rotating unit called the threshing drum (commonly known as the cylinder) and a concave (a perforated grid) whose position can be adjusted relative to the cylinder through a manually or automatically operated mechanism.

The speed of the cylinder is continuously adjustable, as required by the threshing process of different crops.

In a tangential threshing unit (*figure 1*), the crop material passes through the narrow space bounded by the rotating scraper bars of the cylinder and the concave surface.

As high-speed films show, the threshing process primarily occurs due to the impact of the rasp bars or other active elements on the material, accompanied by friction and pulling by the rasp bars and concave surface (Leontescu M., 2016).

The action of the ribbed bars and the concave bars in separating the grains and chaff from the straw is controlled by the adjustable rotation of the cylinder relative to the concave grid, through which the threshed mixture (seeds and fragmented plant residue) is separated and then falls onto the cleaning system.

The tangential threshing module and straw walkers have been completely replaced with a larger rotary threshing system. In this system, the continuous material flow moves in a helical path within the space bounded by the rotor and a 360° wrap-around concave and cage system.

The axial flow threshing unit (*figure 2*), AFX, consists of three zones: feeding, threshing, and separation. The feeding transition cone draws large volumes of crop material into the threshing space. Inside the concentric cage of the rotor, there are adjustable vanes to control the crop flow rate.

This configuration allows for higher material throughput and lower power requirements. Compared to tangential threshing systems, rotary systems offer the following advantages:

- Reduced damage to fragile grains;
- Better adaptability to all crop processing;
- Low cereal losses;
- Low sensitivity to variations in volumetric feed rate;
- Small variation in grain losses with increasing residue-to-grain mass ratio;
- Very efficient in threshing crops with relatively high moisture content;
- Although the specific power requirement (kW/(kg/s)) of the axial system is 16% to 20% higher, the throughput capacity is 50% to 90% higher in axial systems compared to tangential systems, thanks to increased separation intensity in rotary threshing;
- Fewer adjustments, lower vibration levels, and less maintenance compared to straw walkers.

Because rotary combines do not preserve the straw quality, it is more challenging to bale or remove it from the field, although it is easier to incorporate the crop residues resulting from rotary combines into the soil furrows during plowing.

Figure 1 **John Deere 9560i conventional tangential threshing unit**

Figure 2 **John Deere S660i axial threshing unit**

MATERIAL AND METHOD

The research was conducted within an agricultural unit. The research aimed to test threshing and separation systems in the field for wheat and corn crops, adjust speeds, distances, clearances, and other parameters at various values to identify optimal settings, identify the slip coefficient, identify and quantify losses, calculate energy consumption per unit area and per ton of harvested product.

The analysis and interpretation of the data considered:

- Identifying the main causes of reduced productivity and seed quality;
- Establishing adjustments based on threshing technology to increase productivity and reduce fuel consumption;
- Comparing the two threshing systems in terms of forward speed, productivity, loss levels, energy consumption, and optimizing these factors.

The research material used consists of two combine harvesters for cereal and oilseed crops, namely the John Deere S660i and John Deere 9560i. Both are equipped with similar engines that develop the same power, have grain headers of 6 meters, and oilseed headers with 8 rows. These combine harvesters were monitored during winter wheat and corn crops.

The John Deere S660i is an axial flow combine harvester with a single rotor from the year 2019 and a power of 335 kW (450 horsepower). It is equipped with a 6-meter-wide grain header for cereal crops, which includes a rapeseed extension, and for oilseed crops, it has an 8-row Geringhoff header equipped with a crop residue chopper at its base.

The John Deere 9560i combine harvester is a transverse flow combine with 6 straw walkers and a power of 335 kW (455 horsepower). It is equipped with a 6-meter-wide grain header for cereal crops and an 8-row Geringhoff header for oilseed crops, which also includes a plant residue chopper at its base.

The quality of work performed by grain combine harvesters can be determined using the following quality indicators: grain losses, grain breakage rate, and grain purity.

Grain losses at the cutting platform consist of cut or uncut grains and ears left on the ground. These losses are determined using a frame with an area of 1 m^2, which is positioned at various equidistant locations on both sides of the straw windrow left on the ground after the combine passes.

Common areas where losses are typically observed include at the cutting platform joints, at the fan housing, at the cutting platform's junction with the threshing unit, at the threshing unit, at the grain elevator housing, at the grain bin, at the corners, and so on.

Quality indicators for corn harvesting machines may include the following: when harvesting corn in the form of grains, quality indicators refer to the percentage of losses, damage, and grain purity. Corn harvesting losses can occur as free grains on the ground from the cutting platform, from the snapping rolls, or from the shakers and cleaning components. They can also be in the form of grains left on the cob and free on the ground and on unharvested plants. Total grain losses in the full harvesting of corn using a combine that is equipped and adjusted correctly should not exceed 2.0% of the harvest. The percentage of grain damage should be below 8.0%, and grain purity should be over 98%. Additionally, there should be no more than 0.5% of grains left on the cobs, and 0.4% of grains in the husks.

For the tests we used the Glossa wheat variety and and Pioneer P1241 FAO 560 corn.

RESULTS AND DISCUSSIONS

Quality indicators for grain combines are metrics that assess the performance and quality of the combine's work in the harvesting and cleaning process of grains. These indicators can vary depending on the model and technical specifications of the respective combines.

Separation Quality indicates how well the combine separates grains from straw and other plant residues. Effective separation ensures a high yield of clean grains and minimizes impurities in the harvest. Grain Breakage indicates the proportion of grains that break or get damaged during the harvesting and cleaning process. A low level of grain breakage is essential to maintain the quality and value of the harvested grains. Grain Losses represent the quantity of grains lost during the harvesting and cleaning process. Grain losses must be minimized to achieve maximum yield and superior crop quality.

Uniformity of Grain Moisture measures how uniform the moisture content of the harvested grains is. These quality indicators can be influenced by various factors, including the technical characteristics of the combine, proper settings and adjustments, as well as harvesting and crop conditions. From *table 1* and *table 2*, we can assess the performance of the John Deere S660i combine compared to the John Deere 9560i based on the quality indicators obtained during the wheat and corn harvests at the speeds of 6 km/h for wheat and 9 km/h for corn.

Table 1

Grain loss indicators for John Deere S660i and John Deere 9560i

	John Deere S660i		John Deere 9560i	
	Wheat	Corn	Wheat	Corn
Total grain loss	1 %	0.8 %	1.5 %	1.4 %
Header grain loss	0.69 %	0.60 %	0.90 %	0.85 %
Threshing unit grain loss	0.21%	0.11 %	0.35%	0.30 %
Straw grain loss	0.10 %	0.09 %	0.25 %	0.25 %

Table 2

Seed purity and breaking degree for John Deere S660i and John Deere 9560i

	John Deere S660i		John Deere 9560i	
	Wheat	Corn	Wheat	Corn
Seed purity	99.0 %	98.9 %	98.8 %	98.5 %
Seed breaking degree	0.8 %	0.5 %	1 %	0.8 %

CONCLUSIONS

The total loss percentages obtained for wheat and corn were 1% and 0.8%, slightly lower than those of a conventional combine.

Total grain losses during combine harvesting were influenced by several factors:

- Incorrectly adjusted combine settings can lead to grain losses. This includes improper adjustment of the threshing and separation system, the unloading system, and other relevant components. It is essential to follow the combine's user manual and make proper adjustments to minimize losses;

- Excessive combine harvesting speed can result in grain losses. Slower harvesting can help reduce losses because it allows the threshing and separation system to work more efficiently.

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