Conclusion. We can summarize the main results of the previous works in the following main points:

1. Under the influence of the probiotic feed additive Basulifor, the body's physiological, hematological, biochemical, and immunological blood serum parameters in animals and birds are activated.
2. On using the probiotic feed additive, there is an increase in the meat productivity of animals and birds, which is expressed by stimulation of the intensity of the average daily weight gain.

Future Plan for our experiments: Our experiments aim to specify the recommended amount of Basulifor in the broiler parent stock's mixed feed to improve the chickens' safety and reproductive qualities.

1) The scientific and economic experiment will be carried out on chickens of the parent flock of broilers of the Cobb-500.
2) The duration of the experiment will be 42 weeks. Three groups of 100 animals each will be formed using pairs-analogs by live weight.
3) The birds of each group will be kept in a separate house. Chickens of the control group will receive the main diet adopted in the economy.
4) The hens of the experimental groups will be given the primary diet of 0.3 kg/t and 0.5 kg/t of probiotic compound feed (Basulifor).

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ANALYZING SOME DESIGN AND PERFORMANCE PARAMETERS OF A COMBINE HARVESTER IN TERMS OF ITS AUTOMATION

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Abstract. *The paper article examines the relationship between header width and engine-rated power in combine harvesters (CHs), with an emphasis on the influence of automation on operational and quantifiable performance characteristics. The least squares method was used for analysis, and a logistic regression model was found to be the best fit. The article goes through several aspects to consider while conducting CHs selection methods.*

Keywords: *Combine harvester, logistic regression, operator, AI*

Introduction: Combine harvesters (CH) have passed succession of technological evolutions since the development of world's first CH in 1885 by Hugh Victor McKay and combined with steam engine by George Stockton, following the utilization of horse powered harvesters of 1830. In a nut-shell, CHs have advanced from the horse and mule pulled/pushed, tractor operated, through the self-propelled and electronic assist system to the fully automated/autonomous system of today's combines [1].

With the progressive sophistication of CH precision of operation has captured the minds of investors and researchers. Both qualitative and quantitative grain losses, variation in throughput, and measured yield that occur across neighboring harvest swaths were evaluated as features of possible machine/operator variability [2]. The task facing combine operators is not simply to drive around the field in a serpentine pattern, mowing the crop there; rather, there are hundreds of things they must observe while keeping their eyes focused on the edge of the field to ensure that they travel alongside it with precise accuracy. Because one cannot harvest grain without moving forward, driving takes precedence over the other large number of operational factors demanding operations/responses, which negatively affect harvesting efficiency [2].

The large number of tasks thus contributes greatly to the facilitation of operator fatigue, increases the response time of operators over time in general, and is quite challenging for inexperienced operators. This has a negative influence on the qualitative and quantitative aspects of the output that impacts the entire performance of CH and, thus, the profitability of the harvesting system as well. Consequently, the concept of complete (sensor-based) automation [2] and/or artificial intelligence (AI) – came into effect to reduce the tasks of an operator [3].

Moreover, selecting the right CH for specified situations that are advantageous in all aspects is quite challenging.

Objectives: The objectives of the study are to determine the relationship between the increase in engine rated power and the header cutting width of the CH and the effect of the operating mode and the level of complexity of control on the productivity of the CH.

Methodology: In this article, the pattern of increase in the cutting width of the CH header with the rated engine power and the effect of change in a single factor (input) of a parameter (from the set of parameters) on the complications in the decisions that need to be taken to improve the CH performance that led to partial or complete automation are analyzed. The role of the operators in the CH productivity and progress towards full automation are also briefly discussed.

Information was gathered on 75 models of New Holland CHs from different years of production (1975-2023 figure 1[A]) in order to assess the relationship between the width of the header and the rated engine power (kW). The least squares approach is used to choose the relationship, which leads to further analysis.

Result and discussion:

1. Analysis of the header cutting width and rated engine power

The randomly selected CH of a range of models and made in different years are plotted in Figure 1 [A]. The bars indicate the number of CH of range of models produced in the respective year/range of years. Least square method was selected and the following observations were recorded: the pot of actual versus predicted values (cutting width) were relatively close to each other, with $r^2 = 0.81$ and $P<0.0001$, leverage plot had no influential points (outliers) with $P<0.0001$. In the case of the residual vs. predicted plot, however, the variability was not constant (Fig. 1 [C].), which led to the selection of another model to represent the data – a logistic regression model. The analysis of variance is summarized in *Table 1*. From the parameter's estimations the slope of the line of fit (least square) and the intercept were found as 0.01435 and 2.735, respectively.

Table 1.

Variance analysis

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	1	82.17494	82.17494	321.35	<0.0001
Error	73	18.66743	0.255718		
C. Total	74	100.8424			

Based on the above results of the least square analysis and on the nature of the data it was found that the logistic regression model with the equation below best reflects the relationship between the cutting width and the increase in rated power.

$$Y = \frac{1}{1 + e^{-(2.745+0.01435X)}}$$

In the first phases, the width increased as the rated power increased at an increasing rate; however, as the power grew more, the width expansion goes asymptotically as expected (Fig. 1[B]).

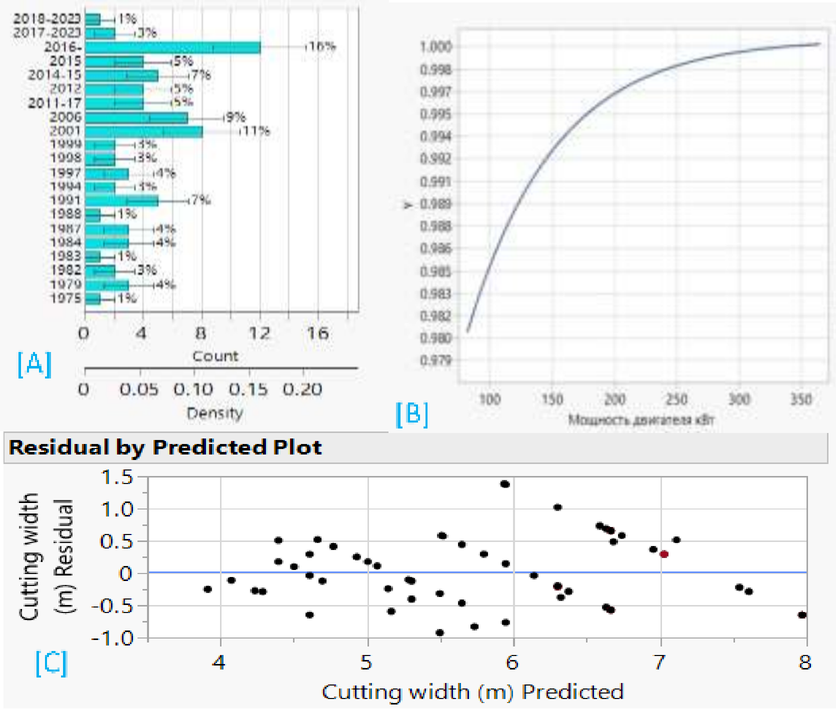

Figure 1: Combines distribution over the years [A], width of cut versus rated power of combines [B] and cutting width residuals versus predicted of the [C]

2. Effect of parameter change on CH performance

A combine's performance has been improved throughout time by a variety of technical changes, which have increased the amount of power needed. The efficiency of each processing unit determines the machine's total performance, which relies on a variety of dynamic or static circumstances for specific parameters (design, operational, and crop parameters). It is necessary to continually alter the operational settings for a particular design when the crop parameters vary [4].

The forward speed of the CH can be increased to increase throughput, but this escalates cutterbar losses and material feed rate, which necessitates an increase in the threshing cylinder speed and/or the concave-grate and threshing cylinder clearance. Higher threshing cylinder speed can minimize unthreshed grains and improve separation efficiency, but grain damage escalates exponentially[2,4,5]; raises straw breakup that intensifies the amount of chaff on the cleaning unit, which calls for raise in fan rotational speed and sieve oscillation amplitude. But fan speed increase results in lighter grains being blown away, contributing to the sieve loss; increases material feed rate to the separation unit, which may call for an increase in crank speed of the straw walker (conventional combines) or rotational speed of the separator (rotary separators), or otherwise results in an elevated chance of free and unthreshed grains to leave the combine with the straw mat. Increasing the concave-threshing cylinder clearance reduces grain damage, but leads to a larger amount of unthreshed grain and separation efficiency is reduced.

The best combination of combine forward speed, threshing cylinder rotational speed, and concave-grate-threshing cylinder clearance is necessary to maximize separation efficiency, minimize threshing loss, and minimize grain damage. These parameters are influenced by the grain and straw moisture content, type of crop, and material feed rate, which is determined by cop-cutting height.

The crop cut height determines the material feed rate (which in turn influences the operational parameters described above) and the MOG/grain. For different MOG/grain, the threshing, separation, and cleaning units have to determine suitable operational situations to optimize the overall performance of the CH. Because of this, the effectiveness of a CH would rely on the operators' ability to choose the best operating parameter combinations for a certain design and crop condition.

In order to improve machine and operator efficiency, reduce loss, and maintain grain quality while minimizing costs, CHs need to continuously alter their processing settings, depending on the conditions encountered. The operator's capability to handle various duties and make the optimal choices is constrained by the technical complexity of integrated harvesting processes. Additionally, since they must supervise the threshing, separation, and grain unloading operations, as well as keep an eye on crop flow input, combine operators are highly susceptible to fatigue [2].

3. Effect of operators on CH performance

The CH throughput can be seen on the perspective of inexperienced and experienced operator-operated, and automated. Generally, operators’ productivity decreases over time, mainly due to fatigue, i.e. the response capability of operators slows down overtime as they become more fatigued [4,6].

The throughput quantity and quality of the combines are far lower in cases of inexperienced operators compared to experienced operators, as they can be reluctant or slower to understand the operational changes required. The performance of the CH suffers as the operator’s productivity declines during extended operations. The ever-growing number and complications of additional accessories to be continuously manipulated have pushed the system towards complete automation. Hence, sensor-based automation of the operating parameters has been implemented to address these drawbacks.

In order for the operator to concentrate on steering and unloading grains, sensors are mounted on the major processing units to automatically control the operating state and performance of that particular unit and adjust the operation as required.

Consequently, a high degree of automation in CH processes that led to designing fully autonomous machines, called for enhancements in sensor technology, the incorporation of fine-adjustment mechanisms, the collecting and processing of data in real-time, and the application of algorithms for process maximizing, decision-making, and machine control, thus necessitating the development of mechatronic CHs capable of adapting to spatially varying crop yields – precision agriculture.

Various sensor types that measure and monitor material properties, process parameters sensors, mechanism/device adjustment monitoring sensors, machine-steering and speed control sensors, cab ergonomic sensors, system functionality diagnostic sensors, and sensors for multispectral remote sensing data, are combined in a single CH to enhance and maintain consistent harvesting performance.

Even if the mechanical design and manufacturing method have altered somewhat in recent years, CH design has incorporated several innovations in sensor and control technology, improving functionality, overall efficiency, work quality, and operating conditions [2].

CHs are highly variable depending on their operation and level of automation. Some are operator-dependent, while others are totally automated with high performance, adaptability to changeable scenarios, little grain loss, and maximum grain quality processing. Internal systems may need highly trained personnel and operators, as well as complex service and maintenance procedures.

Conclusion: Logistic regression model is used as a best fit (as expected) to the CH data. When employing combine harvesters for pre-defined purposes and situations, many factors should be taken into account, one of which is a clear knowledge of the totality of variability and level of complexity required for a specific task: yield, situation, environment, social sphere, etc. The degree of complexity is determined by the level of automation in this study, which, in turn, depends on the use of sensors.

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