Sweetcorn grain production technology

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Abstract: *The presented research results concern the amount of work and energy incurred in the grain production technology and the aspect of the quality of separating grain from the cob cores. The dynamic increase in the area of sweet corn cultivation for processing purposes (canning, freezing) affects the fact that manual harvesting is increasingly being replaced by combine harvesting. It ensures higher and energy-efficient work efficiency, as well as harvesting at the optimal stage of ripeness, which is particularly important in the case of sweet corn. Sweet corn cobs of the Candle variety were harvested with a Bourgoin combine harvester at the stage of late-milk maturity, and then subjected to processing consisting in de-shirting and cutting off the grain The quality requirements of the separated grain are, m.in: smooth surface and equal length of the cut grains, no mechanical damage and low losses of weight and nutrients. The quality of the separated (cut) grain was analyzed by measuring the length and surface condition of the cut grain. Grain with weight losses was classified as grain of inferior quality. The grains were cut off on a cutter for variables ranging from 167.5 to 301.2 rad/s angular velocity of the knife head and constant linear speed of the cob feeder 0.31 m/s. For comparison purposes, grain is divided into three classes. The workload incurred for the combine cob harvesting was the highest for post-harvest processing of cobs - 31% and soil cultivation - 27%, and energy expenditures for soil cultivation - 341 kWh/ha and for combine harvesting - 285 kWh/ha. The length of the cut grain increased by 26% in class I, and decreased by 14% in class II and by 11% in class III. On the other hand, the share of grain of inferior quality decreased in class I by 5%, in class II by 7% and in class II by 3%.*

KEY WORDS: *SWEET CORN, LABOUR AND ENERGY INPUTS, HARVESTING, GRAIN CUTTING*

Introduction

Sweet corn is a plant whose sown area, both for the needs of the so-called fresh market and for processing purposes, in Poland and in the world is steadily increasing (Czarnecka 2024; Hryhoriv et al., 2023; Revilla et al., 2021; Cartea 1996). According to the Central Statistical Office, in 2023 the area under sweet corn in Poland was about 14,000 ha. The cob harvest is about 150 thousand tons. (data from 2021). It is produced mainly to supply processing plants (cans, freezing), a small amount is directed to the fresh vegetable market (Czarnecka, 2024).

Interest in it results both from the high nutritional and nutritional value of grain, as well as from the new form of its acquisition. Unlike fodder varieties, the cobs of which are harvested at full maturity and intended mainly for fodder purposes, sweet corn cobs are harvested at the stage of milk or late-milk ripeness and intended for human consumption. Harvesting at this stage of maturity means that commonly available and used machines for harvesting cobs or separating grain cannot be used. The continuous adaptation of foreign varieties to domestic conditions, the lack of tradition in its cultivation, the lack of sometimes close proximity to markets (processing plants, agricultural exchanges), as well as the increase in the quality requirements of the raw material on the part of the consumer and the processing plant cause that its dissemination encounters a number of difficulties. Currently, due to the relatively high fragmentation of this crop and the high cost of specialized equipment, about 95% of manual harvesting is carried out in the country. Harvesting using this method guarantees a relatively high quality of the harvested raw material, but requires a lot of labour, especially on large areas, where the time of harvesting and the speed of its storage affect the quality of the grain. The increase in labour costs, as well as competition from countries with larger acreages and better climatic conditions (France, Hungary), will mean that only raw material from large areas and from combine harvesting will be able to compete on the market.

Harvesting cobs for processing purposes (freezing, canning) is the first stage in grain extraction. Further confluences related to the separation of cover leaves and grain from corn cobs are carried out using special machines. The requirements for the quality of the separated grain include, m.in: smooth surface and even length of the cut grains, no mechanical damage and low losses of weight and nutrients. They depend on the morphological characteristics of the cobs and grain, its moisture content and mechanical strength, as well as on the parameters of the cut-off process (Brecht 1998).

The introduction of modern technologies is conditioned by the possession of efficient and energy-saving sets of machines, ensuring timely performance of all agrotechnical treatments. Hence, research is undertaken to reduce both labour and energy inputs and the production costs of maize grain.

The aim of the study was to determine the amount of work and energy (mechanical and electrical) incurred in the production technology of maize grain and the quality of its separation from the cob cores.

Material and methods

The basic research was preceded by the determination of the characteristics of the material, including selected morphological and physical properties of sweet corn cobs (Table 1).

Table 1. *Characteristics of the studied morphological and physical properties of sweet corn cultivar Candle*

Specification	Results		
	from	to	mean
Weight of the cob with leaves	278,1	436,2	352,2
Weight without leaves, (g)	301,1	399,2	332,1
Weight 1000 grains, (g)	451,2	445,2	448,7
Share of grain in the cob, (%)	70,2	75,3	74,3
Grain moisture, (%)	72,1	7,5	74,3
Corn cob length, (cm)	18,4	24,6	19,8
Corn cob diameter, (mm)	46,8	52,3	49,8
Number of grains per row, pcs.	34,5	44,1	36,4
Number of grain rows, pcs.	12,2	16,6	14,2

The starting material were cobs of the Candle variety, the grain of which was intended for processing purposes (canning). In the grain production technology, technical equipment was used, consisting of a self-propelled Bourgoin harvester with a power of 166 kW and a URSUS U-1204 tractor with a power of 86 kW and a transport trailer. The cobs harvested at the late-milk maturity stage were transported to a processing plant about 2 km away, where they were further processed (separation of cover leaves and grain from the cobs) (Fig. 1).

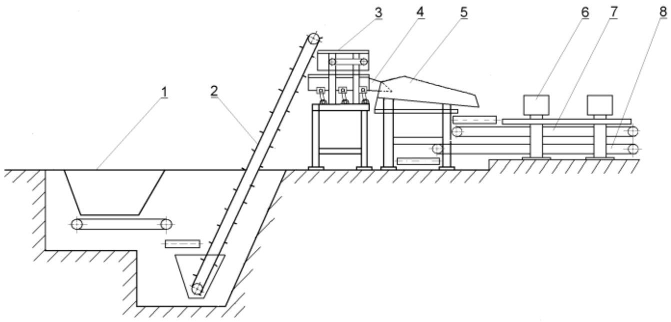

Fig.1. *The technological line for separating sweet corn grain: 1 - charging tank, 2 - cob conveyor, 3 - dosing tank, 4 - vibrating table, 5 - cover leaf peeler, 6 - grain cutter, 7 - grain collection chute, 8 - casing leaf and core conveyor*

To calculate the workload *Nr* incurred in the sweet corn grain production technology, the following formula was used:

$$N_r = \frac{\sum_{i=1}^{n} L_i}{F} \text{ [h/ha]} \quad (1)$$

On the other hand, the expenditures of mechanical and electrical energy *Ne* incurred in technological procedures were calculated according to the following relations:

$$N_e = \frac{\sum_{i=1}^{n} M_i \cdot K \cdot L_1}{Q_z} \text{ [kWh/ha]} \quad (2)$$

where: F – area of sweet corn, (ha),
M_i – nominal power of the tractor, (kW),
K – tractor power utilization factor, (K = 0.6-0.9),
L_i – the number of working hours for a given procedure, (h/ha),
Q_z – Corn cob yield, (t/ha).

Bench tests to determine the quality of the process of separating grain from cobs were carried out on the test stand (Fig. 2). The separation quality was based on the length of the grain cut off and the condition of its surface.

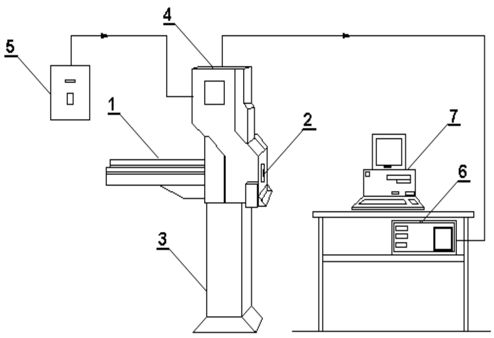

Fig. 2. *Test stand for cutting off maize grain: 1 - cob feeder, 2 - rotary head with cutting knives, 3 - base, 4 - electric motor, 5 - electric current frequency converter, 6 - power and electricity recorder, 7 - computer*

Due to the lack of literature data and industry standards regarding the division of cut grain into dimensional classes, the following ranges have been adopted:
- class I - grain from a length of more than 8 mm,
- class II - grain with a length of 4 to 8 mm,
- class III - grain with a length of less than 4 mm.

The quantitative shares of each class were determined according to the formula:

$$f_i = \frac{n_i}{\sum_{i=1}^{3} n_i} \cdot 100 \text{ [\%]} \quad (3)$$

where:
n_i – the number of the first interval.

The condition of the grain cut-off surface was determined on the basis of its scan. The quality of the cut was considered good when the cross-section was smooth and there were no weight losses. Any other cross-section qualified the grain as of inferior quality. The share of such grain was calculated according to the formula:

$$U_g = \frac{n_c - n_d}{n_c} \cdot 100 \text{ [\%]} \quad (4)$$

where:
n_c – the number of good and inferior quality grain [pcs.],
N_d – the number of good quality grain [pcs.].

Separation of grain from cobs by cutting it off was performed on a cutter, whose speed of the head with knives was changed in the range of 167.5–301.2 rad/s. On the other hand, the linear speed of the flask feeder was constant and amounted to 0.31 m/s. The feeder and head were driven by 0.65 and 1.1 kW motors.
The evaluation of the obtained study results was carried out on the basis of the method of univariate analysis of variance. If significant differences were found between the objects on the basis of the significance test F, multiple comparisons were tested using the Tukey method for the significance level α = 0.05. The accuracy of individual measurement results was determined by providing the value of the standard deviation for the arithmetic mean and the smallest and largest value of a given set of numbers.

Results

The energy assessment of sweet corn production technology took into account the work, mechanical and electrical energy inputs incurred for tillage, fertilization, sowing seeds and plant care, as well as harvesting, transport and processing of cobs (separation of leaves and grain).

The structure of labour inputs (Fig. 3) shows that the most labour-intensive is the processing of cobs and soil cultivation, which account for about 31% and 27% of the total inputs. On the other hand, the least outlay technological procedure, amounting to about 7%, turned out to be sowing seeds and transporting cobs.

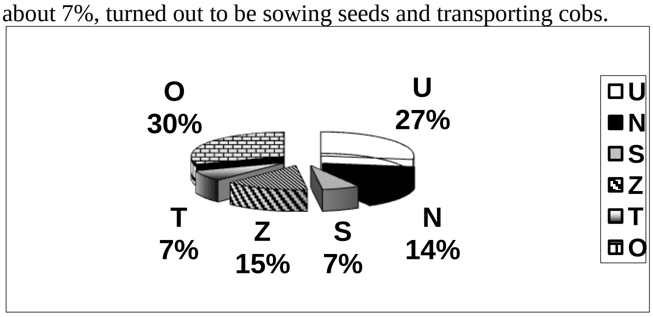

Fig. 3. *Structure of the workload for combine cob harvesting: U – soil cultivation, N – fertilization and plant protection, S – sowing seeds, Z – cob harvesting, T – cob transport, O – cob processing*

The structure of energy inputs presented in Figure 4 showed that the highest energy expenditures are incurred for soil cultivation (approx. 341 kW/ha and approx. 29 kW/t) and combine harvesting (approx. 285 kW/ha and 27 kW/t). The lowest energy inputs were recorded for sowing (approx. 45 kW/ha and 7 kW/t) and cob processing (approx. 66 kW/ha and 6 kW/t).

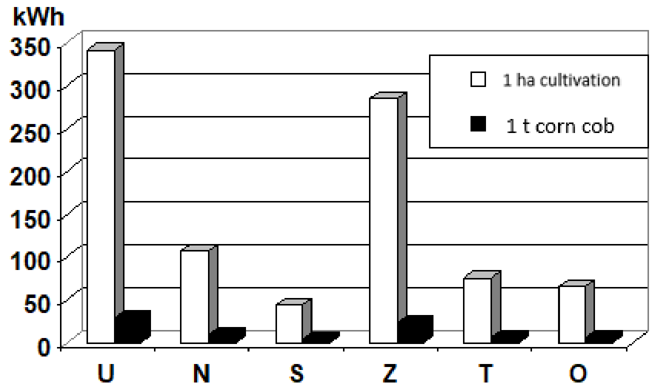

Fig. 4. The amount of energy expenditure for combine harvesting of cobs: U – soil cultivation, N – fertilization and plant protection, S – sowing seeds, Z – collection of cobs, T – transport of cobs, O – processing of cobs

A change in the angular velocity of the knife head in the range from 167.5 to 301.2 rad/s increased the length of the cut grain from about 11 to 37% for class I and reduced its share from about 60 to about 46% in class II and from about 29 to about 18% in class III (Fig. 5).

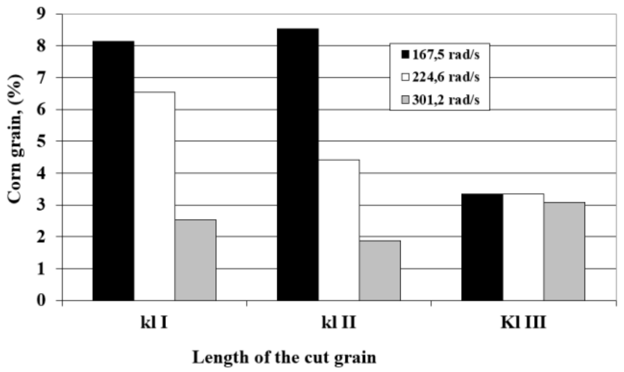

Fig. 5. Share of maize grain classes depending on the cutting speed and length of the cut grain, at corn cob feeder speed v = 0.31 m/s

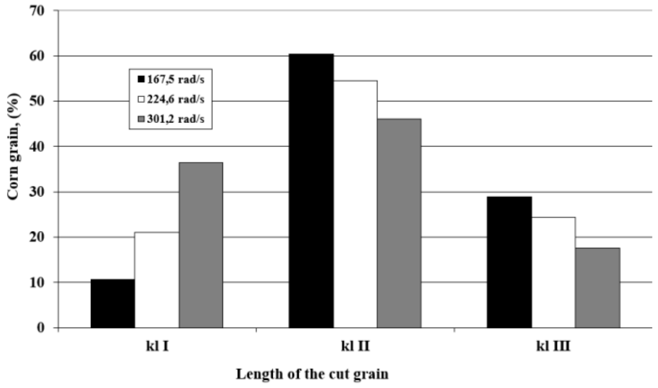

Fig. 6. Structure of grain grades of inferior quality depending on the cutting speed and the length of the cut grain, at the speed of the cob feeder v = 0.31 m/s

The change in the speed of the knife head in the studied range resulted in a decrease in the share of grain of inferior quality in class I and II, respectively, from about 8 to about 3% and from about 9 to about 2% in class II. In class III, there were no significant statistical differences in the changes in the share of grain of inferior quality, which was at the level of about 3% (Fig. 6).

Conclusions

1. In the production technology of sweet corn, the highest energy expenditures were incurred for soil cultivation and cob harvesting. In the case of cultivation, they amounted to about 341 kWh/ha, while for the collection of flasks – about 285 kWh/ha. Therefore, the use of combine harvesters for harvesting cobs is advisable on larger plantations.
2. The quality and length of the cut sweet corn grain was greatly influenced by the rotational speed of the knife head. With an increase in speed from 167.5 to 301.2 rad/s decreased the share of grain length below 4 mm by about 11% and grain length 4–8 mm by about 14%, while the share of grain length above 8 mm increased by more than 16%.
3. The total amount of sub-quality grain cut also depended on the head speed and ranged from 20% for the speed of 167.5 rad/s to 7.5% for a speed of 301.2 rad/s.

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