POWER ENGINEERING OF SWEET CORN CUTTING PROCESS

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INTRODUCTION

Corn is characterized by a great variety of shapes with different botanical and utility characteristics. Among its many subspecies, apart from fodder and common one, sweet corn is of growing importance. Its utility value is due to high nutritional quality, amiable taste and wide possibilities of use in food industry. It can serve as well for immediate consumption as for vegetable and fruit processing industry or milling industry [3, 6, 7].

Complex kernel structure and low content of dry matter, i.e. 24-28% at cropping, cause their high vulnerability to mechanical damage. Moreover the shape and size of both corn ears and the kernels on their cobs change in a wide range. Depending on corn crossings there appear ears with cylindrical or oval sections, shaped as a cylinder or a cone. Also kernels differ in size and texture especially on the edge parts of an ear. That is why the process of corn removal from ear cobs is a real challenge for the processing industry [1, 4, 5].

Sweet corn collected for food industry is usually mechanically processed by cutting the kernels off ear cobs. The demands for the quality of the separated raw material include, among others, even surface and equal length of the cut-off kernels, lack of mechanical damage, insignificant loss of mass or nutritional elements. The fulfillment of demands is dependent on both morphological characteristics of ears, kernel size or their mechanical endurance and the cutting process parameters, i.e. knives geometry, rotary cutting head speed as well as the speed of the ear feed [2].

MATERIALS AND METHODS

The research aimed at the determination of energy consumption in the process of kernel removal from sweet corn ear cobs. Measurements of power input were made as well as of electric energy consumption during kernel removal from cobs. Before the measurements morphological characteristics of the ears were determined including their length, diameter and mass, the number of kernel rows as well as the number of kernels in a row and their percentage in the ear's mass. Also, the content of dry matter in the corn kernels was determined by the drier-weight method according to PN-90/A-75101.03.

The measurements of energy consumption in the process of kernel removal from ear cobs were carried out on the research stand presented in Figure 1. It included corn kernels cutter and an electric current transmitter-transducer with the power and energy consumption recorder. Measurements results were stored in a computer's memory by means of special software. During the tests the stripped ears were moved by the feed to the rotary cutting head. The ear feed was driven by an electric engine with the power of 0,65 kW, and the rotary head obtained the drive from an electric engine with the power of 1,1 kW. The linear velocity range of the ear feed was changed in the interval 0,3-09 m-s^{-1}. And the rotational speed of the cutting head ranged from 100-250 rad.s^{-1}.

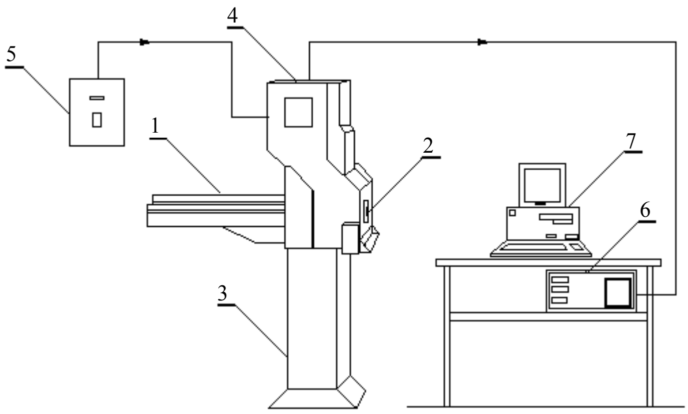

Fig. 1. Diagram of the test stand for kernel removal from corn ear cobs: 1 – ear feed, 2 – rotational head with cutting knives, 3 – cutter's base, 4- electrical engines, 5 – an electric current transmitter-transducer, 6 – recorder of power and electric energy, 7- computer with the software

In order to change the velocities of the ear feed and cutting head, the electric current transmitter-transducer was used. In case of the ear feed driving engine, the frequency of the current was changed every 10 Hz in the range 20-60 Hz, whereas for the engine driving the cutting head the interval was 30-75Hz. At measurements 5 velocity ranges of the ear feed were assumed and they were applied for six different velocities of the cutting head. The research was carried out on three sweet corn cultivars grown in Poland for vegetable and food processing industry. Ear samples for kernel removal counted 5 items each. Three repetitions of measurements were made for each combination of the ear feed and cutting head velocities. The obtained tests results were presented in a tabular form, statistically analysed and graphically described.

TESTS RESULTS AND THEIR ANALYSIS

Results of power input measurements during kernel removal from corn ear cobs, of mean efficiency and unitary energy consumption were presented in Table 1. Mean power input in a cutter depended both on the velocity of ear feeding and of the cutting head and was contained in the interval 0,06-0,14 kW/corn ear (Fig. 2). Smaller values of power input were recorded at higher ear feed velocities and lower cutting head velocities, whereas the greatest values of power input were observed at lower ear feed velocities and higher cutting head velocities (Fig. 3). The dependency was due to the low flow capacity in the cutter and increased power input into the rotary head with the knives cutting smaller quantities of kernel off the ear cobs.

Table 1. Unitary energy consumption during tests of kernel removal from sweet corn ear cobs

Velocity of the head, $rad \cdot s^{-1}$	Velocity of the ear feed, $m \cdot s^{-1}$	Mean power, kW/corn ear	Mean efficiency, corn ear/s	Unitary energy consumption, kJ/corn ear
100.8	0.31	0.058	0.31	0.187
	0.47	0.078	0.38	0.205
	0.62	0.079	0.62	0.127
	0.77	0.081	0.64	0.127
	0.92	0.083	0.48	0.173
134.4	0.31	0.071	0.38	0.187
	0.47	0.072	0.50	0.144
	0.62	0.074	0.68	0.109
	0.77	0.091	0.74	0.123
	0.92	0.100	0.61	0.164
168.0	0.31	0.091	0.56	0.163
	0.47	0.092	0.62	0.148
	0.62	0.100	0.68	0.147
	0.77	0.110	0.93	0.118
	0.92	0.122	1.10	0.111
201.6	0.31	0.110	0.58	0.190
	0.47	0.111	0.66	0.168
	0.62	0.117	0.72	0.163
	0.77	0.018	1.00	0.018
	0.92	0.122	1.36	0.090
235.6	0.31	0.125	0.62	0.202
	0.47	0.126	0.82	0.154
	0.62	0.130	0.94	0.138
	0.77	0.131	1.13	0.116
	0.92	0.132	1.61	0.082
252.0	0.31	0.132	0.71	0.186
	0.47	0.135	0.84	0.161
	0.62	0.139	1.20	0.116
	0.77	0.142	1.34	0.106
	0.92	0.143	1.68	0.085

The mean cutter efficiency ranged between 20-100 ears/min (at the mean ear length 0,25m). It was dependent both on the speed of ear feeding and on the speed of corn kernel removal. In case of smaller values of ear feeding and kernel removal, apart from the worse efficiency, also lower mass of the cut-off kernel was obtained. It was caused by a smaller depth of cut due to greater kernel resistance and lower rotational speed of the cutting head. On the other hand, too fast ear feeding at low rotational speeds of the cutting head in some cases resulted in the head getting stuck as well as worse quality and smaller quantity of the cut–off kernels.

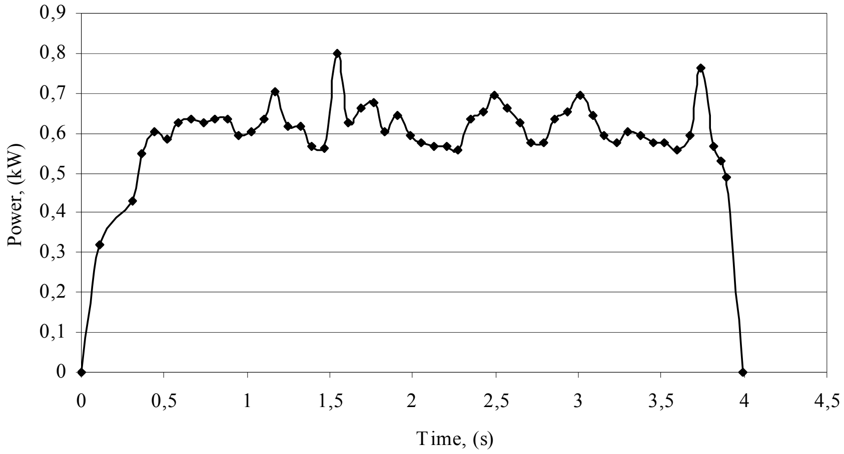

Fig. 2. The course of power input during the test of kernel removal from sweet corn ear cobs at the feeding velocity 0.92m.s^{-1} and the cutting head's velocity 201.6 rad.s^{-1}

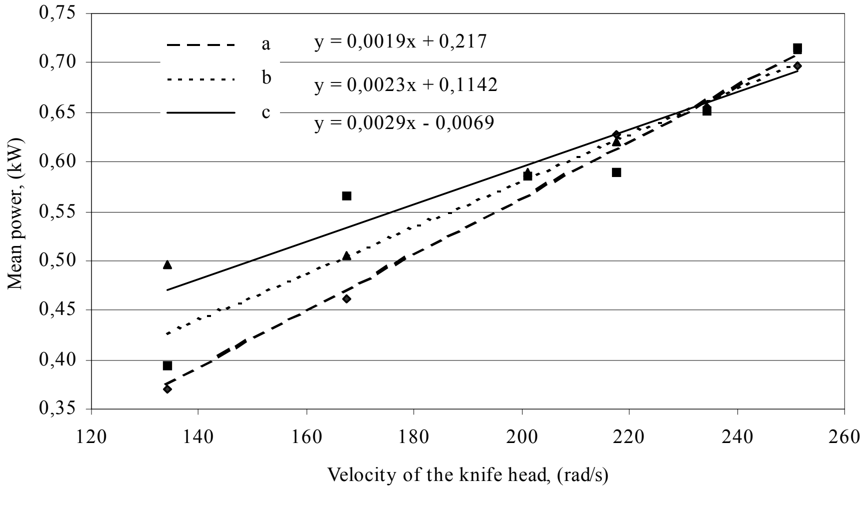

Fig. 3 The dependency of the mean value on the cutting head's velocity and on different velocities of the ear feed; a) v_p = 0.62m.s^{-1}, b) v_p = 0.77m.s^{-1}, c) v_p = 0.92m.s^{-1}

Unitary energy consumption per one corn ear ranged from 0,08-0,21 kJ. The lowest values of energy consumption showed in the kernel removal process at the maximum velocities of ear feeding and the rotational speeds of the cutting head ranging from 202-252 rad.s^{-1}.

They resulted from the high flow capacity of the cutter as well as from high quality and quantity of the cut-off kernel. Whereas the highest energy consumption values were recorded while using the lowest velocities of ear feeding into the cutting head. It was connected with non-optimum use of the cutting possibilities of the heads with knives.

CONCLUSIONS

On the basis of the carried out stand research on the process of kernel removal from corn ear cobs the following conclusions were made:

1. Mean power input depends on the ear feeding velocity and the rotational velocity of the cutting head. The lowest power input values were recorded at the ear feeding velocity 0,3-0,6m·s^{-1} and the head's rotational speed ranging from $101^{-1}34$ rad·s^{-1}.
2. Mean capacity flow of the cutter depended primarily on the ear feeding velocity, and to a lower extent on the rotational velocity of the cutting head. The mean cutter's efficiencies ranged from 30 ears/min for the feeding velocity 0,3m·s^{-1} to 70 ears /min for the feeding velocity 0.9 m·s^{-1}.
3. Unitary energy consumption changed in the range 0.08-0.21 kJ/ear and depended mainly on the cutter's flow capacity. Lower values of energy consumption were recorded at the ear feeding velocity 0.9 m·s^{-1}, whereas the highest energy consumption was observed for the feeding velocity 0.3 m·s^{-1}.

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SUMMARY

The paper presents the results of the research on energy consumption in the process of kernel removal from ear cobs of sweet corn. The measurements of power input, flow capacity and energy consumption were taken on a research stand. An influence was tested of the ear feeding velocity and the kernel removal from the cobs velocity on the analysed parameters of the cutter's work. The highest effectiveness and energy consumption were observed at the velocities of the corn ear feed 0.77-0.92 m·s^{-1} and of the cutting head 168-252 rad·s^{-1}