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ECONOMIC ASSESSMENT METHODS FOR SWEET CORN KERNELS PRODUCTION

This study presents a comparison between production cost of sweet corn by cutting and threshing methods. Before threshing sweet corn cobs are frozen in vapour of liquid nitrogen. Production cost of sweet corn kernels by cutting method is 73.7 zl·t^{-1} and by threshing method 97.8 zl·t^{-1} and 95.8 zl·t^{-1} respectively from variant with purchase or rent of vessel for liquid nitrogen. The calculations show that the highest share of production cost in threshing method is cost of cobs freezing. It amounts about 88%. At the same size of annual labour the cutting method is more profitable. At higher possibility to obtaining annual utilization, higher efficiency of process and quality of obtained kernels as well as possibility of gaining kernels after the period of labour accumulation threshing methods can be more profitable than the cutting one.

Keywords: *agriculture, sweet corn, production cost, cutting, threshing.*

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МЕТОДИ ЕКОНОМІЧНОГО ОЦІНЮВАННЯ ВИРОБНИЦТВА КУКУРУДЗИ

У статті представлено порівняння собівартості виробництва кукурудзи методами обрізки та обмолочування. Перед обмолочуванням качани кукурудзи заморожують рідким азотом. Вартість виробництва кукурудзи методом обрізки — 73,7 злотих/т, методом обмолочування — 97,8 і 95,8 зл/т, залежно від варіанту покупки або оренди техніки для застосування рідкого азоту. Розрахунки показують, що найбільш витратна стадія виробництва методом обмолочування (близько 88%) — заморожування качанів. При тому ж обсязі витраченої праці метод обрізки є більш вигідним. Але за рахунок можливості цілорічного використання, більш високої ефективності процесу та якості одержуваного продукту метод обмолочування може стати більш вигідним, ніж метод обрізки.

Ключові слова: *сільське господарство, кукурудза, вартість виробництва, обрізка, обмолочування.*

Табл. 3. Літ. 18.

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МЕТОДЫ ЭКОНОМИЧЕСКОЙ ОЦЕНКИ ПРОИЗВОДСТВА КУКУРУЗЫ

В статье представлено сравнение себестоимости производства кукурузы методами обрезки и обмолота. Перед обмолотом початки кукурузы замораживают жидким азотом. Стоимость производства кукурузы методом обрезки — 73,7 злотых/т, методом обмолота — 97,8 и 95,8 зл/т, в зависимости от варианта покупки или аренды техники для применения жидкого азота. Расчеты показывают, что наиболее затратная стадия производства методом обмолота (порядка 88%) — замораживание початков. При том же объеме затраченного труда метод обрезки является более выгодным. Но за счет возможности круглогодичного использования, более высокой эффективности процесса и качества получаемого продукта метод обмолота может стать более выгодным, чем метод обрезки.

Ключевые слова: *сельское хозяйство, кукуруза, стоимость производства, обрезка, обмолот.*

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Introduction. Corn (Zea mays L.) is one of the most important food crops in the world agriculture, being the staple food crop of several civilizations. It is the most efficient converter of the sun's energy into food and has a great potential as a food for the "new world agriculture" in the future (Turk et al., 2001). Quality is critical in sweet corn production, so intensive management practices are needed from planting to harvesting for best results (Kwabiach, 2004). Processing of sweet corn is used to increase its shelf life but as a consequence, a significant loss of nutrients may occur via heat degradation or leaching (Scott and Eldridge, 2005). Sweet corn residue is a byproduct of the sweet corn processing industry accounting for 60–70% of the initial yield and consists of husk leaves, cobs, discarded kernels, and small amounts of stalk (Fritz et al., 2001; Mustafa et al., 2004). Commercially, the most common method of separating kernels of corn from the cob is by cutting the kernels with a sharp blade. Unfortunately, it is not possible to obtain whole grains of corn. The cutting operation severs the upper part of the kernel from the lower part which remains on the cob. Thus, the hull of the kernel is broken open and part of each kernel is wasted (approximately 20% remains on the cob), including much or all of the germ of the kernel. Furthermore, during subsequent wet-processing, including washing and blanching of the severed kernels, part of the corn meat is leached from its pouch and lost (Szymanek, 2011b). Whereas the amount of cut off kernels is strictly connected with its moisture and physical and morphological properties of kernel and cob (Niedziolka et al., 2003). Depending on a variety kernel yield reaches only 25–40% of total cob mass and recovery of cut corn ranged from 30 to 55% (Feibert et al., 1996; Szymanek, 2008). It has been estimated that sweet corn processing industry in the USA produces 1.5 mln. tons of corn waste per year (US Department of Commerce, 2006). Removing sweet corn kernels from the cob for consumption purposes is performed with the use of special cutters the operation of which is described in the papers by many authors (Kunjara and Ikeda, 1995). Separation of kernel by means of cutting, although commonly used in food production and agricultural industries, is however linked to the occurrence of relatively high quantitative and qualitative losses of raw material (Brecht, 1998). Depending upon the corn variety type and ripeness and given the cutting process applied, only about 70–80% of kernel have been cut from the cobs. The remaining kernel portion containing the major part of the germ becomes production waste (Riad and Brecht, 2001). As a result of subsequent technological processes (rinsing, blanching) other nutrient and food components of kernel are also subject to massive losses. The losses occurring in the production process have negative effects not only in economical terms, but also cause considerable environmental problems. The loses of sweet corn kernels can be significantly reduced by applying shelling method to removing kernels from frozen cobs (Szymanek, 2011a). In the first step corn cobs are frozen and then kernels are threshing. Economical effectivness of freezing systems must take into account the quality of products (Briley, 1980). The advantage of cryogenic freezing in comparison to conventional freezing methods means that using liquid cryogenic for freezing of sweet corn is particularly profitable for process efficiency and products quality (Chourot et al., 2003).

The objective of the study was the cost comparison of 2 methods (cutting and shelling) of removing sweet corn kernels from cobs.

Methods. The experimental material was made up by sweet corn cobs of Candle variety. The cobs for the study were collected by hand from random sites of a plantation at late milk ripeness phase. The corncobs selected for tests were healthy, of straight shape and high degree of kernel filling. Characteristics of sweet corn cobs is presented in Table 1.

Table 1. **Characteristics of sweet corn cobs**

Specification	Results	
	from-to	mean
Mass of cobs without husk, g	291.2–342.2	318.2
Length of cobs, cm	19.4–22.1	22.4
Maximum diameter of cobs, mm	46.6–54.7	48.6
Number of kernel per row, pcs.	27–34	28.0
Number of kernels rows, pcs.	12–16	14.0
Moisture of kernel, %	76.2–77.6	76.7
Cob yield, %, $t \cdot ha^{-1}$	15.8–16.9	16.2

Table 2. **Output date for calculation cost of analyzed process**

No.	Specification	Unit	Methods	
			MI	MII
			Value	
1.	Cost of thresher, brutto	zl	60,000.0	14,000.0
2.	Cost of Dewar flask, brutto	zl	-	9, 00.0
3.	Cost of lease, brutto	zl/month	-	40,0
4.	Total cost of machines and equipments, brutto	zl	60,000.0	23,000.0
5.	Cost of technological water, brutto	$zl \cdot m^{-3}$	4.0	4.0
6.	Price of liquid nitrogen, brutto	$zl \cdot t^{-1}$	0.0	400.0
7.	Cost of electric energy, brutto	$zl \cdot kWh^{-1}$	0.29	0.29
8.	Cost of labour, brutto	$zl \cdot h^{-1}$	15.0	15.0
9.	Cost of cobs, brutto	$zl \cdot t^{-1}$	400.0	400.0
10.	Cost of product, brutto	$zl \cdot t^{-1}$	9,000.0	9,000.0
11.	Consumption of electric energy	kWh	1.15	0.88
12.	Consumption of technological water	$m^3 \cdot t^{-1}$	0.40	0.00
13.	Consumption of nitrogen	$t \cdot t^{1}$	0.0	0.2
14.	Recovery of corn kernels	%	0.40	0.68
15.	Production efficiency	$t \cdot h^{-1}$	0.44	1.10
16.	Annual using of machines	h/year	320	320
17.	Annual production	t/year	140.80	391.68
18.	Processing field of kernels	$t \cdot ha^{-1}$	14.3	15.5
19.	Prediction of machines exploitation	years	20.0	20.0
20.	Depreciation rate	%	5.0	5.0
21.	Coefficient of insurance cost	%	0.3	0.3
22.	Coefficient of service cost	%	0.5	0.5
23.	Coefficient of repair cost (annual)	%	3.0	3.0

After husking the kernels were removed from sweet corncobs by cutting (Method I) and threshing (Method II). Kernels were cut from the sweet corncob core using a SC-120 Corn Cutter from FMC FoodTech. Measurements were taken at 268.1 $rad \cdot s^{-1}$ of the angular speeds of the cutter head and a linear cob feeder speed of 0.31 $m \cdot s^{-1}$. The efficiency of corn cutter was about 1.1 $t \cdot h^{-1}$. The threshing was done with a "classical" beater type thrasher unit adopted for the purpose of threshing dent corn. Kernel threshing was carried out at 57.8 $rad \cdot s^{-1}$ angular speed of the thrasher drum with a 35 mm admission port and 18 mm exhaust port. The thresher drum concave girdle angle was 108°. Before threshing the corncobs were frozen in liquid nitrogen. The cobs were frozen in a special (vacuum) container at which liquid nitrogen was discharged from the Dewar flask (Taylor-Wharton model LD 25) through a special applicator (Szymanek, 2011a). The temperature of kernels before freezing was about 20°C and after freezing (before threshing) about -7°C. The measurement was carried out using the sample of 100 cobs. The final value of the parameter in question was calculated as the arithmetic mean of 3 repetitions.

Assessment of the test results was performed by single-factor variance analysis. Where any essential differences were found between the objects upon F-test of significance, then a multi-comparison method of Duncan was used for $\alpha = 0.05$ significance level. The accuracy of particular test results was determined by specifying additionally the value of standard error and the 0.95% confidence intervals for the arithmetic mean.

Table 2 contains the data to calculate the cost of removing kernels form corncobs by two methods.

The cost calculations for threshing were realized in 2 variants. The first variant (MII) takes into account the purchase and the second (MIIA) the leasehold of a Dewar flask.

In the study the coefficients were chosen according to literature (KTBL – Taschenbuch Landwirtschaft, 2002) and were modified to specific technical and economical process conditions. The costs of interests were not taking into account.

Results. Table 3 gives the results of cost calculations of removing sweet corncobs by 3 methods.

Table 3. **Annual and unitary cost for cutting and threshing method**

Cost	Unit	Method		
		MI	MII	MIIA
Amortization	zl/year	3,000.0	1,150.0	700.0
Insurance	zl/year	100.0	57.5	35.0
Maintenance	zl/year	200.0	115.0	70.0
Repair	zl/year	1,200.0	690.0	420.0
Electricity	zl/year	107.3	81.9	81.9
Auxiliary materials (water, nitrogen)	zl/year	225.3	31,334.4	31,232.0
Labour	zl/year	4,800.0	4,800.0	4,800.0
Total cost	zl/year	10,382.6	38,228.8	3,733.9
Unit costs: - per working hour	zl/year	32.4	119.5	116.7
- per tone of product	zl/year	73.7	97.8	95.8

By cutting method the total costs yearly using 320 hour amount about 10,000 zl but by threshing method the costs are about 38,000 zl. However, in reference to the work unit amounts about 8 $zl \cdot t^{-1}$ for MII and about 96 $zl \cdot t^{-1}$ for MIIA. The costs of the variant MIIA are lower only for about 2 zl.

The difficulty in close calculations of some factors causes they weren't taken into account. However, these factors can significantly influence the size of charges and it can decide profitability of methods. These factors are: date of harvest, choice of varieties, the working machines efficiency, the field of corncobs, the percentage of kernels recovery.

The threshing method in relation to cutting methods allows for earlier harvest of corncobs (from 2 to 4 days) at higher moisture content (78–80%), as well as higher quality of raw materials (kerels tenderness, sugar content). In the cutting method, higher moisture of kernels is, the higher loses of them will be (leakage of semiliquid kernel flesh). Therefore, in practice the date of harvest is delayed to lower moisture (72–68%).

The efficiency of corn cutters compares to threshing machines is lower as well as their working sets are more sensitive for corn varieties and the quality of corncobs (shape of cobs). According to Bhumiratana et al. (1987) only 70–80% of corncobs are useful for cutting, while for threshing methods – over 90%. Consequentially, higher yield of corncobs results in higher percentage of kernels recovery and higher output of kernels. The advantage of threshing methods is the size-reduction of corn core as well as the potential reduction of costs on this process.

4. Conclusions:

1. The cost calculations proved that for assumption of technical, technological and organizational conditions the unit costs of removing kernels from cobs by threshing is higher than by cutting. In relation to 1 ton of corn cobs and 1 hour of labour it is higher by about 23% and by about 400% respectively.

2. The profitability of removing kernels from cobs by threshing decides first of all the cost of liquid nitrogen. Its share in total costs is about 88%.

3. Out of quantitative economical factors, it is important to take into account at comparison of removing kernels the factors difficult to measure, such as: quality of removed kernels, size reduction of corn core, reduction of season labour etc.

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