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Input analyses of maize harvesting and ensilaging technologies

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Abstract. The paper presents analysis and evaluation of different technologies for preparing maize silage: ZSs – maize harvesting with self-propelled harvester and chaff storage in silo; ZSw – maize harvesting with self-propelled harvester and chaff storage in a plastic bag; ZPp – maize harvesting with harvester attached to the tractor and chaff storage in a pile. The carried out investigations and calculations gave possibilities to elaborate some criteria indicators. The following indicators were taken into account: unit fuel consumption, unit labour consumption and unit costs. It was confirmed that the lowest unit costs concern maize silage preparation using ZPp technology with cost of €7 t^{-1}; however, the highest unit costs were observed with ZSw technology, amounting to €10.25 t^{-1}.

Key words: Maize, harvesting technology, costs, labour consumption of ensilaging, fuel consumption.

INTRODUCTION

In milk and beef production, besides green low crop fodder, an essential feed component is maize. It is most frequently utilized as silage made from whole plants, mainly for use during the winter season; sometimes it is also used to compensate energetic requirements due to pasture feeding. It is often observed that high yield milk cows can achieve proper results only when from the energetic and feeding point of view, silage is utilized in a feeding dose.

The development of hybrid ensilage varieties can be characterized by the growth of share of corn cobs in total yield, which affects the growth of energetic and caloric value of the feed (Michalski, 2002; Podkówka, 2003). It is important for the share of corn cob dry matter in total plant mass (about 50%) and dry matter content of whole plants to be in the range of 28–35%, which allows to achieve the highest quality of ensilaging plant material and high feed digestibility (Michalski, 2002). Energetic value is growing together with growing maize maturity, but because of high sugar content and low protein content, maize is known as a very good plant for ensilaging (Podkówka, 2003; Ustinovs & Ivanovs, 2003).

The whole utilization of components present in a feed is possible due to the application of proper harvesting and ensilaging methods (Podkówka et al.,1979; Sek et al., 1996). Corn crops for ensilaging will be rational if proper machinery is applied for harvesting to guarantee proper split of plants and grain (Kowalski, 2008; Lisowski, 2006; Ott, 2000; Sek et al., 1996).

Maize is a plant which allows very good ensilaging in all conditions because of its low buffer capacity, which is connected with low protein content, but high content of soluble sugars. However, because of the fact, that in addition to the necessary milk acid, ensilage mass contains also bacteria of butter acid, putrefactive bacteria, moulds and leaven, conditions should be created to stop the development of all such organisms. In spite of this, it is also very important to prepare non oxygen conditions, that can be achieved by the proper compaction of maize chaff and the use of hermetic cover to avoid air access (Chlebowski et al., 2006; Gancarz et al., 2003; Kowalski, 2008).

Currently, the important research problem is to know inputs implemented when preparing silage from whole maize plants. Work input, fuel consumption and costs referred to area unit or mass unit of raw plant material for ensilaging or when calculating dry matter establish criteria coefficients for technology evaluation.

The main goal of the paper was first of all to compare material and cost input during harvesting and ensilaging of maize with different technology.

MATERIAL AND METHODS

Maize harvesting for ensilaging with different harvesting, grinding, transportation and storage systems takes different inputs. Discovering the inputs connected with fuel consumption, labour consumption, costs referred to unit area or mass unit of raw plant material for ensilaging or calculated dry matter content can be very useful for decision makers when choosing specific production plan on the farm. To evaluate specific inputs it is necessary to provide exploitation tests of certain machinery and machine aggregates.

Three technologies were tested using different methods of chaff storage:

- ZSs – self-propelled harvester and storage in horizontal silo**,**
- ZSw – self-propelled harvester and storage in plastic bag,
- ZPp – harvester attached to the tractor and storage on a pile**.**

For harvesting of maize in case of ZSs variant the cutter Jaguar 690 SL equipped with adapter Claas RU 450 was used. Chaff was thrown directly on trailers D-737.02 at capacity of 11m^3 aggregated with tractors Ursus 5714. After transportation chaff was discharged directly to horizontal silo. Then chaff was distributed and compacted using the tractor Ursus 1224 equipped with a front loader Tur 6. When silos were exactly compacted, foil and some used tyres were put on top to protect ensilaging material from being penetrated with ambient air.

In case of the ZSw variant maize plants were harvested with the self-propelled cutter John Deere 7500 equipped with the non row assembly cutter Kemper Champion 4500. Chaff was thrown on the trailers Pronar T680 Special at capacity 18 m^3 aggregated with tractors Ursus 5714. The transported material was unloaded on a feeding table of the silo press AG-BAG G-7000, which delivered material to a plastic bag at the size of 60m long and 2.4m wide. Press was driven by the tractor Ursus 1224.

As for ZPp technology, the cutter blower Z 374 equipped with a two row adapter attached to the tractor Ursus 1224 was used. Chaff from the cutter was thrown directly on the trailer Pronar 653/2 at capacity 8 m^3. The trailer transported the material to the pile. The material on the pile was distributed and compacted with the tractor Ursus 1224 and the front loader Tur 5. After formation, the pile was covered with foil and soil to protect it from ambient atmospheric conditions.

Exploitation tests of harvesting cutter and other equipment were provided according to actual standards and methodology. To analyse fuel consumption, the full reservoir method was used. To find out maize chaff dry matter value, the drying method was included. The costs were calculated based on present prices of farm equipment (Muzalewski, 2006).

RESULTS AND DISCUSSION

The description of harvested plants presented in Table 1 includes the fundamental properties of plants, such as yield, plant size, grain percentage in the yield and the most important data concerning harvesting conditions.

Table 1. Characteristic of harvesting conditions and harvested plants.

Description of parameters	Units	Technology		
		ZSs	ZSw	ZPp
Air temperature	°C	18	16	20
Maize variety	-	Buran	Duet	San
Plant density in the field	Piece m^{-2}	9.9	8.7	8.8
Plant length	cm	152.0	138.0	124.0
Height of corn cob location	cm	54.0	38.0	34.0
Plant diameter on cutting site	mm	19.6	15.3	15.8
Height of the stubble	cm	19.4	19.7	20.1
Plant yield	t ha^{-1}	34.2	29.3	24.8
Plant humidity during harvesting	%	69.8	69.9	69.8
Grain humidity during harvesting	%	40.9	38.9	45.6
Number of corn cobs on one plant	Piece	1.3	1.1	1.1
Percentage of corn cob mass in the yield	%	42.3	48.2	52.0
Percentage of grain mass in the yield	%	32.7	38.1	39.5
Row spacing	cm	59.4	64.1	74.9
Area of harvested maize	ha	4.56	6.8	4.92
Distance from the field to the store	km	1.86	1.12	0.95

Source: own investigations

While analysing data of Table 1 we can see that the highest plant density in a tested field is presented by the variety Buran. In addition to that, this variety had the longest plants, the highest position of corn cobs, the highest diameter of plant on cutting site and the highest yield. But taking into account the percentage of corn cobs in general yield and the percentage of grain mass in general yield, the best result is obtained by the variety San.

The different tested technologies of maize harvesting were characterized by different yield capacity. The highest capacity was equal to 0.95 ha h^{-1} and applied to ZSw technology which used a high capacity self-propelled harvester and also very effective way of chaff storage. The technology of chaff storage in horizontal silo ZSs, where a self-propelled harvester was used for harvesting, had average capacity in exploitation time equal 0.69 ha h^{-1}. The lowest capacity of harvesting obtained with harvester attached to the tractor was equal to 0.42 ha h^{-1}. Harvester attached to the tractor equipped with axe cutter assembly obtained quite good capacity compared to drum cutter assembly of self-propelled harvesters, but as shown in Table 1, the attached harvester was working in the field of lower maize yield.

The unit costs depend on many parameters, such as fuel consumption, labour requirement, transportation distance, and green fodder yield. Fuel consumption is described in relation to elementary area of crop and elementary mass of green fodder. Fuel consumption calculated in 1 tonne of dry matter of fodder obtained in the described technologies was diversified, as shown in Table 2. The highest level of fuel consumption was found in ZSw technology – 1.96 dm^3 t^{-1}, but in case of two other technologies fuel consumption was very similar, i.e. 1.68 dm^3 t^{-1} for ZSs technology and 1.66 dm^3 t^{-1} for ZPp technology.

Table 2. Fuel consumption for harvesting and ensilaging of maize using different technologies.

Description of parameters	Technology		
	ZSs	**ZSw**	**ZPp**
	dm^3 t^{-1}	dm^3 t^{-1}	dm^3 t^{-1}
Maize harvesting	0.95	1.02	0.98
Chaff transportation	0.46	0.42	0.23
Chaff storage	0.27	0.52	0.45
Total fuel consumption	1.68	1.96	1.66

Source: own calculations

Considering the structure of fuel consumption it can be found that the highest effect on technology evaluation showed harvesting operation value from 0.95 dm^3 t^{-1} (ZSs) to 1.02 dm^3 t^{-1} (ZSw). In case of ZPp technology (0.98 dm^3 t^{-1}) fuel consumption for chaff transportation (0.23 dm^3 t^{-1}) was about twice as low as with the other technologies. But fuel consumption for chaff storage was the lowest for technology ZSs (0.27 dm^3 t^{-1}).

Labour consumption concerning the considered technologies was diversified as it is shown in Table 3. Labour input results were as follows: ZSw technology had value

0.214 m h t^{-1}, ZSs technology had 0.219 m h t^{-1}, but ZPp technology had value 0.328 m h t^{-1} (m h t^{-1} -man-hours per ton). In the structure of labour input the highest share in all technologies showed operation of chaff transportation and it was equal to 0.107 m h t^{-1}in ZSw, 0.127 m h t^{-1} in ZSs, and 0.127 m h t^{-1} in ZPp technology. The lowest input required for maize harvesting ranged from 0.036 to 0.09 6m h t^{-1}. ZPp technology presented the lowest unit costs of maize ensilaging (€6.9 t^{-1}), but the highest unit costs were presented by ZSw technology (€10.25 t^{-1}), as it is shown in Table 4.

In the structure of total cost of maize ensilaging while using ZPp technology predominates harvesting cost which is equal to €3.6 t^{-1}; it is followed by storage cost which is equal to €2.13 t^{-1} and transportation cost which is equal to €1.23 t^{-1}. Harvesting costs with ZPp technology were lower in comparison with those of ZSs technology and equal to €3.85 t^{-1}, but lower than with ZSw technology with value of €1.23 t^{-1}. With ZSs technology, storage cost was comparable to harvesting cost, but transportation cost was about twice as low. The higher storage cost with ZPs technology was affected by construction and exploitation cost of silos. However, with ZSw technology, storage cost was equal to €4.53 t^{-1} and was a little higher than harvesting cost, but they were three times higher than transportation cost. Considerably high storage costs with this technology were generated by the use of tractor and silo press process to fill the plastic bag with chaff.

Table 3. Unit labour costs required for maize ensilaging using different technologies.

Description of parameters	Technology		
	ZSs	**ZSw**	**ZPp**
	m h t^{-1}	m h t^{-1}	m h t^{-1}
Maize harvesting	0.042	0.036	0.096
Chaff transportation	0.127	0.107	0.126
Chaff storage	0.050	0.071	0.106
Total labour requirement	0.219	0.214	0.328

Source: own calculations

Table 4. Unit costs of maize ensilaging using different technologies.

Description of parameters	Technology		
	ZSs	**ZSw**	**ZPp**
	€ t^{-1}	€ t^{-1}	€ t^{-1}
Maize harvesting	3.85	4.23	3.6
Chaff transportation	1.6	1.5	1.23
Chaff storage	3.58	4.53	2.13
Total costs	9.03	10.26	6.96

Source: own calculations

CONCLUSIONS

1. The lowest unit fuel consumption is characterised by ZPp technology using harvester attached to the tractor and chaff storage on a pile with 1.66 $dm^3\ t^{-1}$, but a higher value of this parameter was found with ZSw technology, resulting with 1.96 $dm^3\ t^{-1}$. In the structure of fuel consumption the highest share concerning all technologies had harvesting operation with value ranging from 0.95 $dm^3\ t^{-1}$ (ZSs) to 1.02 $dm^3\ t^{-1}$ (ZSw).

2. The lowest labour consumption was found with the technologies with self-propelled harvesters and was equal to 0.210 m h t^{-1}; such a value is 1.5 times lower than the value with ZPp technology. The highest share concerning all technologies had chaff transportation operation with value 0.127 m h t^{-1} belonging to ZSs technology.

3. The lowest unit costs of maize ensilaging characterized ZPp technology, resulting with €6.96 t^{-1} and the highest unit cost belonged to ZSw technology with the result of €10.26 t^{-1}.

4. In a structure of total cost of maize ensilaging in all technologies the highest costs of all operations were generated by harvesting and storage activities.

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