INVESTIGATION OF THE MAIZE STALK GATHERING FOR ENERGETIC USE

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Abstract

During the investigations of maize stalk gathering we carried out many field tests with different combination of existing technologies. In all cases the corn seed (as main product) harvesting was carried out by combine harvester with corn harvesting adapter which was installed with chopper unit. In this case the stubble field was between 150 to 200 mm high. After the harvesting one more chopping machine was required to reduce the stubble field height and to facilitate the gathering phase. The maize stalk gathering investigations were extended to analyze different types of maize species too. We analyzed different hybrids. The average weight results showed that the seeds are 40-45% of the whole plant, from the rest 35-40 % was the stalk, 7-8 % was the leaf, 4-6% was the cornhusk and 5-6% was the corn cob. We also investigated the moisture content of different parts of the plants. After harvesting the moisture content of the stalk could reach 80 %. By the proper technology this "very" high value can be reduced to 30% within 10 hours on the field. More information on physical and mechanical properties of corn stalk are required to develop the proper gathering and safe storing technology and the machines. In this paper we show the technological problems, the developmental possibilities. Presently we are investigating the characteristics of corn stalk, which are needed to the design gathering and storing technologies and machines.

Key words: agricultural by-product, maize stalk, gathering.

1. Introduction

Among the agricultural by-products of the industrial crop production the straw of various cereals, the corn stalks and some other plant remain to use for energy purposes. Worldwide the amount of annually generated by-products of the agricultural plants weight of 73.9 Tg dry matter. From this amount the corn stalk amount is 204 million tons each year, which is the third largest by-product of mass and energy content [2].

In Hungary significant amount of biomass may come from after corn harvest of about 1.2 million hectare maize production. For energy purposes, corn stalk harvest technology development studies are ongoing, but so far no satisfactory solution has been developed. From technical and economical aspects the baling of corn stalk (round or big square bale) technology may be the ideal to collect the corn stalk. The lack of national knowledge and information, foreign experience are also not available. In order to obtain correct information the MGI and AXIAL Ltd. launched common research by CLAAS machines. In the frame of this research we carried out investigations of different technologies from energetic and working quality point of view.

1.1. The test conditions

In the framework of the field tests were performed at two different locations for corn stalk baling by different constructions of baler. Laboratory investigations of the baler field works were carried out as well. The circumstances of the first studies are summarized in Table 1.

TABLE 1: Test conditions of the balers tests

Nr.	Type of the tractor and baler	Location of the test	The investigated plant		
			type	yield	moisture content
–	–	–	–	(t/ha)	(%)
1	Claas Rollant 66 + MTZ-82	Agárdi Agrárgazdság Zrt. Zichyújfalu	Maize DKC 5143 desiccated with Fozat-480	9,0	24,2-27,6
2	Claas Quadrant 2200 RC + Atles 936 RZ	Mezőfalvi Mezőgazdasági Termelő és Szolgáltató Zrt. Nagyhörcsök	Maize LGT Alexandra 380	8,5	22-23

During the field test the used fuel quantity was measured by refueling the fuel tank of the operator tractor. For the refueling a calibrated fuel meter was used and the specific values were determined by calculation.

FIGURE 1: *CLAAS ROLLANT 66* Round baler (fix chamber)

FIGURE 2: CLAAS QUADRANT 2200 RC Big Square Baler

Laboratory measurements were carried out on the whole corn plants (stalk, leaf, ear of corn, husk, seed, cob). Mass ratio and moisture content were determined of natural state and artificially desiccated plants. The samples were analyzed from both test fields.

FIGURE 3: Test field of natural state corn

FIGURE 4: Artificially desiccated plants

1.2. Technology of corn stalk gathering

The period of maize harvesting is depending on varieties and weather conditions. The normal harvesting period in Hungary is from mid-September till end of November. Two technologies were investigated and compared to each other to analyze the differences between them. The investigated technologies were compiled as follows in the Figs. 5 and 6.

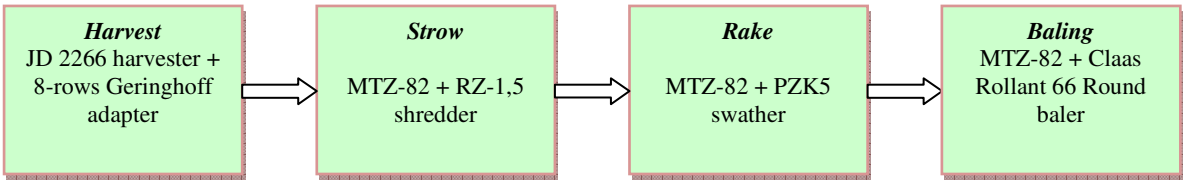

FIGURE 5: Technology I.

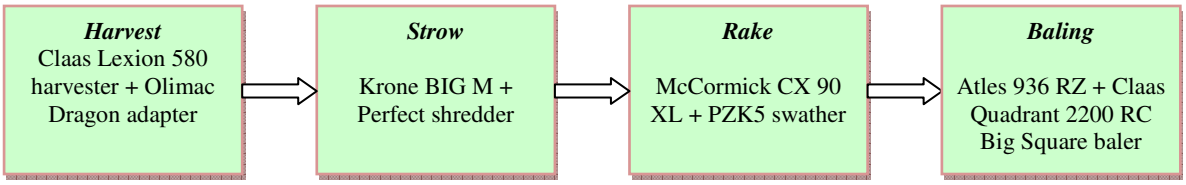

FIGURE 6: Technology II.

The most important operating characteristics of the applied machines of different technologies are summarized in Table 2.

TABLE 2: Important operating characteristics of the applied machines

Location of the test	Operating characteristics	Unit	Machines of the technologies			
			Harvest	Shrdeder	Rake	Baling
			JD 2266 + 8-rows Geringhoff	*MTZ-82 + RZ 1,5*	*MTZ-82 + PZK 5*	*MTZ-82 + Claas Rollant 66*
Agárdi Agrárgazdaság Zrt., Zichyújfalu	Filed performance	ha/h	2,28	1,3	3,59	–
	Mass performance	t/h pcs/h	21,48 –	– –	– –	10,2 21
	Fuel consumption	l/h kg/h	32,0 26,72	13,60 11,39	10,09 9,10	16,09 13,44
			Claas Lexion 580 + 8-rows Olimac Dragon	*Krone BIG M + Perfect*	*McCormick CX 90 XL + PZK 5*	*Atles 936 RZ + Claas Quadrant 2200 RC*
Mezőfalvi MgSz Zrt., Nagyhörcsök	Filed performance	ha/h	2,40	4,09	3,59	–
	Mass performance	t/h pcs/h	23,0 –	– –	– –	37 74
	Fuel consumption	l/h kg/h	36,0 30,0	36,0 30,0	10,09 9,10	61,28 51,25

During the study of the technology we determined the geometrical parameters of the crushed corn stalk windrows and mass meters. The measured and calculated data for the third table were recorded.

TABLE 3: Parameters of the shredded corn stalk windrows

Location of the test	Name	Unit	Nr of sample						Avg	Dev
			1	2	3	4	5	6		
Agárdi Agrár Zrt. Zichyújfalu	Windrow height	mm	220	230	129	156	160	200	182,50	36,60
	Windrow width	mm	810	920	960	890	780	690	841,67	91,55
	Weight / meter	kg/m	2,84	2,74	1,18	1,31	1,27	1,76	1,85	0,69
Mezőfalvi Mg. Termelő és Szolg. Zrt. Nagyhörcsök	Windrow height	mm	150	125	230	200	220	230	192,50	40,80
	Windrow width	mm	980	1040	980	1070	1020	1050	1023,33	33,99
	Weight / meter	kg/m	4,62	3,71	3,94	3,56	4,02	4,16	4,00	0,34
	Windrow distance	mm	5800	6000	6600	6600	6300	6000	6216,67	307,77

In each technology row the corn adapter of the harvester was equipped with shredder. In the residual stubble with height of between 150-200 mm it is still difficult to operate the windrower machine. Therefore, even before windrower an additional shredder operation should be performed. By this shredder the stubble was about 40 to 70 mm height, also crush and grind more stem residues. This additional operation greatly improves the loss of moisture content, reduces the drying time and increases the intensity of drying.

FIGURE 7: Vertical shaft windrower machine

FIGURE 8: folder rake machine

Considering the amount and loss of different technologies it can be concluded that by the technology I. about 51% of entire stalk amount can be harvested and by using the technology II. 55% was harvested. A larger proportion of the losses remained on the windrowed area.

1.3. Results of the field tests

1.3.1. Parameters of Performance

We summarized the measured performance characteristics of corn stalk-baling in table 4 and 5.

TABLE 4: Performance of CLAAS ROLLANT 66 round baler

Nr	**Time / bale**	**Time of tying / bale**	**Distance**	**Working speed**		**Performance of baling**		
–	(s)	(s)	(m)	(m/s)	(km/h)	(kg/s)	(t/h)	(pcs/h)
1.	213	14	344	1,62	5,81	1,91	6,86	15,86
2.	200	14	310	1,55	5,58	2,03	7,31	16,82
3.	248	14	321	1,29	4,66	1,64	5,89	13,74
4.	153	14	231	1,51	5,44	2,65	9,55	21,56
Avg	***203,5***	***14***	***301,5***	***1,49***	***5,35***	***2,05***	***7,4***	***16,99***

TABLE 5: Performance of CLAAS QUADRANT 2200 RC Big square baler

Nr	**Time / bale**	**Distance**	**Working speed**		**Performance of baling**		
–	(s)	(m)	(m/s)	(km/h)	(kg/s)	(t/h)	(pcs/h)
1.	38	140	3,68	13,26	13,16	47,37	94,74
2.	38	138	3,63	13,07	13,16	47,37	94,74
3.	34	142	4,18	15,04	14,71	52,94	105,88
4.	37	133	3,59	12,94	13,51	48,65	97,30
Avg	***36,75***	***138,25***	***3,77***	***13,58***	***13,63***	***49,08***	***98,16***

1.3.2. Parameters of working quality

The CLAAS ROLLANT 66 round baler and the CLAAS QUADRANT 2200 RC big square baler working quality parameters in corn stalk baling are summarized in table 6 and 7.

TABLE 6: Working quality parameters of CLAAS ROLLANT 66

Nr	Moisture content	Parameters of bales				
		diameter	width	weight	volume	density
–	(%)	(mm)	(mm)	(kg)	(m^3)	(kg/m^3)
1.	27,6	1600	1250	400	2,51	159,24
2.	25,8	1620	1220	410	2,51	163,13
3.	25,6	1610	1190	395	2,42	163,13
4.	27,7	1660	1220	404	2,64	153,09

FIGURE 9: Corn stalk round bale

FIGURE 10: Corn stalk big square bale

TABLE 7: Working quality parameters of CLAAS QUADRANT 2200 RC Big Square Baler

Nr	Moisture content	Parameters of bales					
		length	width	height	weight	volume	density
–	(%)	(mm)	(mm)	(mm)	(kg)	(m^3)	(kg/m^3)
1.	28,4	2200	1210	705	500	1,88	266,42
2.	26,1	2250	1220	700	487	1,92	253,45
3.	29,3	2370	1230	715	524	2,08	251,40
4.	30,8	2250	1220	715	510	1,96	259,85

In earlier experiments of whole plant harvesting systems the mass per volume were 51 kg/m3 and 110 kg/m3 pressed in bag [1]. Nowadays the logistical tasks can not be efficiently solved by these results. In our experiments we have achieved the 272 kg/m^3 too.

1.3.3. Energetic parameters

TABLE 8: Energetic parameters of CLAAS ROLLANT 66 round baler and CLAAS QUDRANT 2200 RC Big Square baler

Nr.	Name	Unit	Baler type	
			Claas Rollant 66	Claas Quadrant 2200 RC
1.	Amount of used fuel:	l	4,53	14,97
		kg	3,783	12,50
2.	Fuel consumption per hour	l/h	16,09	61,38
		kg/h	13,44	51,25
3.	Specific fuel consumption	kg/t	1,55	1,245
		l/t	1,85	1,49
4.	Calculated average power demand	kW	47,15	179,8

Of course, during operation higher engine power may occur from this, which mainly occur in high-torque cross points at compression of the bales.

The measured data show that the baler machine prepares appropriate density in corn stalk baling, dimensionally stable and good form bales.

1.3. Evaluation of the results

Evaluating the field test results in the corn stalk baling it can be stated that by the CLAAS ROLLANT 66 round baler – at moisture content between 24 - 30% - solid, rigid, well packed, transportable round bales could be prepared.

About the test results of the CLAAS QUADRANT 2200 RC we can say the same that the prepared Square Bales – at moisture content between 22-30% - have sufficient firmness and well manipulated for transportation or loading.

Studies have shown that after the chopping, windrowing and baling processes the actual baled dry corn stalk remains only the 35-50% of the whole amount of crop. The loss of the majority (~ 66.6%) is the amount of material which remains after windrowing. In lack of extra chopping these losses were increased, because one part of the stubble is not chopped and the larger quantities of the losses caused by these higher stubble which is strongly decreasing the working quality, efficiency of the windrower machine, so high amount of corn stalk remains in the high stubble.

Evaluation of laboratory tests:

From the results of different hybrid examinations it can be concluded that the grain yield 40-45% , the stalk 35-41%,the leaf of 7-8%, the husk 4-6% and cob 5-6% of the plant total weight. During the moisture content investigations we found that at 23-24% seed moisture content so at the beginning of the corn harvesting period the moisture content of the stalk was about 78-80%. At the chemically treated material primarily the grain moisture content was slightly lower (23.75 to 28.15%) compared to the untreated one (24.52 to 31.32%), while at the stalk and the other components of the plant significant difference was not detected. According to the literature if the seed moisture content is over 25% at harvesting then the stalk have to be dried on the field a few days after harvesting and then it is possible to harvest the remaining by-product [7]. Based on the result of our investigations we concluded that by using an appropriate technology this can be reduced to even a few hours.

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