Transport efficiency of straw for energy utilization

Miroslav Zitnak[1*], Vladimir Krocko[2], Maros Korenko[2]

(1. *Department of Structures, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76, Nitra, Slovakia;*
2. *Department of Quality and Engineering Technologies, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76, Nitra, Slovakia*)

Abstract: Nowadays, straw is increasingly used in the world, not only within animal production but also as a source of energy. The technology of straw collection by baling into big bales has many advantages, the use of which is, however, restricted by an ineffective handling when transporting from fields. Currently used balers enable collecting of all types of stalky materials. Picked-up mass is cut and pressed in the baler as necessary. Balers are able to increase the baling pressure by more than 25%. It follows that bales are reaching higher weights, i.e. the specific weight of bales and energy contained in them is increasing, too. Baling and transport of straw bales significantly influences the economic efficiency of heat generation from this product. Therefore, in transport and handling of bales, it is suitable to better use the capacity of transport machines (lower transport costs expressed per ton of transported mass). The objective of this paper was to evaluate the processes of collection, baling, transport and stacking of straw bales. The result was the evaluation of individual components of time, machinery performance, and labor input.

Keywords: transport efficiency, straw bales, energy

Citation: Zitnak, M., V. Krocko, and M. Korenko. 2015. Transport efficiency of straw for energy utilization. Agric Eng Int: CIGR Journal, Special issue 2015: 18th World Congress of CIGR: 168-172.

1 Introduction

Nowadays, straw is increasingly used in the world, not only within animal production but also as a source of energy. By its role agriculture begins to gradually enter into the sector of energy generation, too (Libra, 2007). Agriculture and its new challenges are now increasingly supported, not only in the EU but also in the world (Hussein et al., 2012). The technology of straw collection by baling into big bales has many advantages, the use of which is, however, restricted by an ineffective handling when transporting from fields.

Baling and transport of straw bales significantly influences the economic efficiency of heat generation from this product. Therefore, in transport and handling of bales, it is suitable to better use the capacity of transport machines (lower transport costs expressed per ton of transported mass) (Sloboda, 1999). The objective of this paper was to evaluate the processes of collection, baling, transport and stacking of straw bales. The result was the evaluation of individual components of times, machinery performance, and labor input.

The technology of baling stalky mass (straw and silage of wilting forage) into large-volume giant bales of circular or rectangular cross-section (Börjesson, 1996) represents specific requirements for the design of transport machines. Modern balers allow collecting of all kinds of materials. Picked-up mass is cut and pressed in the baler when necessary. New models of balers are able to increase the baling pressure by more than 25%.

According to Syrovy (2004), several procedures are used for collection, transport and stacking of bales, which remain behind high-pressure balers in fields:

1) loading of bales on the tractor trailer by the tractor or self-propelled loader;

Received date: 2014-11-20 **Accepted date:** 2015-01-07

***Corresponding author: Miroslav Zitnak,** Department of Structures, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76, Nitra, Slovakia. Email: miroslav.zitnak@uniag.sk.

2) the truck with trailer is equipped with mounted hydraulic loader in the rear part of the bed for collection and storage of bales;

3) collection, transport and stacking of bales of various sizes by a special pick-up semi-trailer.

The use of special pick-up semi-trailers for bales substantially streamlines the technology of collection and handling of straw bales at their place of storage.

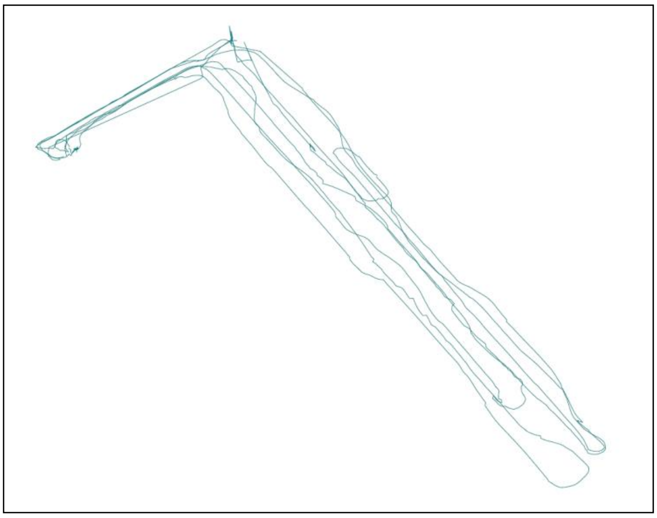
2 Materials and methods

Measurements were performed at the turn of July and August on a plot with barley straw (plains with a slope up to three degrees), using a machine JCB Fastrac 3230 + BIG pack (Figure 1) and a machine JCB Fastrac 3220 + ARCUSIN (Figure 2).

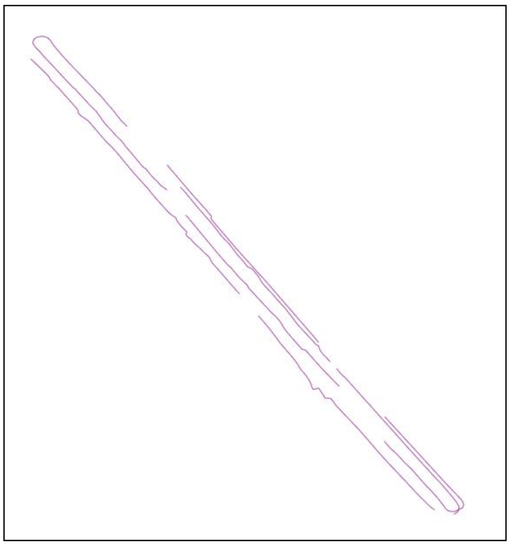
Figure 1 JCB Fastrac 3230 + Krone BIG pack

Figure 2 JCB Fastrac 3220 + ARCUSIN

Individual time of working operations was measured by a stopwatch. To monitor the work of machines, we have used a GPS navigation device Leica GS 20 with an external antenna, by means of which the distance between bales and the travelled path of machines (Figure 3) was recorded. The average yield per hectare in the field was determined as a proportion of the total weight of collected material and the number of hectares.



A



B

Figure 3 Monitored motion paths using GNSS of rover Leica GS20, A – JCB FASTRAC 3220 + ARCUSIN, B – JCB FASTRAC 3230 + Krone BIG pack

Fuel consumption was monitored for the whole work shift, i.e. using a method of refilling the fuel tank. The vehicle started with a full tank, and the tank was refilled again at the end of the day. The method specified in the standard STN 47 0120 was used to determine the individual times and performance. (see Figure 4)

Figure 4 Straw stacking (ARCUSIN F 54.63)

3 Results

Baling of barley straw was performed using JCB Fastrac 3230 + BIG pack (Table 1). After baling the material, bales were collected and stacked at the edge of the field using JCB Fastrac 3220 + ARCUSIN F 54.63 (Table 2).

Table 1 Basic technical parameters of baler

Parameters	Designation	Units	Baler
			BIG pack
Maximum length	l	mm	8,850
Width		mm	2,995
Working height	h	mm	3,110
Bale size			
Height		mm	900
Width		mm	1,200
Length		mm	1,000-2,700

Table 2 Basic technical parameters of vehicle

Parameters	Designation	Units	Vehicle type
			ARCUSIN F 54.63
Curb weight	m	kg	7,540
Maximum length	l	mm	9,850
Storage height	h	mm	5,800-6,400
Minimum working height		mm	6,400-7,000
Maximum total weight		kg	16,800

Weather conditions were not optimal in the year of measurements; straw harvest was performed two to three weeks after grain harvest. Also barley straw yields were low. The average transport distance in the harvested field was 3.2 km.

The evaluation of operative, productive and running time for machines that baled, collected and stacked straw bales are shown in Tables 3 and Table 4.

Table 3 Summary of calculated indicators for JCB Fastrac 3230 + BIG pack

Designation	Indicator	Units	Average value
t_1	main time	h:mm:ss	0:03:05
t_2	incidental time	h:mm:ss	0:00:18
t_3	time to prepare the machine for work	h:mm:ss	0:00:12
t_4	downtime caused by troubleshooting	h:mm:ss	0:00:00
t_8	other downtime	h:mm:ss	0:00:08
t_{02}	operative time	h:mm:ss	0:03:23
t_{04}	productive time	h:mm:ss	0:03:35
t_{08}	running time	h:mm:ss	0:03:43
K_{02}	coefficient of operative time utilization	-	0.91
K_{04}	coefficient of productive time utilization	-	0.86
K_{07}	coefficient of running time utilization	-	0.83
W_{02}	performance per unit of operative time	pcs/h	16.16
W_{04}	performance per unit of productive time	pcs/h	14.41
W_{08}	performance per unit of running time	pcs/h	13.39
v_p	average speed of machine	km/h	9.40
	fuel consumption	L/pcs	0.91

Table 4 Summary of calculated indicators for JCB Fastrac 3220 + ARCUSIN F 54.63

Designation	Indicator	Units	Average value
t_1	main time	h	0:15:47
t_2	incidental time	h	0:01:49
t_3	time to prepare the machine for work	h	0:01:00
t_4	downtime caused by troubleshooting	h	0:00:00
t_8	other downtime	h	0:00:45
t_{02}	operative time	h	0:17:36
t_{04}	productive time	h	0:18:36
t_{08}	running time	h	0:19:21
K_{02}	coefficient of operative time utilization		0.90
K_{04}	coefficient of productive time utilization		0.85
K_{07}	coefficient of running time utilization		0.82
W_{02}	performance per unit of operative time	pcs/h	43.40
W_{04}	performance per unit of productive time	pcs/h	41.07
W_{08}	performance per unit of running time	pcs/h	39.47
v_p	average speed of machine with load	km/h	12.90
L	transport distance	km	3.20
m_1	number of bales per one cycle	pcs	12.00
	fuel consumption	L/pcs	0.39

The calculated coefficients and performances are high; therefore, we can say that this is a top technology suitable for practice. This technology of baling (Figure 1), collecting (Figure 2) and stacking (Figure 4) of straw is characterized by low fuel consumption and labour input. When collecting and transporting straw by special pick-up semi-trailer, time losses due to technological downtimes are very low because the semi-trailer merges several operations concurrently (loading, transport and stacking).

4 Conclusion

To achieve higher efficiency and productivity in transport and handling operations, the following steps should be implemented:

1) a comprehensive solution to every part of the whole logistic chain, covering transportation, handling of bales and stacking;

2) increasing the payload of vehicles by straw baling while optimizing their design of bales loading towards limiting time losses when performing auxiliary operations;

3) material treatment within technological operations (baling) so as to achieve easier loading, unloading and overall handling of material using one labour force while maintaining a high quality of transported material.

When collecting bales using JCB Fastrac 3220 + ARCUSIN, there were low technological and organizational downtimes incurred due to low straw yield when the baler was not fast enough for the machine for collecting and stacking.

The resulting value of average labour input per one baled bale was 3.71 min for JCB Fastrac 3230 + BIG pack. The resulting value of average labour input per one collected and stacked bale was 1.61 min for JCB Fastrac 3220 + ARCUSIN, and average fuel consumption per bale was 0.39 L. Labour input with this technology of collecting and stacking straw was so low because one person can collect, transport and stack, meaning reduced labour costs in practice.

Acknowledgements

The Paper was supported by the projects: Application of the information technologies to increase the environmental and ecological sustainability of the production agrosystem”, project ITMS 26220220014, EU Operational programme RESEARCH and DEVELOPMENT

Development of International Cooperation for the Purpose of the Transfer and Implementation of Research and Development in Educational Programs conducted by the Operational Program: Education, ITMS code: 26110230085

References

Börjesson, P.I.I. 1996. Energy analysis of biomass production and transportation. *Biomass and Bioenergy*, 11(4): 305-318.

Hussein, O. A., L. Nozdrovicky, and M. Macak. 2012. Study of the opportunities of using of plant biomass for pellets production and evaluation of their properties: scientific monograph, 1st ed., Nitra: Published by: Slovak University of Agriculture in Nitra, Faculty of Engineering, 182 p.

Libra, M., and V. Poulek. 2007. Zdroje a vyuziti energie (In Czech). Sources and energy utilization. Prague : Czech University of Life sciences In Prague, Czech republic. 141 pp. Sloboda, A. 1999. Racionalizacia dopravy v polnohospodarstve (In Slovak). Rationalization of Agricultural Transport. In Acta Mechanica Slovaca, SjF-TU Kosice - Slovakia 1999, pp. 49-53.

STN 47 0120. 1987. Slovak national standard: Agricultural and forestry machines and tractors. Time measuring methods and operating indices determination, Available at webside: www.sutn.sk (accessed 06/2014)

Syrovy, O. 2004. Doprava v zemedelstvi (In Czech). Agricultural transport. *Mechanizace zemedelstvi*, 54(6): 44-48.