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OPERATIONAL AND ECONOMIC EVALUATION OF TECHNOLOGY TO PREPARE AND FEED TOTAL MIXED RATION FOR CATTLE

Summary

The paper presents results of studies on operational and economic evaluation of three technologies used to prepare and feed total mixed ration (TMR) for cattle. The experiments were conducted on three farms in the Wielkopolska region, in which feed rations of 2662 up to 3595 kg were prepared. Mean operating output capacities for loading operations of feed mixer wagons ranged from approx. 10.5 t·h^{-1} for front loaders to approx. 12 t·h^{-1} for the telescope loader. Mean operating output capacities of feed mixer wagons ranged from 2.05 to 5.26 t·h^{-1}. Labour outlays per 1 ton prepared and fed TMR varied, ranging from 0.21 to 0.50 rbh·t^{-1}, while labour outlays at loading of the feed mixer wagon chamber with successive total mixed ration components were comparable, ranging from 0.09 to 0.10 rbh·t^{-1}. The total cost of machine operations was lowest for the T1 technology, amounting to 22.53 zł·t^{-1}, for T2 it was slightly higher at 23.92 zł·t^{-1}, while it was the greatest for T3, amounting to 30.73 zł·t^{-1}.
Key words: *feed mixer wagons, efficiency of feed mixer wagons, costs of preparing and feeding TMR*

OCENA EKSPLOATACYJNO-EKONOMICZNA TECHNOLOGII PRZYGOTOWANIA I ZADAWANIA DAWKI PEŁNOPORCJOWEJ DLA BYDŁA

Streszczenie

W pracy przedstawiono wyniki badań dotyczące oceny eksploatacyjno-ekonomicznej trzech technologii przygotowania i zadawania dawki całkowicie kompletnej (TMR) dla bydła. Badania były realizowane w trzech gospodarstwach rolnych na terenie Wielkopolski w których jednorazowo przygotowywano dawki w ilości od 2662 do 3595 kg. Średnie wydajności eksploatacyjne załadunku wozów paszowych wynosiły od około 10,5 t·h^{-1} dla ładowaczy czołowych do około 12 t·h^{-1} dla ładowarki teleskopowej. Średnie wydajności eksploatacyjne wozów paszowych wynosiły od 2,05 do 5,26 t·h^{-1}. Nakłady robocizny odniesione do 1 tony przygotowanej i zadanej dawki TMR były zróżnicowane i wynosiły od 0,21 do 0,50 rbh·t^{-1}, natomiast na zbliżonym poziomie były nakłady robocizny przy załadunku zbiornika wozu paszowego kolejnymi składnikami dawki całkowicie kompletnej i wynosiły od 0,09 do 0,10 rbh·t^{-1}. Łączny koszt wykonania prac maszynowych najmniejszy był w technologii T1 i wynosił 22,53 zł·t^{-1}, nieznacznie większy niż w technologii T1 i wynosił 23,92 zł·t^{-1} a największy w technologii T3 – 30,73 zł·t^{-1}.
Słowa kluczowe: *wozy paszowe, wydajność wozów paszowych, koszty przygotowania i zadawania dawki TMR*

1. Introduction

Maintenance of high and stable milk yields in dairy cow herds requires advanced feeding systems, which should completely cover the requirements for energy, protein as well as minerals and vitamins at individual stages of the production cycle [2]. At present the application of total mixed rations (TMR) or partial mixed rations (PMR) is increasingly often a basic element in feeding dairy cows, requiring the use of mixing and feeding machines or loading-mixing-feeding machines [3, 7, 10]. These machines should within a short time finely comminute ration components with different physico-mechanical properties, mix them until homogeneous structure is obtained and uniformly distribute TMR or PMR [1]. Feed mixer wagons provide feed, which any given amount contains components added to feed mixed at consistently identical proportions. These machines depending on the used equipment may perform many technological functions: loading and weighing of components, mixing and comminution of components, blending and distribution of the prepared TMR or PMR.

Thanks to the varied designs and capacities of feed mixer wagons they may be adapted to herd size and to the facilities, in which they are used. Among other things, feed mixer wagons differ in their capacity and shape of the chambers as well as customized optional equipment [8, 9]. Some feed mixer chambers are smooth and others have special grooves in the walls to prevent rotation of the material with the auger. Augers are also available in different designs, which according to the declarations of manufacturers increase cutting and mixing efficiency of feed ration components. Thus it may be assumed that the considerable variation in machine design and equipment may affect operational parameters. Literature on the subject lacks current data on operational parameters for feed mixer wagons. For this reason performance tests were conducted on these machines together with the units involved in the technological process. Experiments were conducted under commercial scale production conditions on dairy forms and the recorded results were used to determine efficiency of machine units, labour outlays, fuel consumption and operating costs.

2. Aim of study

The aim of the study was to determine operating parameters of equipment used in technologies of preparation

and distribution of total mixed ration for dairy cattle. The experiments were conducted on 3 technologies of TMR preparation and distribution. In the evaluated technologies tests were conducted on feed mixer wagons attached to a trailer with the vertical grinding and mixing system and loaders loading feed ration components to mixer chambers.

3. Material and methods

The performance tests included timing tests for machine units used in the analysed technologies, which covered four control shifts and records of the amounts of performed work. On this basis efficiencies of machine units and operating parameters were determined. Performance tests were conducted in accordance with the standard BN-76/9195-01 [5], while operating parameters were determined following the standard BN-77/9195-02 [6]. Fuel consumption was established using the full fuel tank method. Costs of individual operations in technologies were calculated using the IBMER method [4]. Costs were calculated using data provided by the farms and parameters determined based on performance tests.

Tests and analyses of technologies of total mixed ration preparation and distribution for cattle were performed under the following conditions:

- Technology 1 (T1) was used on a farm in Lutogniew, in the Krotoszyn county. The main unit consisted of a Belarus Jumz tractor with 67 horsepower and a feed mixer wagon by Strautman Verti Mix 1400 Double of 14 m^3 with two vertical auger mixers. The machine was equipped with an electronic scale, a ring preventing feed spill-off during mixing and two manually regulated counterblades, mounted in the front and back of the chamber. Loading operations were performed using a JCB 526-55 Turbo telescope loader with a 100 horsepower engine and loading capacity of 2600 kg. Additional attachments were used to collect and load individual feed ration components – a bucket front loader and a crocodile loader.
- Technology 2 (T2) was used on a farm in Walerianów near Borek Wielkopolski. The main unit was composed of a Zetor 7011 tractor of 70 horsepower and a feed mixer wagon by Metaltech WP10 with chamber capacity of 10 m^3, equipped with one vertical mixing auger. The machine was equipped with an electronic scale, a ring preventing feed spill-off during mixing and two counterblades, mounted in the front and back of the chamber. Loading operations were performed using a Zetor Proxima 85 Plus tractor of 82 horsepower with a Trac Fit 229SL front loader. Additional attachments were used to collect and load individual feed ration components – a bucket front loader and a crocodile loader.
- Technology 3 (T3) was used on a farm in Małgów, the Gostyń county. The main unit was composed of a Massey Ferguson 5455 tractor of 100 horsepower, a Trioliet Solomix – 2 1200 ZK feed mixer wagon with chamber capacity of 12 m^3 with two vertical mixing augers and a Quicke Q55 loader with the maximum load capacity of 2400 kg. The machine was equipped with an electronic scale, a ring preventing feed spill-off during mixing and two manually regulated counterblades, mounted in the front and back of the chamber. The same tractor was used to load the feed mixer chamber and when it was being filled the ball grapple of the mixer wagon was supported on a stand; the machine was additionally equipped with a battery to power the electronic scale.

4. Results and discussion

4.1. Performance test

In technology T1, TMR for 60 dairy cows at an average amount of 3595 kg per 1 work cycle was prepared by two machine units. The mean loading time for feed ration components was approx. 0.173 h, mean mixing time was approx. 0.250 h, while feed distribution time was approx. 0.170 h. TMR was unloaded onto the feeding passage on one side, which required a return run in order to distribute feed on the other side. The Strautmann Verti Mix 1400 Double mixer wagon reached operating output capacity of 5.26 $t \cdot h^{-1}$ at a fuel consumption of 6.01 $l \cdot h^{-1}$ (1.24 $l \cdot t^{-1}$). In this technology an average idle time of 0.080 h was observed, resulting from poor work organisation and connected with manual preparation of straw batches for the feed ration. When the work of the feed mixer was completed, approx. 80 kg of feed were left in the chamber. The JCB 526-55 Turbo telescope loader reached mean operating output capacity of 12.06 $t \cdot h^{-1}$ and consumed 6.48 $l \cdot h^{-1}$ (1.24 $l \cdot t^{-1}$) diesel oil.

In technology T2, TMR for 60 head of cattle at a mean amount of approx. 2662 kg per 1 work cycle was also prepared by two machine units. Mean loading time for feed ration components was 0.181 h and mean mixing time was 0.425 h. Feed distribution was performed in one passage at both sides simultaneously, which took 0.031 h. The WP10 feed mixer wagon by Metaltech reached operating output capacity of 4.18 $t \cdot h^{-1}$ at a fuel consumption of 8.48 $l \cdot h^{-1}$ (2.03 $l \cdot t^{-1}$). Upon the completion of mixer wagon work on average approx. 25 kg of feed were left in the chamber. Loading operations were performed by a Zetor Proxima 85 Plus tractor of 82 horsepower with a Trac Fit 229SL front loader, which reached a mean operating output of 10.73 $t \cdot h^{-1}$ and consumed 7.33 $l \cdot h^{-1}$ (0.75 $l \cdot t^{-1}$) diesel oil.

In technology T3, TMR was prepared for the dairy cow herd of 110 head, at a mean amount of 3100 kg. The Massey Ferguson 5455 tractor was used in this technology to drive the feed mixer wagon and it was also used to load it. Mean loading time of feed ration components was 0.215 h and mean mixing time of 1.08 h. Feed was distributed on one side and the operation lasted on average approx. 0.13 h. At the return passage feed was distributed on the other side. The Solomix – 2 1200 ZK by Troilet reached operating output capacity of 2.05 $t \cdot h^{-1}$ at a fuel consumption of 5.18 $l \cdot h^{-1}$ (2.54 $l \cdot t^{-1}$). At the completion of the feed mixer work on average approx. 30 kg of feed were left in the chamber. Loading of the mixer chamber was performed by the same tractor cooperating with a Quicke Q55 loader, working at a mean operating output capacity of 10.43 $t \cdot h^{-1}$ and using 5.40 $l \cdot h^{-1}$ (0.56 $l \cdot t^{-1}$) diesel oil. In the tested technologies the efficiency of loading devices was relatively low, because the main machine units had to work with different attachments (a bucket loader for loose materials and a crocodile loader), which were replaced during loading of feed mixer wagons. This was connected with the necessity to load the mixer chamber with total feed ration components differing in consistency and physical characteristics. Labour outlays per 1 ton prepared and distributed TMR varied and ranged from 0.21 to 0.50 $rbh \cdot t^{-1}$. In turn, labour outlays at loading of a feed mixer chamber with successive total feed ration components were similar ranging from 0.09 to 0.10 $rbh \cdot t^{-1}$. Tested feed mixer wagons were characterised by very high technological and engineering reliability, as evidenced by

the established K_{41} and K_{42} coefficients, amounting to 1. The most advantageous value of the coefficient of routine technical maintenance K_{31} = 0.96 was recorded for the feed mixer used in technology T3. It was to a considerable degree the effect of the longest mixing time of TMR components in the chamber of the Troilet mixer. It needs to be stressed here that routine technical maintenances in all the technologies were similar, ranging on average from 0.045 to 0.050 h.

Table 1. Statement of exploitation indices for mixer wagons – the average of the four control shifts
Tab. 1. Wyniki badań eksploatacyjnych wozów paszowych – średnie z czterech zmian kontrolnych

Parameter Parametr	Unit of measure Jedn. miary	Machine unit – Agregat maszynowy		
		Belarus Jumz + Strautmann Verti Mix 1400 Double	Zetor 7011 + Metaltech WP10	Massey Ferguson 5455 +Troilet Solomix – 2 1200 ZK
Effective capacity Wydajność efektywna W_1	$t \cdot h^{-1}$	8.64	5.86	2.60
Efficiency in time T_{02} Wydajność operacyjna W_{02}	$t \cdot h^{-1}$	6.07	4.64	2.411
Efficiency in straight time T_{04} Wydajność robocza W_{04}	$t \cdot h^{-1}$	5.30	4.18	2.05
Operating output capacity W_{07} Wydajność eksploatacyjna W_{07}	$t \cdot h^{-1}$	5.30	4.18	2.05
Efficiency in general time W_{08} Wydajność w czasie zmiany kontrolnej W_{08}	$t \cdot h^{-1}$	4.74	4.18	2.05
K_{02}	$t \cdot h^{-1}$	0.70	0.79	0.93
K_{04}	-	0.61	0.71	0.79
K_{07}	-	0.61	0.71	0.79
K_{08}	-	0.55	0.71	0.79
K_{31}	-	0.90	0.90	0.96
K_{41}	-	1.00	1.00	1.00
K_{42}	-	1.00	1.00	1.00
Fuel consumption Zużycie paliwa	$l \cdot h^{-1}$	6.01	8.48	5.18
	$L \cdot h^{-1}$	1.24	2.03	2.54
Labour outlays A_{04} Labour outlays Nakłady robocizny A_{04}	$rbh \cdot t^{-1}$	0.19	0.24	0.50
Labour outlays A_{08} Labour outlays Nakłady robocizny A_{08}	$rbh \cdot t^{-1}$	0.21	0.24	0.50

* costs of machine unit operation do not include labour costs connected with operation of machine and tractor

Source: own work / Źródło: opracowanie własne

Table 2. Operating parameters for loading equipment – means for four control shifts
Tab. 2. Wskaźniki eksploatacyjne urządzeń załadunkowych – średnie z czterech zmian kontrolnych

Parameter Parametr	Unit of measure Jedn. miary	Machine unit - Agregat maszynowy		
		JCB 526-55 Turbo	Zetor Proxima 85 Plus + Trac Fit 229SL	Massey Ferguson 5455 + Quicke Q55
Effective capacity Wydajność efektywna W_1	$t \cdot h^{-1}$	20.94	14.79	14.34
Efficiency in time T_{02} Wydajność operacyjna W_{02}	$t \cdot h^{-1}$	16.90	12.32	12.48
Efficiency in straight time T_{04} Wydajność robocza W_{04}	$t \cdot h^{-1}$	12.06	10.73	10.43
Operating output capacity W_{07} Wydajność eksploatacyjna W_{07}	$t \cdot h^{-1}$	12.06	10.73	10.43
Efficiency in general time W_{08} Wydajność w czasie zmiany kontrolnej W_{08}	$t \cdot h^{-1}$	11.10	9.76	9.64
K_{02}	-	0.81	0.83	0.87
K_{04}	-	0.58	0.73	0.73
K_{07}	-	0.58	0.73	0.73
K_{08}	-	0.53	0.66	0..67
K_{31}	-	1.00	1.00	1.00
K_{41}	-	1.00	1.00	1.00
K_{42}	-	1.00	1.00	1.00
Fuel consumption Zużycie paliwa	$l \cdot h^{-1}$	6.48	7.33	5.40
	$l \cdot h^{-1}$	0.58	0.75	0.56
Labour outlays A_{04} Labour outlays Nakłady robocizny A_{04}	$rbh \cdot t^{-1}$	0.08	0.09	0.10
Labour outlays A_{08} Labour outlays Nakłady robocizny A_{08}	$rbh \cdot t^{-1}$	0.09	0.10	0.10

Source: own work / Źródło: opracowanie własne

Table 3. Operating costs of machine units used in tested technologies
Tab. 3. Koszty eksploatacji agregatów maszynowych użytkowanych w badanych technologiach

Technology Technologia	Machine unit Agregat maszynowy	Unit operating cost Jednostkowy koszt eksploatacji [zł·h^{-1}]	Operating cost per work unit Koszt eksploatacji na jednostkę pracy [zł·t^{-1}]	Total cost of performed machine operations Łączny koszt wykonania prac maszynowych [zł·t^{-1}]
T1	Bielarus Jumz + Strautmann Verti Mix 1400 Double	90.11	17.13	22.53
	JCB 526-55 Turbo	65.11	5.40	
T2	Zetor 7011 + Metaltech WP10	78.80	18.85	23.92
	Zetor Proxima 85 Plus + Trac Fit 229SL	54.43	5.07	
T3	Massey Ferguson 5455 + Troilet Solomix – 2 1200 ZK	52.89	25.80	30.73
	Massey Ferguson 5455 + Quicke Q55	51.46	4.93	

** operating costs of a machine unit do not include labour costs connected with the operation of the machine and tractor. Costs were calculated based on prices for July 2015.*

Source: own work / Źródło: opracowanie własne

4.2. Operating costs of tested technologies

Operating costs of machine units used in loading and preparation of TMR were established based on the data obtained from the farms and operating indexes determined on the basis of analyses conducted by the authors of this study. Fuel consumption for calculations was assumed in accordance with the results obtained by the authors. Thus calculated unit operating costs for the operation of machine units preparing TMR varied, amounting to 90.11 zł·h^{-1} for technology T1, 78.80 zł·h^{-1} for technology T2 and 52.89 zł·h^{-1} for technology T3. The lowest unit operating costs of the machine unit composed of a Massey Ferguson 5455 tractor and the Troilet Solomix – 2 1200 ZK mixer wagon (T3) results from the greatest number of annual effective operation time, as a consequence of approx. two-fold greater TMR mixing time in comparison to technology T2 and approx. four-fold longer than in technology T1. In turn, per unit of performed work, the lowest costs at a comparable level are found for technologies T1 and T2, amounting to 17.13 and 18.85 zł·t^{-1}. In technology T3 they were the greatest amounting to 25.80 zł·t^{-1}, which results from the longest TMR mixing cycle. Unit operation costs of loading devices were also varied and amounted to 65.11 zł·h^{-1} for the telescope loader (T1) as well as 54.43 and 51.46 zł·h^{-1} for tractors with mounted front loaders in technologies T2 and T3. Per unit of performed work operating costs were similar and amounted to 4.93 zł·t^{-1} for technology T3, 5.07 zł·t^{-1} for technology T2 and 5.40 zł·t^{-1} for technology T1. The greatest costs were incurred using the telescope loader (T1), despite the greatest total efficiency at loading of feed ration components (11.10 t·h^{-1}). The total cost of performance of machine operations was the lowest for technology T1 and amounted to 22.53 zł·t^{-1}, whereas it was highest for technology T3 at 30.73 zł·t^{-1}. For technology T2 the total cost of performance of machine work was slightly higher than for technology T1, amounting to 23.92 zł·t^{-1}.

5. Conclusions

Based on the tests and analyses the following conclusions may be formulated:

1. Efficiencies of front loaders mounted on tractors and the telescope loader used in loading of TMR components were relatively low due to the need to replace attachments. The use of a bucket loader for loose materials and the crocodile loader was necessary due to differences in consistency and in physical characteristics of individual TMR components.
2. Operating output capacity of tested feed mixer wagons varied ranging from 2.05 to 5.30 t·h^{-1}. The greatest effect on the obtained total efficiencies of feed mixer wagons was observed for mixing time of TMR components.
3. Unit operating costs of tractors and machines used in the tested technologies varied. The greatest effect on their level was observed for the intensity of annual effective operation and purchase price.
4. Operating costs per unit operation of machine units used in loading of TMR components were similar in all tested technologies and ranged from 4.93 to 5.40 zł·t^{-1}.
5. Total costs of performance of machine operations in tested technologies of TMR preparation and distribution were dependent in approx. 80% on operating costs of mixing and feed distributing units.

6. References

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