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A COMPARISON OF QUALITY OF WORK OF THE FEED MIXER WAGONS WITH VERTICAL AND HORIZONTAL MIXING SYSTEMS

Summary

The paper presents the results of research on the assessment of the quality of fragmentation and the structure of totally complete feed rations in five different technologies (T1-T5) preparation and setting of TMR for cattle. The research was carried out in five farms in Wielkopolska, where dairy cows were kept. During the studies on farms TMR for dairy cows were prepared in the following portions: T1 - 3595 kg, T2 - 2662 kg, T3 -3100 kg, T4 - 3760 kg and in T5 - 4925 kg. Due to different composition, the average dry matter content in the prepared rations was respectively: T1 – 380,52 g·kg^{-1}d.m., T2 – 297,66 g·kg^{-1}d.m., T3 – 476,32 g·kg^{-1}d.m., T4 – 414,60 g·kg^{-1}d.m. and w T5 – 466,60 g·kg^{-1}d.m. Variation in the composition of TMR in the studied technologies resulted from individual feed resources of each farm. Depending on the technology used to prepare the feed, the structure of the granularity of ingredients in the prepared rations of TMR was also different. It was evaluated by separating feed particles into four fractions using sieves.
***Key words**: feed mixer wagons, TMR, quality of work of the mixer wagons, dry matter content in TMR, TMR structure*

PORÓWNANIE JAKOŚCI PRACY WOZÓW PASZOWYCH Z PIONOWYMI I POZIOMYMI SYSTEMAMI MIESZAJĄCYMI

Streszczenie

W pracy przedstawiono wyniki badań dotyczące oceny jakości rozdrobnienia i struktury całkowicie kompletnych dawek paszowych w pięciu różnych technologiach (T1-T5) przygotowania i zadawania TMR dla bydła. Badania przeprowadzono w pięciu gospodarstwach rolnych na terenie Wielkopolski, w których były utrzymywane krowy mleczne. W okresie badań w gospodarstwach przygotowano dawki TMR dla krów mlecznych w następujących porcjach: T1 – 3595 kg, T2 - 2662 kg, T3 -3100 kg, T4 – 3760 kg i w T5 – 4925 kg. Na skutek różnego składu, średnie zawartości suchej masy w sporządzanych dawkach wynosiły odpowiednio: T1 – 380,52 g·kg^{-1}s.m., T2 – 297,66 g·kg^{-1}s.m., T3 – 476,32 g·kg^{-1}s.m., T4 – 414,60 g·kg^{-1}s.m. oraz w T5 – 466,60 g·kg^{-1}s.m. Zróżnicowanie składu dawek TMR w badanych technologiach wynikało z indywidualnych zasobów paszowych każdego gospodarstwa. W zależności od stosowanej technologii przygotowywania paszy różna była także struktura rozdrobnienia składników w sporządzanych dawkach TMR. Była ona oceniona przez rozdzielenie cząstek paszy na cztery frakcje za pomocą sit.
***Słowa kluczowe**: wozy paszowe, TMR, jakość pracy wozów paszowych, zawartość suchej w TMR, struktura TMR*

1. Introduction

Total mixed rations (TMR) or partly mixed rations (PMR) prepared in feed mixer wagons nowadays are the basic way of feeding the cattle in larger farms [5]. The feed mixer wagons are used to prepare, transport and deliver complete feeds which facilitate the organization of work and enable to shorten the cattle feeding time [8]. The machines are equipped with different construction agitators with cutting knives which can be mounted in tanks in a vertical or horizontal arrangement. The varied construction of these working elements can affect the efficiency of cutting and mixing nutrient components. Vertical mixing systems are equipped with augers of various shapes, characterized by versatility, simple construction regardless of the capacity of the tank and do not threaten excessive fragmentation and destruction of the structure of forage [11, 12]. At the edges of the screw rolls, cutting knives are mounted which enable cutting ration components, e.g. hay, silage from low fodder or straw formed into cylindrical bales. In turn, mixing systems with horizontal mixing augers interact aggressively with the mixed components and thus ensure very intensive cutting rations components and high mixing efficiency and obtaining a homogeneous structure of the feed.

The components of total mixed rations differ not only in their nutritional value but also in their consistency. The consistency of organic materials affects their rheological properties, and these have a decisive influence on the quality of fragmentation and mutual mixing of substrates [9]. Therefore, regardless of the correct balancing of full-ration forage, the physical structure is also an essential element of quality [1, 2]. Apart from mixing, feed mixers wagons additionally crumble the forage which may result in excessive fragmentation and lead to its incorrect rumen digestion [1, 2]. Therefore, in the daily preparation of TMR, not only the composition of the ration should be maintained, so that the forage value of the feed does not affect the production results but also its proper form and structure for the proper functioning of the cattle digestive system [7].

Therefore, it should be assumed that a significant diversity in the design of machines, their equipment and the used TMR components may affect the time of mixing TMR components and their fragmentation and structure. The available literature lacks up-to-date data on the objective and real quality of the work of feed carts used on farms. Therefore, work studies of various types of machines in production conditions of farms focused on milk production have been undertaken. Obtained results have also become

the basis for determining the physical structure of feed prepared by the tested feed mixer wagons.

2. Aim of the work

The aim of the work was to compare the accuracy of preparing the total mixed rations (TMR) by feed mixer wagons and to determine the fragmentation of the components of the rations by determining their physical structure. The subject of the research included 5 technologies of preparing and applying a total mixed ration. In the evaluated technologies, 3 feed wagons attached to a farm tractor with vertical shredding and mixing equipment and devices loading the ration components to the tanks were used. In the 4th technology, a feed mixer wagon with a horizontal shredding and mixing system and a self-loading cutter was used. In the 5th technology, a self-propelled feed mixer wagon with a vertical shredding and mixing system and a self-loading device was used.

3. Material and methodology of tests

The tests was carried out in five farms in the Wielkopolska voivodeship in Gostyń, Krotoszyn and Śrem poviats, aimed at milk production. In T1 technology, the main unit consisted of a 67 hp Belarus Jumz tractor and Strautman Verti Mix 1400 Double feed mixer wagon with a capacity of 14 m^3 with two vertical screw agitators. The JCB 526-55 Turbo telescopic loader with a 100 hp engine and 2600 kg lifting capacity was used for loading. The additional equipment - a shovel and a crocodile gripper - were used to collect and load individual dose components. In T2 technology, the machine set consisted of a Zetor 7011 tractor with a power of 70 hp and a Metaltech WP10 feed mixer wagon with a tank capacity of 10 m^3 equipped with one vertical worm agitator. The Zetor Proxima 85 Plus 82 hp tractor with a front loader Trac Fit 229SL was used for loading. Special accessories - a shovel and a crocodile gripper - were used to collect and load individual dose components. In the T3 technology, the main unit consisted of a Massey Ferguson 5455 tractor with 100 hp, a Trioliet Solomix feed mixer wagon - 2,200 ZK with a capacity of 12 m^3 with two screw agitators. The same tractor with a Quicke Q55 loader with a maximum lifting capacity of 2400 kg was used to load the feed mixer wagon tank. During filling, the hook of the wagon was supported on the stand, and the machine was additionally equipped with a battery to ensure the operation of the electronic balance. In the T4 technology, the main unit consisted of a John Deere 6620 tractor with 125 hp and a Kuhn Euromix feed mixer wagon with a self-loading device with a capacity of 8 m^3 with three horizontal screw mixers. The main agitator - placed at the bottom of the tank, had cutting knives along its entire length. Two more augers were placed higher and their task is to transport the forage to the back of the wagon and mixing the ingredients. A cutter controlled by hydraulic cylinders, which was placed in the rear part of the machine, was used to load the feed mixer wagon tank. In T5 technology, the main unit was a self-propelled Faresin Leader Double 2200 feed mixer wagon equipped with a 210 hp engine and a 22 m^3 tank equipped with two vertical auger agitators and a self-loading device.

The average composition of the actual components is included in the set of recommendations for each machine. The composition of the average dose was determined from four replicates. The physical structure of TMR was determined using a set of sieves with a hole diameter of 19,0; 8,0 and 4,0 mm. The recommended percentage of particles in individual sieves was taken into account according to the Heinrichs guidelines [4]. The weight of the sieving sample was 500 g. The dry matter was determined by the drying method. The STATPAK computer program developed at the University of Agriculture in Poznań (currently the University of Life Sciences in Poznań) was used for statistical calculations. The smallest significant difference (NIR) was calculated based on the limit values at the confidence level $\alpha = 0,05$.

4. Results and discussion

The farms covered by the tests had their own resources of forage, which were used to prepare TMR. In the first technology (T1), the TMR was prepared for 60 dairy cows in an average amount of 3595 kg (Table 1). The average dry matter content in the analyzed rations was 380,5 g·kg^{-1}d.m. In the second T2 technology, the TMR for dairy cows was prepared in an average amount of approximately 2662 kg for one working cycle. The average dry matter content in the analyzed rations was 297,7 g·kg^{-1}d.m. In the third technology (T3), the TMR was prepared for a herd of 110 dairy cows, with an average quantity of 3100 kg.

In the fourth and fifth farms a few TMR portions were prepared per day, that is why only one of them was taken for analysis - the composition closest to the T1-T3 doses. On the fourth farm, it was the 3rd portion prepared each day (T4 ration), and on the fifth farm, the 2nd daily portion - called here T5.

To prepare a test portion of TMR called T4 technology, about 690 kg of feed was left from the previous load of the feed mixer wagon and 50 kg of straw, 550 kg of concentrate, 370 kg of sugar beet pulp, 260 kg of barley and 1840 kg of silage were added to maize, which together accounted for the third ration of TMR in an amount of 3760 kg. The average dry matter content in the analyzed T4 technology was 414,6 g·kg^{-1}d.m. (Table 2).

Table 1. Composition of nutritional rations prepared by feed mixer wagons in 1-3 technologies (average of four replications)

Tab. 1. Skład dawek paszowych przygotowanych w wozach paszowych w technologiach 1-3 (średnia z czterech powtórzeń)

Components of TMR	Composition of TMR [kg]		
	Technology **1**	Technology **2**	Technology **3**
Left	77,5	27,5	30,0
Maize silage	2052,5	1392,0	1597,5
Haylage	611,3	872,5	662,5
Straw	57,5	0,0	0,0
Barley threshes	457,5	243,8	0,0
Beet pulp	0,0	0,0	522,5
Pure feed	338,7	126,3	287,5
Total	**3595,0**	**2662,1**	**3100,0**

Source: own study / Źródło: opracowanie własne

Table 2. Composition of nutritional rations in 4-5 technologies (average of four replications)
Tab. 2. Skład dawek paszowych w technologiach 4-5 (średnia z czterech powtórzeń)

Components of TMR	Technology 4	Technology 5
TMR left	690,0	0,0
Maize silage	1840,0	1800,0
Straw	0,0	90,0
Grass silage	0,0	0,0
Alfalfa silage	0,0	270,0
Pickled corn grain	0,0	500,0
Barley threshes	260,0	450,0
Pure feed	550,0	925,0
Beet pulp	370,0	820,0
Straw	50,0	70,0
Total	3760,0	4925,0

Source: own study / Źródło: opracowanie własne

In the fifth technology (T5), TMR rations were prepared twice a day for 180 cows. A portion of the feed was made of the following ingredients: 70 kg of straw, 90 kg of hay, 1800 kg of maize silage, 270 kg of alfalfa silage, 500 kg of pickled corn grain, 925 kg of concentrate, 820 kg of beet pulp, 450 kg of barley, which in total weighed 4925 kg. The average dry matter content in the analyzed doses was 466,60 g·kg^{-1}d.m. (Table 3).

The smallest variability of the dry matter content in TMR characterized technology no. 5, which indicates the selection of individual feed with a similar dry matter content. In turn, the highest variability of dry matter content was found in technology no. 1, in which the dry matter content in the prepared doses ranged from 274,70 to 417,40 g·kg^{-1}d.m. (Table 4).

The average fraction of individual fractions in the analyzed TMR rations was presented in Tables 5 and 6. The smallest average share of 19,72% was found for particles with a length of up to 4 mm, while the highest average share was found for particles from 8,1 to 19 mm and it was about 35,8%.

5. Discussion

Feed mixer wagons used for preparation of TMR in a short time should: thoroughly fragment the components of the ration with different physical and mechanical properties, mix them to obtain a homogeneous structure and evenly prepare TMR. Normal physical structure of TMR should be obtained by sieving on screens within the upper sieve (19.0 mm) 6-10% of the residual mass, the middle sieve (8,0 mm) 30-50% of the residual mass and the bottom sieve (1.18 mm) 40-50% of the residual weight. The dry matter content in TMR should amount from 35 to 55% [10]. In 2013, a modification of recommendations regarding the structure of TMR took place. For high-yielding dairy cows, US scientists have set a new critical threshold for longer particles in the rumen [4]. Currently, the threshold is larger and is closer to 4 mm, which enables to more accurately estimate the NDF content in the ration for dairy cattle.

Table 3. The content of dry matter in TMR (g·kg^{-1}d.m.) - averages from four consecutive days of testing
Tab. 3. Zawartość suchej masy w TMR (g·kg^{-1}d.m.) - średnie z czterech kolejnych dni badań

Technologies (A)	Rations (B)				Average	$NIR_{0,05}$
	1	2	3	4		
T1	367,85	367,97	377,25	409,00	380,52	
T2	285,72	288,82	304,43	311,67	297,66	NIR_A= 4,041
T3	499,57	472,08	468,97	464,67	476,32	NIR_B= 3,614
T4	429,37	430,80	398,52	399,72	414,60	$NIR_{A\times B}$=
T5	454,13	476,98	473,30	461,97	466,60	8,052
Average	407,33	407,33	404,49	414,60	-	

Source: own study / Źródło: opracowanie własne

Table 4. The variability of the dry matter content in TMR g·kg^{-1}d.m.
Tab. 4. Zmienność zawartości suchej masy w TMR g·kg^{-1}d.m.

Technologies	Aver. content of d.m.	Standard deviation	Coefficient of variation	Confidence interval	Minimum value	Maximum value
T1	380,52	20,689	5,44	371,78 – 389,25	374,70	417,40
T2	297,66	11,871	3,99	292,65 – 302,67	276,60	318,00
T3	476,32	15,323	3,22	469,85 – 782,79	453,70	501,90
T4	414,60	16,253	3,92	407,74 – 421,46	392,00	433,80
T5	466,60	9,921	2,13	462,41 – 470,79	446,60	480,20

Source: own study / Źródło: opracowanie własne

Table. 5. The structure of TMR prepared in feed mixer wagons - share of four fractions in%
Tab. 5. Struktura TMR przygotowanego w wozach paszowych – udział procentowy czterech frakcji

The particle size [mm]	No. of technology					Average
	T1	T2	T3	T4	T5	
>19,0	23,03	26,92	25,33	17,19	12,50	20,99
8,1 – 19,0	27,43	44,83	40,43	33,42	32,72	35,77
4,0 – 8,0	25,31	20,93	21,14	27,63	22,61	23,52
<4,0	24,23	7,33	13,10	21,75	32,20	19,72
Average	100,00	100,00	100,00	100,00	100,00	100,00

Source: own study / Źródło: opracowanie własne

Table 6. Coefficients of variation in TMR for individual 4 fractions in the tested technologies in %
Tab. 6. Współczynniki zmienności TMR dla poszczególnych 4 frakcji w testowanych technologiach, w %

The particle size [mm]	No. of technology					Average
	T1	T2	T3	T4	T5	
>19	5,92	4,99	5,04	13,11	18,18	9,45
8,1 – 19,0	7,48	3,31	3,37	11,55	6,17	6,38
4,0 – 8,0	3,67	4,54	6,48	11,17	6,47	6,47
<4,0	5,74	9,73	6,42	10,65	3,77	7,26
Average	8,70	5,64	5,33	11,62	8,65	-

Source: own study / Źródło: opracowanie własne

According to the new recommendations for TMR, 2-8% of the sample weight should remain on the upper sieve (19,0 mm), on the middle sieve (8,0 mm) 30-50% of the sample weight, on the bottom sieve (4,0 mm) 10-20% of sample weight and 30 to 40% of sample mass [4].

In own tests, which concerns five technologies of preparing TMR, different results of TMR fragmentation and its structure were obtained. In the first technology (T1) the share of particles over 19,0 mm was larger than the recommendations and amounted on average to around 23%, the proportion of particles in the range 8,1-19,0 mm was on average 27,43% and was lower than the recommendations, the share of particles in the range of 4,0 to 8,0 mm amounted on average to 25,31% and was larger than the recommendations. However, the share of particles below 4,0 mm was 24,23% and was smaller than the recommended values. Hence, the portion of test feed in T1 technology did not meet the requirements of the structure of the ration intended for dairy cows. In technologies T2, T3 and T4, the share of particles in the range of 8,1-19,0 mm was on average 44,83, 40,43 and 33,42%, respectively, and met the requirements, while for the remaining ranges: over 19,0; from 4,0 to 8,0 mm and below 4,0 mm the size of the feed particles deviate from the recommendations. Therefore, TMR did not meet the requirements for the correct structure of fragmentation of the components. In the T5 technology, the results of the analysis of the TMR fragmentation structure were the closest to the requirements. The proportion of particles below 4 mm and from 8,1-19,0 mm was in the recommended ranges and amounted to 32,2 and 32,72%, respectively. However, the average share of feed particles in the range of 4,1-8 mm and above 19,0 mm was 22,61 and 12,50% and slightly exceeded the requirements. The share of feed particles in the range of length from 4,0 to 8,0 mm was exceeded by 2,61%, and above 19,0 mm by 4,50%, which is the smallest deviation from the assessed rations. In this case, the TMR also did not meet the recommendations for dairy cattle despite the fact that it was the closest to the structure of fragmentation to Heinrich's recommendations [4]. The study of feed mixer wagons was also conducted by Vegricht et al. [13] and evaluated the length of the feed particles in the following compartments: over 19 mm: 19-7,8 mm; 7,8-1,3 mm and which are similar to previous recommendations for TMR fragmentation from 2002 recommended by Heinrichs and Kononoff [3, 6]. The fragmentation structure of TMR also did not meet the requirements regarding the share of individual ranges of particle length in the feed ration. Particles above 19 mm were much more numerous than the recommendations, in the range 19-7,8 mm and 7,8-1,3 mm-too little and only in some cases the requirement for feed particles below 1,3 mm was met. The correct structure of an all-animal feed should consist of particles of the recommended size, maintaining their mutual proportion to ensure good production efficiency [1, 2]. Therefore, it can be stated that a well-functioning feed mixer wagon, which should be regularly reviewed, is one of the basic conditions of a properly prepared TMR dose. It seems to be justified due to the consuming working elements and the mixing feed components with different content of dry matter. The recommendations indicate that TMRs should contain from 35 to 45% of dry matter with acceptable small deviations, but not more than 55% [10]. When they contain less than 40%, they are reluctant to be taken by cows because of caking. In turn, when they contain more than 50% of dry matter, they are sorted by animals. In the own tests, the average dry content in the studied technologies and the assessed doses of TMR varied from 297,66 to 476,32 $g \cdot kg^{-1}$d.m. Two rations of TMR with technologies T3 and T5 met the recommendation. In T4 technology, the dry matter content slightly differed from the requirements (41,5%, in T1 and T2 technologies it was below 40%). The smallest changeability of the dry matter content in TMR was characteristic for T5 technology.

6. Conclusions

1. The rations of TMR in the tested technologies differed significantly both in the dry matter content and in the physical structure. Rations of TMR in T1-T4 technologies did not meet the requirements for the structure of feed ingredients fragmentation. The TMR ration in T5 technology met the fragmentation structure for the first three length ranges. The fourth range above 19 mm has been exceeded slightly.
2. In practice, feeding dairy cows, feed rations for correct structure are controlled very rarely or not at all. Thus, the fragmentation structure is primarily due to the recommended mixing time for a given type of feed mixer wagon.
3. Too little attention is paid to the actual dry matter content in the ingredients used to prepare fully complete doses. Also, attention is paid to the progressive wear of the working parts of the feed mixer wagon, which are responsible for cutting TMR components.
4. Increased proportion of feed particles with a length of over 19 mm results from the use of ingredients in a ration such as straw and haylage in cylindrical bales. It results in exceeding the recommended level of particle length of the prepared feed.

7. References

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