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EFFICIENCY OF LABOR OPERATIONS WHEN FEEDING MIXTURE ON FEEDING TABLES

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The article presents the results of the analysis of labor operations carried out in the process of mechanized distribution and feeding of feed mixtures in free housing of animals The article presents the results of the analysis of labor operations carried out in the process of mechanized distribution and feeding of feed mixtures in free housing of animals The article presents the results of the analysis of labor operations carried out in the process of mechanized distribution and feeding of feed mixtures in free housing of animals, free housing. When comparing the above manual methods of pusher feed mixtures, it was established that when using a shovel for 100 cows at a time, 5.01 minutes of working time were spent, when using forks – 8.12 minutes, and when using a hand scraper – only 2.12 minutes. In modern complexes, the fastest way to hill feed is with a tractor. This takes 1.02 minutes per 100 cows. The "Butler Gold" robot works much more slowly. It takes 4.96 minutes for this operation.

It was found that the feeding behavior of dairy cows depended on feeding management factors, including the frequency of feed distribution and its pusher. The activation of the feeding behavior of animals was characterized by an increase in the number of animals near the feed table when performing the technological operations of feed distribution and pushing (moving feed to the animal on the feeding table). Performing the technological operation of distributing feed mixtures twice a day led to an increase in the number of cows near the feed table by 20.9 % – 22.0 % of the total number of animals in the pen (126±5.2 heads). Performing the technological operation

of pusher feed also led to an increase in the number of cows near the feed table by 2.3 % – 11.3 % of the total number of animals in the group. The remains of feed removed beyond the border of the feed table were perceived by the animals as fresh bedding for rest, which led to a reduction in the total feeding front.

Keywords: dairy cattle, free housing, feed table, manual technological operations, feed pusher, feeding behavior of cows.

ЕФЕКТИВНІСТЬ ТРУДОВИХ ОПЕРАЦІЙ ПРИ ЗГОДОВУВАННІ КОРМОСУМІШЕЙ НА КОРМОВИХ СТОЛАХ

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У статті викладено результати аналізу трудових операцій, що здійснювались у процесі механізованого роздавання та згодовування кормосумішей при безприв'язному утриманні тварин. На основі даних проведеного фотохронометражу встановлено, що технологічні операції складалися із наборів елементарних трудових рухів та мали певну циклічність виконання у часі. При виконанні механізованого роздавання кормів персонал виконував тривалі піші переходи вздовж кормових столів, а також трудові операції з відкриттям-зачиненням різного роду воріт. Підгортання кормів здійснювалось працівниками ферм за допомогою різних інструментів. При порівняні вищенаведених ручних способів підгортання кормосумішей встановлено, що при використанні лопати на 100 корів за один раз було витрачено 5,01 хвилини робочого часу, за використання вил – 8,12 хвилини, а при використанні упору – лише 2,12 хвилини. На сучасних комплексах найбільш швидко корм підгортається трактором. При цьому витрачається 1,02 хвилини на 100 корів. Робот Butler Gold працює значно повільніше. Він витрачає на цю операцію 4,96 хвилин.

Встановлено, що кормова поведінка молочних корів залежала від факторів управління годівлею, включаючи частоту роздавання корму та його підгортання. Активізація кормової поведінки тварин характеризувалась збільшенням кількості тварин біля кормового столу при виконанні технологічних операцій роздавання та підгортання кормів. Виконання технологічної операції роздавання кормосумішей двічі на добу приводило до збільшення чисельності корів біля кормового столу на 20,9 %–22,0 % від загальної кількості тварин у загоні (126±5,2 голів). Виконання технологічної операції підгортання корму також приводило до збільшення чисельності корів біля кормового столу на 2,3 % – 11,3 % від загальної кількості тварин групи. Залишки кормів віддалені за бордюр кормового столу сприймалися тваринами як свіжа підстилка для відпочинку, що приводило до скорочення загального фронту годівлі.

Ключові слова: молочна худоба, безприв'язне утримання, кормовий стіл, ручні технологічні операції, підгортання кормів, кормова поведінка корів.

Introduction. Identifying factors that influence dairy farm performance is crucial for improving cow productivity and profitability, as well as protecting animal welfare and the environment (Bava L. et al., 2014; Skevas T. et al., 2020). Management techniques at the individual cow or herd level can increase herd milk production, improve dairy farm efficiency, and reduce production costs (Britt J. H. et al., 2018; Pulina G. et al., 2020). As dairy farms continue to grow in size, monitoring and managing cows becomes increasingly complex and requires improved management skills (Edwards et al., 2014; Bewley, 2016). The use of automation and sensors, commonly referred to as precision technologies, is increasingly providing farmers with the means to reduce labor requirements and improve management of large herds (Eastwood et al., 2015).

A significant part of all farm costs is feeding costs. Full-fledged balanced feeding of cows affects the efficiency of milk production and farm economics (Bach A. et al., 2020). Therefore, the development of effective feeding strategies is one of the main problems for dairy farms around the world, since feeding is the main factor that affects both the milk yield of cows and the quality of milk (Khanal A.R. et al., 2010). Increasing the efficiency of using feed resources in livestock farming is associated with the introduction of industrial milk production technology, year-round uniform feeding, mechanization and automation of feed distribution, specialization and individualization of feeding according to need, taking into account a complex of endogenous and exogenous factors (Deming J. A. et al., 2013; Ericksona Peter S. et al., 2020). Feeding management on modern dairy farms is becoming increasingly important from an economic and technological perspective, as well as from a dairy cow comfort and welfare perspective (Mattachini G. et al., 2019). Feed distribution stimulates dairy cows to consume feed (DeVries T. J. et al., 2005; King M. T. M. et al., 2016) regardless of the time of day and milking.

It is well known that dairy cow behavior is influenced by feeding management factors, including feed frequency and feeding time (King M. T. M. et al., 2016), although the effect of feeding time on behavioral patterns is less clear. Research suggests that providing fresh feed has a greater effect on stimulating feeding behavior than returning cows from milking. Changes in feeding management can affect both feeding and lying behavior in dairy cows (DeVries T. J. et al., 2005). There is evidence that feeding manipulation around the time of milking increases the percentage of cows lying down after milking compared to feeding manipulation hours after milking (Watters M. E. A. et al., 2013). Other researchers have also found a positive relationship between feed toss frequency and total daily lying time of cows, suggesting that improved feed availability may allow cows to feed more efficiently and spend more time lying down (Deming J. A. et al., 2013). Studies have also found that as the feeding front of cows at the feed table decreases, they are more likely to be at the feed table (Lobeck-Luchterhand K. M. et al., 2015; Krawczel P. D. et al., 2012), namely, they spend more time standing in the feeding area (Wang, F. X. et al., 2016), consume less feed (Huzzey J. M. et al., 2006), and eat faster (Olofsson J., 1999). These changes in feeding patterns may affect feeding efficiency, as rapid feed consumption is associated with lower feeding efficiency (Faith S. R. et al., 2024). Cows that are lower in the social hierarchy are more easily displaced from the feed table, especially when there is insufficient feed frontage (Huzzey J. M. et al., 2006). Thus, these cows tend to eat at different times, which are offset from the time of feed distribution. Other researchers have also concluded that herds with improved access to feed, including increased feed table area, feed distribution frequency, and its pusher, have higher average milk production per group and show less feed sorting (Sova A. D. et al., 2013). It has been established that the implementation of technological operations of distributing and staking feed activates the general activity of

animal feeding behavior (Greben L. G., 2009). Therefore, periodic staking of feed is a common practice in feed table management. Establishing the full composition and time spent on performing staking operations manually and using mechanization and automation is necessary to assess the effectiveness of its implementation and optimize the overall technological process. Therefore, the purpose of the work is to study the effectiveness of labor and mechanized operations when feeding feed mixtures on feed tables.

Materials and methods. The studies were conducted under conditions of mechanized distribution of feed mixtures by mobile mixers to feed tables of the dairy farm of the State Enterprise "Kutuzivka" in the Kharkiv region with free housing of cows on deep straw bedding and the farm of LLC "OLTO" in the Kirovograd region with box housing. The studies determined the list and features of the personnel's performance of manual operations related to the mechanized distribution and feeding on feed tables in free housing, as well as the definition of labor operations that affect the behavior of animals.

The obtained data were processed using standard methods of variational statistics using computer programs.

Research results. Based on the data of the conducted photo-chronometry, it was established that technological operations consist of sets of elementary labor movements and have a certain cyclicality of execution in time.

The activation of the feeding behavior of animals was characterized by an increase in the number of animals at the feed table and was manifested when performing technological operations related to the distribution and pushing of feed. Performing the technological operation of distributing feed mixtures twice a day led to an increase in the number of cows at the feed table by 20.9% - 22.0% of the total number of animals in the pen (126 heads) with each pusher. Performing the technological operation of distributing additional feed (molasses) led to an increase in the number of cows at the feed table by 10.2% - 5.3% of the total average number of animals in the pen. Performing the technological operation of pusher feed also led to an increase in the number of cows at the feed table by 2.3% - 11.3% of the total number of animals in the group.

When performing mechanized feed distribution, the staff performed long walking movements along the feed tables, as well as labor operations with opening and closing various types of gates. These are unproductive labor movements, since they are aimed only at servicing the work of the mobile feed dispenser. In this case, the animals actively reacted not to the presence of the employee walking along the feed table, but only to the freshly distributed feed.

When performing the technological operation of pushing the already distributed feed, the worker performed a different set of labor movements, which depended on the tool he used. The analysis showed that these movements were periodically repeated during the technological process. The set of movements that were repeated periodically made up a full cycle of labor movements. As the feed was cleared and hilled in front of him, the worker moved along the border of the feed table from beginning to end.

The full cycle of the technological operation of shoveling feed with a shovel included the following set of labor movements: shovel withdrawal 0.49±0.005 s, arm extension 0.43±0.007 s, lifting the shovel with feed up 0.72±0.01 s, arm rotation 0.51±0.007 s. Of all the above operations, the longest and most difficult was lifting the shovel with feed residues. Its duration was 9.76-13.48% longer than other labor operations of the cycle ($p<0.05$) (Fig. 1). However, in the cycle, labor movements not directly related to lifting the shovel with feed residues occupied a greater proportion.

The average duration of a full cycle of labor movements associated with shoveling feed was 2.15±0.029 s. At the same time, on each meter of the feed table length, the farm worker performed an average of 2.33 full cycles of such labor movements.

The labor movements that make up the cycle of the technological operation of pushing feed with forks included the following set of movements: retracting and lowering the forks 0.50±0.003 s, advancing the forks forward 0.50±0.005 s, raising the forks with the feed up 0.2 s, which respectively accounted for 41.0%, 41.0%, 18.0% of the duration of the full cycle of this technological operation (Fig. 2). The data show that the greatest proportion was occupied by labor movements not directly related to retracting and lowering the forks and advancing the forks forward.

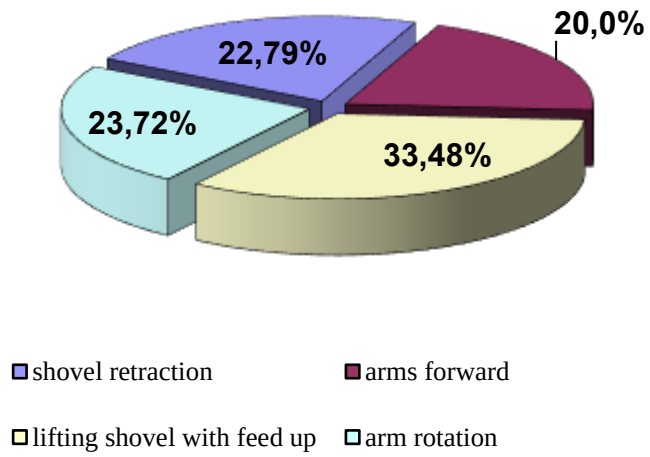

Fig. 1. **Time spent on labor movements when performing the technological operation of pushing feed with a shovel**

The average duration of the cycle of labor movements associated with pushing feed with forks was 1.22±0.058 s. On one meter of feed table length, personnel performed an average of 6.7 complete cycles of labor movements.

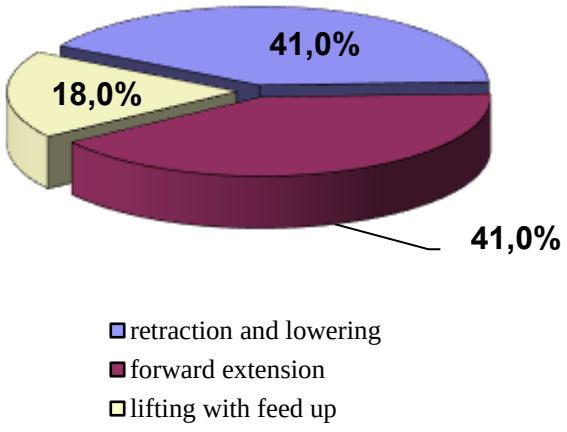

Fig. 2. **Time spent on labor movements when performing the technological operation of pushing feed with a pitchfork**

The technological operation of hilling the feed with a wide hand scraper was performed cyclically and included two operations. The withdrawal and lowering of the wide hand scraper took 0.70±0.008 s, and the advancement of the wide hand scraper forward took 0.71±0.007 s. This was 50.0% and 50.0% of the duration of the full cycle, respectively (Fig. 3).

The average duration of the cycle of labor movements associated with pushing the feed with a wide hand scraper was 1.41±0.037 s. At the same time, for each meter of the feed table length, the farm worker performed an average of 1.5 complete cycles of such labor movements.

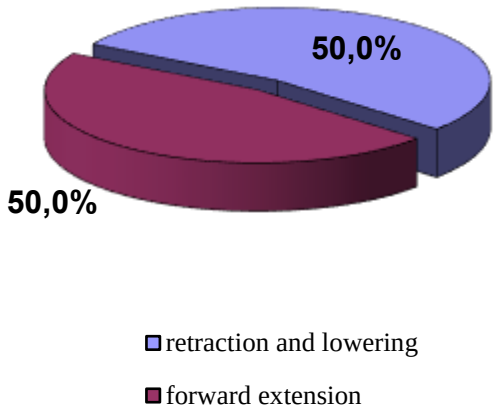

Fig. 3. **Time spent on labor movements during the technological operation of pushing feed with a wide hand scraper**

It should be noted that although the technological operation of pusher feed using a wide hand scraper was characterized by the smallest composition of labor movements and the duration of their execution, it required significant force efforts from the worker. Therefore, when the feed mixtures had a humidity of more than 65% and a bulk density of more than 750 kg/m^3, pusher feed was performed by the sequential use of two tools: first with a shovel (fork), and then with a wide hand scraper.

When comparing the above manual methods of pusher feed mixtures, it was found that when using a shovel, 5.01 minutes of working time was spent on 100 cows at a time, when using a pitchfork – 8.12 minutes, and when using a wide hand scraper – only 2.12 minutes.

On modern farms, the operation of hilling fodder is performed using mechanization tools - a tractor with a slanting bulldozer shovel, and automation - “Butler Gold” robot (Fig. 4).

Fig. 4. **Means of mechanization and automatization of pushing forage**

The fastest pushing to feed is with a tractor. It takes 1.02 minutes per 100 cows. The “Butler Gold” robot works more slowly. It takes 4.96 minutes for this operation. It is important to note that the robot works without a human and needs free access to all feed tables for normal operation.

It is important to consider the monetary costs incurred by a dairy company for pusher feed for 100 cows if this operation is performed 6 times per day. Given a performer’s monthly salary of 20 thousand UAH per month, a minute of human work will cost 1.59 UAH. When working with a shovel, the costs for 100 cows are 47.8 UAH (1.59×5.01×6), and when pusher with a pitchfork – 77.46 UAH (1.59×8.12×6).

The average life of a tractor is 5000 hours. With a tractor costing about 1 million UAH, a minute of depreciation costs 3.33 UAH. (1000000/5000/60). If fuel consumption is 6 liters per hour, then at a price of 1 liter of 50 UAH. per minute, fuel is used for 5 UAH. (6×50/60). Together with the tractor driver's salary, 60.77 UAH is spent on pusher feed for 100 cows with a tractor. ((3.33+5.00+1.59) ×1.02×6).

If the life of the robot is equal to the tractor, then the depreciation costs for one minute of its use are 4.17 UAH (1250000/5000/60), with electricity costs of 0.29 kW or 2.18 UAH per pusher. All costs, respectively, are 137.18 UAH ((4.17×4.96+2.18) ×6).

Thus, the work of a person with a shovel to hill the feed mixture on the feed table is the least expensive.

The final operation in the distribution of feed and feeding is the technological operation of removing feed residues from the surface of the feed table. In production conditions, this technological operation is carried out, as a rule, in the morning before the moment of feed distribution. On the farm where the observations were made, this technological operation was carried out in the morning from 4 to 5 a.m. before the distribution of feed. The removal of feed residues was carried out by a farm worker by scooping the feed residues onto a shovel and throwing them over the side of the feed table border to the pen section. According to the data obtained on the basis of the analysis of the performance of the technological operation of removing feed residues, the average duration of one cycle of labor movements was 1.59±0.15 s.

It was established that the list of labor movements that made up the cycle of the technological operation for removing feed residues beyond the curb of the feed table included the following set: pushing the shovel forward 0.32±0.01 s, raising the feed 0.37±0.01 s, lowering the shovel 0.51±0.02 s, throwing the feed over the curb 0.39±0.15 s, as well as other operations. These included other body movements - straightening the torso, tilting the torso, and others. Their duration in the cycle occupied only 0.61% of the duration of the full cycle of this technological operation (Fig. 5). At the same time, on each meter of the length of the feed table, the farm worker performed an average of 5.0 full cycles of such labor movements.

It was found that with the manual method of removing feed residues with a shovel for 100 cows at a time, it is necessary to spend 7.59 minutes (1.59×3×100/60) of working time. In monetary equivalent, the costs are 12.06 UAH (7.59*1.59). The tractor removes feed residues from the feed table for 100 cows for 1.02 minutes. Total monetary costs for fuel, tractor driver's salary and depreciation for performing this operation for 100 cows by tractor are 10.11 UAH (5.00+1.59+3.33)×1.02). This is 1.95 UAH cheaper than the manual method of removing feed residues. In addition, removing feed residues from the surface of the feed table to the surface of the pen had a specific effect on the behavior of the animals. A peculiarity of the behavior was that the removed food residues in the pen were perceived by the animals as freshly introduced bedding for resting.

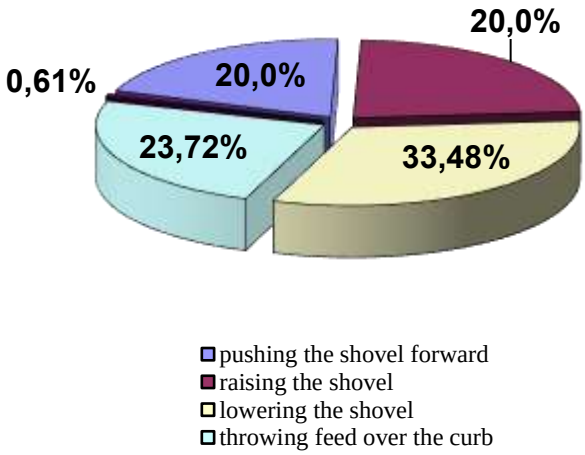

Fig. 5. **Labor movements in the structure of the cycle of the technological operation of removing feed residues**

Observations showed that during the day, from two to six animals (a total of 127 animals in the group) constantly lay near the feeding table. When lying down to rest on the leftover feed, the animals placed their bodies along the edge of the feeding table.

Fig. 6. **Reducing the feeding front while animals rest on feed residues near the border of the feed table**

One animal lying along the feed table line reduces the feeding front by 2-2.5 meters and prevents other animals from freely accessing the feed.

Discussion. Dairy cow welfare has become a hot topic in recent years, especially given the growth in the number of large dairy farms. Increasing the production efficiency of dairy cows by improving their health is impossible without proper feeding and maintenance (Martins L. F. et al., 2022). The involvement of people and technical devices is a characteristic feature of technological processes in dairy farming (Gaworski M., 2021). Modern and innovative concepts in dairy cattle production technology are closely related to the level of mechanization. The claim that a high level of mechanization on dairy farms allows for increased comfort of working conditions and the production of high-quality milk requires clarification of what is meant by the term “high level” and

what the boundary is between high and medium levels of mechanization (Romaniuk W. et al., 2021). We investigated the full cycle of labor movements of a worker when performing the technological operation of raking distributed feed with various manual tools, mechanized and automated raking. It was found that human work with a shovel for raking the feed mixture on the feed table is the least expensive. The essence of the technological index level is to compare mechanical labor costs with manual labor costs spent in this technological process. Of course, other factors can also be selected to assess production technology, including descriptive factors related, for example, to various aspects of modernity. Precision dairy production technologies are one such example (John A. J. et al., 2016). The purpose of implementing these technologies is to reduce the demand for labor (Gargiulo J. I. . et al., 2018). The demand for manual labor is included in the formula for determining the level of the technological index, which thus confirms the usefulness of this index, for example, for assessing the modernity of technologies, including dairy production technologies. It is well known that dairy cow behavior is influenced by feeding management factors, including feed distribution frequency and raking (King M. T. M. et al., 2016), although the effect of raking on behavioral patterns is less clear. Our studies found that increased feeding behavior was characterized by an increase in the number of animals at the feed table and was manifested during technological operations related to feed distribution and raking.

Conclusions:

1. It was found that manual operations performed by personnel at feed tables during the process of distributing, raking and removing feed residues included a set of separate labor movements that made up periodically repeated cycles of labor movements.

2. It was found that the behavior of animals was influenced by the performance of manual operations related to distributing and raking feed. Auxiliary manual operations of farm workers, associated only with opening and closing gates, as well as with transitions from one feed table to another, did not affect the feeding behavior of animals.

3. The use of mechanization and automation is not always economically feasible.

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