COMPARATIVE ASSESSMENT OF FEED PREPARATION TECHNOLOGIES FOR UKRAINIAN BREEDS OF DAIRY COWS[1]

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ABSTRACT: The analysis of variance of the breed's influence on the milk yield in the farms has established that there is no difference between the milk yields of Ukrainian black-and-white dairy breed and Ukrainian red-and-white dairy breed. Influence of breed on milk yields was not significant (P>0.05). Therefore, an assessment of feeding technologies and development of a model for prediction of milk yield were carried out without taking into account the breeds. Average duration of working action, called "feed unloading from the shovel", amounts 6.82±0.43 s without weighing and 14.94±3.61 s with weighing during loading. The measure of influence of the feed unloading type on the duration of that working action η^2=0.217 (P<0.001). Coefficient of correlation between number of forage in feed mixture and: total number of working actions of feeder in cycle of feed preparation amounted 0.58 (P<0.01); specific number of working actions of feeder for service 1 cow in cycles of preparing of feeds was 0.41 (P<0.05); expenses of forage loader for servicing 1 cow in cycles of forages loading equaled 0.60 (P<0.05). The mechanisms of influence of ergonomic components' characteristics of preparation, delivery and distribution of feeds on behavior, milk productivity, labor productivity and efficiency of different technological processes were found and formalized. The model of evaluation of expected milk yields at the farm on base of feeding technology characteristics was developed. The model includes the variables: method of feeding of different forms of forages (total mixed / mixed + separately / separately), number of forage types in ration and method of dosage. The model describes 83% of variation of milk yields significantly (P<0.01). Ceteris paribus, the farms, which apply feeding a total mixed rations ad libitum, are capable to get milk yields on 1581-2585 kg higher than farms, which realize feeding technology less rationally.

Key words: cattle breeding, breed, feeding technology, feed preparation, milk yield, prediction model.

INTRODUCTION

The complex biotechnical system works in the modern highly mechanized livestock. It consists from three sections: human-operator, machines (or mechanisms, premises and facilities) and animals, which take management activities (McNulty and Grace, 2009).

The basis of this biotechnical system is animals, the breed and breeding value of which depends on the potential of dairy productivity, reproductive capacity and other characteristics, as well as the efficiency of the technological processes of the entire farms (Shortall et al., 2018; P. Dillon et al., 2003; Ruban et al., 2018).

In addition to the breeding value and breeds, the efficiency of the system operation is caused by which extent it guarantees necessary environmental parameters for animals. So, comfort of keeping conditions effect on animal productivity, their behavior, health, biological safety of production. Also, this system has an effect on human too. It is responsible for ergonomics and productivity of its labor, resulting on increasing or decreasing of fatigability, comfort and safety. During the working process the system accepts different effects (Douphratea et al., 2009), that has an impact on results by utilization of technology.

On the other hand, ensuring of the comfort conditions for animals and operating personnel should be conformed to real economic opportunities of farms. In such a case, the rationality and practicality of one or another technological solution (Lundgvista et al., 1997) usually acts as criterions of optimality of these conditions.

Analysis of modern organization in feed preparation and distribution process shows that there are variety of technical and technological solutions (either national, or foreign ones), introduction of which doesn't always correspond to the biological nature of cattle concerning realization of potential of productivity, adaptation, health and productive longevity.

Each of these solutions is characterized by specific parameters of efficiency, which are based on the level of their ergonomics and processability with respect to organization of the processes of loading, mixing, delivering, distributing and feeding of forage (Karszes and Howlett, 2016; Pezzuolo et al., 2016).

Purpose of the research consists in establishment and formalization of mechanisms of influence the most important breeding and ergonomical components of technologies, destined for forage preparation, distribution and feeding, which affect on cows behavior and productivity, as well as on efficiency of these technological processes.

MATERIALS AND METHODS

The research was performed at the 13 cattle breeding farms of Ukraine with different breeds of dairy cattle, technologies of the maintenance and feeding (Table 1).

An analysis of variance was conducted to determine the effect of the breeds on milk yield of cows in the farms. The breeds of dairy cattle (Ukrainian Black-and-White Dairy breed or Ukrainian Red-and-White Dairy breed) used as fixed factor, and milk yield in the farm in the year of researches was the dependent variable.

Technological processes of forage feeding (loading, preparing, delivering, distributing and pushing) were studied by means of video recording of these processes in several replications at each farm.

The research methodology is to determine the relationships between the main characteristics of forage feeding technologies and the subsequent construction of a model for estimating the expected milk yield on the basis of the most influential and available ones.

According to methods which developed by Shablia (2013), the chronometry of video records was conducted. Ergonomical assessment was realized for working activities, operations and cycles, which were carried out by 11 types of mobile feed distributors, by 8 types of loaders, and also by other technical equipment and farm workers.

For example, the work of a mobile feeder was divided into the following working actions:

- Moving without cargo forward;
- Moving without cargo back;
- Moving of partially loaded feeder in the process of loading forward;
- Moving of partially loaded feeder in the process of loading back;
- Moving of fully loaded feeder (without unloading of forage) forward;

Table 1 - Comparison of breeds and technologies of feeding in different farms

Name of Farm	Breeds	Feed Preparation Technologies	Number of forage's names	Feed Weighting Technologies	Milk Yields, kg/cow/year
Terezino	Ukrainian Black & White Dairy	Total mixed ration (only forage mixture)	5	Weighting at loading	7594
Gorniak	Ukrainian Black & White Dairy	Total mixed ration (only forage mixture)	8	Weighting at loading	7008
Zoria	Ukrainian Red & White Dairy	Total mixed ration (only forage mixture)	6	Weighting at loading	6380
Kutuzivka	Ukrainian Black & White Dairy	Total mixed ration (only forage mixture)	6	Without weighting	6230
RVD-Agro	Ukrainian Red & White Dairy	Forage mixture + some kind of forage separately	5	Without weighting	6077
Olto	Ukrainian Black & White Dairy	Forage mixture + some kind of forage separately	5	Without weighting	5120
Biliy Stik	Ukrainian Black & White Dairy	Forage mixture + some kind of forage separately	5	Without weighting	4650
Rossia	Ukrainian Red & White Dairy	Forage mixture + some kind of forage separately	5	Without weighting	4671
Progress	Ukrainian Red & White Dairy	Forage mixture + some kind of forage separately	5	Without weighting	4580
Gontarivka	Ukrainian Black & White Dairy	Each kind of forage separately	4	Without weighting	4214
Dontsovski MK	Ukrainian Red & White Dairy	Forage mixture + some kind of forage separately	6	Without weighting	4050
Chervoniy Veleten	Ukrainian Red & White Dairy	Each kind of forage separately	4	Weighting on stationary weigher	5310
Obroshino	Ukrainian Black & White Dairy	Each kind of forage separately	4	Without weighting	4080

- Moving of fully loaded feeder (without unloading of forage) back;
- Moving a partially unloaded feeder (without unloading of forage) forward;
- Moving a partially unloaded feeder (without unloading of forage) back;
- Unloading of forage mixture from the feeder with moving forward;
- Unloading of forage mixture from the feeder with moving back;
- Unloading of forage mixture from the standing feeder (without moving);
- Waiting without cargo with the engine on;
- Waiting with cargo with the engine on;
- Waiting without cargo with engine off;
- Waiting with cargo with the engine switched off.

Certain sequences (aggregates) of these working actions were grouped into cycles (for example, "loading of one forage type", "moving between warehouses of different kinds of forages", etc.), and operations (for example, "loading of forage", "transportation of forage to cowsheds", "distribution of feed mixture to cows", "transfer from cowsheds to warehouses with forages").

Under such algorithm, the timekeeping of video recordings and ergonomic evaluation of the work of the other participants in the

processes of preparation, distribution and feeding of forages (loaders, pastoralists, etc.) were carried out. For all participants, the number, duration and sequence of major operations, cycles and working actions for different technologies were defined.

In particular, the duration of the working actions of forage loaders "picking up forage in the bucket / shovel" and "unloading feed from the bucket / shovel", which must be carried out to load the feeder, were determined. At the same time, the moment of the beginning / end of these work actions considered the moment of the start / end of the movement of a specialized working unit (boom, arm, bucket or shovel) for picking up / unloading the feed.

Quantity, duration and order of technological processes, cycles and work activities by different technologies was analyzed. The results were included into data base. They included ergonomical characteristics of activities, which were performed using the machines (n=2081), as well as by technical equipments for mechanization of minor operations and manually (n=8253). The other basic characteristics of forage feeding processes, breeds as well as resultative traits were included into data base too. As the resultative traits (dependent variables) were used characteristics of productivity of work, costs of time, activities and means for realization of technological processes as well as milk yield of cows.

For statistical analysis, the SPSS-20 statistical analysis package was used.

Using analysis of variance ("General Linear Model" procedure of SPSS-20), the measures of influence of breeds, ergonomical and other basic characteristics of forage feeding processes on resultative characteristics were defined.

The estimation of correlations between mentioned above characteristics was performed. The procedure "Correlation" of SPSS-20 was used.

Using the most significant established patterns, the model of expected milk yields on base of set of characteristics of forage feeding technologies at the farm was developed. "General Linear Model" procedure of SPSS-20 was used for that too.

RESULTS AND DISCUSSION

The analysis of variance of the breed's influence on the milk yield in the farms has established that there is no difference between the milk yields of Ukrainian Black-and-White Dairy breed and Ukrainian Red-and-White Dairy breed. Influence of breed on milk yields was not significant (P>0.05).

Such a result agrees with the results obtained by Miah et al,. (2018), who established that average daily milk yields of different genotypes were not influenced (P>0.05) by different farms. A similar point of view is also shared Mondal et al., (2010).

Thus, the influence of breed on milk productivity in this study could be neglected. In view of this, an assessment of feeding technologies and development of a model for prediction of milk yield were carried out without taking into account the breeds of dairy cattle.

Three major ergonomical components, which were connected with organization of feeding technology, were highlighted. They are the following: method of weighing of feed, procedure of feeding of different types of forage (in mixed form or separately) and number of forage's names in the diet.

Weighing of feeds in majority of types of studied feeders provided at loading with use of inbuilt electronic scales. It gives a possibility to dose precisely the mixed forage for technological groups in accordance with their diets. However, weighing of feed was realized in real practice only sometimes, even when weighing-machine were available. Instead, the dosing by eye, by number of buckets, shovels, by duration of bran's pouring, etc had a place often. Another option there was a weighing of only some types of feed (for example concentrates). In practice only 2 farms ("Gorniak" and "Terezino") from 13 studied ones, implemented this opportunity to the full extent. And just these farms are characterized by the highest milk yields per year (7008 kg and 7594 kg respectively).

The function of weighing during loading by feeder "KTU-10" is absent totally. To provide weighing caused by lack of such parameter, built-in the feeder, many machine hours were expended for the movement of feeder from forage area to the weighing place, and from

weighing place to the livestock buildings. This process tooks up to 40% of time of the feeder's work and it costs up to 500 UAH (about $ 60) per a day for farms.

It was established that for the working action of "picking up forage in the bucket / shovel" it takes an average of 1.42 seconds more time to work than the "unloading feed from the bucket / shovel" (Table 2).

It's naturally, that the average duration of working action, called "feed unloading from the bucket / shovel", amounts 6.83±0.43 s without weighing and 14.94±3.06 s with weighing during loading. The unloading of each type of forage from the last shovel takes an especially long period of time. As a result, the standard deviation of the working action of "unloading forage from the bucket / shovel" with the technology "weighing at loading" is also 2.6 times more. Influence, which caused by type of feed unloading on the duration of working action, called "feed unloading from the bucket / shovel", was equal n^2=0.217 at P<0.999.

The main methods of feeding of different types of forages are: total mixed ration and feeding each kind of forage separately.

If all kinds of forage give in mixed ration, and especially with using of the structure of ration in accordance with the physiologic norms by nutrients and by amount of dry matter simultaneously, the selective feeding by some type of forage and advantage of the strongest animals during feeding are decreasing in essential measure. Feeding by complete mixture ration ad libitum is a logical technological method that complements this scheme. It allows largely align the consumption of forages by all and each animals in a group.

In a number of farms the medium variant has used. It is feeding by approximate balanced combination of forages only for some groups of cattle. One another prevailing variant is giving of forage mix, but only partly mixed from some types of forages along with feeding by a number of forage types separately.

Each of these technologies of feeding has its peculiar advantages, problems and limitations. Feeding by total mixed ration is considered to be progressive, although it requires some extra expenses, organizational efforts and high-qualified specialists. The problems of separate feeding of different types of forage can be caused by competition between animals for forage and by selectivity of its consumption often. As a consequence, the actual ration, consumed by animals, is unbalanced; it does not meet their needs.

In case of feeding of certain forages separetly important factor is the kind of feed and closely related with it amount of specified feed as well as technological characteristics of feeding (feeding ad libitum / giving of nutrients according to the average physiological norm). These characteristics affect on behavior reactions of animals on feed distribution, feed consumption, amount of consumed feed and uneaten food. Described factors should be

Table 2 - Characteristics of variability of forage loaders' work actions "picking up forage in the bucket / shovel" it takes an average of 1.42 seconds more time to work than the "unloading feed from the bucket / shovel"

Option of forage weighing technology	Number of work actions	Mean duration of work actions, s	Standard deviation, s	Standard error of mean, s
Picking up forage in the bucket / shovel				
Without weighting	108	7.85	4.37	0.42
Weighting at loading	45	11.18	9.05	1.35
Weighting on stationary weigher	7	11.86	14.33	5.41
In total	160	8.96	6.77	0.54
Unloading feed from the bucket / shovel				
Without weighting	96	6.83	4.24	0.43
Weighting at loading	13	14.94	11.03	3.06
Weighting on stationary weigher	6	2.99	1.79	0.73
In total	115	7.54	5.97	0.56

carefully assessed and taken them into account.

Our researches figured out, that realization of the technological operation "distribution of forage mixture" at farm "Kutuzivka" led to increase of cows number near feeding table on 20.96-22.00%, and at distribution of feed supplements (treacle) number of cows, which ate near feeding table, grew on 10.2-15.3% from total amount of animals in group. Mantysaari et al. (2006) had a similar effects.

Using technology of separate feeding of forage mixture and oilcake ("Zoria"), immediately after distribution of forage mixture 51.2% of cows from studied group have consumed this feed. At the same time, after distribution of oilcake 88.1% of cows have consumed it; these animals have ate all given oilcake at a time.

When the above-mentioned technology was improved at farm "Zoria", all kind of forages were entirely given at forage mixture. In a group, which was fed ad libitum, a part of cows, that consumed feed simultaneously, didn't exceed 48% (at once after distribution of forage mixture). Meanwhile, in another group of cows, that consumed amount of the forage mixture, that corresponded to the average norm of nutrients, a part of cows, that consumed feed simultaneously, reached 98.6%.

If distribution of feed performed according to the average norm of nutrients per one cow, mass of consumed forage mixture per cow was less on 36.7% and uneaten food was less in 6.2 times as compared with distribution at libitum. Accordingly, time for consumption of feed by animals in case of feeding in accordance to norm decreased on 15.3%, and the fights for feed became more often on 31% compared with giving of forage mixture to ad libitum. Naturally, such differences in feeding behavior and consumption are reflected in the milk yield, daily gain (Lage et al., 2013) and profits from cows.

Number of forage kinds in feed mixture is an important ergonomical component, which effects on duration of technologic cycles of loading and preparation of feed.

Each type of forage, which is introduced into mixture, requires additional time to move the feed distributor and loader to forage warehouses with this forage, and realization of specific preparative and final operations, connected with loading, even upon condition of stability of total volume of loaded forages. But if the total volume of feeds increases too, then in addition to working actions mentioned above, adds actions by loading of additional quantity of forages. Thus, along with increasing number of forage types in forage mixture the expenses of working actions, time and material resources for loading and preparation of forages also increase.

A correlation analysis of the relations between the main characteristics of feeders' feed preparation cycles was conducted (Table 3, 4). It points out the significant correlations between the "number of forage's names in the feed mixture" and several other

Table 3 - Basic characteristics of feed preparation cycles by feeders (number of cycles = 27)

Characteristics	Mean	Standard deviation
Number of forage's names, pcs	4.41	1.58
Number of cows served by the feeder, heads	201.48	72.89
Height of feeder's bin, mm	2468.70	532,41
The number of working actions in the cycle, pieces	22.89	16.01
Duration of the feed preparation cycle (total duration of working actions), s	917.01	355.76
Average duration of 1 working action in a cycle, s	57.64	62.25
The number of feeder's working actions spent on 1 cow, pieces	0.13	0.07
Time spent per 1 cow, s	5.86	4.70
The cost of servicing a cow by feeder, UAH *	0.26	0.20
Cost 1 cycle servicing of feed preparation by feeder, UAH*	40.69	17.20

* 1 UAH ≈ 0.12 $ during research

Table 4 - Coefficients of correlation between basic characteristics of feed preparation cycles by feeders

Characteristics	Number of forage's names, pcs	Number of cows served by feeder, heads	Height of feeder's bin, mm	Number of working actions in cycle, pieces	Duration of feed preparation cycle (total duration of working actions), s	Average duration of 1 working action in a cycle,s	Number of feeder's working actions spent on 1 cow, pieces	Time spent per 1 cow,s	Cost of servicing a cow by feeder, UAH	Cost 1 cycle servicing of feed preparation by feeder, UAH
Number of forage's names, pcs	1	-0.012	-0.466*	0.580**	0.195	-0.541**	0.413	0.061*	0.087**	0.265
Number of cows served by feeder, heads	-0.012	1	-0.462*	0.288	-0.155	0.118	-0.563	-0.799*	-0.783	-0.085
Height of feeder's bin, mm	-0.466*	-0.462*	1	-0.909**	-0.315	0.179	-0.397*	0.208	0.166**	-0.437
The number of working actions in the cycle, pieces	0.580**	0.288	-0.909**	1	0.361	-0.419*	0.588	-0.090**	-0.046	0.480
Duration of feed preparation cycle (total duration of working actions), s	0.195	-0.155	-0.315	0.361	1	0.372	0.452	0.629	0.657	0.989
Average duration of 1 working action in a cycle, s	-0.541**	0.118	0.179	-0.419*	0.372	1	-0.353	0.157	0.148*	0.302
Number of feeder's working actions spent on 1 cow, pieces	0.413*	-0.563**	-0.397*	0.588**	0.452*	-0.353	1	0.631*	0.654**	0.490*
Time spent per 1 cow, s	0.061	-0.799**	0.208	-0.090	0.629**	0.157	0.631**	1	0.999	0.558**
Cost of servicing a cow by feeder, UAH	0,087	-0.783**	0.166	-0.046	0.657**	0.148	0.654**	0.999	1	0.591**
Cost 1 cycle servicing of feed preparation by feeder, UAH	0.265	-0.085	-0.437*	0.480*	0.989**	0.302	0.490	0.558*	0.591*	1

important characteristics.

Coefficients of correlation between the number of forage's names in the feed mixture and the total or specific number of feeders' working actions in feed preparation cycles are particularly important for the estimation of efficiency.

The coefficient of correlation between the number of forage's names in the feed mixture and the cost of servicing 1 cow by loader in loading cycles is significant too ($r=0.60$; $P<0.95$).

Consequently, usage of not large variety of feed types, which together can provide required parameters of nutrients of forage mixture, is advisable.

On the basis of using the complex of the most significant regularities and mechanisms of the influence of ergonomical components on characteristics of feeding technologies (analyzed above), the models of estimation of resultative characteristics of these technologies were developed.

In particular, model of milk yield prediction of cows at farms basing on data about method of feeding of different types of forage in ration, method of weighting of forage and number of feed kinds was developed (Table 5). This model is the best among several developed variants of models.

It is easy to use and describes principal regularities of relations between characteristics of feeding technology and milk productivity on farm accurately ($R^2=0.83$). Significance level of this model is $P=0.01$. With help of it there is possibility to assess and to predict average milk yield on farm, that can expect by using of one or another configuration of feeding technology characteristics.

In respect to the effect of the method of feeding of different feed types, it should be observed, that marginal average values, estimated with use of the developed model,

Table 5 - Model of estimation of expected milk yields by complex of characteristics of feeding technology*

Feeding technology characteristics	Definition of feed technology characteristics	Fixed effect (kg) / regression coefficient (kg/pcs)		Significance level P
		B	Standard error of B	
	Constant	5998.3	1439.2	0.004
Method of feeding	Total mixed ration (only forage mixture)	2584.8	937.6	0.028
	Forage mixture + some kind of forage separately	1003.7	600.7	0.139
	Each kind of forage separately	0	-	-
Method of forages weighting	Without weighting	-847.6	730.9	0.284
	Weighting on stationary weigher	315.4	1061.3	0.775
	Weighting at loading	0	-	-
Number of forage's names, pcs		-250.9	267.9	0.380

* R^2=0.83; P=0.01

demonstrated the following expected characteristics (table 6).

With use of developed model it was established that, ceteris paribus, the farms, which apply feeding a total mixed rations ad libitum, are capable to get milk yields during year higher on 1581-2585 kg than farms, which realize feeding less rationally. Such situation is caused by that the main advantage of feeding a total mixed rations is precise dosing of mixture specially for animal group with certain level of productivity. In this case mixture should be prepared in such a way so that each animal consumes all necessary nutrients provided that animal has ate physiological norm of dry matter. Just compliance these requirements gives possibility to farms, which practice feeding a total mixed rations, expect milk yields in approximately 7093 kg, ceteris paribus.

In case of feeding by the medium variant (forage mixture + some kinds of forage separately) correct individual dosing of feed doesn't realize on above mentioned principles. Herewith, the only advantages of this technology of feeding by forage mixture stay just some improvement of feed consuming level and partial decrease of competition for less useful types of forage. All together it makes an opportunity to get productivity at the level of 5512 kg of milk per one year.

Feeding by each kind of forage separately should recognize the least effective variant. Due to such technology the above mentioned negative factors have occur. As a consequence, the animals, which are higher then others by hierarchy in group have a risk of fatty degeneration, and animals lower by hierarchy suffer by malnutrition, that can effect negatively on health and productivity of both the first and second categories of animals. As a result by such method of feeding the average marginal milk yields amounted 4508 kg.

It should be noted, that despite to significant positive paired correlation between number of forage types in ration and milk yields on farms (r=0.52; P=0.09), partial regression coefficient of milk yield per number of forage types, included to the model, is negative, although number of forage types affects insignificantly on the result (R^2=0.11; P>0.05). This is due to the fact, that number of forage types is related to other, more significant factors, which are involved into the model.

For example, farms, which have feeders with functions of mixing and distribution, and which feed cows with total mixed rations, use more number of forage names practically always (extra expenses are minimum if additional forage type is involved), than those, which apply separate feeding (additional full cycle of loading and distribution are necessary for each name of forage).

CONCLUSIONS

Theree is no difference between the milk

Table 6. Marginal average milk yields by the groups with different methods of feeding, kg

Methods of feeding	Average marginal milk yield, kg		95% confidential interval of milk yield, kg	
	M	Standard error	Lower limit	Upper limit
Total mixed ration (only forage mixture)	7093	558.1	5774	8413
Forage mixture + some kind of forage separately	5512	436.1	4481	6543
Each kind of forage separately	4508	529.2	3257	5760

yields of Ukrainian Black-and-White Dairy breed and Ukrainian Red-and-White Dairy breed. Influence of breed on milk yields was not significant (P>0.05). Therefore, an assessment of feeding technologies and development of a model for prediction of milk yield were carried out without taking into account the breeds.

When feed distributor has available function of automatic weighting of feeds at loading, the possibility of accurate dosing of feed mixture in according to the ration emerges. That results the higher milk productivity of cattle compared with feed mixture preparing without weighing (fixed effect of technology without weighing is B= –847.6 kg of milk).

It was found, that every additional forage type, which introduce into the composition of feed mixture, require extra working activities for its involvement. Coefficient of correlation between number of forages in feed mixture and total number of working actions of feed distributor in cycle of feeding is r=0.58 (P<0.01).

Model of estimation of expected milk yields was developed on base of the complex of characteristics of feeding technology: method of feeding with different types of feed; number of forage types in ration; and method of dosing (weighing) of forages. The model describes 83% of variation of milk yields significantly (P<0.01).

With use of the developed model it was established that, ceteris paribus, farms, which practice feeding by total mixed rations ad libitum, were able to get milk yields during one year to 1581-2585 kg higher than farms, which realize feeding technology less rationally.

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