RESULTS OF OPTIMAZING THE TECHNOLOGICAL PARAMETERS OF A TOTAL MIXED RATIO (TMR) MACHINE

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ТЭЖЭЭЛ ХОЛИХ (TMR) МАШИНЫ ТЕХНОЛОГИЙН ҮЗҮҮЛЭЛТИЙГ ОНОВЧИЛСОН ДҮН

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ABSTRACT

New intensive cattle farm is being built with government support in order to meet the self-sufficiency of milk and meat products for Mongolian residents, keep stability, and reduce the seasonal dependence on food supply. It is urgent for us now to produce the mixed feed that is suitable for livestock type and age in the intensive farming. The feeding scientific approach should be specially paid attention to when using the multifunctional Total Mixed Ration (TMR) machine and effectively applying the TMR technology. When using the feed mixer TMR machine, it is necessary to optimize the main parameters of the machine operation and determine the mode parameters according to the characteristics of the grass, the amount of roughage, concentrated feed, additive and ingredients used in the preparation of mixed fodder. This paper made an experiment in Total Mixed Ration (TMR) machine and provided research results combining the parameters of feed mixing uniformity, palate ratio, subdivision rate, rotor speed, mixing time and feed moisture.

ХУРААНГУЙ

Монгол улс хүн амын хүнсний хэрэгцээг дотооддоо хангах, тогтворжуулах, стратегийн хүнсний нийлүүлэлтийн улирлын хамаарлыг бууруулах зорилгоор эрчимжсэн үнээний фермүүдийг бодлогоор дэмжин шинээр байгуулж байна. Эрчимжсэн фермерийн аж ахуйд малын төрөл, насны онцлогт тохирсон холимог тэжээл бэлтгэх ажил тулгамдсан асуудал болж байна. Эрчимжсэн фермийн аж ахуйд олон үйлдэлт тэжээл холих (TMR) машиныг ашиглаж, технологи ажиллагааг үр ашигтай явуулах, малыг тэжээх арга, технологид онцгой анхаарал хандуулж, шинжлэх ухаанчаар хандах явдал чухал байна. Тэжээл холигч TMR машиныг хэрэглэх тохиолдолд өвс ургамлын онцлог, холимог тэжээл бэлтгэхэд орж байгаа бүдүүн тэжээл, хүчит тэжээл, нэмэлт тэжээл, орцын хэмжээнд тохируулан машины ашиглалтын үеийн үндсэн үзүүлэлтүүдийг оновчилж, горимын параметрүүдийг нарийн тогтоох шаардлагатай байдаг. Тус өгүүлэлд тэжээл холигч（TMR） машин дээр туршилт хийж холимог тэжээлийн уртын хэмжээ, нунтагийн түвшин, төрөлшлийн зэргийг машины үндсэн үзүүлэлтүүдээс хамааруулан тодорхойлж дүнг гаргалаа.

INTRODUCTION

Demand for fresh vegetables and dairy products are growing even in the cold season of our country, which has a harsh and thetic climate. The intensive dairy farming has developed with the support of the government to meet this increasing dairy product demand (*Nyamtseren,* 2017).

It has been shown in statistical data from the Ministry of Food, Agriculture, and Light Industry, showing the country's milk production for the six years 2012-2017 (Figure 1).

63.3 million liters of milk and dairy products were processed by industrial production method in 2016 and 81.2 million liters of milk and dairy products were produced in 2017. The volume of production of milk and dairy products in 2017 increased by 28% compared to 2016 (*Ministry of Food, Agriculture and Light Industry*, n.d.).

Milk and dairy products of Mongolia per capita was 24.11 kg in 2014 and it increased up to 27.87 kg in 2017. But it is four times less than world milk and dairy product consumption, 109.6 kg per capita.

In recent years, the government has increased animal husbandry production to a certain extent, improved the food supply and security of the urban population, and gradually reduced the import of animal products (*Michelle, 2020*). Therefore, the number of intensive cattle farms and the number of entrepreneurs in this field has been increasing.

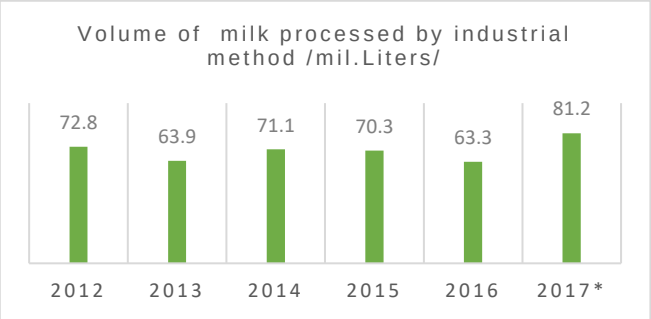

Fig. 1 - Milk production of Mongolia

However increasing the number of cow is important to rise dairy production, the cow feeding methods also play an essential role for the cattle farming *(Yumchmaa, 2015)*.

Adequate feeding of farm animals is one of the main factors in increasing the productivity of animal husbandry *(Nurmatov et al., 2020)*. People are feeding their cattle with mixture of grasses and hays. This method produces a lot of waste from dry grass, disturbs the dynamic balance of cattle digestion and metabolism, and is unsuitable for intensive farming condition *(Luo et al., 2017)*. This method affects the amount of dry matter ingested, reduces milk production, and makes the rumen of cattle pH fluctuate greatly and is relatively unstable *(Gerlach et al., 2020)*. When the herders feed their cattle with such a different composition of forages it cannot be fermented simultaneously in the cow's paunch and the feeds produce different pH values during fermentation *(Zhi, 2018)*. When herders feed their cattle in this way, it is easy to cause waste of feed, produce nutritional imbalances, and even nutritional metabolic diseases (*Shuxuan*, *2021*).

Therefore, thick forages and pungent fodder should be separately fed for cattle to be with stabilized pH. Different types of fodders have different tests and compositions, the cows easily reject and reluctant from that feeds *(Xueyou, 2018).*

Developed countries are commonly using Total Mixed Ration (TMR) machine in cattle farming to overcome disadvantages of traditional feed methods. It can make a variety of raw materials get evenly mixed, the feed thickness of the dairy cow feeding is uniform, the nutrition is balanced, the emergence of the cow picky eating phenomenon is reduced, the cow's feeding desire and feeding volume are improved, and the dry matter ingested by the cows meets the ideal state of the formula requirements *(Hongwei et al., 2021).* It is based on the required nutrients for different stages of cow growth, and all the feeds needed by the cow are fed into a dedicated TMR machine on a daily basis according to the ingredients developed by the feed specialist and fed into forages in standard sizes and mixtures *(Lei L., 2019*).

MATERIALS AND METHODS

In our research, we used a 9SJW-1200 TMR machine, made in Italy (Figure 2). The machine is mounted on a tractor as a trailer and is driven by a power extending shaft.

Fig. 2 - Forages mixing 9SJW-1200 TMR machine

The ingredients of mixed diets for milk cow are shown in Table 1.

Table 1

The composition of mixed diets

№	Compositions	Percentage (%)
1	Grass	2.10
2	Alfalfa silage	16.80
3	Silage	25.20
4	Oat	2.94
5	Cotton seed	3.80
6	Sugar beet mixture	3.15
7	Corn flakes	6.30
8	Corn flour	25.20
9	Fatty acid calcium	1.04
10	Antioxidant	0.04
11	Sodium bicarbonate	0.83
12	Water	12.6

Zoo technical requirements

- Average length of chopped grass should not exceed 40 mm *(Yihong, 2016*).
- The added unit length should be 3-5 mm and at least 20% of the forage should be longer than 35 mm after mixing (*Dongling, Chunyan, Chunping, Yanwen,2016*).
- Spray water should be 210 l for 1 preparation.
- Technical requirements
- The mixing blade of the equipment should be sharp (not worn) and complete (n=8)
- The main and auxiliary augers are not worn.
- Mixing chamber filling efficiency with ingredients should be 80% (η=80%) (*Keqiang, 2015*).

Application and technological parameters of diets mixing process have designed and target function model is shown in Figure 3.

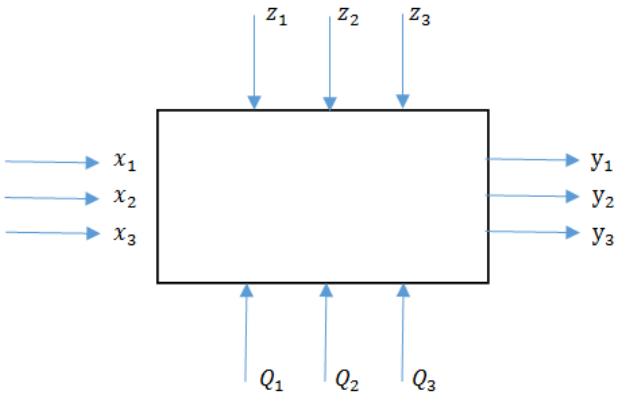

Fig. 3 – Target function model

x_1 –rotation frequency, x_2 – mixing time, x_3 –feed moisture, z_1 – silage moisture, z_2 – additive feed moisture, Q_1 – feed contamination, Q_2 – silage quality, y_1 – homogeniety rate %, y_2 – proper percentage of forage, y_3 – powdering grade %.

$$y_1=f(x_1,x_2,x_3)>80\%$$
$$y_2=f(x_1,x_2,x_3)>80\% \quad (1)$$
$$y_3=f(x_1,x_2,x_3)<30\%$$

Parameter levels that represent y-value are determined not only by the values of X_{iMax}, X_{iMin}, but by box planning or second-order rotatable planning with 3rd and 5th grade changes *(Avdai and Enkhtuya, 2019*).

Table 2

Experimental condition

Parameters	$-x_\alpha$	X_{iMin}	x_{i0}	X_{iMax}	$+x_\alpha$	I_i
	-1.682	-1	0	+1	+1.682	
Shaft rotating frequency x_1, rpm	16	19	24	29	32	5
Mixing time x_2, min	3	6	11	16	19	5
Feed moisture x_3, %	36.6	40	45	50	53.4	5

RESULTS & DISCUSSION

Results of powdering grade, proper percentage of forage and feed homogeneity rate, depending on the mixer shaft rotation, mixing time and moisture of feeds for mixing machine are shown in table 3.

Table 3

Results of experiments

№	Matrix of standards			Experimental matrix			Results		
	Parameters			Real values of the parameters					
	x_1	x_2	x_3	X_1	X_2	X_3	y_1	y_2	y_3
1	-	-	-	19	6	40	68	65	13
2	+	-	-	29	6	40	71	69	19
3	-	+	-	19	16	40	68	68	17
4	+	+	-	29	16	40	73	79	24
5	-	-	+	19	6	50	66	61	15
6	+	-	+	29	6	50	71	67	24
7	-	+	+	19	16	50	67	67	26
8	+	+	+	29	16	50	73	74	32
9	**-1.682**	0	0	16	11	45	68	68	16
10	**+1.682**	0	0	32	11	45	72	84	29
11	0	**-1.682**	0	24	3	45	66	67	19
12	0	**+1.682**	0	24	19	45	71	83	30
13	0	0	**-1.682**	24	11	36.6	70	74	19
14	0	0	**+1.682**	24	11	53.4	73	67	29
15	0	0	0	24	11	45	82	68	18
16	0	0	0	24	11	45	83	71	27
17	0	0	0	24	11	45	84	72	23
18	0	0	0	24	11	45	85	72	21
19	0	0	0	24	11	45	79	74	20
20	0	0	0	24	11	45	82	76	22

The mathematical processing of the numerical values of the measurements was governed by the law of normal distribution, and the calculated value of the Shapiro and Wilka W criteria was W_{calc} greater than the table value W_{table}. The calculated value of the Cochrane criteria G, G_{calc} was less than the table value G_{table}, indicating that the dispersion was homogeneous. Regression coefficients for factor dependence was determined and a multivariate regression model for dependence was obtained. The formulas are as following:

Real formula of homogeneity rate

$$y_1 = -353.265 + 8.824X_1 + 4.396X_2 + 13.356X_3 - 0.177X_1^2 - 0.19X_2^2 - 0.148X_3^2 \quad (2)$$

Real formula of proper percentage of forage

$$y_2 = -99.458 + 0.81X_1 + 0.788X_2 + 6.838X_3 - 0.078X_3^2 \quad (3)$$

Real formula of powder grade

$$y_3 = -28.86 + 0.72X_1 + 0.68X_2 + 0.58X_3 \quad (4)$$

From the real model, the optimal values of the main parameters during the operation of the TMR machine were determined as the shaft rotating frequency X_1 = 25 rpm, mixing time X_2 =13 min and feed moisture X_3 = 47%.

Variation of homogeneity of mixed diets for the feed is expressed by y_1 and its correlations of shaft rotating frequency X_1 and feed mixing time X_2, can be seen on the following diagram.

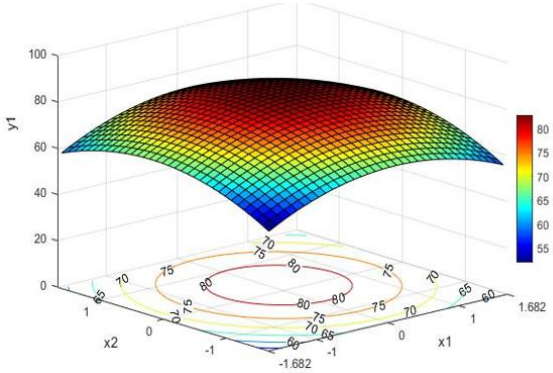

Fig. 4 – Homogeneity reflecting surface and its correlation graph $y_1 = f(x_1, x_2)$

From the figure above, it can be seen that the maximum rate of homogeneity y_1 can be found when both the shaft rotation frequency (X_1) and the mixing time (X_2) are taken to be close to zero level.

Effects of shaft rotating frequency and feed moisture to the feed homogeneity rate are shown in fig. 5.

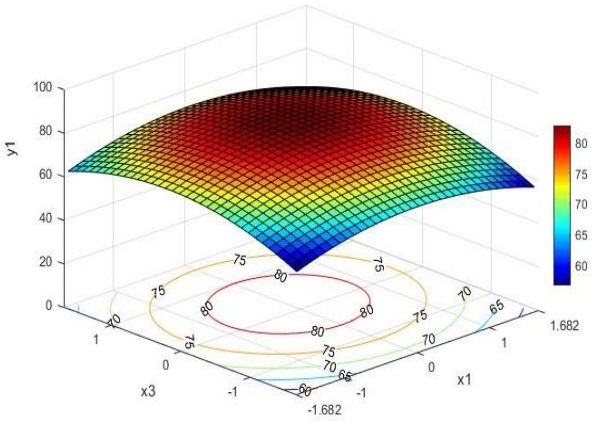

Fig. 5 – Homogeneity reflecting surface and its correlation graph $y_1 = f(x_1, x_3)$

Figure 5 shows that the feed homogeneity can be produced when the values of shaft rotating frequency (x_1) and feed moisture (x_3) come to zero as much as possible.

The shaft rotating frequency and mixing time have the following correlation to the proper percentage of diets (Figure 6).

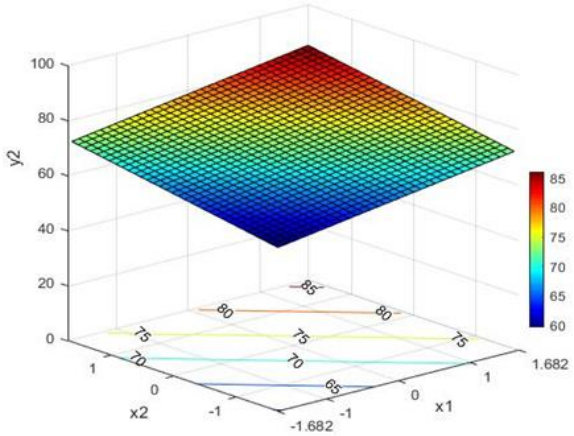

Fig. 6 – Proper percentage of diets reflecting surface and its correlation graph $y_2=f(x_1, x_2)$

This graph shows that the proper percentage of diets (y_2) increases when the shaft rotating frequency (x_1) increases. And when the feed mixing time (x_2) increases, the proper percentage of forages (y_2) increases too. They have linear correlations.

CONCLUSIONS

It is important to use TMR technology, to operate the technology efficiently, to pay special attention to cattle feeding methods and technologies, and to take a scientific approach for the intensive farming.

Type of grass, thick forages of feed ingredients, pungent fodders, additives, TMR machine technical and feed mixing parameters have to be accurately optimized when using the feed mixing TMR machine.

The feed mixing TMR machine process's optimal values of the inlet parameters were determined as 25 rpm of a shaft rotating speed, 13 min of mixing time, and 47% feed moisture. At this point, the outlet parameters were the homogeneity rate of the feed was 82.8%, 81.4% propriety percentage, and 12.2% powdering grade. When dairy cows were fed with prepared feed using TMR machine technology, the milk yield increased by 421.1 kg, and fat content increased by 0.11% during the lactation period (305 days).

This research work has practical significance to save feed resources and increase milk production in cow farms by clarifying the technological parameters of the TMR machine used in Mongolia.

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