Research of the operating process of the mobile mixed fodder dispenser with a spiral-crewed dosing unit

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Abstract. Highly productive dairy cows require additional distribution of concentrated fodder. Many farms of Russia and the Perm Krai use displacement feed propotioners, one of them is a spiral-crewed dosing unit. This dosing unit has good dosing accuracy and can be installed on the battery-driven dispenser. The device is equipped with the battery capacity of 55 A·h, a transporting spiral has the diameter of 97 mm with the pitch of 73 mm and the rotating frequency of 43 min-1. The dispenser was tested at several commercial dairy farms of the Perm Krai. Since the amount of concentrated fodder is individual for every cow, it must be calculated according to corresponding methodology taking into account the milk yield per day. In-process tests show operating capacity of the designed dispenser with a spiral-screwed dosing unit and its efficiency in mixed fodder distribution. The volume of dispensed fodder is equal to 552…604 g during the test. Taking into account the loss of time to move the dispenser between the animals, its productivity is equal to 3.11 kg/min, inequality in the dose of bulk bran does not exceed 4.18%, and 3.27% in the dose of granulated mixed fodder. Power consumption for fodder distribution is 45 … 47 W/h. In-process tests justify the value of earlier conducted scientific research.

1 Introduction

Important tasks of agricultural production are to increase the production of livestock products, increase labour efficiency and reduce the cost of the resulting products. The implementation of these tasks can be achieved only with the holistic mechanization of labour-intensive processes and the introduction of modern technologies. The efficiency of production and the volume of livestock products directly depend on the level and quality of animal feeding, as well as the balance of diets, taking into account the nutritional value of feed [1].

For highly productive cows with the annual milk yield equal to 6000 kg, consumption of concentrated fodders can reach 40% of daily nutritional value of animal's diet [1].

The general diet for groups of animals is based on their physiological state and daily milk yield. When feeding highly productive dairy cows, it is necessary to take into account the rate of feed intake during the milking process. It is known that dairy cows can eat up to 2.5 kg of loose and about 3 kg of granulated feed within 8–10 minutes [1, 2].

The redistribution of the volume of fed compound feeds over lactation periods (45...60% in the first period) increases the concentration of energy in the dry matter of the diet, and the adopted feeding system (2-3 times a day) causes poor eating of the main type of feed [3, 4].

The research of the Federal Research Center for Animal Husbandry (FRCAH) established that the optimal distribution of concentrated fodders is the following. Six-fold is in lactation phase I, three- or four-fold in lactation phase II, and two-fold in lactation phase III or 380…410, 290…360, and 140…240 g of concentrated fodder per 1 kg of milk yield. At the same time, the one-time delivery of concentrates shall not exceed 3 kg per one animal. When dairy cows are fed six times with compound feed, the optimal dispensing interval is 3 hours. At the same time, the maximum amount of compound feed given out during the day should not exceed 12...14 kg [2, 5].

Various types of dosing devices can be used for metered distribution of mixed fodder [6-9]. One of such devices is a spiral-screwed dosing unit that performs fodder dosing according to the number of full turns of the spiral. The dispenser is manufactured at the Department of Agricultural Machinery and Equipment of the Perm State Agro-Technological University [10, 11].

In the course of tests, the dosing unit yielded good results in the accuracy of dosing the dry mixed fodders [10]. Therefore, the aim of research is formulated as follows: to determine the efficiency of the mixed fodder dispenser with a spiral-screwed dosing unit in production conditions, to determine the inequality of fodder distribution, productivity and power consumption of the dispenser.

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2 Materials and methods

The task of in-process tests of the spiral-screwed dosing unit is to study and estimate its operating process directly at a commercial dairy cattle farm. In order to solve this problem, the mobile dispenser of bulk concentrated fodder with a spiral-screwed dosing unit was designed and manufactured at the Perm SATU (Fig. 1) [10].

Fig. 1. Mobile fodder dispenser with a spiral-screwed dosing unit: 1 – SM8238 turn counter, 2 – MYLB-G.T. Power RC 130A measuring system, 3 – control panel, 4 – mode switch, 5 – handcart, 6 – tanker for concentrated fodder, 7 – battery, 8 – tubular enclosure, 9 – spiral.

The dispenser contains: a trolley with a pair of wheels and a handle for moving, a feed bin 6, in the lower part of which a spiral screw dispenser is installed. It consists of a cylindrical casing 8, a spiral 9 made of a rectangular section tape and an electric drive, which is controlled by a control panel 3. It includes sensor 1 of the counter of full revolutions of the spiral 9, a microprocessor and a “start” button 4, there is a battery 3 to power the electric drive-geared motor with appropriate control circuit. To prevent loss of feed, the spiral is set in such a way that the last turn when it stops is always in the lower position.

The distributor works as follows. Before starting work, the microprocessor of the distributor enters data on the norms for issuing compound feed to each animal, converted into the number of revolutions of the spiral 9, according to its serial number. Next, the feed is loaded into the hopper 6, after which the dispenser is moved manually by the handle to the places where the feed is dispensed to the animals. At the place of distribution of feed to the first animal, the operator presses the "start" button 4 on the control panel 3 and, due to the power supply from the battery 7, the electric drive starts the rotation of the dispenser spiral, dispensing feed to the animal. When the spiral 9 rotates, the revolution counter 1 transmits data to the microprocessor on the number of completed revolutions. Upon reaching the specified number, the microprocessor sends a signal to stop the dispenser electric drive, while the spiral 9 stops in such a way that its last coil is in the lower position at the end of the casing 8. After this, the operator moves the distributor to the next animal and presses the “start” button again. Thereby a signal is sent to the microprocessor that the distributor is located at the second animal and it is necessary to make another number of revolutions of the spiral 9 in order to dispense the appropriate portion of the compound feed. At the end of the feed distribution to the second animal, the operator moves the dispenser to the third and subsequent animals, and the process is repeated. In case of emptying hopper 6, it is filled again and the distribution process continues from the animal on which it was interrupted.

The tests of the dispenser were carried out as prescribed by the procedure guidelines according to the standard technique of the STO AIST 19.2-2008 (Industry Standard) [12, 13].

General and main technical specifications of the tested dispenser are represented in Table 1.

Table 1. Technical specification of the mixed fodder dispenser with a spiral-screwed dosing unit.

No.	Parameter	Measuring Unit	Value
1	Power of Electric Motor	W	50
2	Spiral Rotating Frequency	min^{-1}	41-45
3	Spiral Diameter	mm	97
4	Spiral Pitch	mm	73
5	Distribution on: - bulk bran - granulated mixed fodder	kg/min	 7.2 13.9
6	Tanker Capacity	m^3	0.14
7	Carrying capacity, max	kg	90
8	Mixed Fodder Distribution Height	m	0.41
9	Overall Dimensions, max - length - width - height	m	 1.3 0.75 1.1
10	Weight	kg	63
11	Battery Capacity	A-h	55

The amount of mixed fodder required for animals is determined as follows:

$$Q_{day} = m_{day} \cdot q_i, \quad (1)$$

where m_{day} is daily milk yield per cow; q_i is normal rate of mixed fodder distribution.

The normal rate of fodder distribution in turn depends on the period of lactation [1, 2].

The amount of one-time distribution of mixed fodder is defined by the following formula:

$$Q_{one} = Q_{day} / k_d, \quad (2)$$

where k_d is multiplicity of distribution.

To distribute the estimated amount of mixed fodder, the spiral shall make the following number of turns:

$$n_{turn} = Q_{one} / q_{turn}, \quad (3)$$

where q_{turn} is portion mass dispensed per one spiral turn.

Value q_{turn} can be determined by means of the graph in Fig. 2, where its values are given for various spirals used in the tested spiral-screwed dosing unit.

More correct mass of one portion can be determined experimentally by giving, for instance, 10 portions into a receiving container and the weighting it. Dividing this mass by 10, we get the mass of one dose. This check and calibration must be carried out for each new batch of mixed fodder as its properties change.

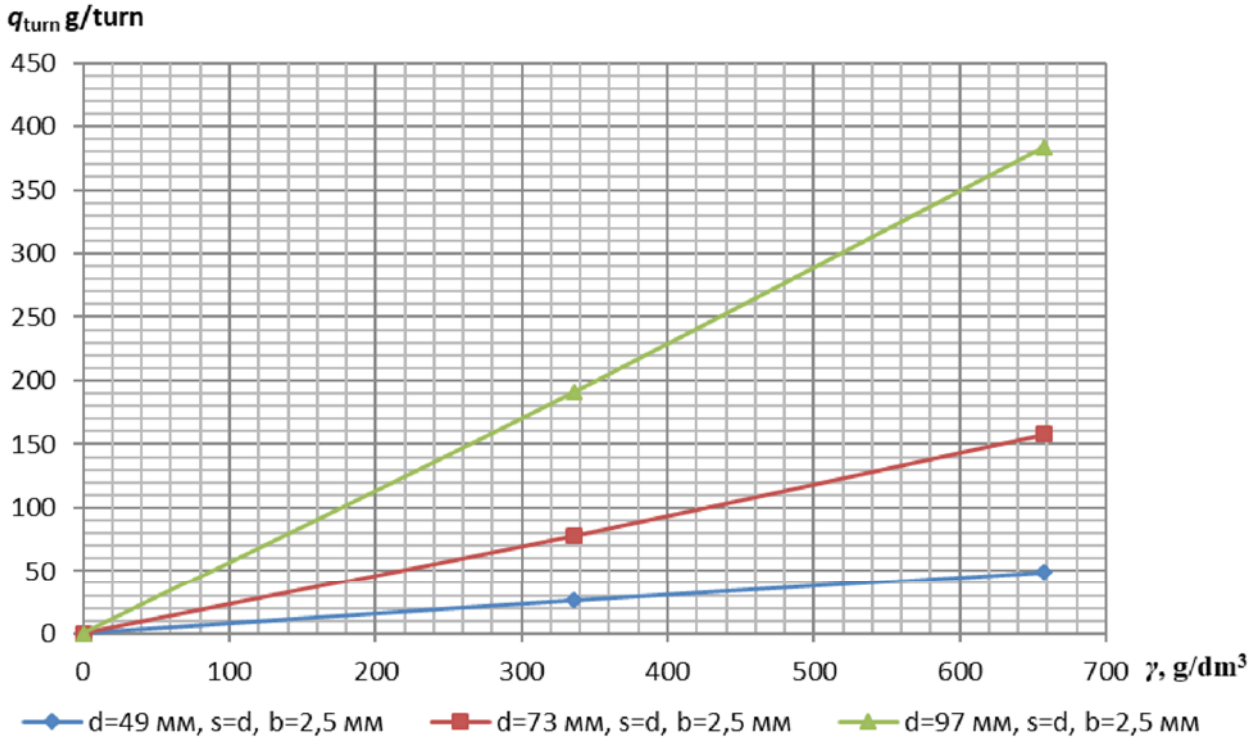

Fig. 2. Dependency graph of portion mass dispensed per one spiral turn (q_{turn}) depending on γ as the bulk density of mixed fodder

In the end of determining the amount of fodder required for each animal and a dose mass given out per one spiral turn, the distribution of mixed fodder is carried out to the entire range of animals with the preset multiplicity and interval. The volume of dispensed portions is weighted and mass values are entered in the test log. During the tests, the voltage value and current drain are recorded to determine the power consumption of spiral-screw dosing unit as well as the time of test start and its end to calculate the productivity of fodder dispenser.

Distribution of mixed fodder is carried out as follows. Fodder dispensers stop in front of the first feeding station and the operator switches on the dosing unit. When the intended amount of fodder is dispensed, as it is shown on the turn counter, the dosing unit is switched off and automatically set up to its initial position. After that, the dispenser moves to the next animal and the procedure is repeated.

3 Results and discussion

In-process tests of the fodder dispenser with a dosing unit were carried out at the “Rus” Lobanovsk dairy farm of the Perm District, where mixed fodders were distributed to heifers. Since there are no dairy cows, the distribution rate for all animals was the same. Taking into account the assigned distribution rate, the spiral with the diameter of d = 97 mm and the pitch of s = 0.75 d = 72.75 mm was installed in the fodder dispenser. The gap between the spiral and enclosure was b = 5 mm.

The following tests were carried out at the “Ocherskoe” commercial dairy farm (Fig. 3), where the one range of animals consisted of 42 cows was served with 42 portions of bulk or granulated mixed fodder per day.

Fig. 3. Process of metered mixed fodder distribution with a dosing unit

The results of tests are shown in Table 2.

Table 2. Results of in-process tests of the mixed fodder dispenser with a dosing unit

No.	Bulk Mixed Fodder			Granulated Mixed Fodder		
	X_i, g	$X - X_{av}$, g	$(X - X_{av})^2$	X_i, g	$X - X_{av}$	$(X - X_{av})^2$
1	566	-5.8	33.64	544	-17.6	309.76
2	573	1.2	1.44	570	8.4	70.56
3	560	-11.8	139.24	572	10.4	108.16
4	584	12.2	148.84	544	-17.6	309.76
5	576	4.2	17.64	572	10.4	108.16
6	552	-19.8	392.04	556	-5.6	31.36
7	570	-1.8	3.24	572	10.4	108.16
8	602	30.2	912.04	560	-1.6	2.56
9	604	32.2	1036.84	570	8.4	70.56
10	584	12.2	148.84	562	0.4	0.16
11	594	22.2	492.84	580	18.4	338.56
12	571	-0.8	0.64	574	12.4	153.76
13	554	-17.8	316.84	570	8.4	70.56
14	566	-5.8	33.64	574	12.4	153.76
15	570	-1.8	3.24	548	-13.6	184.96
16	560	-11.8	139.24	562	0.4	0.16
17	552	-19.8	392.04	540	-21.6	466.56
18	554	-17.8	316.84	548	-13.6	184.96
19	568	-3.8	14.44	556	-5.6	31.36
20	574	2.2	4.84	572	10.4	108.16
21	576	4.2	17.64	552	-9.6	92.16
22	566	-5.8	33.64	550	-11.6	134.56
23	578	6.2	38.44	568	6.4	40.96
24	600	28.2	795.24	550	-11.6	134.56
25	570	-1.8	3.24	564	2.4	5.76
26	574	2.2	4.84	562	0.4	0.16
27	564	-7.8	60.84	570	8.4	70.56
28	560	-11.8	139.24	568	6.4	40.96
29	570	-1.8	3.24	554	-7.6	57.76
30	562	-9.8	96.04	564	2.4	5.76
Average	**571.8**	**0.00**	**14.070**	**561.6**	**0.00**	**10.820**
Standard Deviation	0.00			0.00		
Variation Coefficient	2.46			1.93		
Minimal Dose	552			540		
Maximal Dose	604			580		
Deviation	**±23.91**			**± 18.38**		
% of Inequality	**4.18**			**3.27**		

4 Conclusion

As a result of in-process tests using the mixed fodder dispenser with a spiral-screw dosing unit, we established the following.

1. Distribution inequality reconciles with the livestock requirements (±5%) and is equal to 4.18% with the bulk mixed fodder distribution, and 3.27% with the granulated mixed fodder distribution, whereas the amount of the portion accounted for 571.8 and 561.6 g, respectively.

2. The productivity of the dispenser is 3.11 kg/min with the dose mass of 552…604 g taking into account the time for its movement, and the power consumption is within the range of 45…47 W·h.

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