SOME METRICS OF ELECTRONIC WEIGHT CONTROL USED IN CATTLE CUBS FEEDER

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Abstract. There were evaluated metrics of milk powder feed mixing, consumption of electric power and time of processing digital daily data volume sent to the main PC for cattle cub feeder with an electronic weight control. Mixing 0.5…1.5 kg of milk powder feed dose takes 27…38 s. The final weight differs from the desired one by 3.82…4.55 g. Temperature of feed dose is +32…38 ºC. It is possible to mix any dose within 0.18…1.50 kg with a milk powder concentration about 10 % following a cub feeding plan with non-linear daily gains of weight. A daily consumption of electric power for three diverse types of feeders (milk powder or whole milk only or a combined machine) differs negligibly. It was evaluated to 0.184±0.009 kWh for 60 calves feeding or to 7.0±0.3 W per 1 kg for feed mixing or 28.1±1.3 W per one calf daily feeding. A processing time takes less than 2 s of PC calculation and saving for whole daily data volume received from a feeder using FTP transfer.

Keywords: precision animal husbandry, electronic weight control, cattle cub feeder, automatic feed mixing.

Introduction

The all known cattle cub feeders built before 2006-2010 [1] have a non-weight, with a switching time of liquid pumps duration and volume low and high level electronic control (Fig. 1).

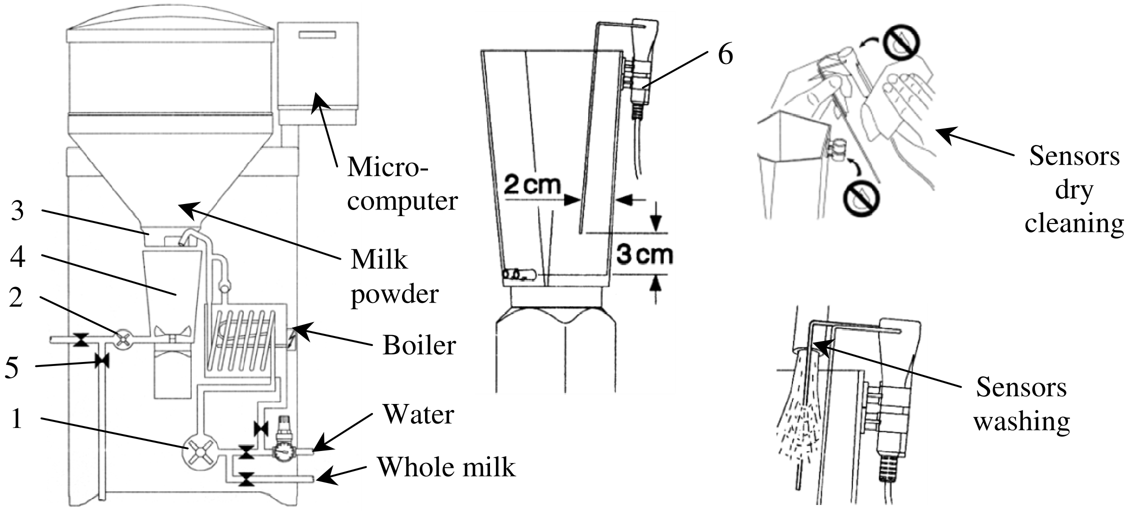

Fig. 1. **Mix control parts in calf feeder [1]:** 1 – input liquid pump; 2 – output liquid pump; 3 – milk powder hopper; 4 – mixing cup; 5 – electromagnetic valves; 6 – mix level sensors

These units have some shortcomings like difficult washing or fault switching etc. In 2008 a calf feeder with electronic weigh control of mix dose and its ingredients using a strain gauge [2] was developed and patented in our organization. The weight control does not depend on mix ingredient consistence. It has appropriate precision and reliability to mix considerably different doses for cattle cubs with high precision non-linear daily live weight yields feeding plans exactly [3; 4]. The most important metrics of new unit like mixing precision, electric power consumption and digital data processing time were evaluated during the labor tests. Positions 1, 2, 6 were excluded and changed for single strain gauge mounting the mixing cup 4 on.

Materials and methods

At present, stair-step daily feed plans are used for manual calves feeding (for example, 0.65 kg of live weight daily yield at the 1st month, 0.80 kg at the 2nd month etc.). It is necessary to pay attention to really small daily changes of cattle cub body score condition for more physiological feeding with small daily in(de)crease of daily volume of milky feed. Hence, it appears that calf feeder must mix different sizes of milk powder (MP) and whole milk (WM) feed doses precisely. To evaluate limits of mix dose and its ingredient size, basic models of really non-linear daily growing of cattle cub were developed (Fig. 2).

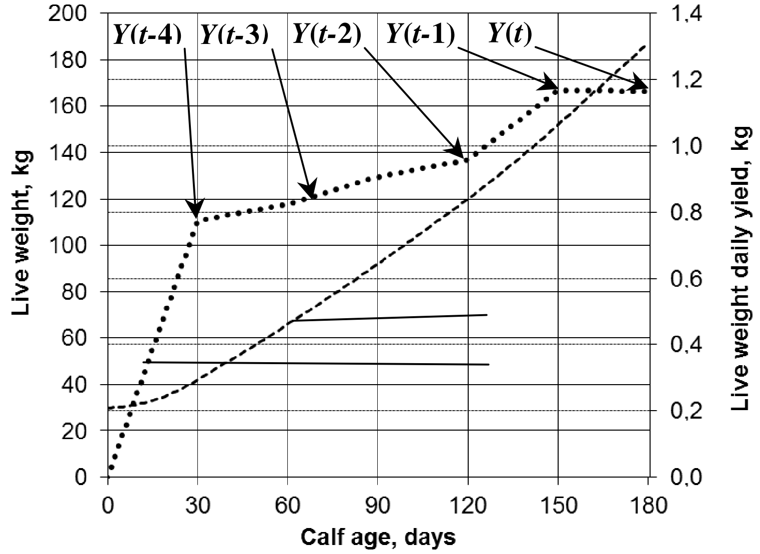

Fig. 2. **Live weight plan of milky calf:** 1 – live weight $W(i)$; 2 – live weight daily yield $Y(i)$

The whole milky period contains some periods enumerated as $t = 1,2,3,\ldots$ Every period has the length of $n(t)$ days, linear increase of live weight daily yield by $\Delta Y(t)$ kg, start and final values of live weight $W(t\text{-}1)$, $W(t)$ and live weight daily yield $Y(t\text{-}1)$, $Y(t)$. The $W(0)$ value means the birth weight and $Y(0) = 0$. The formulas for both weight metrics (Fig. 2, pos. 1, 2) for day number $I = 1,2,\ldots,n(t)\text{-}1,n(t)$ are

$$\begin{cases} W_i = W(t-1) + i \times \left(Y(t-1) + \dfrac{i+1}{2} \times \Delta Y(t) \right) \\ Y_i = Y(t-1) + i \times \Delta Y(t) \end{cases}. \quad (1)$$

Limits of single feed dose size of MP mix with dry matter and water as its ingredients for concentration of 1:9 are obtained with energy equivalents from (1) results and shown in Table 1.

Table 1

Limits of mix dose and its ingredient weight

Statistical parameter	MP mix	Dry matter	Water
Minimal amount, kg	0.18	0.018	0.162
Maximal amount, kg	1.500	0.150	1.350
Average daily in(de)crease, kg	0.145	0.015	0.130

To study appropriating of the real mix dose size to the assigned dose size and other metrics of the mixing process numbers of doses within 0.5, 1.0 and 1.5 kg weight were mixed. Pure water was used instead of WM. The values of weight, mixing time and temperature for 30 doses of MP in 3 replications and weight only for 30 doses of WM in 3 replications are shown in Table 2.

The tests 1-10 have concern to MP doses within 0.5, 1.0 and 1.5 kg. The tests 11-20 have concern to WM doses within 0.5, 1.0 and 1.5 kg. On the whole, the measurements of the dose weight have been grouped in 6 replications that mean 3 and more replications to standard processing method of tests results chosen. At first, homogeneity of variances (Bartlett χ^2-criteria) and averages (Fisher F-criteria) were checked with $L = 6$ (replications) and $N = 60$ (measurements) for weight and with $L = 3$ (replications) and $N = 30$ (measurements) for mixing time and temperature (Table 3-5).

Table 2

Values of measurements of weight, mixing time and temperature of MP and WM doses

MP dose	Number of test					Assigned weight, g
	1	2	3	4	5	
Real weight, g	485.10	499.87	486.70	505.00	493.00	**500.0**
Mixing time, s	28.0	30.0	29.0	27.0	27.0	
Temperature, ºC	54.0	54.5	55.0	55.5	55.2	
Real weight, g	968.14	996.46	988.97	1000.71	980.25	**1000.0**
Mixing time, s	31.8	32.2	32.0	32.8	31.6	
Temperature, ºC	49.5	50.5	50.5	50.0	49.5	
Real weight, g	1484.62	1488.13	1479.16	1494.53	1489.84	**1500.0**
Mixing time, s	38.4	36.5	37.8	39.0	37.4	
Temperature, ºC	45.0	44.0	44.5	44.0	44.5	
MP dose	**Number of test**					**Assigned weight, g**
	6	**7**	**8**	**9**	**10**	
Real weight, g	493.35	501.95	498.45	505.40	503.62	**500.0**
Mixing time, s	27.4	26.8	27.0	26.2	27.2	
Temperature, ºC	55.2	55.2	55.0	56.0	54.0	
Real weight, g	992.13	990.35	991.22	993.38	991.80	**1000.0**
Mixing time, s	31.8	35.0	33.8	33.6	32.2	
Temperature, ºC	49.5	49.5	51.0	50.5	49.0	
Real weight, g	1498.29	1479.79	1493.36	1482.80	1514.65	**1500.0**
Mixing time, s	38.4	36.6	38.0	37.0	36.2	
Temperature, ºC	43.5	44.5	43.5	43.0	43.0	
WM dose	**Number of test**					**Assigned weight, g**
	11	**12**	**13**	**14**	**15**	
Real weight, g	503.19	501.10	507.65	506.91	506.38	**500.0**
	1010.22	1005.56	984.13	1000.14	1003.21	**1000.0**
	1489.66	1509.44	1493.11	1508.35	1511.23	**1500.0**
WM dose	**Number of test**					**Assigned weight, g**
	16	**17**	**18**	**19**	**20**	
Real weight, g	504.18	507.13	509.93	487.24	509.49	**500.0**
	999.68	1007.34	997.55	1004.31	1007.82	**1000.0**
	1496.22	1490.72	1502.44	1496.73	1501.22	**1500.0**

Table 3

Variances and averages of dose weight

	MP doses (tests 1-10)			WM doses (tests 11-20)		
Assigned weight, g	**500**	**1000**	**1500**	**500**	**1000**	**1500**
n_i	10	10	10	10	10	10
S_i^2	54.40594	82.98757	112.39340	43.50322	55.26794	61.97788
$\bar{x}_i$	497.24	989.34	1490.52	504.32	1002.00	1499.91

Table 4

Variances and averages of dose mixing time and temperature

	Mixing time, s			Temperature, ºC		
Assigned weight, g	**500**	**1000**	**1500**	**500**	**1000**	**1500**
n_i	10	10	10	10	10	10
S_i^2	1.304889	1.237333	0.884556	1.680444	0.413889	0.469444
$\bar{x}_i$	27.56	32.68	37.53	54.36	49.95	43.95

Table 5

Homogeneity of variances and averages of dose weight, mixing time and temperature

Characteristic	Bartlett χ^2-criteria(for variances)			Fisher F-criteria (for averages)		
	ν	Calculated	Critical	ν_1 / ν_2	Calculated	Critical
Dose weight	5	2.63345	11.07050	5 / 54	28910.08475	2.38617
Mixing time	2	0.36551	5.99146	2 / 27	217.60647	3.35413
Temperature		5.55681			319.48206	

The variances of all the measurements are homogeneous, but averages are not homogeneous (Table 5). As the temperature measurements have the assigned values, it requires the calculating scale of averages and percentage error for every group of replications that have homogene averages. So, it is reasonable to check the homogeneity of the measurements with 500, 1000 and 1500 g assigned weight separately with Student *t*-criteria for a homogeneity of variances with averages. The results of calculating are shown in Table 6.

Table 6

Homogeneity of variances and average weight in groups with different assigned weight

Assigned weight, g	n	$\bar{x}$, g	S^2	Fisher F-criteria			Student t-criteria		
				ν_1/ ν_2	Calc.	Critical	ν	Calc.	Critical
500.00	20	500.78	59.5500	10 / 10	1.2506	2.9782	19	0.4532	2.0930
1000.00		995.67	107.6339		1.5016			1.8671	
1500.00		1495.21	105.8248		1.8134			2.0804	

Now all variances and averages are homogeneous within their groups with different assigned weight. As temperature and mixing time have not the assigned values and belong to the groups with the same assigned weight, the above step can be skipped. Finally, the scales of averages can be calculated for all the averages in these groups. The results of calculating are shown in Table 7.

Table 7

Scale of averages for weight, mixing time and temperature of doses

Assigned weight, g	ε, % (for weight)	Real weight, g	Mixing time, s	Temperature, ºC
500.00	1.282	500.78±3.82	27.56±0.71	54.36±0.80
1000.00	0.826	995.67±4.55	32.68±0.69	49.95±0.40
1500.00	0.635	1495.21±4.51	37.53±0.78	45.95±0.42

The mixing time values (Table 7) are enough for a calf waiting to drink its mix dose forbearingly and comfortable. Consumption of electric power was calculated using AC strength values for unit parts of calf feeder separately and duration of feeder part work during the main operations (Table 8).

Table 8

Scale of averages for weight, mixing time and temperature of doses

Part	AC strength, A	Operation	Power consumption, kWh
Boiler (10 liters)	13.70	**Water boiling**	0.17021
MP hopper	0.52	**Mixing of MP dose (1.5 l)**	0.00164
Mixer in milk tank	0.52	**Mixing of WM dose (1.5 l)**	0.00027
Mixing cup	0.22	**WM mixing in tank**	0.01315
Microcomputer	0.20	**Feeder auto washing**	0.00357
–	–	**Waiting for cub feeding**	0.00440

At present, three types of feeders are known, for MP or WM feeding only or for both MP and WM feeding. If every calf gets 2 kg of WP and 2 kg of WM or 4 kg MP or WM daily and waits for 2 h between two feedings, when the feeder washes-up at suggestion, the total daily work time will take 9.2 h and total feed amount will 240 kg for 60 calves. All the work time of the feeder the microcomputer is on and every 12.5 min the boiler is on for 20 s. Besides, to mix one MP dose of 1.5 kg the MP hopper is on for 15 s and the mixing cup is on for 45 s; to mix the same WM dose of 1.5 kg the mixing cup is on for 10 s. Finally, the mixer in the milk tank is on every hour for 5 min and feeder auto washing takes 70 min totally. In suggestion of all above, the values of daily electric power consumption are estimated and shown in Table 9.

Table 9

Electric power consumption with different types of feeder, kWh

Kind of consumption metric	Feed mixing with a feeder		
	MP & WM	MP only	WM only
Mixing of 240 kg of milky feed for 60 calves	1.72472	1.60501	1.72389
Mixing of 1 kg of milky feed	0.00719	0.00669	0.00718
Feeding of 4 kg (daily dose) of milky feed for 1 cub	0.02875	0.02675	0.02873
Average 1 h of daily work time	0.18829	0.17522	0.18820

It appears (Table 9) that electric power consumption differs for the given types of feeders negligibly, but not for the given metrics. Common electric power consumption values for the given metrics independently of the feeder type are shown in Table 10.

Table 10

Electric power consumption independently of feeder type

Kind of consumption metric	Consumption, kWh
Mixing of 240 kg of milky feed for 60 calves	1.6850±0.0780
Mixing of 1 kg of milky feed	0.0070±0.0003
Feeding of 4 kg (daily dose) of milky feed for 1 cub	0.0280±0.0013
Average 1 h of daily work time	0.1840±0.0090

Digital data about every calf visits to feeder are sent from the feeder microcomputer (Fig. 1) into a PC of dairy management system (DMS) using standard FTP-transfer and processing there. One calf data like transponder number, visit date/time, feed consumption etc. are written in its daily personal file by 10 bytes for every visit of the feeder. Receiving, decoding and saving into database all the daily data for 60 calves take less than 2 s as the test showed on DMS PC. Sending and processing the every calf personal data and setup data prepared on DMS PC beforehand to the feeder microcomputer takes about 1-2 s. Though, these properties are the same as for non-weight mixing dose control.

Results and discussion

1. Milky feed doses can be mixed exactly according to the assigned values with electronic weight control rather than with electronic time and volume control. Indeed, precision of weighting doses in wide interval within 500…1500 g is almost identical with ±(4.1...4.2) g, less than daily in- or decrease 15 g of dry matter and 130 g of whole milky mix. An additional advantage is a simpler mixing unit independent of the mix ingredients consistence and more suitable for full automatic washing. Temperature of mix has good precision. It requires an additional temperature sensor to keep the temperature of milky mix doses within 500…1500 g identical with the assigned value +36…38 ºC, for example. The mixing time fits to cattle cub physiology for forbearing waiting;
2. Electric power consumption differs for three different types of feeders like milk powder, whole milk only or both ones mixing negligibly. It can be used in energy consumption calculations as 1.6850±0.0780 kWh all the cattle cubs daily feeding, 0.1840±0.0090 kWh per hour, 0.0070±0.0003 kWh per 1 kg of milky mix and 0.0280±0.0013 kWh per one cattle cub daily feeding;
3. The duration of data exchange between the feeder microcomputer and dairy management system software is negligible and fits to integrate all the feeders on a milking farm into single DMS using local area network (LAN) exactly.

Conclusions

1. It is possible to build a precise non-linear feeding plan of cattle cub like a calf with non-linear daily live weight yields paying attention to age irregularity of body growing and live weight

increase within the milky period. Different mathematical models can be combined to build that plan for feeding a cub to get a healthy well-grown productive animal in the future purposefully.
2. It is technically possible and reasonable to use special software for creating complex feeding plans and using them in cattle cub feeder with electronic weight control.
3. The most effective use of a feeder will be reached by control of the feeder from PC with dairy management system software. Special cattle cubs management software can be used for building personal growing plans for different groups of cubs with calculating needs of liquid milky mixes and finally managing feeder units.
4. Single milky mix dose weight can be less than 500 g (minimum 180 g by sample feeding plan).
5. It is reasonable to keep the assigned mix temperature in the mixing cup or near the teat.
6. Electronic weight control equipment has too low electric power consumption of 4.4…170.2 W, but AC power conductors must keep more than 14 A as maximum of circuit strength during water or whole milk boiling.
7. Feeder units with electronic weight control can be attached to LAN to be managed successfully in automatic integrated systems based on DMS on large, middle or small cattle farms. Their digital data structure and migration are particular research topics.
8. The given results can be used in developing feeder units with electronic weight control of feed doses for different kinds of cattle and their cubs feeding.

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