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Assessment of selected parameters of automatic and conventional equipment used in cattle feeding

P. Vaculík* and A. Smejtková

Czech University of Life Sciences Prague, Faculty of Engineering, Department of Technological Equipment of Buildings, Kamýcká 129, CZ165 21 Prague 6 - Suchdol, Czech Republic
*Correspondence: vaculik@tf.czu.cz

Abstract. A cattle farming is a very important sector of agriculture. In the Czech Republic, both breeds with 'combined useful' as well as 'meat cattle' are breeding, but especially 'dairy cattle' breeds. Providing feed at the right time, in required quantity and quality is the basis of successful breeding, especially in breeding dairy cows. Automatic systems are present in almost all sectors of human activity, and livestock production is no exception. Fully automatic feeding systems for pigs or poultry are already in use. The process of milking cattle using automated milking systems is also sufficiently mastered. An interesting trend is the installation of automated feeding systems for cattle feeding. They are stationary lines that perform the following operations: they dose the individual components of the feed mixture, mix the feed mixture and distribute it to the relevant feed places. All these activities are usually done without the presence of a person. The automated feeding system Lely Vector and the conventional feeding system using feeding wagon Cernin were compared. The number of automated feed wagon runs has been monitored and then the feed consumption was compared while using automatic and conventional equipment. The aim of this paper is to evaluate the benefits of an automatic feed system with regard to the conventional feed system through a mobile feed car.

Key words: cattle, feed, silage, feeding, conventional feeding system, automated feeding system.

INTRODUCTION

The current speed of automation and robotization is a phenomenon that will lead to a rethinking of the understanding and implementation of a huge amount of human activities in the near future. While voice automates on customer lines or robots in industrial production have long since gained their place, and for example, automotive production cannot be imagined without modern technical solutions, the penetration of modern technology in the form of automatic systems into agricultural production is slower. For this reason, the first stationary automated feed lines for cattle on the Czech farms were launched only in the first half of 2014. Increased interest in automated systems can also be expected in this area (Reger et al., 2018).

All technologies used in livestock farming must meet the conditions of so-called welfare (Pšenka et al., 2016; Šematoviča et al., 2017; Ruska et al., 2017). This requirement must, of course, also be met by automatic technology (Přikryl et al., 1997; Hromasova et al., 2018; Vaculik et al., 2018).

Methods of feeding

Hand feeding is the oldest way to feed cattle, which primarily uses human manual labour with minimal use of mechanization. It is still used in a small extent on some small farms. The feed is brought to the stable where either slowly passes the car from which the feed is thrown into the troughs by workers, or it can be unload into the centre of the stable and then manually re-moved into the troughs.

Today, however, the vast majority of farms use some type of machinery or equipment to feed cattle. These can be divided mainly according to the way of transport and delivery of feed into stationary feeding equipment and mobile feeding equipment (Přikryl et al., 1997; Jehlička & Sander, 2015; Sander & Jehlička, 2016; Vaculik et al., 2018).

Mobile feeding equipment (feeding wagons) are attached behind the towing machine and, when passing stables, they lay the feed on one or both sides, or they can also lay it underneath. Their main advantage over stationary equipment is simple implementtation of replacement operation in the event of a fault. The disadvantage is the disturbed microclimate when passing the stable.

Feed mixing wagons represent an improved special variant of feeding wagons. It is not only used to put the feed into the troughs, but can also form a homogeneous feed mixture. Feeding wagons, that are more modern, also include a strain gauge weight that allows precise weighing of added feed components (Přikryl et al., 1997).

Stationary feeding equipment is firmly built into a stable, where they are used for one or two rows of animals. They can connect to a stationary line for feed transport or to mobile devices that transport feed from the warehouse or directly from the field. According to their location in the stable, it is possible to divide them into these main groups:

- belt feeders (trough conveyers, conveyers above trough),
- electric feeding wagons,
- automatic (robotic) feeding systems.

Since these devices are firmly built into the stable, it is more problematic transition to a different or more modern type of technology than for feed devices that is simply replaced. In the case of a fault, it is necessary to have a prepared alternative feeding solution, which is often solved using a feeding wagon (Přikryl et al., 1997).

The main effort in introducing automated systems is to save people's work, reduce time-consuming and allow more time flexibility. In livestock farming, efforts are also made to improve the conditions of breeding, to better adapt the environment of the stable to the natural behaviour of the animals. The feed is automatically continuously replenished according to the needs of the animals. Accurate dosing of individual feed components independent of human factor and control of feed intake during the day allows an increase in feed intake and thus an increase in livestock performance (Přikryl et al., 1997; Vegricht & Šimon, 2016).

It is important to pay attention to the preparation of feed in cattle breeding (Vaculík et al., 2013), their appropriate analysis (Chládek et al., 2013, Chladek et al., 2018), optimal utilization of raw materials (Smejtková et al., 2016; Smejtkova & Vaculik, 2018) and appropriate energy-efficient transport and storage (Hromasová et al., 2018).

MATERIAL AND METHODS

Basic data on the dairy cattle bred on the evaluated farm and basic data on the characteristics of used feed are given in the table (Table 1).

Table 1. The basic characteristic of Fleckvieh Breed and Feed

Breed		
Basic information		
Breed	(-)	Fleckvieh Breed
Country of origin	(-)	Czech Republic
Degree of breeding	(-)	noble breed
Performance direction	(-)	meat-dairy
Physical characteristics		
Male weight	(kg)	1,200.0–1,300.0
Female weight	(kg)	650.0–750.0
Male height at withers	(cm)	152.0–160.0
Female height at withers	(cm)	140.0–144.0
Body framework	(-)	medium to large
Colour	(-)	red mottled
Classification and standard		
Breeding group	(-)	group of mountain cattle
Milk performance (adult cow for lactation)	(-)	6,500.0
Protein content in milk	(-)	3.6
Feed (daily ration - dairy cows)		
Maize silage	(kg)	22.0
Clover grass silage	(kg)	12.0
Hay	(kg)	5.0
Straw	(kg)	2.5
Grain scrap	(kg)	4.0
Soybean meal	(kg)	1.2
Rapeseed meal	(kg)	1.2
Vitamin-mineral supplement, molasses, grains, sugar beet pulp, glycerol and others	(kg)	about 0.1
Total	(kg)	about 48.0
Physical characteristics		
Bulk density	(kg m^{-3})	900.0

This article deals with the assessment of automatic feeding system Lely Vector and the conventional feeding system using the feeding wagon Cernin C13.

Feeding wagon Cernin C13 (Fig. 1) - this type of feeding wagon is suitable for processing square and round bundles of feed, loose and bulk material, the volume of which can reach up to 13 m^3 and the maximum weight of the mixed feed dose can be 4,550 kg (the technical parameters are given in Table 2).

The wagon is equipped with one vertical stirring auger, on which are placed eight knives against which are two mechanical edges. Vertical mixing has several advantages over a horizontal one. One of them is the rapid preparation of a mixed feed, the mixing of which usually takes up maximum 3 to 4 minutes. The resultant mixture has retained structuring fibre, it is soft and evenly distributed, which allows for easier digestibility. The mixed feed dose containing micro granules and minerals reaches deviation 2.8% of the mixed material. The revolution speed of the stirring auger is set to 27 rpm. A two-speed gearbox can be supplied as an option accessories, by which can be reduced the speed. The mixing wagon is connected to a tractor with a power of 64 kW (47 kW in the case of a reduction gear tractor). The advantage is its own hydraulic system, which allows independence of tractor hydraulics. The uniform distribution of feed on the feed table is solved by a stainless steel double-sided drag conveyer. The mixing wagon is also equipped with a four-point strain gauge weighing system.

Figure 1. Tractor and feeding wagon Cernin C13 (Source: http://www.cernin.cz/p/model-c-i-6-13-m3).

Table 2. Technical parameters of feeding wagon Cernin C13

Mixing equipment	(-)	vertical system
Volume	(m^3)	13.0
Length with conveyer	(m)	5.72
Length without conveyer	(m)	4.21
High	(m)	3.04
Width	(m)	2.40
Total weight without conveyer	(t)	4.40
Total weight witch conveyer	(t)	4.89
Outside width of wheels	(m)	2.15
Input power without two speed gearbox	(kW/hp)	66/90
Input power with two speed gearbox	(kW/hp)	47/64
Auger/knives	(pcs)	1/8

Automatic (robotic) feeding system Lely Vector (Fig. 2) - the entire system consists of two main parts, which are feed preparation and feed wagon (the technical parameters are shown in Table 3).

At the beginning of the whole process, it is necessary to place the straight-cut blocks of roughage at a predetermined location. This placement is usually done every 2–3 days. When using concentrates and feed supplements it

Figure 2. Automatic feeding system Lely Vector (Source: https://www.agropartner.cz/automaticky-system-krmeni-lely-vector-p255.html).

is also necessary to check their stock. The ratios of the individual feed components, ride route and frequency of repetitions are by simple way set into the feed wagon system. The wagon goes through the stables at specified times and feeds the feed. At the same time, it measures its height. If its average quantity is below the set level, the wagon returns to the feed preparation and it is filled by next feed ration. It is picked up by an electronic grab and weighed in a feed wagon. At the same time, individual components are mixed thoroughly. When the feed mixture is ready, the feed wagon returns to the stable and evenly feeds the missing feed. This is repeated 24 hours a day. The main principle is the constant replenishment of fresh feed after small rations, which animals are able to feed.

Table 3. Technical parameters of feeding wagon of automatic feeding system Lely Vector

Mixing equipment	(-)	vertical system
Volume	(t)	0.15–0.60
Length	(m)	2.46
Width	(m)	1.62
Weight	(t)	1.285
Height	(m)	2.00
Height at feeding	(m)	2.90
Minimum passage width in transit	(m)	2.75
Rotation Diameter	(m)	3.10
Maximum number of groups	(-)	16.00
Volume of one feeding wagon	(number of cattle)	250–300
Volume of two feeding wagons	(number of cattle)	300–600
Maximum floor slope	(%)	5.00
Maximum stair height	(m)	0.02
Diameter of the roll	(m)	1.50
Maximum feed height	(m)	0.60
Max breadth of feed	(m)	0.72
Max transfer speed	($km.h^{-1}$)	2.00
Min Rate of Movement	($cm.s^{-1}$)	3.50
Feeding speed	($cm.s^{-1}$)	3.50–4.50
Power supply	(Ah)	55.00
Engine for mixing	(kW)	3.00
Feed distributor engine	(kW)	0.55

Measurement of selected parameters

Measurement was carried out at a family farm located in West Bohemia, which has an average of 191 dairy cows.

The data for the feeding wagon are from 31.12.2016 to 28.6.2017. These data were obtained from company documents. Values measurement when using the automatic system ran from 31 December 2017 to 28 June 2018. The following parameters were evaluated, when assessing automated feeding system Lely Vector: power consumption, regularity of the feeding wagon ride and their number and amount of feed consumed.

The three-phase, one-way DTS 353 electricity meter (Fig. 3) with LCD display is used to measure power consumption and is designed for secondary, informational or workshop measurements (the technical parameters are shown in Table 4).

The electricity meter was connected to the distribution box of the Lely Vector feeding system. Measurement of power consumption covered the entire system, i.e. the feed wagon, together with the crane and the grab. Additional data related to both system operation at the time of measurement and for a longer period of time were obtained from the Management Program T4C. This program is supplied by the firm Lely and is used to configure system Vector.

Figure 3. Electricity meter DTS 353 (Source: https://www.moje-elektro.cz/merice-spotreby/21651-elektromer-na-din-listu-dts-353-l-100a-7m-trifazovy-3f.html?gclid=EAIaIQobChMI472bhdK13wIVCOJ3Ch0kRA4wEAQYBCABEgIOI_D_BwE)

The data related to the feeding system operation include the amount of unloaded feed, the number of rides, and the number of cattle pieces served by the feeding wagon. The value readings were performed according to the order at approximately weekly intervals.

Table 4. Technical parameters of electricity meter DTS 353

Reference voltage	(V)	3x230 / 400
Standard	IEC62052-11, IEC62053-21	
Frequency	(Hz)	50.0–60.0
Reference current	(A)	10.0
Maximum current	(A)	100.0
Accuracy class	(-)	1.0
Impulse constant	(kWh)	800.0
LCD display mode	(-)	6 + 2
Own consumption	(VA)	< 10.0
Own consumption	(W)	≤ 2.0
Working temperature	(°C)	-20.0–55.0
Pulse output	(-)	open collector
Pulse indication	(-)	red LED
Pulse voltage	(V)	< 30.0
Pulse current	(mA)	≤ 27.0
Mounting DIN rail TS	(mm)	35.0
Connection of screw terminal	(mm^2)	25.0
Degree of protection IP	(-)	20.0
Dimensions (7 modules)	(mm)	122.0 x 100.0 x 65.0

Table 5 shows the detected data, both deducted from the electricity meter DTS 353 and then taken from the management program T4C.

Experimental measured values have been evaluated statistically using program in computer.

Table 5. The measured values when used automatic feeding system Lely Vector in period 31. 12. 2017 to 28. 6. 2018

Number	Date	Measurement time	Hours of measurements	Electricity consumption	Average daily el. consumption	Wagon rides	Wagon rides per day	Average amount of feed per day	Average feed	Average feed per dairy cows per day	Dairy cows
(-)	(-)	(-)	(hours)	(kWh)	(kWh day^{-1})	(-)	(rides day^{-1})	(kg day^{-1})	(kg)	(kg pcs.$^{-1}$ · day^{-1})	(heads)
2017											
0	31. 12.	23:59	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	191.0
2018											
1	01. 01.	18:00	25	32.9	31.6	17.5	16.8	8,325.4	8,672.3	43.6	191.0
2	07. 01.	14:00	140	149.8	25.7	85.2	14.6	7,956.7	46,414.1	41.9	190.0
3	14. 01.	16:00	170	198.4	28.0	110.5	15.6	8,495.2	60,174.3	44.8	189.5
4	21. 01.	13:00	165	186.3	27.1	118.3	17.2	7,883.0	54,195.6	41.8	188.5
5	28. 01.	18:00	173	208.6	28.9	115.3	16.0	8,657.5	62,406.1	45.1	192.0
6	01. 02.	18:00	96	115.6	28.9	63.2	15.8	8,426.1	33,704.4	43.9	192.0
7	07. 02.	12:00	138	139.2	24.2	81.7	14.2	8,431.3	48,480.0	44.4	190.0
8	14. 02.	15:00	171	200.5	28.1	126.8	17.8	8,009.6	57,068.4	42.4	189.0
9	21. 02.	17:00	170	195.6	27.6	135.3	19.1	8,302.0	58,805.8	43.8	189.5
10	28. 02.	17:00	168	183.7	26.2	111.3	15.9	7,867.4	55,071.8	41.8	188.0
11	01. 03.	15:00	22	26.5	28.9	13.6	14.8	8,421.5	7,719.7	45.0	187.0
12	07. 03.	16:00	145	178.6	29.6	83.4	13.8	7,988.0	48,260.8	42.3	189.0
13	14. 03.	14:00	166	211.3	30.5	125.9	18.2	7,831.4	54,167.2	41.0	191.0
14	21. 03.	18:00	172	207.4	28.9	111.8	15.6	8,736.5	62,611.6	45.9	190.5
15	28. 03.	20:00	170	222.3	31.4	120.4	17.0	8,726.0	61,809.2	45.4	192.0
16	01. 04.	19:00	95	100.8	25.5	53.8	13.6	8,387.1	33,198.9	43.5	193.0
17	07. 04.	20:00	145	153.9	25.5	102.1	16.9	8,125.9	49,094.0	42.3	192.0
18	14. 04.	21:00	169	194.2	27.6	121.8	17.3	8,364.8	58,902.1	43.5	192.5
19	21. 04.	18:00	165	169.0	24.6	95.6	13.9	7,531.6	51,779.8	39.6	190.0
20	28. 04.	19:00	169	201.3	28.6	101.4	14.4	8,435.8	59,402.1	44.4	190.0
21	01. 05.	17:00	70	87.4	30.0	49.0	16.8	8,325.9	24,283.9	43.7	190.5
22	07. 05.	16:00	143	151.7	25.5	94.1	15.8	8,211.7	48,928.0	42.8	192.0
23	14. 05.	15:00	167	172.4	24.8	114.8	16.5	7,965.2	55,424.5	41.3	193.0
24	21. 05.	18:00	171	194.7	27.3	127.5	17.9	8,002.4	57,017.1	41.6	192.5
25	28. 05.	19:00	169	186.3	26.5	121.1	17.2	8,481.1	59,721.1	44.6	190.0
26	01. 06.	16:00	93	94.3	24.3	64.3	16.6	8,285.3	32,105.5	43.8	189.0
27	07. 06.	17:00	145	139.1	23.0	91.2	15.1	8,165.9	49,335.6	43.0	190.0
28	14. 06.	15:00	166	187.3	27.1	95.5	13.8	8,332.8	57,635.2	43.5	191.5
29	21. 06.	16:00	169	178.5	25.3	104.9	14.9	8,534.1	60,094.3	44.2	193.0
30	28. 06.	17:00	169	190.8	27.1	114.8	16.3	8,244.6	58,055.7	43.1	191.5

The arithmetic average was used for evaluation of the measurement. The arithmetic average is defined as being equal to the sum of the numerical values of each and every observation divided by the total number of observations. Symbolically, if we have a data set containing the values $a_1,..., a_n$. The arithmetic average is defined as:

$$\phi = \frac{1}{n}\sum_{i=1}^{n} a_i \ (-) \tag{1}$$

where $Ø$ – arithmetic average (–); $a_1,..., a_n$ – the values of data set (Feynman et al., 2011).

RESULTS AND DISCUSSION

From the data obtained, it was possible to determine the indicators that are related to the distribution of feed by the feed wagon Cernin (Table 6) and automatic system Lely Vector (Table 7).

Table 6. Average resulting values for the period – feeding wagon Cernin C13

Feeding wagon Cernin C13 Period 31. 1. 2016 to 28. 6. 2017					
Daily electricity consumption	Wagon rides per day	Feed per day	Total amount of feed per period	Feed per dairy cows per day	Dairy cows
E_d (kWh.day^{-1})	R_{pd} (rides day^{-1})	F_{pd} (kg day^{-1})	F_{pp} (kg)	F_{cpd} (kg cs^{-1} day^{-1})	C (heads)
-	2.0	8,900.0	1,645,560.0	46.6 *	191.0

Note: * the value 'Feed per dairy cows per day' is calculated by the formula number 2.

$$F_{cpd} = \frac{F_{pd}}{C} \ (\text{kg cs}^{-1}\ \text{day}^{-1}) \tag{2}$$

where F_{cpd} – feed per dairy cows per day (kg pcs^{-1} day^{-1}); F_{pd} – feed per day (kg day^{-1}); C – dairy cows (pcs).

By evaluating the data, it can be state that the following values were achieved when using the conventional feeding system using the mobile feed wagon Cernin C13. In the monitored season, on average, 191.0 dairy cows were reared and a total of 1,645,560.0 kg of feed was delivered, which means 46.6 kg of feed per day per one cow. The amount of fuel consumed could not be determined because the towing device was also used for purposes other than the distribution of feed.

Table 7. Average resulting values for the period – automatic feeding system Lely Vector

Automatic feeding system Lely Vector Period 31. 12. 2017 to 28. 6. 2018					
Daily electricity consumption	Wagon rides per day	Feed per day	Total amount of feed per period	Feed per dairy cows per day	Dairy cows
E_d (kWh.day^{-1})	R_{pd} (rides day^{-1})	F_{pd} (kg day^{-1})	F_{pp} (kg)	F_{cpd} (kg pcs^{-1} day^{-1})	C (heads)
27.3	16.0	8,248.4	1,523,691.6	43.2 *	191.0

Note: * the value 'Feed per dairy cows per day' is calculated by the formula number 2.

When using the Lely Vector automatic feeding system, it can be seen a uniform distribution of rides in one day, averaging 16.0 rides per day. In the monitored season, there were on average 191.0 dairy cows and a total of 1,523,691.6 kg of feed was delivered by the automatic feeding system. Of this, 43.2 kg of feed per one cow per day.

Although the total feed consumption, when using the system Lely Vector, was lower than when using feeding wagon Cernin, the actual feed intake for one cow increased. This was due to lower feed losses when using system Lely Vector. According to the owner of the farm, the feed losses are about 5% when using the system Lely Vector, while losses when using the feeding wagon Cernin are greater than 10%. Milk yields of dairy cows were the same or higher with this whole lower feed consumption.

Energy saving in livestock farming is a very topical issue, with regard to dairy cow farming and milking it is fundamental issue (Smejtková & Chládek, 2012; Unal et al., 2017; Vaculik et al., 2018). An effort to save energy is also at least partially solved for example by the use of biomass (Kažimírová & Čerešňa, 2015; Skanderová et al., 2015), but with regard to the environmental impacts (Kažimírová & Opáth, 2016, Malaťák & Bradna, 2017). When using the automatic feeding system Lely Vector energy saving has occured. Pezzuolo et al., 2016 reports a reduction in energy consumption when using an automatic feeding system 2.74 kWh per day per 1 cow to 0.76 kWh per day per 1 cow. The average consumption at the farm under review was 0.14 kWh per day per 1 cow. Similar electricity consumption is also reported by Oberschätzl-Kopp, 2018. This energy consumption is low compared to the feed wagon also by Oberschätzl-Kopp et al., 2018. Consideration must also be given to fuel savings for the feed wagon towing equipment.

Reduced labor demand is also a significant saving. According to Pezzuolo et al., 2016 labour was reduced from 2.5 h per day related to the conventional feeding system to 1.02 h per day needed for the management of the automatic feeding system.

Obtaining feeding data and conducting their analysis is important also for further research (Xiong et al., 2017).

CONCLUSION

Automatic systems are increasingly used in livestock farming. They have also begun to be used for feeding dairy cows, they replaced feeding wagons or trough conveyors.

The main benefit of the automatic feeding system is a significant saving in staff time, a reduction in the cost of feeding, improving the microclimate in the stable. After the automatic feeding system was installed, the time required to prepare and distribute the feed for the herd was reduced by about 60%. The system is highly reliable, provides statistical data usable for further work, and allows the more natural all day provision of feed supply.

The need for higher initial investment may discourage from the introduction of automatic feeding systems. Also, employees must be able to operate this system. Problems can be with providing a substitute feeding system in the event of an automatic system failure. The return on investment in the automated system depends on a number of factors. Account must be taken of the purchase price of the system and the need for construction adjustments for the installation of the system, next for example the size of the herd or milk performance and the savings that the system will bring.

According to the farm owner, the benefits of the automatic feeding system will compensate for this investment and there were no major complications during the automatic system operation in terms of its failure.

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