Agricultura 3: 21-25 (2005)

Measuring heart rate of cows in milking parlour

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* The article is a part of the Ph.D. thesis (justification July 4, 2003), supervisor Prof. Dr. Ivan Štuhec, co-advisor Prof. Dr. Andrej Orešnik

In the milking parlour, feeding with concentrates was analysed in order to establish whether too short time for the consumption of concentrate caused increased heart rate (HR), one of the stress indicators. Average HR was 82.38 min^{-1}. In the evening, milking cows had higher HR (83.4 min^{-1}), compared to the morning one (81.2 min^{-1}). In the second month after calving, HR of cows was higher (85.10 min^{-1}) compared to the first (81.04 min^{-1}) and the third month (80.79 min^{-1}) after calving. Higher quantity of consumed concentrate (over 3 kg) resulted in an increased HR. If the cows received larger quantities of concentrate, HR increased towards the end of milking process. It can be concluded that large quantities of concentrate, which could not be consumed in a short period of available time during milking, caused stress in highly productive dairy cows.

Key words: heart rate, dairy cows, milking parlour, Polar monitors

INTRODUCTION

For successful and ethical cattle raising the raisers must be well familiarised with the characteristics of the individual kind and category of animals and with their life needs. The intensive technology of cattle raising must be adapted to physiological and ethological rules. The ethological rules are extremely important if we want to avoid stress. In order to study stress, it is necessary to use studying methods that do not cause stress. The heart rate measuring is one of many parameters of the stress state and from the point of view of animal protection it has an advantage over the measurements implying taking of blood samples (Janžekovič 2003).

Hopster and Blokhuis (1994) stated that changes of heart rate were an important mechanism of adaptation of the organism to the environment or to changes in the organism itself. In cattle, similarly to other animal species, the heart rate depends on the age of the animal, breed, sex and physiological loading or state. Rough values of heart rate in grown up cattle are 55-80 min^{-1} (Wittke et al. 1987) or 65-97 min^{-1} (Hopster and Blokhuis 1994), 48-96 min^{-1} (McGuirk et al. 1990). Baldock et al. (1988) describe the interdependence between heart rate and metabolic activity. The principal responsibility of the blood is to supply oxygen to muscles. The oxygen supply does not depend only on the heart rate but also on the systolic volume of the heart and on the arterial-venous differences in oxygen content. Higher metabolic activity requires an increased supply of oxygen to tissues and higher quantity of blood, and this results in an accelerated heart rate. According the above mentioned authors, the heart rate can be considered as a reliable indicator of the extent of metabolism of energy in the organism of mammals when they rest or work moderately, under the assumption that they are not in a stress condition. Changes of heart rate are therefore, a suitable parameter to evaluate the response of animals to the conditions in the environment, and to evaluate the activity of animals.

One of reactions of the organism to stressor is an increased secretion of adrenalin and noradrenalin from the core of the adrenal gland into blood. Higher concentration of these two hormones in the blood results in an accelerated heart rate. The latter can be measured in different ways. In practice, the methods not requiring surgical intervention on the animal nor direct contact of the human with animal are of interest. For execution of heart rate measurements in cows in the milking parlour a suitable method of measuring has to be developed (Janžekovič 2003). Measuring in the milking parlour is of interest because of finding out how animals feel during one of the most mechanised processes in animal production (i.e., milking). If during the relatively short time of milking, the cow is fed with dry ground concentrate which cannot be swallowed until the animal has wetted it with saliva, the question arises whether feeding of animals with concentrate in the milking parlour is a proper solution. According to our hypothesis, the milking cow is in a stress situation, since at the end of milking its heart rate is

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increased because it must leave the milking place before she has consumed all of the concentrate.

MATERIAL AND METHODS

Heart rate measuring methods

Different ways of heart rate measuring are known, namely: feeling the pulse, listening to heart tones, electrocardiogram and telemeter methods. The heart frequency, which tells how animals feel, can also be analysed by using an implanted transmitter and the animal's heart rate and temperature can be recorded by using a special receiver. The heart rate can be affected also by the measuring equipment and by the manner of measuring. In case of measuring equipment put onto the animal's body surface the time-consuming preparations for measuring and the calibration of devices before their placing into position are not necessary. The equipment can be simply re-placed from one cow to the other. Hopster and Blokhuis (1994) compared the results of heart rate measurements by Polar Sport Tester (PST) and electrocardiogram (EKG). The correlation's between values of ECG and PST during the rest (r=0.88) and movement (r=0.72) were statistically significant and different from cow to cow. The heart rate quickly increased immediately after removal (isolation) of the individual cow from herd. The cows made no signals that the devices disturbed them during the heart rate measuring.

For measuring of heart rate we tested special equipment used by top sportsmen during training: the heart rate meter "Polar Sport Tester-Profi" made by the Finnish equipment maker Polar Electro Oy. The meter was equipped with a transmitter and an elastic belt with movable holder and intermediate unit for connection to the computer "Polar Interface". By increasing the distance between electrodes it was possible to obtain continuous signal also on grown-up animals. Instead of the incorporated Polar transmitter from the Sport Tester-Profi set we used the transmitter with separated electrodes Polar Sport Tester. The two electrodes were connected by two wires and connecting buttons (Figure1). On the special elastic belt for fixing the electrodes, the distance between electrodes could be changed depending on the animal size.

The first electrode was placed at about 10 cm to the left of the central back line, immediately behind the withers (third to fourth inter-rib space) whereas the second electrode was put in the pericardium area. The transmitter was fixed to the animals by tightly fitting elastic belt. The signal could be obtained on the dairy cattle (black white) easier than on the combined breed (simmental) having thicker skin. In spite of carefully placing the electrodes, the response was not optimal yet. We presumed that different filling of pre-stomachs changed the position of internal organs and, consequently, the optimal location of electrodes. By adding 87 g of kitchen salt (NaCl) into 5 litters of heated water 38 °C (311 K), i.e. 17.10 g/l, with which we wetted the contact points (on the skin), the continuous signal in the time of measurements was reached.

Tested cows and statistical analysis of data

On two farms, 162 measurements of heart rate during the morning and evening milking in the milking parlour tandem 2 x 2 were performed on 27 cows of Holstein Friesian breed. In the time of measurements, 9 cows were in the second lactation, 7 in the third lactation and 11 in the fourth consecutive lactation. In addition to heart rate measurements during the first three checkings of the milking capacity we ascertained also the time of milking and the time of consumption of the concentrate, the quantity of the consumed concentrate during milking and quantity of milk obtained.

Directly saved data on all performed measurements of heart rate of milking cows were transferred from the computer programme Polar HR Analysis - version 4.10 into the programme Microsoft Excel 97 and were edited for further processing. The average heart rate, the standard deviation (SD), the coefficient of variation (CV), the standard error of mean (SEM) and the Pearson's correlation coefficient were calculated.

We investigated 162 milkings. Individual milking time lasted from 260 to 600 seconds. Each individual milking period was divided into 10 units. These units represented the base for calculating the heart rate and later for the determination of the linear relationships between heart rates and units of measurements. The data were analysed according to the least square method by GLM process in the statistical package SAS/STAT (1996). P-values ($P \leq 0.05$) were used as the criterion in deciding on the incorporation of the individual influences into statistical model. In the statistical model for the heart rate (y_{ijklm}) we analysed the influences of the stage of measurements (x_{1ijklm}), obtained daily quantity of milk of the measured cows (x_{2ijlm}) and quantity of the consumed

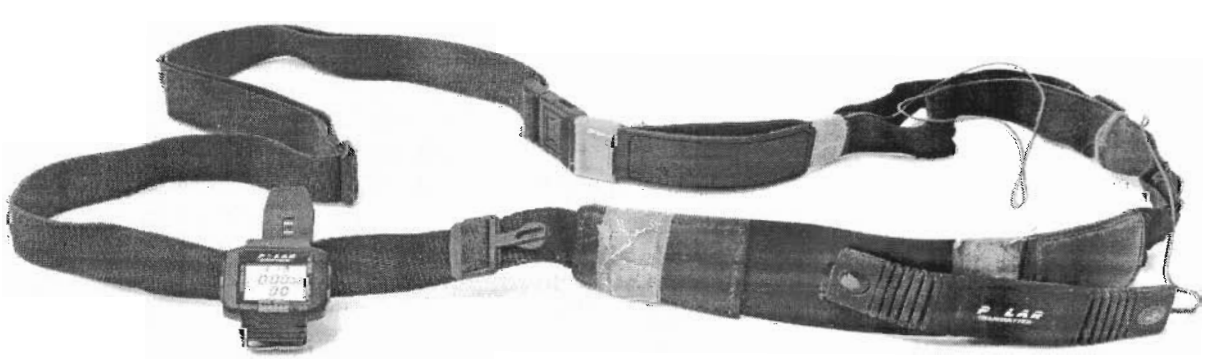

Fig. 1. The alteration on girth belt with Polar Sport Tester transmitter and receiver adjusted by the author.

concentrate in the milking parlour (x_{3ijklm}) as independent variables. For the first one we used polynomial of the first degree and for the second and third one the polynomial of the second degree. We evaluated the differences in the heart rate between two farms (K_i), between consecutive measurements (M_j) and time of milking (T_k). By using Pearson's correlation coefficients we studied the relationship between heart rate and the parameters of the milking capacity of studied cows and the consumed concentrate during milking.

For analysing the influences on the heart rate of cows at the time of milking the following statistical model was used:

$$y_{ijklm} = \mu + K_i + M_j + T_k + A_{il} + b_1(x_{1ijklm} - \bar{x}_1) + b_{2l} (x_{2ijlm} - \bar{x}_2) + b_{2ll}(x_{2ijlm} - \bar{x}_2)^2 + b_{3l}(x3_{ijklm} - \bar{x}_3) + b_{3ll}(x_{3ijklm} - \bar{x}_3)^2 + e_{ijklm}$$

RESULTS AND DISCUSSION

Table 1 shows the P - values for different influences on heart rate at the time of milking. All influences included in the statistical model, except the quantity of consumed concentrate in the milking parlour (x_{3ijklm}) were statistically highly significant. As in the hypothesis we anticipated

Table 1. P - values for the effects on heart rate during milking.

Influence	P - values
Phase of measurement heart rate	0.0002
Consecutive measurement	0.0001
Milking time	0.0001
Farm	0.0047
Cow in the farm	0.0001
Daily milk yield (linear article)	0.0187
Daily milk yield (square article)	0.0001
Consumed concentrate (linear article)	0.8959
Consumed concentrate (square article)	0.0001

that higher quantity of concentrate would increase the heart rate we retained that property in the model. In the beginning, the independent variable x_{3ijklm} was included in the statistical model as the first degree polynomial, but it was not statistically significant (P=0.8959). However, x_{3ijklm} was statistically highly significant (P=0.0001) as the second degree polynomial. By the described model, 65.03 % of variance were explained.

Relationship between heart rate and the parameters of the milking capacity of cows and the consumed concentrate during milking in the milking parlour tandem 2x2 are presented in Table 2.

Influence of stage of measurement

The duration of the milking period was different, so each milking was divided into tenths representing the stages of milking. Heart rate dropped with the duration of milking. Heart rate increases already on cows waiting to be milked, when they start to eat the concentrate (Arave et al. 1991) and at the beginning of milking (Royle et al. 1992). On the basis of the above mentioned findings higher heart rate is expected in the beginning of milking of cows fed with concentrate in the milking parlour (Figure 2), however it decreases, if the cow is not exposed to stressor.

Influence of consecutive measurement

The highest milk yield occurs during the first mounts after calving. Therefore, we decided to measure heart rate of cows during the first three chekings of milking capacity in the course of each lactation. It was established that heart rate was significantly higher during the second measurement (85.10 min^{-1}), as compared to the first (81.04 min^{-1}) and third (80.79 min^{-1}) one. In spite of increased heart rate during the second measurement there were no statistically significant differences in the milk yield between measurements. The increased heart rate at the end of the second month of lactation is caused probably by on increased activation of the body reserves for the milk yield. According to Purwanto et al. (1990) a higher daily milking capacity is related to greater needs for nutritive substances. At the some time, more intensive digestion and metabolism, consequentially influencing the increase of heart rate, take place in the animal organism. Our investigation indicated that in case of the second measurement the cows consumed a little more concentrate and consumed it faster, however the differences were not significant. In the time of the second measurement, the normal reproduction cycle appeared in most cows concerned and insemination took place. During estrus, a series of changes take place in the secretion of hormones which significantly influence the animal behaviour.

Table 2. Pearson correlation coefficients between heart rate, milk production and concentrate consumption in milking parlour.

	DMP	MT $_{(n=162)}$	CT $_{(n=162)}$	CS $_{(n=162)}$	ACC $_{n=162)}$	AHR $_{(n=161)}$	$AHR_{1-30\ (n=161)}$
DMP	1.00	0.65***	0.78***	0.52***	0.75***	-0.03	-0.06
MT		1.00	0.80***	0.52***	0.77***	-0.11	-0.16*
CT			1.00	0.46***	0.84***	-0.12	-0.15
CS				1.00	0.85***	-0.02	-0.08
ACC					1.00	-0.06	-0.13
AHR						1.00	0.87***
AHR_{1-30}							1.00

* - P ≤ 0.05; *** - P ≤ 0.001; $_n$ – number of measurements; DMP - daily milk production; MT - milking time; CT - consumption time; CS - consumption speed (per minute); ACC - average concentrate consumption in milking parlour; AHR - average heart rate for total milking period; AHR_{1-30} - average heart rate for the first 30 sec.

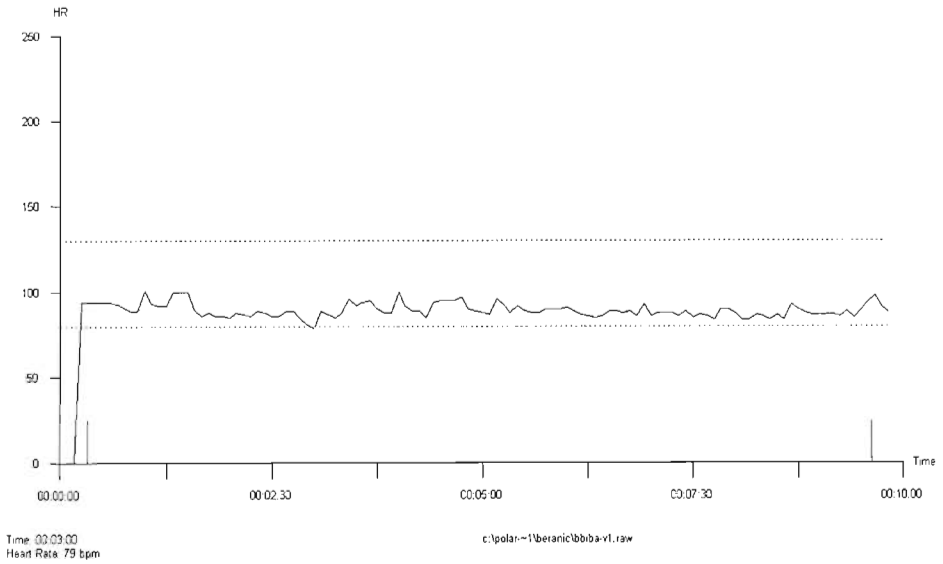

Fig. 2. Heart rate oscillation during milking in individual standing position (original graph).

Influence of milking time

The heart rate was significantly higher during the evening milking (83.4 min^{-1}), when compared with the morning milking (81.2 min^{-1}). In the morning 2.14 kg more milk were obtained, the milk flow was faster for 0.20 kg/min and the duration of milking was longer for about 22 seconds. In the morning, due to longer milking, the time for consumption of the concentrate was longer and the quantity of the consumed concentrate was greater. Greater heart rate during the evening milking can be attributed to the metabolic activity. Baldock et al. (1988) describe the interdependence between the heart rate and the metabolic activity. A greater activity of metabolism requires an increased supply of oxygen to tissues, a greater supply of blood is necessary and this leads to an increased heart rate. It is easier to explain the smaller quantity of milk obtained during the evening milking. During the day, cows are more active than during the night. Rulquin and Caudal (1992) state that the blood flow through the lacteal gland on the average is higher for 24 % when the milking cow is lying, whereas the heart rate decrease for 7 % in comparison to the standing milking cow.

Influence of farm

Altrough the two farms, at which the measurements were performed, were only 80 m distant, the influence of the farm on the heart rate was statistically significant. In farm A, the cows had a heart rate 83.24 min^{-1} and in farm B 81.38 min^{-1}. The difference between the two farms was caused by intensity of rearing. In farm A, during the first successful insemination the heifers were 151 days younger than the heifers in farm B. The cows in farm A gave 1875 kg milk or 1698 kg FCM or 1721 kg ECM more during the lactation than cows in farm B. Differences in heart rate between animals with different milk yield were proved by Le Neindre (1989) who measured 81.1 min^{-1} on cows of the Friesian milking breed and 71.7 min^{-1} on cows of the robust meat breed Salers.

Influence of daily milk quantity and concentrate consumed

The beginning of lactation is the critical stage in the production cycle of the individual animal and therefore the total milk yield depends to a large extent on a correct preparation of cows for the period of milk production. Various errors in the technology of rearing and particularly feeding can lead to reduction of the reached peak of the yield, which is hardly corrected in the later stage of lactation. From this point of view it is very important that the cow rearing system should allow checking of the daily yield of quantities of milk and individual feeding. This is allowed in the system of tied cows where, however, the working time consumption is rather high. In the system of rearing untied cows there are several possibilities of dosaging the concentrates ensuring higher milk yield than the basic food. A high-quality basic meal can procure nutritive substances for a 15 kg milk yield (Janžekovič 1995). High quality basic food was fed also in farm A and B, since voluminous food assured 15 kg daily milk yield.

The two negative regression coefficients of the daily milk quantity, affecting the heart rate, show that heart rate decreases with increased daily milk quantity. In cows with low quantity of concentrate the heart rate is high due to agitation of the animals for which that food is a real supplement or reward as Kovalčik and Kovalčiková (1986) called it. The increase of the concentrate quantity decreases the heart rate up to the quantity which the animals can devour during milking. In our case, that quantity was between 2 and 3 kg of concentrate. When the animal is given more concentrate than it can consume, the fact that it cannot consume it is a stressor for it and the heart rate increases more and more with the increasing quantity of the concentrate.

Influence of season

In our climatic condition (Slovenia) the seasons differ significantly. That has an effect on the heart rate which is significantly higher in summer than in winter; significant

differences are also between spring and winter. This can be explained by the fact that heat and adaptation to heat are a problem for cows. Baldock et al. (1988) come to similar findings on sheep. They established a minimum heart rate in winter, in December (81.2 min^{-1}) and maximum heart rate at the transition from spring into summer, in June (124.5 min^{-1}). Between the season there were not such significant differences in the milk yield as in the heart rate. Obviously, by means of ethological and physiological thermoregulation the animals manage to resist to the heat stressor.

Influence of consecutive lactation

Testing covered the cows of second, third and fourth lactation. The influence of lactation was negligible for all properties of the heart rate, milk yield, body mass and size of front part of body at the time when those cows were still in the first lactation. When planning the tests, great attention was paid to highest possible uniformly of investigated cows according to the criterion of the consecutive lactation. Obviously that influence was overestimated.

CONCLUSIONS

The main objective of the study was to examine the influence of the speed of consumption and the amount of the consumed concentrate on cows in the milking parlour during the effective milking, and to investigate whether too short time for the consumption of concentrate induces stress in dairy cows. For this purpose, the heart rate (HR) of dairy cows was measured by a measuring device without a direct intervention on animal body. For heart rate measurements, a special equipment »Polar Sport Tester Profi«, which is normally used by top-level athletes, was applied. This instrument was altered and tested in the preliminary test period on different cattle categories. During milking, the approximate 82.38 min^{-1} HR was established; the highest HR was established in the first 30 seconds (84.70 min^{-1}), in the middle of milking period a decrease of HR was observed (82.18 min^{-1}) and thereafter it remained stable. In the last 30 seconds it was 82.20 min^{-1}. In the second observation, during which the cows already entered the normal estrus period the highest HR (85.10 min^{-1}) was observed. Therefore, remarkable changes in hormonal status of animals and behaviour were noticed. Statistically significant increase in heart rate (83.4 min^{-1}) during evening milking in comparison to the morning milking (81.2 min^{-1}) was established. The amount of daily milk yield was highly statistically significant ($P \leq 0.001$) related with the time of milking, time of feeding, the speed of consumption and the average amount of concentrate consumed in the milking parlour. Between the speed of consumption and the amount of concentrate consumed, a significant high correlation coefficient was established ($r=0.85$; $P \leq 0.001$). An average speed of consumption was 249.7 g per minute. In case of 2.5 kg of consumed concentrate, no increase in HR was observed. But the increase in the consumed amount of concentrate over 2.5 kg resulted in a noticeable increase of HR. Considering the mentioned relationship between the amount of concentrate and HR, our assumption is that cows could not consume all the available concentrate and for that reason the HR was higher. It has therefore been concluded that high HR, regarded as one of the stress indicators, was caused by larger quantity of concentrate which the animals were not able to consume during the limited milking time. Thus, our results confirmed the hypothesis that feeding on concentrates in the milking parlour is not the most suitable feeding technology for the highly productive dairy cows.

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Received: April 4, 2005;
Accepted in final form: July 4, 2005