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TECHNIQUES OF MEASURING HEART RATE IN CATTLE

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Preliminary notes

The intensive animal breeding systems can cause severe environment degradation. However, the highly productive animals are extremely sensitive to the environmental changes. The animal welfare can be in direct contradiction with the need for highly intensive and economically successful milk production. The research is aimed at complementing the method of establishing the stress in calves, race heifers, fattened cattle and milk-cows with different body masses. Measuring of heart rate is one of painless measurements of physiological parameters of stress and, from the point of view of animals it has many advantages over the measurements including taking of blood samples. For measuring the heart rate of different categories of cattle without interference into their body we have tested the usefulness of special apparatuses used worldwide by top sportsmen during training for following up, measuring and monitoring the heart rate. These are Polar monitors of the heart rate, made by Finnish company Polar Electro Oy and working wirelessly with ECG precision. The receiver counts the heart rate on the basis of pulse-to-pulse time average algorithms in 5, 15 or 60-second intervals. The computer interface ensures magnetic transfer of measured and saved data on animals into a PC where the analysis of each collected data file follows. The used type of transmitter "Polar sport tester profi" having two electrodes in an airtight sealed frame has enabled us to obtain a good signal on calves of up to 180 kg body mass. Periodic response in case of young cattle of up to 280 kg body mass has been registered only if electrolyte was added between the animal skin and the feeler. By further modifications and tests of the mentioned apparatuses the expected response has been reached also on adult animals. We found that use of these apparatuses on animals did not have any influence on special animal acting behaviour. The production of milk and meat in herds did not change during the test.

***Key words**: polar monitors, modified apparatus, heart rate, cattle, measuring*

Tehnike mjerenja brzine otkucaja srca kod goveda

Prethodno priopćenje

Intenzivni životinjski rasplodni sustavi mogu prouzročiti žestoku degradaciju okoliša. Međutim, visoko produktivne životinje su ekstremno osjetljive na ekološke promjene. Životinjsko blagostanje može biti u direktnom proturječju s potrebom za visoko intenzivnom i ekonomski uspješnom proizvodnjom mlijeka. Istraživanje je usmjereno na kompletiranje metode utvrđivanja stresa kod teladi, sortnih junica, goveda za tov i mliječnih krava s drugačijim tjelesnim masama. Mjerenje brzine otkucaja srca je jedno od bezbolnih mjerenja fizioloških parametara stresa, i sa stajališta životinja ono ima mnoge prednosti u odnosu na mjerenja koja uključuju uzimanje krvnih uzoraka. Za mjerenje brzine otkucaja srca različitih kategorija goveda bez smetnji za njihovo tijelo testirana je korisnost posebnih uređaja koji se rabe u cijelom svijetu kod vrhunskih sportaša tijekom obuke zbog praćenja, mjerenja i nadgledanje brzine otkucaja srca. To su Polar monitori brzine otkucaja srca, koje je izradilo finsko poduzeće Polar Electro Oy i rade bežično s ECG točnosti. Prijemnik broji otkucaje srca na bazi prosječnog vremena bilo-prema-bilu u 5, 15 ili 60-sekundnim intervalima. Računalno sučelje osigurava magnetski prijenos izmjerenih i pohranjenih podataka na životinjama u PC gdje slijedi analiza svakog prikupljenog podatka. Korišteni tip odašiljača "Polar sport tester profi" s dvije elektrode u hermetički zapečaćenom okviru omogućio je dobivanje dobrog signala na teladima do 180 kg tjelesne mase. Periodičan odziv u slučaju mladih goveda do 280 kg tjelesne mase bio je bilježen samo ako je elektrolit bio dodan između životinjske kože i ticala. Kod daljnjih izmjena i testova spomenutog uređaja očekivani odziv je bio također dosegnut na odraslim životinjama. Otkriveno je da uporaba ovih uređaja na životinjama nije utjecala na posebno ponašanje životinja. Proizvodnja mlijeka i mesa u stadima se nije promijenila tijekom ispitivanja.

***Ključne riječi:** Polar monitori, modificirani uređaji, brzina otkucaja srca, goveda, mjerenje*

1
Introduction
Uvod

One of the reactions of the organism to stress 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 [10]. Measuring in the milking parlour is also of interest because of finding out how animals feel during one of the most mechanised processes in animal production (i.e., milking). No effects of milking system were found during milking, indicating that the stressor in the automatic milking system was not the milking process itself [4].

For successful and ethical cattle raising the raisers must be well familiarized 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 laws. If the latter are not considered the risk of animals experiencing stress appears [3]. In order to establish stress the methods not causing themselves the stress states must be used. 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 [9]. Hopster and Blokhuis [6] 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.

Baldock et al. [1] 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 to 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.

2
Heart rate measuring method
Metoda mjerenja brzine otkucaja srca

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 [6] compared the results of heart rate measurements by Polar Sport Tester (PST) and electrocardiogram (ECG). The correlations 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. Hagen et al. [4] recorded heart rate with a monitoring system that stored IBIs for about 4 h continuously (horse trainer transmitters and S810 monitors from Polar Electro Oy, Helsinki, Finland). The transmitters were attached to a horse girth and fitted to cows as described by earlier study [6]. The cows were not shorn or shaved where the electrodes were placed, but ample electrode gel was used to ensure good contact, and an extra elastic girth kept the transmitters in place. Prior to the study, cows were accustomed to wearing this equipment.

For measuring of heart rate we have tested special apparatuses used by top sportsmen during training. This was 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". As the elastic belt is 70 cm long, the said device could be placed only on suckling and weaned calves of up to 180 kg body mass. With lengthened elastic belt, into which simply a transmitter was inserted, during the tests we received periodic response in animals of up to 280 kg body mass (Figure 1) only if electrolyte was added between the animal skin and the feeler.

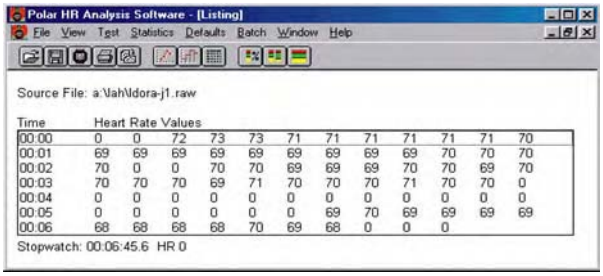

Figure 1. Periodic signal of heart rate in young cattle (original copy)
Slika 1. Periodički signal brzine otkucaja srca kod mladog goveda (originalna kopija)

The response was a little better when the hair was removed from the skin at the point of contact between electrodes and skin. The hair was shaved by electric scissors Attila 2000 made by German maker Forfex. On animals of more than 280 kg body mass the desired response was not received. By further modifications of the Polar device the distance between the two individual electrodes was increased and thus, the response was received also on grown-up cattle.

2.1
Description of transmitter of heart rate signals
Opis odašiljača signala brzine otkucaja srca

The elastic belt with transmitter was placed around the chest of animals. The used type of the transmitter has two electrodes of 20,7 cm^2 size, placed in a tightly closed frame. The electrodes are 9 cm long so that the ECG signal can be reliably identified. Such design ensures complete water-tightness. It has a ribbed surface for better contact with the skin. The two electrodes are spaced at 9 cm on the calf. The first electrode was located on left side between the shoulder-blade and dorsum areas and at 3 to 4 cm below the central back line. The second electrode was placed in the sternum area.

If the two electrodes and the two points of their placing on the skin were wetted with ordinary water better conductivity between the skin and the two electrodes was reached. The heart rate signal was telemetrically transmitted to the hand receiver. The latter was worn on the hand; later on it was fixed to the sternum. Figure 2 shows original Polar transmitter with elastic belt and Polar heart rate monitor.

Figure 2. Polar transmitter with elastic belt (left) and Polar heart rate monitor (right)
Slika 2. Polar prijenosnik s elastičnim remenom (lijevo) i Polar monitor brzine otkucaja srca (desno)

2.2
Receiving of heart rate signals
Primanje signala brzine otkucaja srca

The receiver calculated the heart rate on the basis of the time average algorithm between two successive heart beats and counted it in 5, 15 or 60 second intervals. For measurements the apparatuses were set to 5-second interval.

The first value read is calculated from the first four values of the heart beat [5]. In accordance with the manufacturer's instructions during settings of measuring of parameters two different chronometers and the limit values of the desired heart rate were set. By means of the manufacturer's computer programme (programme package Polar HR Analysis, version 4.10) the data were electronically transferred to the personal computer (Figure 3).

Figure 3. Data transfer from Polar heart rate monitor and interface to PC computer
Slika 3. Prijenos podataka od Polar monitora brzine otkucaja srca i sučelje ka osobnom računalu

With the original apparatus the heart rate measuring was good only on calves of up to 180 kg body mass. The first electrode was located at 3 to 4 cm to the left of the control back line; the receipt of signal from the transmitter on the body to the 1 m distant receiver was excellent. On heavier animals we first wanted to receive better response by wetting the skin with ordinary water. However, the response did not improve. Also the use of salt water did not give better results. With any small movement of the body of heavier animals (e.g. lifting of leg) also the electrodes moved and the signal was interrupted [15]. Figure 4 shows the original copy of the loss of cow's heart rate signal in time of measurements.

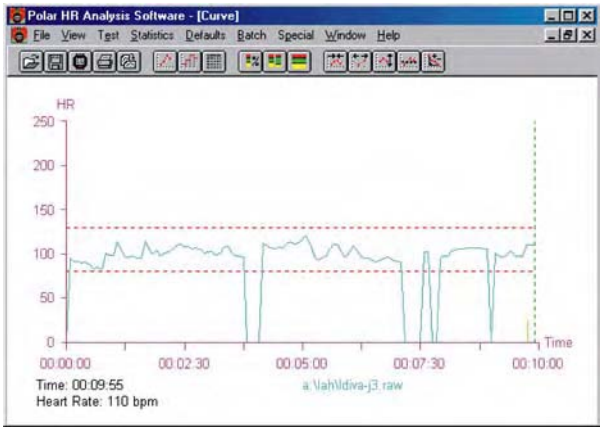

Figure 4. The loss of cow's heart rate signal in time of measurements (original copy)
Slika 4. Gubitak signala brzine otkucaja krvaljeg srca u vrijeme mjerenja (originalna kopija)

By the use of such equipment on the cattle of different age categories and sex, kept in tied system of raising (Grabner's tie with short stalls) [14] we obtained the following average values of heart rate with interruptions in the time of measuring. Calves of 110 kg body mass: 125 min^{-1}, fattened cattle of up to 280 kg body mass: 80 min^{-1}, race heifers of up to 300 kg body mass: 84 min^{-1}, cows of 550-600 kg body mass: 82 min^{-1}, cows of 600-650 kg body mass: 78 min^{-1}, and cows of 650-700 kg body mass during rumination: 55 min^{-1}. The measurements on the animals lasted five minutes; the receiver counted the heart rate in five-second intervals. The obtained average values of heart rate during test measurements are only provisional and do not reflect the measuring problems.

3
Modification of girth belt with receiver and its positioning
Modifikacija remena kolana s prijemnikom i njegovo pozicioniranje

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 (Figure 5).

Two wires and connecting buttons interconnected the two electrodes. On a special elastic belt for fixing of electrodes the distance between electrodes could be changed depending on the animal size.

Figure 5. The alteration on girth belt with Polar Sport Tester transmitter and receiver adjusted by the author
Slika 5. Promjena na remenu kolana s Polar Sport Tester prijenosnikom i prijemnikom

The first electrode was located at about 10 cm to the left of the central back line immediately behind the withers (third to fourth inter-rib space) and the second electrode 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.

Figure 6 and 7 show placing of the girth belt with electrodes on the cow.

Figure 6. Mounting the girth belt on the simmental cow
Slika 6. Opasavanje remena kolana na kravi simentalki

We tested with adjusted Polar Sport Tester and receiver on the animals with body mass 700 kg and more in place with Grabner's tie with short stalls. At the moment of measurement there were in this barn 8 cows of simmental breed, 4 black and white cows and 10 other categories of cattle. With elastic belt without apparatus we habituated our animals for following measurements.

In spite of carefully placing the electrodes, the response was not optimal yet. We presume that different filling of pre-stomachs changed the position of internal

Figure 7. Mounting the girth belt on the black white cow
Slika 7. Opasavanje remena kolana na crno-bijeloj kravi

organs and, consequently, the optimal location of electrodes. Therefore, we resorted to skin wetting. By adding 87 g of kitchen salt (NaCl) into 5 litres of heated water 38 °C (311 K), i.e. 17.10 g/l [7], with which we wetted the contact points, continuous signal in the time of measurements was reached (Figure 8).

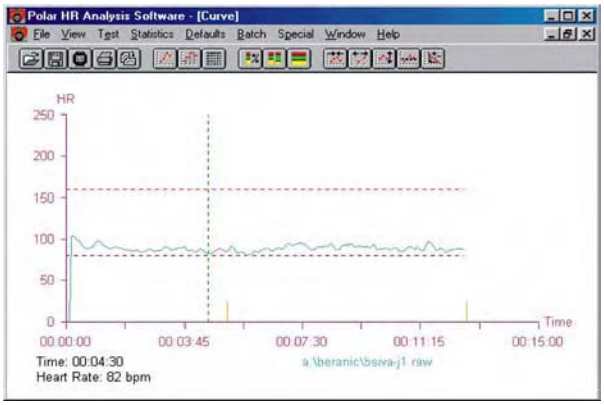

Figure 8. Normal heart rate level during milking in individual standing position (original copy)
Slika 8. Normalna razina brzine otkucaja srca tijekom mužnje u pojedinačnom stojećem položaju (originalna kopija)

4
Testing of modified apparatus for measurements of heart rate in milking parlour tandem 2 x 2

Provjera modificiranog aparata za mjerenje brzine otkucaja srca u tandemskom prostoru za mužnju 2 x 2

On 27 cows of Holstein Friesian breed with 26 kg average daily milking capacity, 162 measurements of heart rate were performed on two farms during the morning and evening milking in the milking parlour tandem 2 x 2. 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. Before entering the

milking parlour, each cow was fed 1 kg concentrate, and later in the milking stand, additional 1, 2, 3 or 4 kg concentrate were given according to the cow's daily milking production [11]. Milking time was recorded and the left over concentrate was weighed at the end of milking time.

Five days before the first measurement of heart rate a "blind elastic girth belt" (Figure 9) was placed on the selected animals to enable them to adjust themselves to wearing a belt round the thorax and to prevent subsequent placing of the measuring device from causing stress by itself. During measuring we wore an identical coat and covering as the supervisor inspecting milking in the milking parlour once a month in the morning and in the evening. Thus the habituation and/or the control of situation by animals, adjusting themselves to repeated irritations and not responding to them with stress, was taken into account [13].

Figure 9. Blind elastic girth belt for habituation
Slika 9. Slijepi elastični kolanski remen za navikavanje

At the end of the barn, easily accessible for vehicles, a 2 x 2 tandem milking parlour with two standing points of 3 m width and 7,5 m length was located. The cows came from the waiting place into the milking parlour onto the milking point up to the milker. In the middle of the milking parlour there is a channel deepened by 85 cm so that during milking the milker can hold himself upright. Milking in it was effected with two milking units. It was located between two rows of lying boxes and the dairy, calving room and the storage for feed concentrates. Through the milk duct the milk flowed into the collecting container. A pump pumped the milk through the milk filter directly into the cooling basin. In it the formation of microorganisms was prevented by cooling from 36÷37 °C to + 4 °C.

Figure 10 shows the cross-section (a) and ground plan (b) of milking parlour tandem 2 x 2.

After activation of the vacuum pump in the dairy before the start of milking the milch-cow themselves gathered in front of the milking parlour at the place of the dropping corridor between two rows of lying boxes, i.e., in the accumulation. The feeding room was separated at that time by two bulkheads to avoid mixing of milked and non-milked cows. The cows entered individually and arranged themselves one after the other on both sides of the milking parlour. Both sides of the

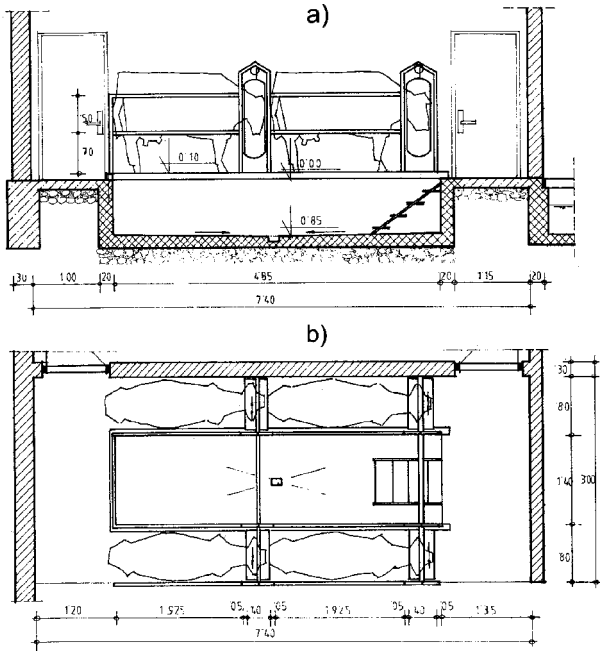

Figure 10. Cross-section (a) and ground plan (b) of milking parlour tandem 2 x 2 [8]
Slika 10. Presjek (a) i tlocrt (b) tandemskog prostora za mužnju 2 x 2 [8]

milking parlour were identical (Figure 11). When the milch-cow had come to the milking point, the entrance door closed stressfully [1] the cows stood with their heads towards the exit into the feeding room into which they individually retired after completion of milking. The milker who knows all the cows of his herd identified the cows.

Figure 11. Milking parlour tandem 2 x 2
Slika 11. Tandemski prostor za mužnju 2 x 2

At the milking point itself the milch-cows with lower milking capacity were given 1 kg of feed mixture and the cows with higher milking capacity 2,3 or 4 kg. During the morning milking, on the spot of milking we first wetted with warm salt water the points anticipated for placing of electrodes on the cow. Then, the modified apparatus for heart rate measuring was attached. By gradual tightening of the elastic belt (girth belt) good contact between the two electrodes and the cow's skin

was ensured. In addition, the Polar receiver was attached to the girth belt and activated immediately prior to placing of the milking unit. After completion of milking the receiver was deactivated and the heart rate meter removed. The entire procedure was repeated still in the evening of the same day. The data saved in the memory of the receiver PST were electronically transferred into the personal computer through interface (Polar Interface) and were intended for further studying of feeling of animals [12].

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 oestrus period the highest HR (85,10 min^{-1}) was observed. Therefore, remarkable changes in hormonal status of animals and behaviour were noticed.

5
Conclusion
Zaključak

- We have developed the non-invasive method of measuring of heart rate in cattle, having certain advantages over the methods involving taking of blood samples. By modifying the measuring device Polar Sport Tester (PST) a stable signal was reached at any time of measuring.
- The usefulness of the polar heart rate monitors on cattle is different. By wetting the contact points of the skin and electrodes with cold water we obtained with the heart rate meter PST-profi a continuous signal of heart rate beating on calves of up to 180 kg body mass without modification of the device.
- By the use of the lengthened elastic belt and the inserted transmitter with scaled electrodes we reached periodic response on animals of up to 300 kg.
- On grown-up fattened cattle and on cows we used the polar transmitter having physically separated electrodes. Both electrodes were interconnected with additional wires and connecting buttons and were mounted into a special girth belt. Continuous response was reached on motionless animals.
- Due to different size of the belly it is hard on the cattle to reach optimum location of the electrodes of the receiver. For better transfer of the signal in all measurements the skin was wetted with warm salt water in the area of placing of electrodes.

6
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