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The application of cluster analysis methods in assessment of daily physical activity of dairy cows milked in the Voluntary Milking System

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ABSTRACT

A great individual variability of dairy cows and the diversity of conditions of their maintenance make it difficult to unequivocally interpret the animals' behaviour and, consequently, to assess their welfare objectively. Thus, technical support to cattle breeders seems increasingly important in this respect at the stage of data collection, the analysis of data and assessment of rearing conditions. Therefore, the aim of the project was to examine the possibility of using cluster analysis to assess physical activity of dairy cows milked in the Voluntary Milking System while taking into account environmental conditions. The research included ten Holstein-Friesian cows in June, September, and December of 2015. The data concerning the cows' physical activity were classified with Ward's method and the Kohonen's networks. In general, during individual months, the distribution of cows' average daily physical activity was similar and its variability small. Nevertheless, over the individual months, the following three groups for this feature were distinguished with the use of the cluster analysis: night-morning, morning before noon, and afternoon-evening. At the same time, it was observed that, in at least a few cases, the division could be associated with such environmental conditions as daytime light length changes, temperature, or relative humidity of the air. Therefore, in our opinion, cluster analysis can be helpful in classifying dairy cows physical activity, thus contribute to an objective assessment of behavioural indicators of their welfare.

1. Introduction

The need to maintain the welfare of dairy cows at an optimum level arises out of the need to pursue a sustainable development in agriculture, including animal husbandry (Axelsson, 2013). In practice, for the purpose of assessment of welfare of dairy cows, apart for production indicators (*e.g.* a variation in daily milk yield) it is behavioural indicators that often help assess the welfare of dairy cows, in particular the physical activity (PA) of the animals (Edwards and Tozer, 2004; Mattachini et al., 2011). During the PA analysis it is necessary to take into account individual features of the cows (*e.g.* their genotype, parity, level of milk yield), the system of their maintenance, feeding, and milking as well as other environmental and the microclimate conditions in the cowshed (Nicol, 2011; Brzozowska et al., 2014; Cook et al., 2005; Herbut et al., 2015). Indisputable differences can be observed in regard to PA when comparing loose and stanchion housing of animals (Rushen et al., 2008). Also in the loose housing system, depending on the milking system, significant changes in the circadian rhythm of cows' PA are found. In the automatic milking systems (AMS), the behaviour of diary cows as compared with milking in milking parlours can depend more on geographical factors, especially seasons of the year, the meridian and the latitude at which the barn is located, and on the hours of sunrise and sunset (Angrecka and Herbut, 2016). This is of paramount importance because, in the case of AMS, the time of milking is not imposed on the animal by the breeder/milker (Wagner-Storch and Palmer, 2003; Adamczyk et al., 2011a; Jacobs and Siegford, 2012).

The currently applied assessment of PA is characterized by high objectivity, which primarily arises from the wide-scale introduction into the breeding practice of automated methods of measuring of this feature with activity meters and pedometers (McGowan et al., 2007; Brehme et al., 2008). The rapid technological progress gives hope that in the future the most significant forms of cows' PA will be measured even more precisely and the analysis thereof will be made in real time in production conditions. This is evidenced, for instance, by the promising results of research into cows' PA concerning x- y- z-positioning with the use of accelerometers (Helmreich et al., 2011).

Furthermore, the application of advanced methods of multi-dimensional analysis of data on the basis of the PA analysis also

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serves the aim of greater objectivity in the assessment of cows' welfare. With their use, one can assess the information obtained with an increased precision taking into account both animal groups and individual animals (Liao et al., 2012; Pinter-Wollman et al., 2014).

The techniques include cluster analysis (CA) methods which are applied effectively to classify data and describe phenomena from various fields of life. Among other algorithms, the following methods of cluster analysis can be distinguished: agglomerative and divisive hierarchical clustering, density-based clustering, methods optimizing initial partition of objects, and neural networks. In this paper, two of the above-mentioned methods were applied, namely the Ward's method and Kohonen's networks (Kaufman and Rousseeuw, 2005).

The Ward's analysis is a hierarchical agglomeration method and is considered to be one of the most effective methods of this type. The effectiveness is conditional on the fulfilment by the analysed data set of a number of conditions such as separability of the data, a fairly low number of units, or a lack of non-typical values (Milligan and Cooper, 1987). In terms of the approach to assessing the distance between clusters, it shows features of the variance analysis and consists in minimising the sum of squares of any clusters that can be formed at individual phases of agglomerating. As a result, the class of clusters is selected within which the observations have the smallest variability (Murtagh and Legendre, 2011). Therefore, in this case the initial assumption is to adopt a number of classes equalling the number of features forming the analysed set and then to reduce their number by combining the most similar features.

A completely different approach represents methods based on neural networks in which the initial number of classes is not known at first and which is verified only in the self-organising process. Such methods include the Kohonen's self-organising map (SOM), which was applied in this work as an alternative method. The SOM's specific feature is that its learning algorithm utilises the properties of the created topology map for grouping observations. The process consists in the appropriate selection of weights of the topology map, thanks to which they recognise specific types of models characteristic for clusters of the set of data being explored (Kohonen, 2013). The SOM requires one to assume *a priori* a number of neurons in a typology map, which often results in a greater number of nodes on the output map than the number of the identified target groups. However, when defining an optimum structure of a topology map, one usually aims to maintain the lack of empty classes. In the case of determining the distance between clusters, such a situation provides one with the assurance that a distance exists between the identified sets that is required to recognise them as being separate (Kiang, 2001; Mostafa, 2010).

As regards the research into cattle welfare and behaviour, CA methods have been used in relatively few research projects until recently. It concerned mainly the analyses of feeding behaviour of beef and dairy cows kept in different housing systems (Mülleder et al., 2003; Mac et al., 2007; Wesley et al., 2012; Dutta et al., 2015). Furthermore, (Kielland et al., 2010) applied CA with fairly good results to research associations between measures of dairy cows' welfare at a farm level and farmer's attitudes and empathy toward animals.

The presented study aimed to analyse the daily physical activity of Holstein-Friesian cows milked in the Voluntary Milking System by means of Ward's method and Kohonen's networks with regard to varying environmental conditions.

2. Material and methods

2.1. The animals and the conditions in which they were kept

In this experiment, the data concerning ten Holstein-Friesian lactating cows were used (Table 1). The criterion for the selection of the cows was the lactating phase with the preference of the animals of the smallest number of current lactation so that the onset of their dry period could be excluded over the entire period of their observation. The experimental animals stayed in the same technological group and constituted 20% of the entire group.

The cows were kept in the freestall barn of external dimensions ca. 13.0 × 55.0 m, maximal height 9.0 m, located on a north-south direction of the longitudinal axis (Fig. 1). The barn area with 74 cubicles and manure alleys was 535 m^2 – stocking density was 7.4 m^2 per cow and airspace 44.6 m^3 per cow. The area of the milking parlour and auxiliary rooms was ca. 70 m^2. All the cubicles were bedded with cut straw (4–5 kg of straw per cow daily). Manure and feeding alley floors were made of grooved concrete.

The barn ventilation was provided by a ridge vent as air exhaust and air supply was in the form of a longitudinal curtain wall. The barn's longitudinal wall (from the east) was completely open during the research period. In the summer there was no additional ventilation system such as a ventilator or air mixer.

The cows were fed with the Total Mix Ration (TMR) system. Milking took place with the use of the one unit of the DeLaval's Voluntary Milking System (VMS). During research, the cows remained under zootechnical and veterinary supervision.

2.2. Data

Three months of the year 2015 were selected (June, September, December) which in the geographical latitude of the research location (49°51′20.5″N, 20°34′1″E) usually show clear differences in the climate resulting from the changing of the seasons. Every month the average physical activity (PA) over three days for every cow was taken into account, representing its consecutive 10-days periods. Information was obtained in this way about the following data:

a. the daily physical activity of the cow. PA of the cows was measured automatically every hour using neck mounted tags of the DeLaval DelPro™ System activity meters (the cows' physical activity was expressed in the measurement units of the Voluntary Milking System – VMSU). Moreover, the System converted the cow's neck movement signals to walking/non-walking activity that was the subject of our analysis;
b. lactation phases (the first phase: the period from calving to peak of daily milk yield, the second phase: the period from the peak of daily milk yield to the end of the lactation);
c. daylight duration (sunrise and sunset times);
d. temperature of the air (T);
e. relative air humidity (RH).

Table 1
Basic characteristics of cows in individual data collecting months.

Items	Mean ± standard deviation	Minimum	Maximum
June			
Age of cows (months)	40.3 ± 14.6	24	71
Milk yield per day (kg)	30.6 ± 6.0	18.5	43.2
September			
Age of cows (months)	43.2 ± 14.7	27	74
Milk yield per day (kg)	23.7 ± 5.2	3.2	29.9
December			
Age of cows (months)	46.3 ± 14.7	30	77
Milk yield per day (kg)	22.2 ± 8.5	10.9	46.8

The data obtained in each month concerned the same ten cows. Lactation phases: 1 – the period from calving to peak of daily milk yield, 2 – the period from the peak of daily milk yield to the end of the lactation. The range of the cows' lactation number was 1–4 in each month. The percentage of the cows in the first lactation phase was 20% (June and September) and 10% (December).