The effectiveness of an automated heat detection system in Brown Swiss heifers when using sexed semen at a large dairy unit

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Abstract

The identification of cows and heifers in heat and their timely artificial insemination (AI) is an important issue for large dairy units. The objective of the research was to study the efficiency of insemination of oestrous Brown Swiss heifers using am automated heat detection system (AHD) compared to heat detection by visual observation (VO). The AHD system application increased the fertility of heifers by 8.9% when using conventional semen (unsexed) and by 14.4% using sexed semen. The number of services per conception when using sexed semen decreased from 3.7±1.08 with VO to 2.4±0.68 with AHD. Two-factor analysis of variance showed that an 89% effect of managerial decisions such as the detection of heifers in heat by means of AHD and the use of sexed semen on the efficiency of insemination. This study showed that professional breeders and veterinarians should pay particular attention to AI management when making these managerial decisions in large dairy units.

Key words: *heifers; heat detection; sexed semen; artificial insemination*

Introduction

The use of sexed sperm is one of the most state-of-the-art and innovative mechanisms to ensure the required fertility of animals, allowing breeders to fully use productivity potential (Holden and Butler, 2018; Skliarov et al., 2022). The advantage of using sexed semen is to ensure a guaranteed yield of heifers (up to 90%), which allows for expanding herd reproduction without any additional

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costs for purchasing replacements (Healy et al., 2013). However, disadvantages include the complexity and high cost of the sperm distribution process, and the low percentage of fertilization for its use (De Jarnette et al., 2009). Therefore, the use of sexed semen should be considered an effective tool that can bring significant economic benefits only when used properly (Boro et al., 2016).

Despite the fact that artificial insemination (AI) is currently the most effective way to massively improve cattle herds (De Jarnette et al., 2009), timely detection of cows and heifers in heat and their effective insemination is one of the main problems associated with the use of AI in large dairy complexes (Skliarov et al., 2020; Wang et al., 2020; Pishchan et al., 2021).

To improve cattle reproduction, various methods are applied to, ranging from simple natural methods (using the presence of a male), to rigorous methods such as hormonal synchronisation of ovulation (followed by insemination at a certain time), and others.

The most promising of those methods are systems that use motor activity sensors (detectors, meters) (Reith and Hoy, 2018). They are relatively inexpensive, enable simplified herd management, and offer a number of other benefits that reduce the cost of livestock reproduction, and improve the health and life expectancy of cows (Saint-Dizier and Chastant-Maillard, 2012; Shahriar et al., 2015).

However, despite some successes in the use of transducers and a fair amount of experience in their use, the precise diagnosis of the optimum time for insemination of female cattle is still a subject of technical and scientific debate.

The information available in the literature on the efficiency of such devices is quite contradictory. Detectors show a large range in sensitivity, specificity and positive prognostic values (Rutten et al., 2014; Roelofs and Van Erp-van der Kooij, 2015). In addition, there are contradictions in the interpretation of the optimal time of insemination. For example, according to the manufacturer's instructions for transponders, cows must be inseminated after the maximum increase in activity indices; however, previous studies have shown that fertility number was highest if insemination was carried out 6-17 hours after the peak of motor activity (Maatje et al., 1997; Nebel et al., 2000; Saumande, 2002).

The aim of this study was to evaluate the effectiveness of an automatic heat detection system in Brown Swiss heifers when using artificial insemination with sexed semen.

Material and methods

Experimental Design

The research was carried out at a large commercial dairy unit (1300 dairy cows) breeding brown Swiss cows near the city of Dnipro (48°34′03.1″ N, 34°54′47.0″ E) in central Ukraine. The study was carried out within the framework of the project "Ensuring Sustainable Development of Animal Husbandry and Natural Resistance to Environmental and Technological Factors" (state registration number 0120U103848). This experiment was conducted in accordance with the animal welfare requirements and approved by the Bioethics Committee.

The study was carried out over eight months, from October 2018 to May 2019. Brown Swiss heifers of breeding age were kept untethered in naturally ventilated barns (NVB) without cubicles on straw bedding. The animals were fed with a nutrient mixture based on corn silage, with balanced nutritional content according to the recommendations of the National Research Council (NRC, 2001). The NVB premises had feeding alleys and freely accessible group drinking bowls.

The heifers, whose oestrus was detected by pedometers attached to the hind limbs (AfiTag, Afimilk Ltd, Kibbutz Afikin, Israel), and heifers without pedometers, whose oestrus was detected visually, were kept together. The animals on which the pedometers were attached were chosen at random. The choice of semen (sexed or unsexed) used for AI of heifers was decided on an individual basis, in accordance with the breeding programme for herd improvement at the dairy complex. For animals with more valuable genetics, sexed semen was used.

After inseminating heifers and confirming pregnancy, all data obtained were processed by analysis of variance to determine the effectiveness of the different methods of identifying heifers in heat, and to assess the influence of individual factors on heifer insemination performance, which allows for factorial ANOVA.

Detection of Oestrous Heifers, AI and Diagnosis of Pregnancy

Visual detection of heifers in heat was performed daily at intervals of 2 hours from 8:00 to 17:00 every day. When heat was detected, the animals were inseminated immediately. AI of heifers was performed by the cervical method with uterine fixation through the rectum. Disposable catheters were used for this purpose (Minitüb GmbH, Tiefenbach, Germany). Cryogenic containers from a Dewar vessel (MVE XC 20 Signature Bio, MVE Biological Solutions, USA) were unfrozen in a Minitub water bath (Minitüb GmbH, Tiefenbach, Germany) at 37°C for 30 seconds. Upon determining sperm motility, it was used for insemination. Sperm was supplied by Semex Alliance Ukraine.

The manufacturer of the automated heat detection system (AHD), known as AfiAct II, which includes AfiTag pedometers (Fig. 1), is Afimilk Ltd company (Kibbutz Afikin, Israel). The data from pedometers was first online transferred to the recorder (router), and then uploaded to the AfiFarm computer system with the data on the motor activity of each animal represented in the form of graphs (Fig. 2).

When heifers in heat were detected with the AHD, they were inseminated once, because the program analyses behavioural patterns to indicate the perfect time for insemination.

To determine the rates of conception and embryo loss, all heifers were scanned b of linear ultrasound using a 7.5 MHz transrectal transducer (Kaixin KX5200; Xuzhou Kaixin Electronic Instrument Co., Ltd, Jiangsu, China) at 31–37 and 56–58 days after AI.

Treatments

The heifers that did not show natural cyclicity by the age of up to 15-16 months and had a live weight > 350 kg or were infertile after a previous AI were subjected to hormonal stimulation (Ovsynch protocol, double PGF2α with an interval of 14 days and one with GnRH antagonist). Synchronisation protocols were initiated for those animals at a random stage of the oestrous cycle. Intramuscular injection of $PGF_{2\alpha}$ contained 25 mg of dinoprost (trometamol) (Enzaprost; Ceva Sante Animale, Libourne, France). The second PGF2α injection was performed 14 days after the first. Intramuscular injection of a GnRH antagonist contained 100 μg of gonadorelin (Ovarelin; Ceva Sante Animale, Libourne, France). The gonadorelin injection was administered 56 hours after the last $PGF_{2\alpha}$ injection. All heifers receiv-

A  B

Figure 1. Motor activity recording to detect heifers in heat. The photo shows the Afimilk recorder (A), which receives data from AfiTag pedometers attached to one of the hind limbs of heifers (B).

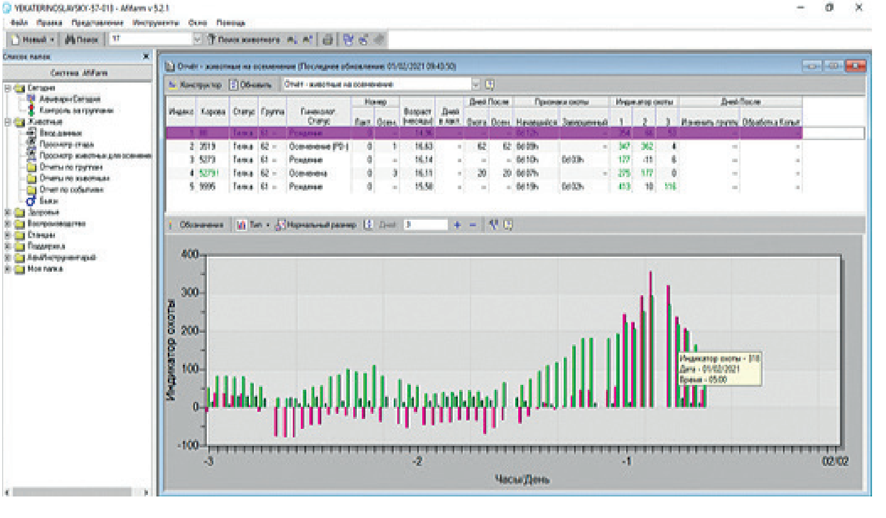

Figure 2. Visualisation of motor activity for each animal in graphical form created by the AfiFarm computer system. This graph shows the peak of the heifer's motor activity with the time of optimal insemination.

ing the Ovsynch protocol were artificially inseminated 16 hours after the GnRH injection. In this study, animals receiving hormonal stimulation were excluded from the experiment.

Statistical Analysis

The obtained digital data were presented as mean values (Mean) and the standard error of the mean (SE). The difference between the samples, determined by Student's t-test with Bonferroni correction, was considered significant at P <0.05. Systematisation of the output data prior to the analysis of variance was carried out according to the principle described in our previous study (Mylostyvyi et al., 2021a). The influence (percentage) of the factor associated with the method of determining heifers in heat (AHD / visual observation) and semen type (conventional and sexed) was measured by biometric analysis (Kovalenko et al., 2010) based on the results of Factorial ANOVA using the Statistica 12 software (StatSoft, Inc., Tulsa, OK, USA).

Results

Of the total number of oestrous Brown Swiss heifers identified using pedometers, 416 heifers were artificial-

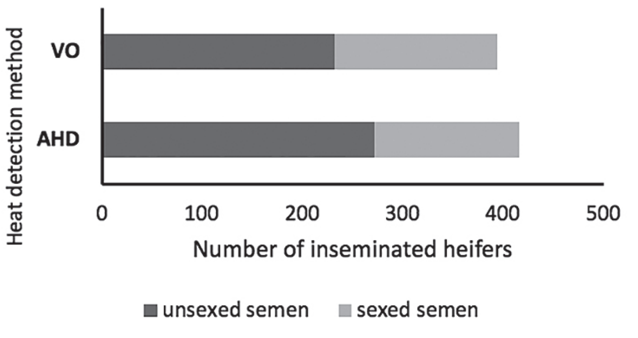

Figure 3. Number of heifers in heat identified by different methods, which were inseminated with unsexed and sexed semen. VO is heat detection in heifers by visual observation; AHD is heat detection in heifers with an automated heat detection system.

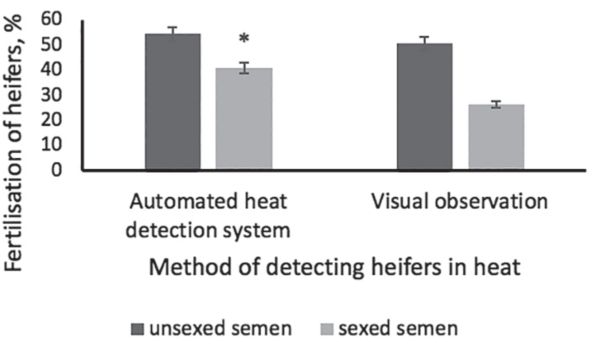

Figure 4. Heifer fertilisation efficiency using different methods of heat detection

ly inseminated (Figure 3). Among them, 272 females (65.4%) were inseminated with conventional semen and 144 heifers (34.6%) with sexed semen. Visual observation identified 394 heifers in heat, of which 232 females (58.9%) were inseminated with unsexed semen and 162 heifers (41.1%) with sexed semen.

After ultrasound diagnosis of pregnancy, it was found that when heifers in heat were detected using the automated heat detection system (AHD), 207 females (49.8%) became pregnant, while after detection of heifers in heat by visual observation (VO), 161 heifers were fertilized (40.9%). The use of pedometers increased the detection of fertility of heifers by 8.9% compared with the detection of oestrus using VO method. Equally important, the fertilisation efficiency with sexed sperm increased by 14.4% when using AHD (Fig. 4).

The number of services per conception (SPC) for the detection of heat using AHD was on average lower (2.0±0.24) than that of females in heat detected by VO (2.4±0.91). In addition, SPC differed significantly depending on whether the semen was unsexed or sexed (Fig. 5). The lowest SPC (3.7±1.08) was in the case of insemination with sexed semen when detecting heifers in heat using VO. With the use of AHD, this indicator for the use of sexed semen was significantly reduced (2.4±0.68). When inseminating heifers with non-sexed semen, the SPC was almost the same for AHD and VO (1.8±0.37 and 2.0±0.57, respectively). Sexed semen yielded 86.9% heifers, compared with 48.3% for conventional semen.

The factorial ANOVA (Table 1) showed that the percentage of influence on the fertilisation of heifers by the factor "Method of detection in heat" was 75% ($P<0.0001$). The percentage of influence of the factor "Type of semen" was 13% ($P<0.02$). Accordingly, the percentage of influence of these management decisions on the result of fertilisation of heifers during AI was 89%.

Factor A is the method of detection in heat (AHD/visual observation); factor B is the type of semen (unsexed/sexed).

The obtained data indicate that particular attention should be paid to the implementation of these elements in the management of animal reproduction, as they have a significant and reliable effect

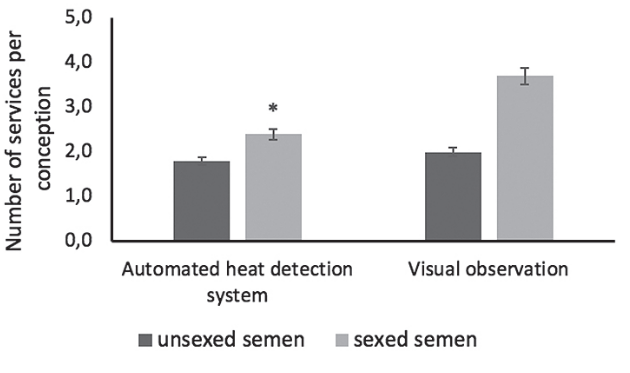

Figure 5. The value of the number of services per conception (SPC) depending on the method of detecting heifers in heat (automated heat detection system / visual observation) and the type of semen (unsexed / sexed).

Table 1. Results of ANOVA to assess the effect of the method of identifying heifers in the heat and semen type on conception

Source	Sum of squares	Mean square	F	Prob > F	*P*-value	Distribution, %
A	3147.78	1573.89	32.34	4.26	0.0001	75.52
B	558.99	279.50	5.74	4.26	0.0247	13.41
A*B	23.52	23.52	0.48	5.12	0.5045	0.56
Error	438.00	48.67				10.51
Total	**4168.29**					**100.00**

on the efficiency of insemination of heifers under AI.

Discussion

Sexed bull semen was a long-awaited tool for dairy farmers to produce more heifers; however, the difficulties involved in integrating its use into commercial dairy farming programmes posed a problem. In particular, high costs and low fertility rate limited the application of this potentially valuable tool (McCullock et al., 2013; Oikawa et al., 2019). Moreover, from the total volume of ejaculate, no more than 15% of sperm with a certain sex chromosome can be isolated. At the same time, a number of adverse factors (colouring, pressure, laser and electromagnetic radiation) affect the sperm cells during isolation process, so a certain percentage of semen remains biologically defective (Klinc and Rath, 2006; de Graaf et al., 2019). However, due to improved fertility and sorting technology (Garner and Seidel, 2008), the widespread commercial use of sexed semen has become possible over the last decade (Hutchison and Bickhart, 2016).

Through experience, it has been found that the use of sexed semen can result in up to 89% of heifers born (49% with the use of conventional cryopreserved semen), though fertility remains only half that of when normal semen is applied (De Jarnette et al., 2009). However, the rate of use of sexed semen on farms and the efficiency of fertilisation of dairy cows in recent years have been growing, reaching about 30% (Hutchison and Bickhart, 2016).

In Ukraine, sexed bull semen has been used in dairy farming since 2005. The high cost of semen-sorting equipment restrains the spread of this biotechnological method in Ukraine. This makes it impossible to obtain sexed bull semen of own production. The use of imported sexed semen has increased dairy productivity by improving dairy cow numbers in a short period of time. Even though less than 50% of cows are inseminated, more heifers are eventually produced than when cows are inseminated with conventional semen. Unfortunately, not all farms in Ukraine have had a positive experience with the use of sexed semen (Goncharenko and Pelykh, 2019).

The choice to use sexed semen on this farm was due to the fact that when cows were selected for a set of traits (reproductive capacity, milk production, duration of economic use), this herd did not have sufficient breeding stock to replenish the herd.

Another problem is the excess of male calves on dairy farms. Their fattening out of pasture is unprofitable. This problem is inherent not only for the domestic livestock industry. For example, the contribution of dairy steers to the U.S. fed beef supply has increased from 6.9% to 16.3% over the last two decades (Jaborek et al., 2023). The production of beef from a dairy herd is not without its challenges (for example, dairy steers have a lower dressing percentage and yield less red meat, and present problems in the beef packing industry).

In addition, Maher et al. (2021) report that the increasing number of male dairy calves could lead to welfare problems in the coming years if these animals are not properly cared for (including their transport over long distances or slaughter on the farm). Therefore, the way out may also be to encourage the wider use of sexed semen, along with improving the meat quality of these calves.

Determining the optimal time for insemination of cows and heifers produces a significant effect on livestock profitability. Classical approaches, such as visual identification, are no longer suitable for use in large dairy herds (Wang et al., 2020). Thus, errors in the diagnosis of oestrus lead to an annual loss of over USD300 million for the US dairy industry (Senger, 1994).

As in our case, while examining the effectiveness of the AHD device in Holstein cows, Marques et al. (2020) found that due to AHD application, high-yielding cows were 6% more likely to be successfully fertilised after the first insemination, while no significant differences were observed between the groups of low-yielding cows. The activity monitoring system also had good results in detecting heat in pasture conditions (Pereira et al., 2020). In our study, the fertilisation of heifers using AHD increased by 9% compared to animals in which heat was detected by visual observation.

In fact, there is a growing interest in fully automated technologies capable of combining activity monitoring data and other methods, which may lead to better results in terms of sensitivity and specificity of heat detection in dairy cows (Dolecheck et al., 2016). Future improvements are likely to require more multivariate detection of oestrous cows based on data and systems already available on farms (Reith and Hoy, 2018).

The research by Oikawa et al. (2019) showed that the average level of fertilisation of heifers after AI was 56.9% with the use of normal semen and 47.3% with sexed semen. Significantly, heifers inseminated with sexed semen were approximately 21 days younger than those inseminated with normal semen.

Although we did not analyse age differences in fertilisation of heifers in this study, it is important that the efficiency of AI of heifers with sexed semen increased by 14% when using AHD, which is of great economic importance given its high cost.

Oikawa et al. (2019) concluded that stable fertilisation with sexed sperm required a more careful implementation of AI, especially in warm months, when the fertilisation rate after AI with sexed semen decreased significantly compared to the use of normal semen. Although this experiment was carried out during the cool season and was performed on heifers, our previous study of brown Swiss cows (Mylostyvyi et al., 2021b) showed that the effect of seasonality on reproductive function can be significant.

Sexed sperm can contribute to effective selection management, faster and more profitable growth of the dairy herd, and an increase in the number of born replacement heifers (Boro et al., 2016; Holden & Butler, 2018). However, the successful use of sexed semen requires excellent management, proper handling of semen, and engagement of qualified professionals (Manzoor et al., 2017; Boneya, 2021; Chernenko et al., 2022).

Conclusions

Thus, the results of this study indicate that the use of AHD increased the conception of heifers, especially when using sexed semen. Considering the significant influence of the method of detection of heifers in heat on their conception, AHD can be a useful reproductive management tool on a large dairy complex. Further research should be aimed at studying the effectiveness of using pedometers in high-yielding cows, when it is difficult to detect their heat using visual observation (without the use of ovulation synchronisation).

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Učinkovitost sustava automatske detekcije tjeranja u junica smeđeg goveda kada se rabi seksirano sjeme na velikoj farmi mliječnih goveda

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Identifikacija krava i junica koje se tjeraju i njihovo pravovremeno umjetno osjemenjivanje (AI) predstavljaju problem za velike mliječne farme. Cilj je ovog istraživanja bio ispitati učinak osjemenjivanja junica smeđeg goveda u estrusu uporabom sustava automatske detekcije tjeranja (AHD) u usporedbi s detekcijom tjeranja vizualnim promatranjem (VO). Primjena AHD sustava povećala je plodnost junica za 8,9 % kod uporabe konvencionalnog (neseksiranog) te za 14,4 % kod uporabe seksiranog sjemena. Broj umjetnog osjemenjivanja po začeću prilikom uporabe seksiranog sjemena spustio se s 3,7±1,08 s VO na 2,4±0,68 uporabom AHD sustava. Analiza dvaju čimbenika odstupanja pokazala je da je učinak upravljačkih odluka poput detekcije junica koje se tjeraju pomoću AHD-a i uporaba seksiranog sjemena na učinkovitost osjemenjivanja bio 89 %. Ova studija pokazala je da bi profesionalni uzgajivači i veterinari posebnu pozornost trebali posvetiti upravljanju umjetnim osjemenjivanjem u provedbi tih upravljačkih odluka na velikim mliječnim farmama.

Ključne riječi: *junice, detekcija tjeranja, seksirano sjeme, umjetno osjemenjivanje*