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Effect of vibration emissions during shipping of artificial insemination doses on boar semen quality

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ABSTRACT

The shipping of semen doses to sow farms can impair boar semen quality. Unfortunately, there is currently no practice-oriented information available regarding general shipping conditions of boar semen. For this reason, a special mobile sensing app (TransportLog 1.0), utilizing the built-in sensors of smartphones, has been programmed to capture vibration emissions during shipping of semen doses (QuickTip Flexitubes®, Minitüb). Data were analyzed, transformed and used as standards for simulating vibration emissions from an orbital shaker IKA MTS 4 (Laborgeräte München) in a spermatological reference laboratory. Twenty ejaculates were collected randomly and diluted using a one-step isothermal process in a split-sample procedure in Beltsville Thawing Solution (BTS, Minitüb). The sperm concentration was adjusted to 24×10^6 sperm/mL. The dose filling volume was 85 ± 1 mL. Samples were stored for seven days at 17 °C. The results showed that circular horizontal vibration emissions with frequencies of 300 rpm for a duration of 6 h led to a significant alkalization of the BTS-extended semen. Semen motility, mitochondrial activity, acrosome and plasma membrane integrity as well as thermo-resistance all demonstrated a frequency-dependent negative response to vibration emissions during long-term storage. This study leads to new insights and recommendations for the shipping of boar semen in the artificial insemination industry. Furthermore, a new monitoring tool for boar semen shipping was established using mobile sensing.

1. Introduction

With the rapid development of artificial insemination (AI) of pigs over the last 20 years, the efficiency of boar semen usage has greatly increased. As a common practice, raw semen is diluted with the aim to extend the longevity of the spermatozoa and increase the usability of boars of high genetic value to more than 50 semen doses per ejaculate (Knox, 2016). Increased requirements for semen quality while simultaneously decreasing the number of spermatozoa per AI dose are driving sperm processing procedures in AI stations towards lab automation (Schulze et al., 2017).

Various exogenous components affect the boar sperm function during and after processing including, for example, the temperature and steps at which semen is diluted (Lopez Rodriguez et al., 2012; Schulze et al., 2013a), the dilution procedure (Schulze et al., 2017) or the storage conditions (Vyt et al., 2007; Schulze et al., 2015). Boar studs have to consider the high susceptibility of boar spermatozoa to chilling injury (De Leeuw et al., 1990; Schmid et al., 2013) and dilution (Centurion et al., 2003) for minimizing harmful effects that might compromise fertility of the processed semen. Currently, extended semen for AI use in pigs is typically stored in volumes of 50 mL with 1.0–1.5 × 10^9 sperm for post cervical AI (Bortolozzo et al., 2015) or 80–100 mL with 1.5 to

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3.0×10^9 sperm for conventional AI (Riesenbeck, 2011) for up to five days at 16–18 °C. Further reduction of sperm numbers per insemination doses together with extended storage periods are planned (Gonzalez-Pena et al., 2016).

To date, not much is known about possible shipping effects caused by vibration emissions. It can be assumed that, in addition to a stricter centralization and professionalizing of boar semen processing in the future, optimizing boar semen shipping is of increasing importance. Consequently, the size of shipping batches is growing and semen doses need to be shipped across increasingly large distances worldwide within ever-shorter timescales. The basic problem of identifying critical factors that could be improved during the shipping of boar semen can be resolved by real-time recording using a mobile sensing app in field trials. Modern smartphones contain several built-in sensors (such as an accelerometer, digital compass, gyroscope, Global Positioning System (GPS), *etc.*). These sensors can be used as measurement instruments enabling new applications across a wide variety of domains, and give rise to a new area of research called mobile sensing (Liu, 2013; Macias et al., 2013).

The aim of the present study was to collect shipping data using a special custom-programmed mobile sensing app (TransportLog 1.0). This allowed for real-time recording of vibration emissions during boar shipping using various types of transportation vehicles on roads at different speeds and on different surfaces. Moreover, it was possible to study the effect of vibration emissions on boar semen quality under standardized laboratory conditions. For this, sensitive methods were used to detect subtle effects on sperm quality. Furthermore, it was possible to identify threshold values for vibration emissions that could interfere with semen quality and to develop new recommendations for boar semen shipping.

2. Material and methods

2.1. Chemicals

All chemicals used in this study were of analytical grade. Unless stated otherwise, they were purchased from Merck (Darmstadt, Germany) and Roth (Karlsruhe, Germany). Propidium iodide (PI) and rhodamine 123 (R123) were obtained from Sigma-Aldrich (Steinheim, Germany), whereas fluorescein-isothiocyanate conjugated peanut agglutinin (FITC-PNA) and *Pisum sativum* agglutinin (FITC-PSA) were purchased from Axxora (Lörrach, Germany).

2.2. Programming of a mobile sensing app (TransportLog 1.0) and mobile application

The app TransportLog 1.0 has been designed by a team of veterinarians and computer scientists to study the impact of transport stress on boar semen quality. TransportLog 1.0 was developed as a native app for the Android platform using the Java programming language and collects sensor data from the accelerator sensor, the GPS sensor and an external temperature sensor (without significance for the current study). The data collected is stored in the local memory of the smartphone. The MeasureService within the app captures the data from the sensors with a default sampling rate of 100 Hz (sampling period of 10 ms). The app uses open source software libraries to periodically collect transport data from physical and software sensors in the phone (accelerometer, location). The data collected through the app is stored on the device's file system in csv format. The following data are recorded: (a) measurements from the triaxial acceleration sensor (x, y, z axis), (b) latitude and longitude readings from GPS, and (c) timestamp. The accelerator assumes a standard three-axis coordinate system to express data values. This coordinate system is defined in relation to the device screen when the device is held in its default orientation. In this orientation, the x axis is horizontal and points to the right, the y axis is vertical and points up, and the z axis points outward from the screen face. In this system, coordinates behind the screen have negative z values.

2.3. Data collection and analysis

Measurements recorded as datasets in csv files are organized into five basic data fields. Field 1 stores the time in epoch seconds, field 2 stores the sensor type describing the type of values stored in fields 3–5, and fields 3–5 store one of the following possible sets of values: (a) field 3 alone stores the temperature values from the external temperature sensor, (b) fields 3–4 store the latitudinal and longitudinal values from the GPS internal sensor and (c) fields 3–5 store the positional coordinates (XYZ) from the internal triaxial acceleration sensor, which are further separated into gravity based acceleration (ACC_HW) and linear acceleration (ACC_SW).

A perl script was applied to convert epoch seconds to standard UTC/GMT time and to filter datasets according to acceleration sensor data types. The sampling rate during all recordings was set to a fixed value of 1 Hz (one sensor sample each second). Furthermore, the script calculated the distance D between each of two consecutive spatial points pn and pm described by their triaxial coordinate sets $\{x_n, y_n, z_n\}$ at time point n and $\{x_m, y_m, z_m\}$ at time point m based on Eq. (1).

$$D = |\overline{p_n p_m}| = \sqrt{(x_n - x_m)^2 - (y_n - y_m)^2 - (z_n - z_m)^2} \tag{1}$$

The parameter D was taken as approximation of the sensor displacement per time unit (or simply sensor movement), such that the shaking or vibration of a sample box containing the mobile sensor device can be quantified as a locational shift over the measured time. Next, all measured values below a time interval of one second were combined into an average data point per second (Ds). The precision of this data point was estimated by calculating the respective confidence interval. For comparison of the overall sensor displacement under different conditions and over a time span of T = 40 s, the index value D_{sT} was calculated (Eq. (2)). The first and last five seconds were omitted to compensate for startup variations. D_{sT} is meant as a normalized value to monitor the changes of D_s