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A mobile and automated walk-over-weighing system for a close and remote monitoring of liveweight in sheep

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ABSTRACT

Monitoring bodyweight (**BW**) is a critical practice used for management purposes (e.g. assessing weight gain, body condition or establishing slaughtering schedules). Measuring BW indoors is relatively easy although time and labor consuming. However, recording BW outdoors may become difficult. The aim of this project was to trial an automated small ruminant weighing prototype using the remote weighing concept of walk-over-weighing (**WoW**), combined with radio-frequency identification and designed to be light, resistant, transportable and autonomous in energy. The BW is collected as the animal crosses freely over the WoW platform, strategically placed in an obligatory path combined with a small yard containing water and mineral salts as incentives. We studied the system's efficacy in a series of experiments under a range of sheep farming situations (i.e. indoor and outdoor). Time required for achieving individual voluntary passages, the number of daily visits and the proportion of biologically plausible BW records were analysed. The Lin's concordance correlation coefficient (**CCC**) was used to establish the agreement between WoW records and the gold standard BW measurements (static weighing scale). Our results showed the feasibility of recording BW with free and voluntary passage of sheep with controlled sheep flow over the platform while preventing congestion. After 2–3 weeks of adaptation, 100% of animals crossed daily. Sheep misbehaviour (e.g. speed of passage) can result in spurious values and accounted for many of the larger weight discrepancies. Once outliers were removed, the prediction accuracy of the system and the CCC ranged between 0.89 and 0.98, showing a substantial agreement between the two methods. Using this standalone WoW system, it was possible to record daily individual BW, which may contribute to save labor and time while providing timely information to improve productivity and animal welfare under varying farming conditions.

1. Introduction

Bodyweight (**BW**) is typically used for management purposes in several different ways e.g., for monitoring weight gain, body condition, animals' health and nutritional status, responses to feeding programs, or setting slaughtering schedules (Brown et al., 2015; Wishart et al., 2017). As BW is a common parameter which can be useful for farmers' decision making, the frequency of recording and analysing weighing events might change depending on the farmer's management objectives.

The BW of one animal is traditionally measured using conventional static weighing systems, which require animals to be individually walked onto a set of scales and a measurement recorded when the system comes to equilibrium. This process is time consuming, labour intensive, and places stress on both the animals being weighed and the operator carrying out the process (Alawneh et al., 2011; González et al, 2014). Recording individual BW outdoor may become a difficult task due to factors such as adverse weather conditions, topography or animals being scattered over a large area. As an alternative to static weighing, automatic technologies may provide a more sensitive, objective and less labour-intensive method for tracking BW change, thus allowing easier identification of animals at risk of disease or with reduced reproductive performance or improved management at the herd level (Dickinson et al., 2013). Automated weighing systems provide more information and what could be lost in the accuracy of the

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equipment may be regained in the number of records available for the analysis (Brown et al., 2012).

Providing several advantages over static methods such as higher frequency of BW measurements without stress, the walk-over-weighing (**WoW**) systems require animals to pass through a specially designed crate, which allows body mass to be estimated using continuous averaging techniques (Long et al., 1991; Ren et al., 1992; Peiper et al., 1993). However, results from existing reports evaluating WoW in ruminants are scarce and inconsistent. Alawneh et al. (2011) reported good agreement results between WoW and static BW measurements when analysing 79,697 WoW records from 463 pasture-fed dairy cows. Dickinson et al. (2013), despite obtaining high agreements in a very short assay (1 h) with 46 dairy cows, reported low repeatability of WoW when compared to static weighing. To our knowledge, the only works available in the literature with small ruminants, and particularly on sheep, have been those carried out by Brown et al. (2012, 2014a, 2014b). In their mob-based experiment, positive results and conclusions were reported after filtering raw datasets for monitoring BW in sheep flocks without radio-frequency electronic identification (RFID). However, the results were less encouraging when evaluating WoW technologies for individual BW monitoring. All authors agree on the high importance of carrying out relevant filtering methods on raw data obtained with WoW in order to remove spurious BW records (e.g. resulting from animal behaviour issues) and to achieve the required accuracy and repeatability of data for reliable interpretation.

To contribute to such efforts and get new insights in the use of promising WoW technologies in small ruminants, the aim of this project was to trial the feasibility of using an automated weighing prototype suitable for a range of contrasting sheep farming systems (e.g. indoor and grazing outdoor in spring or winter). We hypothesize that the strategic conception and design of the WoW system would allow the collection of (accurate) liveweight data to be collected on individual sheep on a daily basis. The accurate WoW data would be comparable to the static or gold standard weighing to within a defined level of tolerance. Thus, the present study involved i) designing a new WoW prototype platform, ii) designing a device to control the flow of animals through the WoW system to increase the accuracy of WoW data, and iii) training the ewes to traverse the WoW unit in a single direction and file to access attractants in a small yard.

2. Materials and methods

The project was approved in the scope of a research grant of INRA PHASE Division (*Physiologie Animale et Systèmes d'Elevage*) and a collaboration developed in the framework of an INRA-CSIRO (Australia) linkage program. The investigation was carried out at INRA Experimental Farm *La Fage*, Causse du Larzac (43°54′54.52″N; 3°05′38.11″E; ~800 m altitude), Roquefort-sur-Soulzon, Aveyron, France. Use of animals and procedures were approved by the Regional Ethics Committee *Science et santé animales* (AFAPIS#4597; file reference 2016031819254696), Toulouse, France.

2.1. Design and conception of the prototype

The prototype was conceived and designed with the objective of developing an experimental tool for carrying out projects on feed efficiency and adaptive capacities of ruminants. A fine and continuous monitoring of individual BW is often required in these projects e.g. validating a non-invasive method for estimating individual forage intake in sheep (González-García et al., 2017). The original prototype (Fig. 1) was constructed by *Marechale Pessage* (Chauny, France) with a design taking into account key elements like energy autonomy (i.e. equipped with solar panel and a 12 V power vehicle battery), being light for easy transportation and mobility and with corrosion resistant materials (e.g. aluminium frame). The main components of this automatic WoW device consisted of a set of two electronic load bars which contain weight sensing load cells and a weigh scale (model MP600; Tru-Test Ltd., Auckland, New Zealand), an indicator with data logging capabilities (model XR3000 indicator; Tru-Test Ltd., Auckland, New Zealand), an RFID antenna (Allflex) and an electronic identification tag panel reader (XRP2; Tru-Test Ltd., Auckland, New Zealand). The load bars are placed beneath the platform and connect the indicator via cables. As it is mandatory in France, all the ewes were equipped with RFID ISO 11784/11785 transponders allowing permanent individual identification. The weight measured by the load cells and the RFID read by the reader panels are both sent to the indicator which calculates the weight of each animal and logs this together with the RFID, date and time. The antenna was placed in the left side of the WoW unit and connected via a serial connection cable (9 pin universal RS232 connector cable) to the indicator storage. The XR3000 indicator have internal rechargeable batteries that provide a running time of up to 14 h when fully charged and was installed with patented algorithms that calculate weight of a shifting object (Tru-Test Ltd., Auckland, New Zealand). The WoW aluminium platform weight is 97 kg and the dimensions are: length 2.5 m, width 0.45 m and height 0.90 m (Fig. 1).

The WoW system was completed with a customized metallic structure with *S* shape (Fig. 2) which was placed at the entrance of the WoW platform. This structure was designed to control the flow and to force ewes to cross the platform with sufficient succession distance to prevent congestion. The height of the *S* structure can be adjusted to suit the frame size of sheep. In the present study the intermediate position (0.45 m) was used to cater for the medium-framed sheep. The overall result is a light, mobile and autonomous experimental unit that can be used in a wide range of farming situations including harsh outdoor conditions (Fig. 3).

2.2. Experimental design

The project started in November 2015 and the last trial was carried out at the end of 2017. The study has been structured in four consecutive and complementary stages (Table 1) consisting of 4 trials i.e. (i) a trial without animals, for evaluating the sensitivity of the WoW unit to different speeds of passage and progressive variations of small amounts of weights (Trial 1); (ii) a first trial with animals for calibration of the experimental device under controlled (indoor) conditions (Trial 2); (iii) a trial to validate the device under intensive grazing conditions (Trial 3); and (iv) a trial to validate the device under extensive (rangeland) conditions (Trial 4). A simplified diagram showing the sequence of project activities is presented in Table 1.

2.3. Trial 1: The sensitivity test (without animals)

Once the construction of the WoW prototype was finished it was transported to the *La Fage* Experimental Unit to conduct the project. The trial without animals was thus carried out. The objective was to verify the repeatability and accuracy of the device. The effects of different speeds of passage through the WoW on the repeatability and accuracy of the registered individual weight were evaluated. In addition, we checked the effects of adding different previously defined small quantities of weights on the accuracy of the WoW unit. A $2 \times 3 \times 8$ factorial experimental design was used comprising the combination of two operators from our research team (i.e. a man and a woman) with contrasting BW (77.11 vs. 57.22 kg). They mimicked the passage of sheep through the WoW unit at three contrasting speeds (checked with a chronometer) i.e. crossing "on all fours" at fast speed (0.85 m/s), intermediate speed (0.30 m/s) or slow speed (0.15 m/s). Each speed was combined with eight progressively additional weights (i.e. control -0-, 100, 200, 300, 400, 500, 800 and 1000 g). Each combination was replicated five times. Thus, a total of 120 passages per subject were performed.