Growth and behaviour of post-weaned *Mérinos d'Arles* ewe lambs, as measured by a Walk-over-Weighing system under Mediterranean grazing conditions

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Abstract

Liveweight (**LW**) is a key and conventional indicator for monitoring and assessing overall animal performance and welfare, representing the progress along different physiological stages, while providing close indication of individual physical and health status. Measuring LW in practice is still, however, quite rare and infrequent under commercial sheep farming conditions, mainly because sessions are time-consuming, stressful either for the operator and the animals. A Walk-over-Weighing (**WoW**) system, already evaluated with other breeds under different conditions, was tested in this experiment lasting 14 weeks (i.e. 3 for acclimation and adaptation and 11 for data collection). We validated its use for routine and frequent monitoring the growth rate in post-weaned *Merinos d'Arles* ewe lambs, reared under Mediterranean grazing conditions. Similarly to previous work, the necessity for an initial adaptation period of the animals as well as for an essential data cleaning procedure of the raw database automatically collected by the WoW, were corroborated. Adaptation of naive ewe lambs enabled the required voluntary passages across the weigh platform and a high volume of individual and daily data after 2-3 weeks. Close monitoring of individual growth was then possible after performing sound data cleanings. A strong concordance of WoW LW data with the gold standard (a standard static scale) LW reference data was demonstrated. At the individual level, even with the lowest number of LW values collected with WoW, it was possible to monitor variations in LW at daily intervals. The establishment of an early warning system to help farmer decision making could therefore be possible. Our results show interesting perspectives for more precise and frequent monitoring of LW in grazing sheep without human intervention, compared to what is currently carried out on commercial farms.

Keywords: Walk-over-Weighing system, sheep, Merinos, ewe lambs, liveweight, growth monitoring

Implications

We validated the use of Walk-over-Weighing system by the first time under Mediterranean grazing conditions, with post-weaned ewe lambs. The system provides enough quantitative and qualitative data (after performing a sound filtering procedure of the raw database) for effective monitoring of individual daily growth rates of lambs on grassland. Good perspectives emerge for developing early warning systems in the future with new expected progresses in the automatic filtering of raw database and easy of interpretation of the final data and graphs by the farmers and interested end-users.

Introduction

Monitoring liveweight (**LW**) of young animals is needed to guarantee adequate growth rates, maintain good health, respect welfare, and for assuring good performances along their productive lifetime. Controlling LW of ewe lambs during the first months could prevent the deterioration of reproductive performance (Kenyon and al., 2014), which is mainly due to the stress of the weaning period after separation from the dam, and effects of dealing with a new environment and feeding regime (Karakuş, 2014). Nevertheless, frequent monitoring of LW in commercial sheep farms is rare because it is time-consuming and stressful for both animals and farmers due to the manipulation and restraint of the animals. Furthermore, the picture is poorer when the flock is reared on pasture, because its includes, for example, transportation of animals to the barn/handling area where the weighing platform is located or, *vice versa*, creating weighing and handling facilities within the paddock. Solutions using Walk-over-Weighing (**WoW**) systems, have been previously tested on adult ewes to measure LW without human intervention (Brown et al., 2012; González-García et al., 2018a, 2018b, 2021; Morris et al., 2012; Polat et al., 2013). The WoW has been demonstrated to be less stressful compared with human handling and capable of collecting a much higher volume, and with a higher frequency, of LW records per unit of time compared to the standard static weighing system (Brown et al., 2014a; González-García et al. , 2018a, 2018b, 2021). Even if this system seems highly promising, there are still only few reports on the use of this technology in small ruminants (and here only for sheep) and most of them have tested the WoW only with adult females, sometimes with their lambs (Brown et al., 2012; González-García et al., 2021, 2018b; Morris et al., 2012; Polat et al., 2013). The objective of the current work is to push forward the state of the art on this matter, by testing the use of the WoW for monitoring the progression of individual LW (growth rate) in recently weaned ewe lambs under grazing conditions. We hypothesised the possibility of collecting a large number of longitudinal LW records with the WoW. After an indispensable raw database cleaning process for filtering spurious LW values, a precise and timely LW monitoring would then be possible, either at the flock or individual levels. The last would enable seeing the growth trajectory with greater precision and greater resolution along the time period of interest

Materials and methods

Experimental location and conditions. Animals and farming system

The study was conducted at the Experimental farm of *Domaine du Merle*, Salon-de-Provence, France (43°38’37”.15” N; 5°00’58.66” E) which belongs to the Institut Agro –Montpellier SupAgro. One hundred recently weaned *Mérinos d’Arles* ewe lambs (106±6 days old; 24.8±3.44 kg of LW), born in early October (i.e., October 4th ±6 days) and weaned on January 13th, were chosen for the study, at five days after weaning (i.e., LW > 18 kg; Table 2). The ewe lambs were chosen according to their LW and then further classed into three subgroups: **Light** (LW average: 21.2±1.4 kg; n= 33), **Medium** (average LW: 24.4±0.8 kg; n= 33) and **Heavy** (LW over the average: 28.8±2.0 kg; n= 34). During the experiment one lamb died (belonging to heavy subgroup). The experiment started two weeks after weaning (i.e., on January 25th) and lasted for 14 weeks (i.e., until April 30th).

Animals were reared under Mediterranean pastureland conditions, grazing a mixed sward composed mainly by ryegrass and other native herbaceous grasses and legumes. A rotational grazing system was established with paddocks (each averaging 0.29±0.08 ha) that were grazed on average for 4.7±1.4 days each. Water, molasses, minerals and salt blocks were only provided in an attraction area (around 150 m^2 of average surface; Figure 1). In a similar manner as previously reported by our team (González-García et al., 2018), the access to the attractant area was possible only by a one-way passage through the WoW, with the exit placed on the other side with a non-return gate. When an animal passed through the platform, the RFID of the animal was read by the antenna placed on the left side of the system, registered to a XRP2 reader (TRU-TEST^{TM}, Auckland, New Zealand; released by Marechale Pessage, Chauny, France). This reader was linked by Bluetooth® to the weigh scale indicator WoW2 (TRU-TEST^{TM}, Auckland, New Zealand) which records the average LW of each animal at each passage and together with their RFID identity and date and the time of passage.

Experimental sequence: trials, design and measurements

The Figure 2 illustrates the experimental design. The study was divided in two complementary periods i.e., 1) the adaptation phase, lasting three weeks (until February 14th), corresponding to the theoretical time required (based in our previous experience) for the ewe lambs getting well adapted to the system then involving some interventions by the operator, and 2) the data collection phase, without any intervention aiming to facilitate the voluntary individual passages through the WoW.

Phase I: Adaptation

The Adaptation phase lasted three weeks (Figure 2) and aimed to prepare the animals and the whole setting of the experimentation in order to achieve the main purpose: getting the animals well-adapted enough to the voluntary and daily passage through the WoW without human intervention. At the start of the experiment, the lambs were trained with forced passages three to five days a week with one to four passages per day for the three first weeks of the experiment. During the first 15 days, the training was also accelerated by the presence of five adult ewes which were previously adapted to the WoW in other experiment. During this phase, the progressive voluntary daily number of passages through the WoW (**N°Pass**) was recorded, as was the progression of the number of biologically plausible LW records (**PlausLW**) which were assessed thanks to comparison with individual LW reference values (i.e., Gold Standard **-GS-** LW measured with the static animal position and recorded once a week, every Tuesday at 9:00 am). These GS measurements were performed manually in the field using the same WoW platform but with a weight scale indicator XR-5000 (TRU-TEST^{TM}, Auckland, New Zealand). During this first phase, a total of 5411 WoW records were transferred every 1 to 3 days at the same time (9:00 am GTM+1) through a smartphone linked to the WoW2 with Bluetooth®.

Phase II: Fully automated data collection

The second phase lasted 10 weeks (Figure 2) and aimed to evaluate i) the possibility of using the WoW system for growing animals from this *Mérinos d'Arles* breed under grazing condition and ii) the feasibility of automatically measuring their LW with full confidence and precision, and the resultant calculations of individual growth rates (Average Daily Gains - **ADG**, g/d). The progression in the N°Pass and PlausLW variables were also recorded. The GS measurements continued to be performed every Tuesday at 9:00 am and the data transfer was performed almost every day at the same hour (9:00 am) when no lamb was on the platform. During this second phase, a total of 25172 WoW records were collected.

Calculation and statistical analyses

Database development and outlier detection

Daily downloaded raw WoW-records were registered in CSV file format on a laptop (see Table 1 for specifications of the data sets). Data from the GS measurements were available in another CSV file. Using the GS, individual lamb ADG between each two weekly measurements was calculated. Thanks to the calculated ADG, each daily LW was estimated for each ewe lamb. Before further analyses, different data filtering procedures were carried out with the R software (R Core Team, 2021) using the *dplyr* package to manipulate data. Firstly, records were removed if they did not capture the RFID identity of the individual, or if the registered LW was equal to zero. Then, a three-step data filtering approach was followed to detect and remove lamb misbehaviours and outliers, respectively. The first filtering step was performed at the group level. Records falling outside the LW range (i.e., minimum, and maximum) of the group (i.e., classified as misbehaviours) were removed by detecting extremely low and high values as well as data higher than twice the LW mean of the group (e.g. meaning that more than one lamb was at the same time on the platform). The second filtering step was made at the LW subgroup level. All the data outside the interval [group weekly minimum of LW –2.5 kg; group weekly maximum of LW +2.5 kg] aimed to take into account LW fluctuations during the day due to the content in the digestive and urine tracts (INRA, 1989), but exclude weight data beyond this range. Finally, a third filtering step was carried out at the individual level. The daily estimated LW of each individual, used as a reference value, was first calculated after calculating ADG thanks to the available weekly LW records obtained with the GS measurements. Then, all values falling out of the individually accepted range (i.e., daily estimated LW based on GS ±2×SD) were removed from the database. At the end of the three-step data filtering approach, the result was a cleaned database able to be further processed and interpreted.

For each step of the filtering process, the concordance of the records obtained with the WoW and the GS data was evaluated using the concordance methodology proposed by Bland and Altman (Bland and Altman, 1999). The bias coefficient of concordance evaluates the repeatability of the system. The Lin's concordance correlation coefficient (**CCC**) was also calculated to evaluate the extent of agreement between the WoW and the GS method (Lin, 1989). The CCC combines the measurements of accuracy and precision to define how far the WoW-data deviate from perfect concordance (i.e., CCC = 1.0). It evaluates the reproducibility of the system. It also provides the correction bias factor to estimate how far the method is from the perfect correlation. These analyses were assessed using the *BlandAltmanLeh* and *CCC* packages, and the linear models function on R software, with the use of *ggplot* package, for plotting graphics.

LW data procedure and analysis

A complex mixed model was followed based on the interacting effects of the LW measurement system (n= 2; WoW vs. GS), the time (measurement week) and the LW subgroup (Heavy, Average and Light), and based on the nested effect of the individuals in each LW subgroup. The LW monitoring week, the LW subgroup and their multiple interactions were considered as the fixed effects in the model. Interactions between the LW subgroup and the LW measurement system were taken into account to check if any difference exists in the information provided by the system according to each LW subgroup

The weekly individual ADG was calculated for each animal using its LW records collected in a time-phase (i.e., between two weekly GS sessions for the LW reference data, and between the same days for the WoW with the measured or estimated Tuesday data). Such ADG, calculated for each week, enabled to determine the individual and daily LW either for calculating the individual daily LW progression shape either for the WoW or the GS scale. The ADG obtained by both methods were compared and further calculations were performed to estimate the agreement between ADG assessed by the automated (WoW) and reference static (GS) scales.

To evaluate the intra LW subgroup variability and the use of the WoW at the LW subgroup level, mixed models on LW and ADG are respectively built on the same process than previously explained as for each group separately.

Results

Database filtering outputs

A summary of the number of records obtained in the WoW database before and after the cleaning procedure is shown in Table 3. From the total of 21 days during the adaptation phase, 6 days were excluded due to battery dysfunction issues. A total of 5411 records were initially downloaded and 1429 (i.e., 26.4%) were retained after the removal of LW spurious values (misbehaviours and outliers), which represent an average of 95 records/effective day during the adaptation phase. During the second phase of the experiment (data collection), a total of 25172 records were collected during the 65 effective days (from the total 74 i.e., 9 days lost due to battery issues).

38.7 % of those data were retained after the filtering process, representing in average 150 records/effective day –i.e., 1.5 records/animal/effective day.

Validation of the WoW system

Validation of WoW was made after the adaptation of the animals, on the second phase of the experiment. Table 4 presents the descriptive statistics, the linear regression and CCC reports. The linear regression coefficient of the LW WoW measured values explained by the GS reference estimated values is about 0.92 with a 1.181 kg of error (Figure 3). The CCC (0.94) shows moderate agreement between the two LW measurement methods. On the raw database, the Bland and Altman concordance coefficient is -6.95 ±30.12 kg, which it is considerably improved after the full cleaning process (i.e., -0.83 ±2.32 kg on the final clean database after the three-steps procedure; Figure 4).

Adaptive behaviour

The Figure 5 shows the adaptive behaviour of the lambs according to the daily percentage of animals' voluntary crossing the system. By the end of the adaptation phase, the percentage of ewe lambs crossing the platform increases. This rate is on average higher during the second phase of the experiment compared to the first one (65.4 ± 32.9 % and 90.5 ± 7.4 % respectively for the phase I and II), which demonstrate the positive impact of time and training on the adaptation of the animals. The number of forced passages does not influence this rate.

Growth rate monitoring

Flock level

The LW values collected with each weighing system are presented in Table 5. At the beginning of the data collection phase, the ewe lambs were 127 ±6 days old and weighed 28.5 ±3.9 kg. After 74 days (i.e., at 201 ±6 days), the average LW of the flock measured by the WoW was 34.3 ±3.8 kg. During this phase II of the experiment, the ewe lambs gained 6.1 ±1.9 kg (as measured with the WoW system). The *p*-values of the variables Group, System and their interaction are also presented in Table 5. There is no influence of the interaction Group×System: the effect of LW subgroup on the LW is the same regardless of the weighing system. There is no significant difference of the weighing system on the LW values. Moreover, the weighing System was not significant ($p > 0.05$) when analysing the initial and final LW values and the LW gain during phase II. Table 6 shows an average ADG of 0.08 kg/d with a high variability (0.21) for the whole flock. There are no significant differences between the LW subgroup, the weighing System and their interaction. There is also no significant difference between weeks on the ADG values ($p = 0.72$).

LW subgroup level

LW subgroup growth rates are shown on Figure 6 for each weighing system. Globally, the LW increases during the experiment but with some variations without difference between WoW and GS scales (variation of 3 kg in each subgroup, Table 5; $p > 0.05$). The ADG variation of 227, 196 and 195 g/d within each LW subgroup (respectively Heavy, Medium, and Light) is observed without any inter-individual effect between WoW and GS.

Individual level

Due to the validation of the WoW-data and the absence of significant differences between WoW and the GS reference scale for the flock and subgroup data, the individual growth monitoring with the WoW is considered as possible. Three extreme ewe lambs were chosen as examples of the individual growth monitoring i.e., the individuals identified as number 3537 (with the higher number of correct LW recorded), 3601 (with the smaller number of correct LW recorded) and 3954 (ewe lamb dead during the experiment; Figure 7). The graphs show the LW monitoring with all data measured. For the lambs 3537 and 3954, there is more LW values obtained with the WoW than with the GS. Their growth rates curves show similar shapes whatever the LW measurement system. The graph for the ewe lamb 3954 shows an abrupt LW decrease since March 19th using the WoW, whereas this visual information is recorded only after March 25th with the weekly LW data recorded with the GS scale. The LW progress of the ewe lamb 3537 follows a similar shape as the growth rate of the flock, with its final LW being higher than the average LW of its subgroup. The ewe lamb 3601 remained in a stable LW during the experiment, with similar LW values collected irrespective of the LW scale.

The variations of the ADG per week for the three individuals are illustrated in Figure 8. The first ADG obtained with WoW for the ewe lamb 3601 is in week 8, because no LW value is obtained before the 15 first days of phase II. Its ADG per week do not vary and are low (around 0 g/day). The ADG of the ewe lamb 3537 is around 200 g/day during the experiment. Concerning the ewe lamb 3954, the decrease in LW observed results in a loss of more than 1000 g/d during week 10. For the three individuals, no differences were detected due to the weighing system to estimate the individual ADG during this period. The initial raw database produced in the scope of this work is available in the Data Repository https://doi.org/10.15454/IXSHF7.

Author's point of views

The main objective of this study was to validate the feasibility of setting the WoW system to provide a significant contribution of this Precision Livestock Farming technology to the precise monitoring of growth of ewe lambs reared on pasture. The first phase of the experiment allowed the calibration of the system and the adaptation of the ewe lambs. The importance of the adaptation phase and the data cleaning steps has been previously reported by several authors (Alawneh et al., 2011; Brown et al., 2014a, 2014b; Dickinson et al., 2013; González-García et al., 2018a, 2021). Filtering of outliers has been carried out using individual variations. Alawneh et al. (2011) removed all values outside the mean ± 4×SD interval, which corresponded to only 12% of outliers. The process used in this study was carried out in three stages, the last stage corresponds to the removal of outliers at the individual scale according to the mean interval ±2×SD. In a previous report by our team (González-García et al. 2018a) 80% of the raw data are eliminated with this method at the individual scale. In the current study, fewer (61.3%) of initial raw data were removed. Brown et al. (2012) reported to retain the harvested WoW records within an interval of 10% of the predetermined LW.

Data eliminated in our study correspond to misbehaviour of the lambs on the platform. Despite the "*S*" structure designed for the animals to pass one by one (González-García et al., 2018a), often two animals were climbing together on the platform. For Brown et al. (2014a), these misbehaviours cause low repeatability of the system when they are not removed. In this study, data cleaning decreases the number of records actually available but according to the Bland and Altman coefficient (-0.83 ±2.32), enabled considerably increased repeatability of WoW data (Grenier et al., 2000). The reproducibility, evaluated by Lin's CCC (= 0.94), also increases as the cleaning process progresses. This coefficient shows however only a moderate agreement between the two weighing systems. This could be explained by the lack of controlled flow of animals crossing the platform (Alawneh et al., 2011; González-García et al., 2021). Even with an individual level of data cleaning, some misbehaviour data are still present and seem undetectable. Despite this moderate agreement, the values obtained show a good distribution around the perfect correlation line at 45°.

After the entire three-step data cleaning process, the resulting data corresponds to plausible values of LW that can be used for monitoring ewe lamb growth. They allow the recording of many LW values over a short period of time. The minimum frequency of correct data obtained (1 LW every 9 days) allows regular monitoring of the individual LW and more frequently than typical in conventional, commercial farming, and importantly, without human intervention. The adaptation phase of the animals strongly helped to have such results. One of the main objectives of this study was to adapt the ewe lambs for voluntary and frequent passages on the platform. The ewe lambs from the *Domaine du Merle* were reared on pasture with their mother until weaning, they did not have to adapt to a new environment for the study. Nevertheless, they had to deal with the separation from the dam and the new feeding regime (i.e., from a mixture of maternal milk and grass to a 100% grass diet). Finally, they also had to manage with a new object in their environment (WoW system). The design of the system was the same for all paddocks, only the orientation changed. This regularity in the configuration of the WoW system may help the ewe lambs to learn and adapt rapidly to cross the platform (Hutson, 1980). In order to have more daily passages, more frequently or quicker, the adaptation to the WoW could be carried out during the pre-weaning period (Brown et al., 2014b). The adaptation time defined by González-García et al., (2018a) is still sufficient to obtain an acceptable percentage of ewe lambs crossing the system in a relatively short period of time.

In our study it was then possible to estimate LW of the flock (and according with LW subgroup) by using the WoW. Close individual LW values to those measured with the GS reference static weighing, and without significant difference, were obtained. Using the WoW, it is possible to observe variations over time more precisely due to the quantity of data recorded. At the beginning of phase II, the ewe lambs were in good physical condition i.e., the LW at 127 ±6 days corresponded to a LW slightly higher than those expected at this age for the *Merino d'Arles* breed (Bénévent et al., 1971). The growth rate of the animals, estimated at 123 g/d and 84 g/d respectively by the static GS weighing scale the WoW, is similar to the ADG reported for *Merino d'Arles* lambs between 130 and 160 days (Bénévent et al., 1971). Without a good adaptation of the ewe lambs, the opposite result would have been observed, due to the stressful factor of such a change (Karakuş, 2014). These results show no apparent problem with the growth and health of the flock or the strata of LW subgroups. In contrast, the progress of LW growth curves show LW decreases were observed on March 9th and April 20th. This is likely related to the fact that animals were weighed just before changing the paddock on the same days. Grass availability was very limited and the animals therefore may have had the rumen less filled compared to the other weighing days influencing their LW (Brown et al., 2015). Monitoring the LW growth rates of subgroups (or the whole flock) would then make it possible to improve the feed management of the animals as proposed by Brown et al. (2014b), with a precision nutrition strategy. This monitoring could also help the overall health management of the flock by identifying events with dramatic LW losses in the flock due to e.g. parasitism or limited herbage availability in the grassland due to dry season effects. But detecting a decrease of the average flock LW could also be the result of a problem with a limited number of individuals. The ultimate goal and big challenge using the WoW system is to be able to follow the individual and daily growth rate of the animals. Here, we approached this issue and advanced in the good direction, with the three extreme groups of animals chosen. The more frequent LW records obtained with the WoW for the dead ewe lamb for example, allowed us to identify much earlier than the GS measures, the significant daily LW losses, signalling an evident health problem in the animal at least 6 days before a measurement with the GS was performed. This could allow the production of sound early warning systems helping farmer decision makings in the future, with the possibility for example of sending early signals by phone of the daily individual LW rates deployed by each member of the flock. Fine scale monitoring of individual growth is then considered as possible. However, uncertainty occurs for animals that have only a few correct passages on the platform in a short period of time.

In summary, the importance of both the initial adaptation period of the animals, and essential data cleaning procedures for data automatically collected by the WoW, were confirmed. Adaptation of naive ewe lambs allowed the required voluntary passages across the platform and a high volume of individual and daily data after 2-3 weeks. Close monitoring of individual growth was then possible after performing sound data cleanings. A strong concordance of WoW LW data with the gold standard (static scale) LW reference data was demonstrated. At the individual level, even with the low number of LW values collected for some lambs with WoW, it is possible to monitor variations in LW at a daily periodicity. The establishment of an early warning system to help farmer decision making would therefore be possible. Our results show interesting perspectives for a more precise and frequent monitoring of the LW in grazing sheep without human intervention, compared to what is currently carried out on commercial farms. Good perspectives emerge for developing early warning systems in the future, therefore, further research and development efforts are warranted for achieving future advances on these aspects.

Ethics approval

This study was approved by the Regional Ethics Committee on Animal Experimentation number 115, Languedoc-Roussillon and followed the European

Convention of the Protection of Vertebrate Animals used for Experimental and Scientific Purposes, directive 86-609 of November 24, 1986 of the council of the EU and directive 2010/63/EU. The study complied too with the Do No Significant Harm principle, as the research was conducted within the respect of climate and environmental priorities of the Union, without causing harm to them. The study did not imply any injury or invasive measure compromising the health of the experimental animals. We complied with the “3Rs” (Refinement, Reduction, Replacement) principles: i) the experiment reduced as much as possible the number of involved animals to the minimum necessary; ii) Refined experimental protocols was settled in order to diminish to an absolute minimum the amount of stress imposed on the ewe lambs used. iii) Replacement of lambs by *in vitro* investigations or *in silico* simulations was not possible as the goal of the project was to validate the WoW system in the growth category of this species animal experiments whenever necessary.

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Declaration of interest

The authors declare the full originality of this work and that there is no conflict of interest for the publication of this paper.

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Table 1

Specifications of the data sets.

Subject	*Livestock Farming Systems*
Type of data	Tables, Image, Figures
How data were acquired	Using two different weighing scales i.e. static (Gold Standard) and Walk-over-Weighing (WoW)
Data format	List the data format(s): CSV files. Raw data (link to the repository): https://doi.org/10.15454/IXSHF7
Parameters for data collection	Already described in the Materials and methods section.
Description of data collection	Already described in the Materials and methods section.
Data source location	Institution: INRAE City/Town/Region: Salon-de-Provence Country: France Latitude and longitude (and GPS coordinates, if possible) for collected samples/data: 43°38'37".15" N; 5°00'58.66" E
Data accessibility	Repository name: *Data Inrae* (https://data.inrae.fr/dataverse/root)
Related research article	González-García, E., Alhamada, M., Pradel, J., Douls, S., Parisot, S., Bocquier, F., Menasol, Llach, I., González, L.A. (2018). A mobile and automated walk-over-weighing system for a close and remote monitoring of liveweight in sheep. *Computers and Electronics in Agriculture*, 153, 226–238. DOI: 10.1016/j.compag.2018.08.022.

Table 2

Overall characteristics of the experimental ewe lambs (n= 100), according to their liveweight subgroup.

		At birth		At weaning	
		Litter size	Liveweight, kg	Litter size	Liveweight, kg
Liveweight range (n= 100)	Heavy (n= 34)	1.2±0.4	5.1±0.8	106±6	28.8±2
	Medium (n= 33)	1.7±0.5	4.1±0.7	107±6	24.4±0.8
	Light (n= 33)	1.9±0.3	4.0±0.5	105±6	21.2±1.4
Group (n= 100)		1.6±0.5	4.4±0.8	106±6	24.8±3.5

Table 3

Summary of a three-step raw database filtering process performed during the two experimental phases with *Merinos d'Arles* ewe lambs for removing spurious liveweight records. Databases were successively cleaned from the primary (raw), to the final database, which was used for comparisons with static LW records.

	Number of animals	Days of automatic BW data collection	Effective days of data collection	Raw database		Database 1 (after misbehaviour removal)		Database 2 (after group outlier removal)		Final database (after individual outlier removal), used for analyses					
				Total of records	Average records / effective day	Total of records	Average records / effective day	Total of records	Average records / effective day	Total of clean records	Average records / effective day	Average records / animal / effective day	% Raw database	% Database 1	% Database 2
Adaptation phase	100	21	15	5 411	361	3 565	238	1 482	99	1 429	95	0.95	26.4	40.1	96.4
Fully automatic data collection phase	100 (99 since the 1st of April)	74	65	25 172	387	17 762	273	9 984	154	9 735	150	1.50	38.7	54.8	97.5
Total	100 (99 since the 1st of April)	95	80	30 583	-	21 327	-	11 466	-	11 164	-	-	36.5	52.3	97.4
Average	100 (99 since the 1st of April)	48	40	15 292	374	10 664	256	5 733	127	5 582	123	1.24	32.6	47.5	97.0

**The days with a battery problem avoiding the correct data collection were deleted.*

Table 4

Descriptive analyses and data validation indicators during the database filtering process.

		Descriptive analysis										Linear regression		Concordance correlation coefficient (CCC)	
		GS					WoW								
		n	Mean (kg)	SD	Min (kg)	Max (kg)	n	Mean (kg)	SD	Min (kg)	Max (kg)	R^2	Residual error	Precision (Cb)	Lin's concordance coefficient
Adaptation phase	Raw database	5411	26.0	3.7	18.4	35.2	5411	29.9	19.15	0	79.2	0.025	18.91	0.36	0.06
	Database 1	3565	26.0	3.6	18.4	35.2	3565	34.6	8.7	10.2	49.8	0.051	8.474	0.38	0.09
	Database 2	1482	26.3	3.6	18.4	35.2	1482	27.4	4.0	16.6	37.6	0.808	1.739	0.96	0.86
	Final database	1429	26.3	3.6	18.4	35.2	1429	27.2	3.8	17	37.6	0.885	1.295	0.96	0.91
Fully automatic data collection phase	Raw database	25172	30.5	3.9	20.3	42.4	25172	37.4	15.9	0	80	0.062	15.37	0.40	0.10
	Database 1	17762	29.7	3.7	20.3	42.4	17762	36.3	8.4	10.4	49.8	0.044	8.186	0.49	0.10
	Database 2	9984	30.2	4.0	20.3	42.4	9984	31.1	4.3	18.2	44.6	0.850	1.661	0.98	0.90
	Final database	9735	30.3	4.0	20.4	42.4	9735	31.1	4.2	18.8	44.6	0.921	1.181	0.98	0.94
Total	Raw database	30583	29.7	4.3	18.4	42.4	30583	36.1	16.7	0	80	0.077	16.09	0.42	0.12
	Database 1	21327	29.1	4.0	18.4	42.4	21327	36.0	8.5	10.2	49.8	0.051	8.235	0.50	0.11
	Database 2	11466	29.7	4.2	18.4	42.4	11466	30.6	4.4	16.6	44.6	0.857	1.672	0.98	0.90
	Final database	11164	29.7	4.2	18.4	42.4	11164	30.6	4.4	17	44.6	0.924	1.199	0.98	0.94

Table 5

Initial, average and final liveweight (LW, kg), and LW gain (ΔLW) during the second experimental phase (fully automatic data collection), as measured by the two weighing systems.

	LW range (Group)			Weighing System		Group×System Interaction						*p*-value		
	Heavy	Medium	Light	GS	WoW	GS-Heavy	GS-Medium	GS-Light	WoW-Heavy	WoW-Medium	WoW-Light	Group	System	Group× System
Initial LW	31.6 ± 2.3	27.2 ± 1.4	23.7 ± 1.8	27.0 ± 3.5	28.5 ± 3.9	30.9 ± 1.9	26.8 ± 1.3	23.2 ± 1.5	33.0 ± 2.6	28.0 ± 1 .3	24.7 ± 2.1	<0.0001	0.22	0.120
Average LW	34.5 ± 3.1	30.5 ± 2.7	27.6 ± 3.1	30.4 ± 4.1	31.3 ± 4.1	34.0 ± 3.1	30.1 ± 2.7	27.1 ± 2.7	35.0 ± 3.1	30.9 ± 2.7	28.0 ± 3.0	<0.0001	0.56	0.57
Final LW	37.3 ± 2.9	33.4 ± 2.3	30.9 ± 2.6	33.4 ± 3.6	34.3 ± 3.8	36.9 ± 2.8	33.0 ± 2.1	30.4 ± 2.6	37.9 ± 2.9	33.8 ± 2.4	31.3 ± 2.6	<0.0001	0.45	0.40
ΔLW	6.0 ± 2.2	6.1 ± 1.9	7.0 ±1.9	6.5 ± 2.1	6.1 ± 1.9	6.0 ± 2.2	6.2 ± 1.7	7.2 ± 2.1	6.0 ± 2.2	5.8 ± 2.1	6.6 ± 1.4	0.85	0.73	0.96

Table 6

Effects of liveweight (LW) range of the ewe lambs (Group), the weighing system (conventional, gold standard –GS- vs. WoW) and their first-order interaction on the calculated average daily gain (ADG, g/d).

	LW range (Group)			Weighing System		Group×System Interaction						*p*-value		
	Heavy	Medium	Light	GS	WoW	GS-Heavy	GS-Medium	GS-Light	WoW-Heavy	WoW-Medium	WoW-Light	Group	System	Group×System
ADG, g/d	97 ± 227	103 ± 196	116 ± 195	123 ± 200	84 ± 213	116 ± 218	122 ± 188	132 ± 189	74 ± 233	82 ± 203	98 ± 199	0.35	0.29	0.91

Figure captions

Fig. 1. Schematic representation of the paddock plan and the setup of the walk-over-weighing system to allow one-way flow of animals to the attraction area, connected to the rotationally grazed paddock. *Mi: mineral blocks; Mo: molasse; S: salt blocks; W: water; WoW: walk-over-weighing.*

Fig. 2. Schematic representation of the experimental design followed for evaluating the feasibility of using a walk-over-weighing system on recently weaned grazing *Mérinos d'Arles* ewe lambs (n=100). The 3-months experiment started on January 25^{th} and lasted until April 30^{th} with a design including two major experimental periods (Adaptation and Data collection). *Wi: week n°i; GS: Gold Standard measurements with the static weight scale indicator XR-5000; e: presence of five WoW-adapted adult ewes to facilitate adaptation of naïve lambs.*

Fig. 3. Illustration of the effects of using a three-step cleaning method to eliminate extreme and outliers from phase II of the experiment, on the correlation between static weighing (traditional) and WoW. *Linear regression: A: from the raw database; B: after step 1 of data cleaning; C: after step 2 of data cleaning; D: after step 3 of data cleaning, final database*

Fig. 4. Bland and Altman graphics during the data cleaning process of the second phase of the experiment. *Bland and Altman graphic: A: from the raw database; B: after step 1 of data cleaning; C: after step 2 of data cleaning; D: after step 3 of data cleaning, final database*

Fig. 5. Daily percentage of ewe lambs (n= 100, 99 after April 1^{st}) passing along the platform of the WoW system during the phases I and II of the experiment (i.e., Adaptation and Collect, $p < 0.001$). indicates days with a battery problem.

Fig. 6. Growth curves obtained for each weight group (Heavy, n = 34 then 33 from 04/01; Medium, n = 33; Light, n = 33) with each of the two measurement systems. *The Gold Standard curve represents the daily live weight values estimated from the weekly static measurements.*

Fig. 7. Growth curves of 3 individuals obtained with each of the two measurement systems. *The Gold Standard curve represents the weekly live weight values measured statically. Individual 3954 died during the experiment (04/01).*

Fig. 8. Average Daily Gain (ADG) of 3 individuals obtained with each of the two measurement systems. *Individual 3954 died during the experiment (04/01).*

Fig. 1

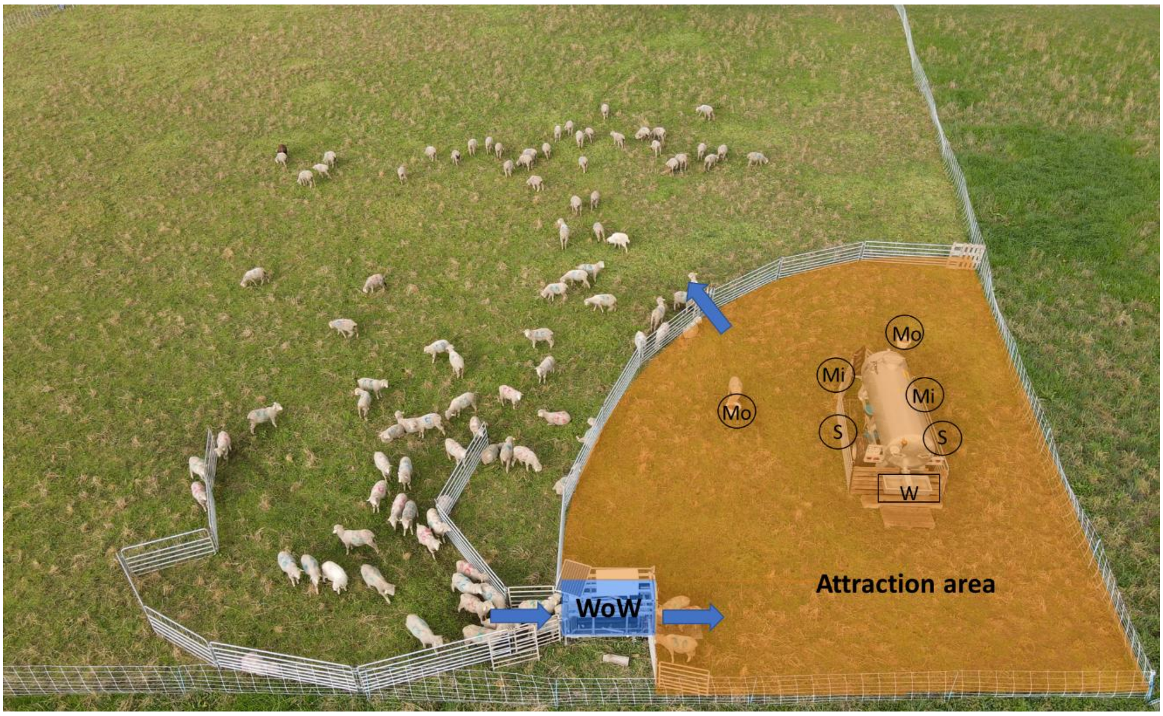
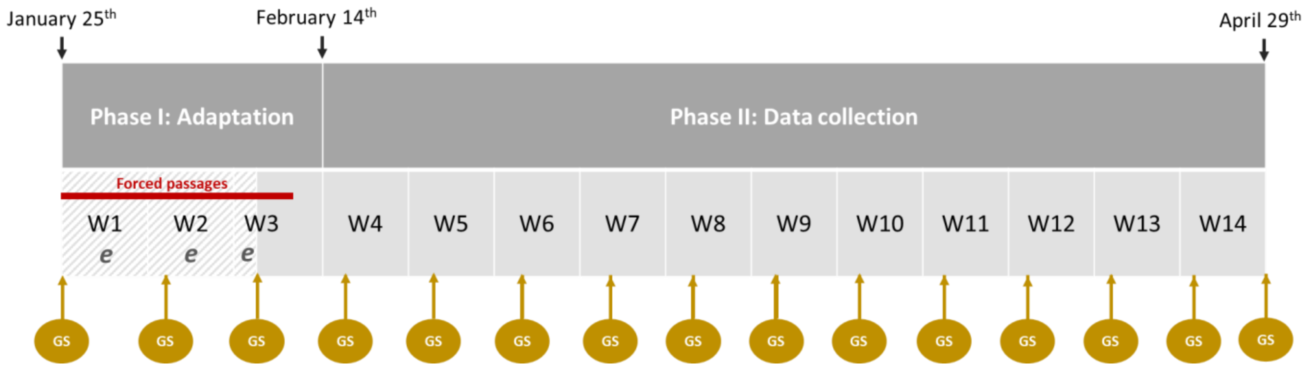
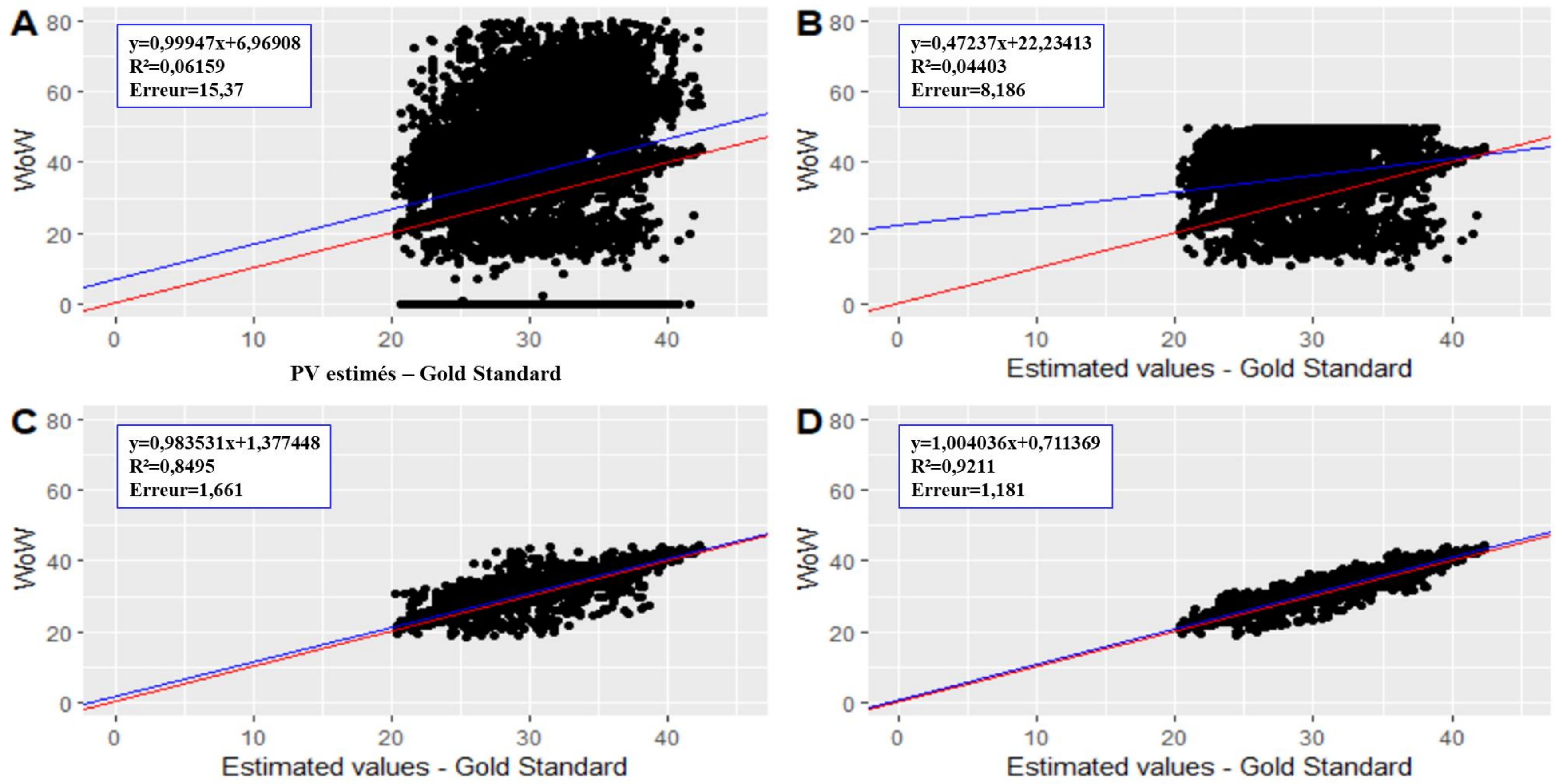


Fig. 2



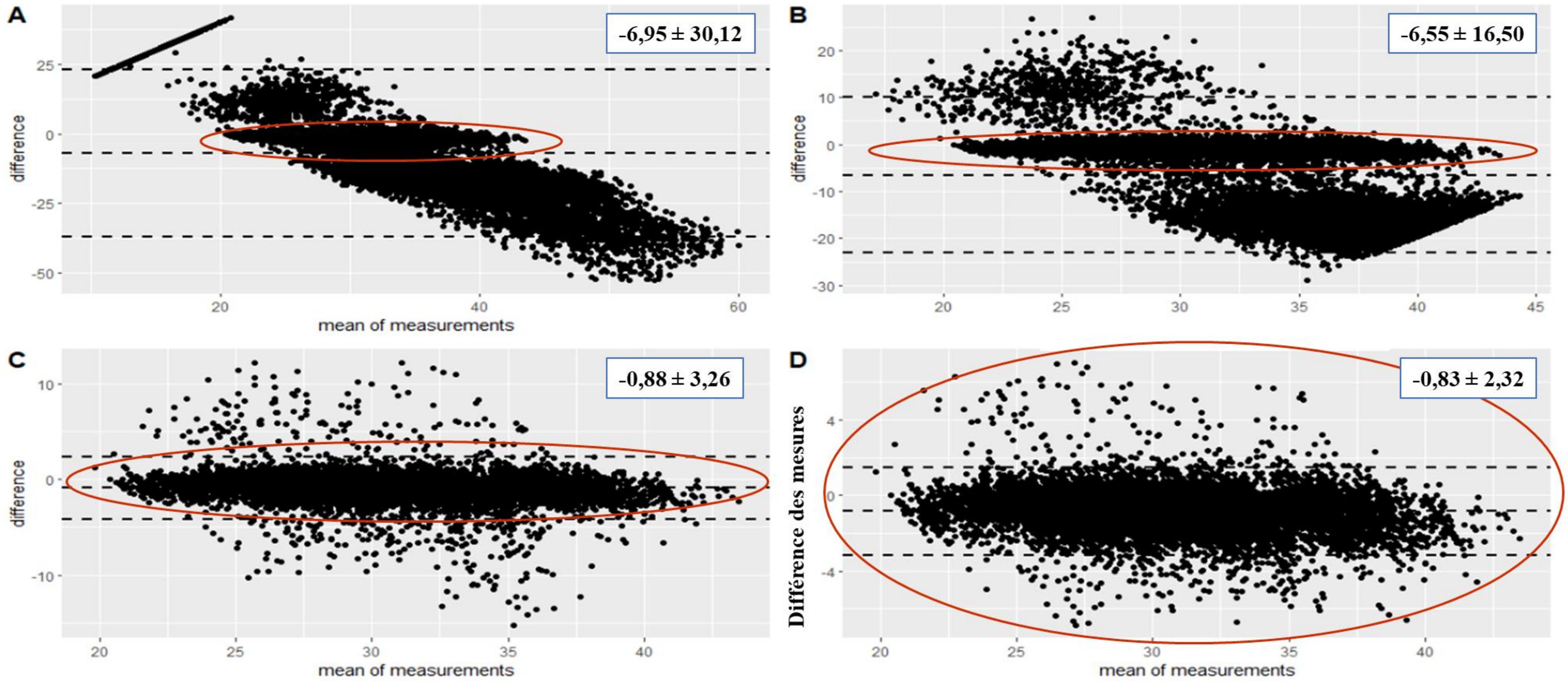
January 25th
February 14th
April 29th
Phase I: Adaptation
Phase II: Data collection
Forced passages
W1
W2
W3
e
e
e
W4
W5
W6
W7
W8
W9
W10
W11
W12
W13
W14
GS

Fig. 3



A
y=0,99947x+6,96908
R²=0,06159
Erreur=15,37
WoW
PV estimés – Gold Standard
B
y=0,47237x+22,23413
R²=0,04403
Erreur=8,186
WoW
Estimated values - Gold Standard
C
y=0,983531x+1,377448
R²=0,8495
Erreur=1,661
WoW
Estimated values - Gold Standard
D
y=1,004036x+0,711369
R²=0,9211
Erreur=1,181
WoW
Estimated values - Gold Standard

Fig. 4



A
-6,95 ± 30,12
difference
mean of measurements
B
-6,55 ± 16,50
difference
mean of measurements
C
-0,88 ± 3,26
difference
mean of measurements
D
-0,83 ± 2,32
Différence des mesures
mean of measurements

Fig. 5

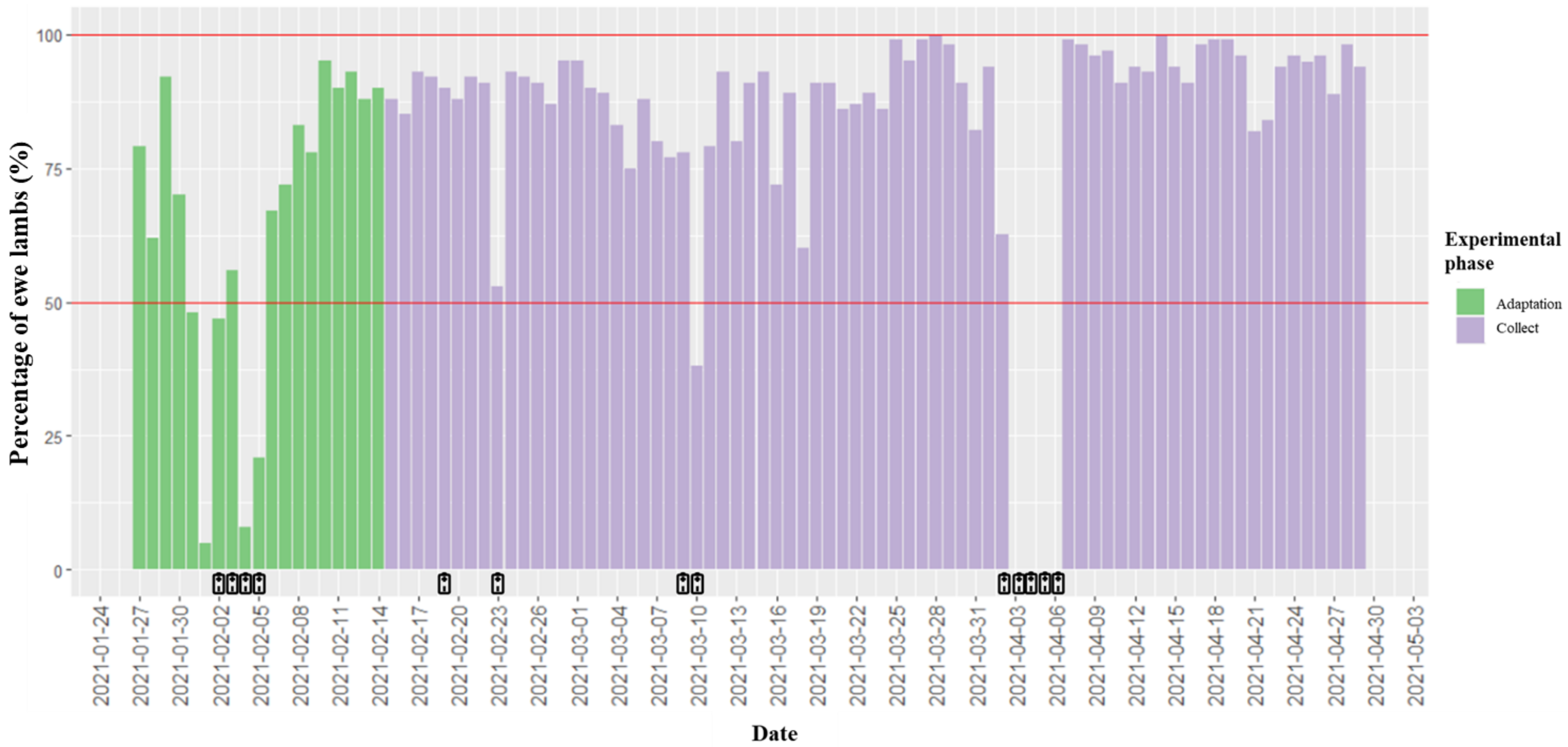
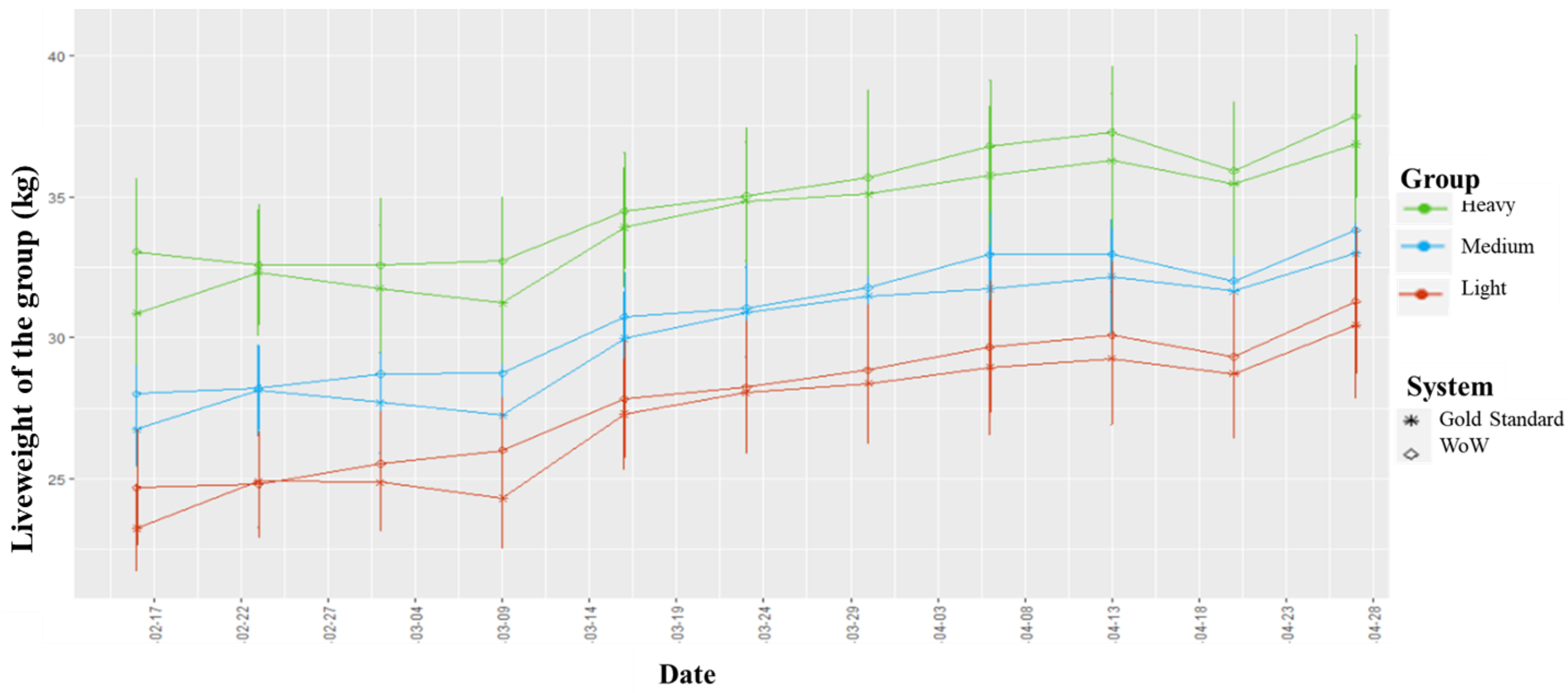

Percentage of ewe lambs (%)
100
75
50
25
0
2021-01-24
2021-01-27
2021-01-30
2021-02-02
2021-02-05
2021-02-08
2021-02-11
2021-02-14
2021-02-17
2021-02-20
2021-02-23
2021-02-26
2021-03-01
2021-03-04
2021-03-07
2021-03-10
2021-03-13
2021-03-16
2021-03-19
2021-03-22
2021-03-25
2021-03-28
2021-03-31
2021-04-03
2021-04-06
2021-04-09
2021-04-12
2021-04-15
2021-04-18
2021-04-21
2021-04-24
2021-04-27
2021-04-30
2021-05-03
Date
Experimental phase
Adaptation
Collect

Fig. 6



Liveweight of the group (kg)
40
35
30
25
02-17
02-22
02-27
03-04
03-09
03-14
03-19
03-24
03-29
04-03
04-08
04-13
04-18
04-23
04-28
Date
Group
Heavy
Medium
Light
System
Gold Standard
WoW

Fig. 7

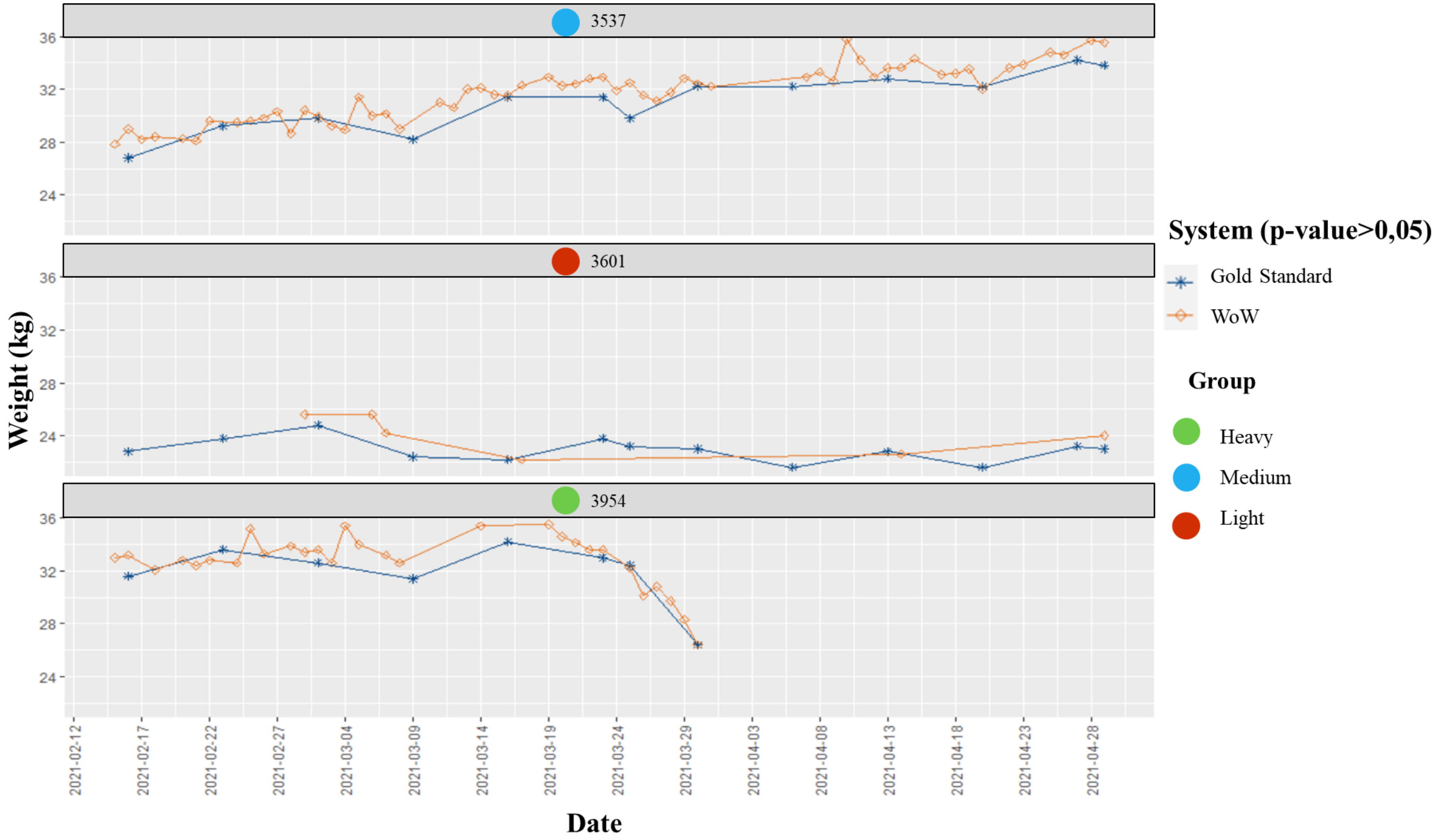
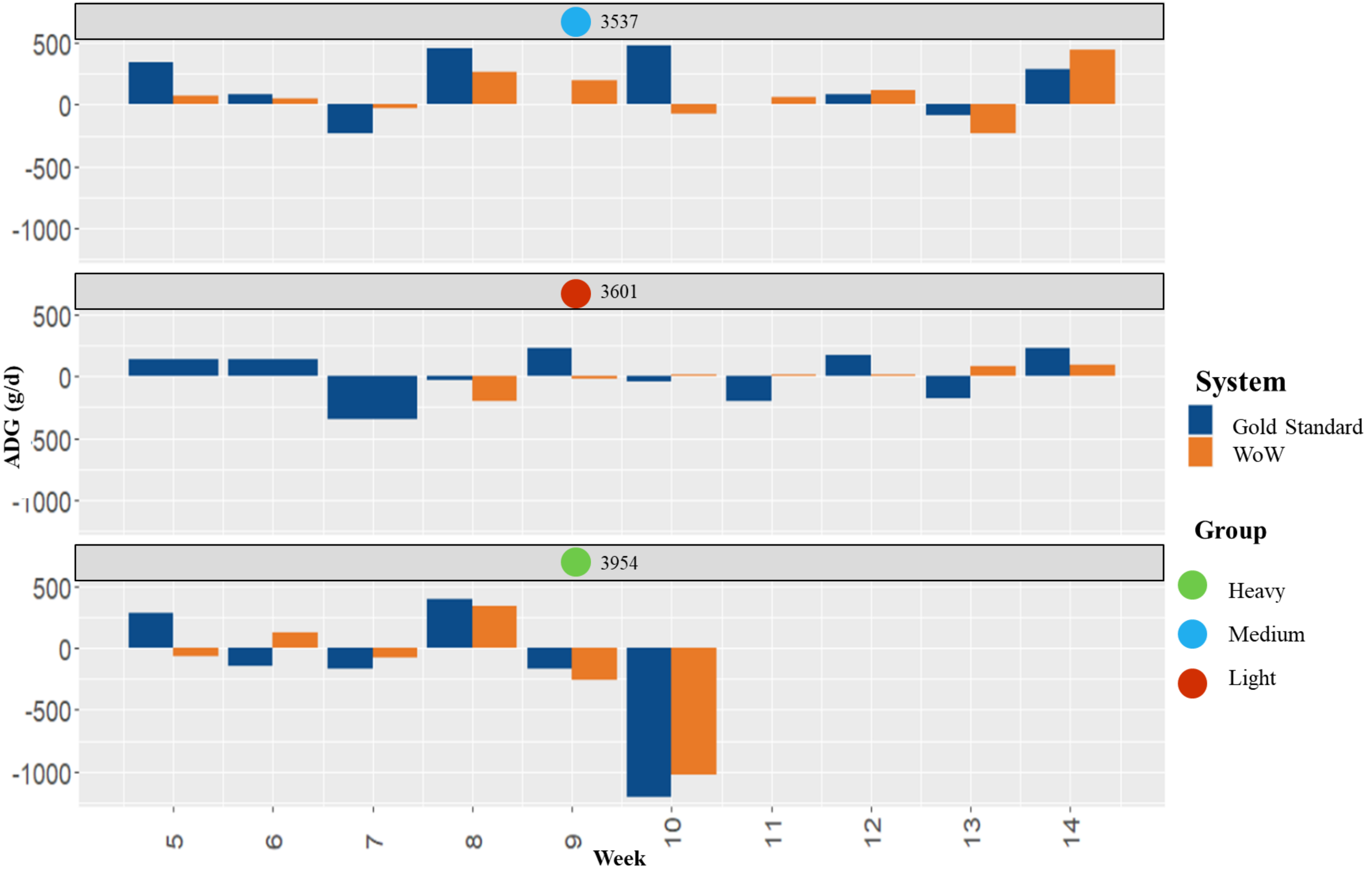

3537
3601
3954
Weight (kg)
36
32
28
24
Date
2021-02-12
2021-02-17
2021-02-22
2021-02-27
2021-03-04
2021-03-09
2021-03-14
2021-03-19
2021-03-24
2021-03-29
2021-04-03
2021-04-08
2021-04-13
2021-04-18
2021-04-23
2021-04-28
System (p-value>0,05)
Gold Standard
WoW
Group
Heavy
Medium
Light

Fig. 8



3537
3601
3954
500
0
-500
-1000
ADG (g/d)
5
6
7
8
9
10
11
12
13
14
Week
System
Gold Standard
WoW
Group
Heavy
Medium
Light