Final report of the project

Automatic weighing as an animal health monitoring tool on pasture

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Sammanfattning
Målet med projektet var att utveckla en automatisk metod för djurhälsoövervakning på bete, där larm erhålls för avvikande djur. Metoden leder till ökad djurhälsa och produktivitet vid betesdrift. Visionärt sett skulle en sådan metod kunna komplettera manuell tillsyn av djur och på så vis underlätta för fortsatt eller eventuellt utökad betesdrift på små och avlägset belägna betesmarker. Projektet fokuserar primärt på detektion av parasitangrepp hos kalvar men tanken är att även andra orsaker till dålig tillväxt ska kunna fångas upp. I projektet utvärderades också om mjölk-köttraskorsningar har större motståndskraft mot betsburna parasiter än renrasiga mjölkraskalvar. Vi har således utprovat en ny teknik för automatisk viktuppföljning på bete baserad på en matematisk tillväxtmodell som kan användas för detektion av parasitinfektion hos kalvar. Vid larm om parasiter vidtas riktad selektiv behandling (targeted selective treatment, TST) där angripna individer - men bara dessa - avmaskas, vilket är i enlighet med reglerna för ekologisk produktion. Metoden leder till ökad djurhälsa och produktivitet vid betesdrift på mångfaldsrika naturbetesmarker i ekologisk produktion där det ofta saknas alternativ till avmaskning.

I studien användes totalt 63 stutar, varav 31 var av mjölkras (SLB eller SRB) och 32 var korsningar (SLB x charolais och SRB x charolais). Två beten användes där betesmarkerna nästan uteslutande bestod av naturbetesmarker. Stutarna delades in i två grupper med 31 respektive 32 stutar i varje grupp, där varje grupp bestod av hälften mjölkras och hälften korsningar. Ena gruppen tilldelades en oral dos innehållande parasiterna *Ostertagia ostertagi* och *Cooperia oncophora*, medan den andra gruppen behandlades med avmaskningsmedel. För att få djuren att väga sig dagligen monterade vi upp de automatiska vågstationerna vid utgången från en mindre fålla i beteshagen där vattenkopparna var placerade. Djuren gick in i fållan genom en självöppnade envägsgrind men var tvungna att passera vågen på väg ut.

Försöket visar att det finns stor potential att använda solcellsdriven helautomatisk vägning som ett sätt att övervaka nötkreatur på bete, mäta tillväxten i vågstationer och tidigt fånga upp djur som avviker. Den matematiska modellen behöver dock utvecklas ytterligare för att även inkludera den viktminskning som normalt ses hos djuren vid betessläpp.

Som väntat växte de avmaskade djuren bättre än de djur som bar på en parasitinfektion. Vid installning vägde de avmaskade korsningsdjuren i medel 37 kg mer än de som bar på parasiter, för djuren av mjölkras var samma skillnad 17 kg.

Summary
The goal of this project was to develop a novel method for animal health monitoring for grazing cattle. It will be based on a system for unmanned automatic precision weighing when kept on pasture, where alarms are obtained for animals with abnormal weight gain curves. The project focuses primarily on the detection of pasture borne parasite infections in calves, but the method could be further developed to include other diseases that impair animal growth performance. In addition, we also wanted to investigate if there is any difference in susceptibility of parasite infection between pure dairy breed calves and dairy x beef breed calves. Thus we wanted to try out if a new mathematical model of weight gain can be used for early detection of parasitic infection in calves. At alarm, so called targeted selective treatment (TST) will be undertaken. This means that only the

affected individuals are dewormed with an anthelmintic. An advantage of the TST approach is that the use of anthelmintics is minimised, which is in accordance with the rules of organic production. In total 63 steers were used in the experiment, of which 31 were of dairy breed (SLB or SRB) and 32 were crossings (SLB x charolais and SRB x charolais). Two pastures were used consisting of permanent semi-natural pastures. The animals were divided into two separate groups with 31 and 32 animals in each group, where each group consisted of half purebred and half crossbred steers. One group of steers were given an oral dose of the parasites *Ostertagia ostertagi* and *Cooperia oncophora* while the other group was treated with anthelmintics. To get the animals to weigh themselves on a daily basis, we placed the automatic weighing stations at the exit from a smaller enclosure on the pasture where the water cups were placed. The animals entered the enclosure through a self-opening one-way gate but had to pass the weighing station on their way out.

The experiment shows that there is a great potential for using solar powered fully automatic weighing as a way to monitor cattle on pasture, measure growth in these automatic weighing stations, and to early detect if the growth of an animal deviate from the expected growth rate. However, the algorithm needs to be further developed to also include the weight loss normally seen in animals in the beginning of the grazing season.

As expected, the dewormed animals grew better than the animals suffering from a parasitic infection. At housing, the dewormed crossbred animals weighed 37 kg more than those having a parasite infection, for the animals of dairy breed the same difference was 17 kg.

Introduction

Grazed semi-natural pastures are of great importance for the conservation of biodiversity in the Swedish agricultural landscape. Sustained biodiversity in pastures, however, requires management and thus grazing animals (Luoto et al., 2003). As an effect of a declining number of potential grazing livestock, it has become increasingly difficult to maintain the management on these lands and thereby reaching the Swedish environmental goals (Official Statistics of Sweden, 2013; Swedish Environmental Objective Council, 2008). For farmers to choose to keep the animals on the semi-natural pastures and not on arable land or indoors requires, however, satisfactory production results on the pasture.

The performance of the animals, that is health and weight gain, can be compromised in many ways. Regular weight management is essential for good production monitoring. The downside is that frequent manual weighing of livestock requires a significant work effort. It is therefore essential to establish a surveillance system based on unmanned precision weighing. Today there are systems for unmanned precision animal weighing in practical use indoors (eg. "LiveStock Planner ®"). This is a web-based production support system for beef production based on automatic reading of electronic identity and frequent weighing in distributed sensor networks developed in Sweden (Hencol, 2013). The information from such production monitoring system is used as a basis for changes in feed rations, slaughter planning, breeding and precipitation of slaughter mature animals by sorting gates etc. As a result, the method can be used in its entirety to detect animals with different weight gain curves. When the weight curve of a constantly fed animal deviates downwards it in general depends on diseases.

A constant and ever-occurring threat to optimal weight gains in grazing cattle is pasture-borne parasites such as the gastrointestinal nematodes (GIN) *Ostertagia ostertagi* and *Cooperia onchophora* (Höglund et al., 2009). The problem is particularly pronounced on permanent pastures, such as semi-natural pastures. First season grazing calves of dairy breed are most exposed, because their diet consists solely of grass and is not, as in suckler calves, complemented with milk. Parasite infections impair animal health and decrease weight gain to varying degrees. The subsequent longer rearing period leads both to increased costs for the animal owner and to a larger greenhouse gas emission per kg produced meat alternative per calving dairy heifer (Mogensen et al., 2013). An optimal and effective parasite control is therefore necessary to decrease the animal production's contribution to the ongoing climate change.

Traditionally parasites are controlled by prophylactic mass deworming of groups of grazing animals at strategically selected intervals. Experience from various Swedish experiment shows that the weight gain in grazing dairy calves may on average be between 20 and 65 kg lower than the weight gains measured in dewormed animals on similar pasture (Höglund, 2010). One of the problems with traditional anthelmintic treatments is that this strategy is unauthorized under the regulatory framework for organic production (Swedish Board of Agriculture, 2013). Overuse of anthelmintic can also select for and emergence of resistance to deworming agents, where the target organisms (i.e. the parasites) survive the treatment (Höglund, 2011). This is a growing problem both nationally and internationally (Sutherland and Leathwick, 2011). It is therefore beneficial if animals with the most parasites can be identified and treated individually instead according to the principles of targeted selective treatments (TST). It's these animals that suffer the most damage and which contributes to pasture contamination. With intensified surveillance efforts, unnecessary anthelmintic treatments can be defeated while animals showing signs of illness are given prompt and adequate treatment (Höglund et al., 2011). This is also in accordance with the rules of organic production (Swedish Board of Agriculture, 2013). In a recently completed experiment it was shown that the effects of grazing borne GIN could be alleviated by such weigth gain based TST compared with calves protected by repeated anthelmintic treatments (Höglund et al., 2011).

So far, unmanned precision weighing is developed for healthy animals indoor, but we are convinced that there is potential to use such systems also for animal health monitoring, in particular on pasture. Hence, the aim of the project was to investigate whether frequent unmanned precision animal weighing combined with algorithms for the detection of weight gain anomalies provide a good basis for an early indicator for veterinary measures to be taken.

Materials and methods

Testing of the automatic weighing stations

In 2014, two prototypes of weighing stations (Livestock Planner ®, Hencol AB, Grebbestad; Figure 1 and 2) were designed and placed on pasture. A few technical problems arose and led to the weighing stations could not be operational as planned. Therefore, testing of the technology was conducted during the summer of 2015 instead. In May, 15 heifers were introduced to the weighing stations on pasture. After some acclimatization, all 15 animals used the scales as intended. The weighing stations required some further adjustments of the settings and upgrade of batteries and solar panels to make them work optimally. The weighing station which the animals passes through (Figure 2) were placed so that the animals had to pass it to get into a small corral where four animals could drink simultaneously. Hence, this type of weighing station has a greater capacity and the one we chose to use in the full scale experiment.

Figure 1. Weighing station in which the animals get access to water.

Figure 2. Weighing station which the animals pass through.

Full scale experiment

<u>*Experimental design*</u>

The grazing trial took place in 2016, starting at turn-out on the 2nd of May and ended at housing on the 20th of September; it had a split-plot experimental design with repeated measures and involved two genotypes of animals; pure dairy breed (D) and dairy x beef crosses (C). Two levels of parasitic exposure (High, H, and Low, L) were used as follows: The H level of parasitic exposure was obtained by deliberately infecting animals of both genotypes at turn-out with a mixture of about 5000 infective third stage larvae (L3) of *Ostertagia ostertagi* and *Cooperia oncophora* (1:1) and by allowing them to graze on a naturally contaminated pasture with nematodes throughout the study. The L level of parasitic exposure was achieved by de-worming animals of both genotypes with ivermectin solution (Noromectin® Pour-on, 0.5 mg per kg body weight) by pouring it on the midline of the back, from the shoulder to the base of tail at four-week intervals from turn-out to housing. At turn-out, the D and C calf pairs were randomly allocated into one of two sections, either the L or the H level of parasite exposure where half of the D animals were turned out on the L section and the other half on the H section. The same was the case for the C calves. Thus, at the start of experiment L animals of both genotypes were grazing on similarly contaminated pastures as H animals. However, as the experiment progressed, the expectation was that parasite contamination would build up in the H, but not in the section grazed by L animals of both genotypes.

<u>*Pastures*</u>

The pasture consisted of 28 ha of permanent semi-natural pastures, which previous year had been used by beef suckler cows and their calves. For the present experiment it was split up into two similar enclosures. Both enclosures consisted of approximately 20% dry, 60% mesic and 20% wet areas. The pasture was mainly open, but included small areas of mixed deciduous trees and the herbage composition was similar in both enclosures. Sward height and chemical composition of the pasture herbage were measured every four weeks from turn-out to housing, to ensure similar conditions in the two enclosures. In each enclosure, sward height measurement followed a Wshaped route according to Frame (1993), with 120-150 recordings performed with a rising plate meter (0.3 × 0.3 m, weight 430 g). To estimate chemical composition, 25-30 herbage samples were cut with a handheld machine in 3 m diameter circles along the route. The samples were analysed for concentrations of dry matter (DM), crude protein (CP), neutral detergent fibre (NDF) and *in vitro* organic matter digestibility. The DM concentration was determined at 130 °C for 24 hours, CP was determined according to Dumas and NDF was determined according to Chai and Udén (1998). Metabolisable energy (ME) concentration was calculated from *in vitro* disappearance of rumen organic matter according to Lindgren (1979).

Each pasture was provided with an area, which the animals had to enter through one-way gates, where water in cups and minerals (Lantmännen effect optimal) was offered to the animals. To exit the animals had to pass through either one of two scales (Figure 3).

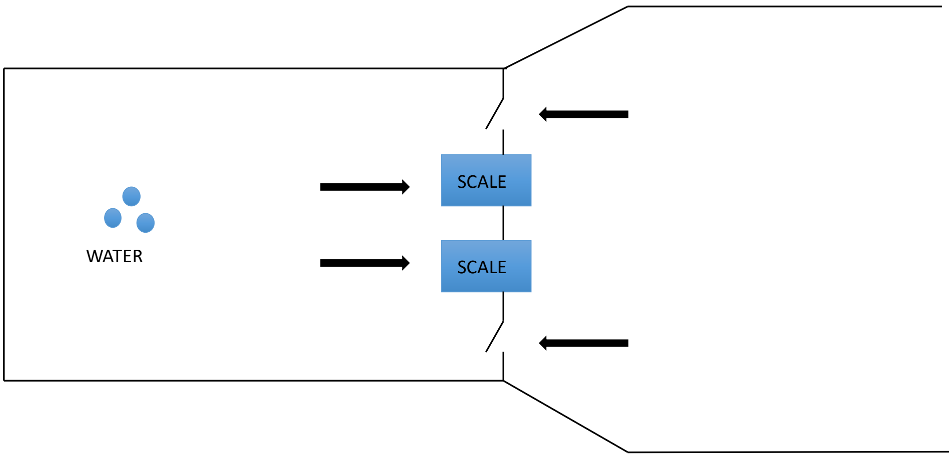

Figure 3. A schematic picture over the water area and placement of the automatic weighing stations, one equipped with solar cells and one operated on line current.

Animals

The study included 63 first season grazing (FSG) steer calves purchased as weanlings at 2-3 months of age from the same commercial farm. A total of 31 animals were of pure dairy breed (D, 12 Swedish Red and 19 Swedish Holstein), whereas 32 animals were crossbreeds between dairy and beef breed (C = 12 Swedish Red x Charolais and 20 Swedish Holstein x Charolais). The birth date of the calves ranged from 18th of April 2015 to 1st of November 2015. During the pre-experimental indoor period, all animals were fed a total mixed ration consisting of grass/clover silage, rolled barley, rolled peas and rapeseed meal *ad libitum* altering the protein and energy concentrations along with increased live weights according to Swedish nutritional recommendations (Spörndly et al., 2003). Average daily body weight gain (BWG) during the pre-experimental period was 1.02 ± 0.13 kg for the D calves and 1.06 ± 0.15 kg for the C calves. All calves were naive grazers at the start of the trial. Before and during the experiment, water, salt and minerals were offered *ad libitum* to all animals.

Weighing, sampling and parasitological examinations

At turn-out and housing the body weight of the animals was recorded over two consecutive days. While on pasture, BW was recorded with two automatic weighing stations (one equipped with solar cells and one was operated on line current) in each enclosure (Figure 3). In addition, the animals manually weighted every fortnight throughout the grazing season. Rectal faecal samples were collected at turn-out and then at four-week intervals until housing. Faeces were used for quantitative analysis of gastrointestinal nematode faecal egg counts (FEC) expressed as nematode eggs per gram of host faeces (epg), according to a modified McMaster technique based on 5 g of faeces and using saturated salt as the flotation medium with a minimum detection level of 20 epg. An additional 5-10 g of faeces was collected from each animal at each sampling point. These samples were pooled from all FSG in the same experimental group, mixed with Vermiculite® and then cultured for at least 10 days at 20 °C. At the end of the incubation period, L3 was retrieved and the percentage of each parasite species in the mixture was determined by qPCR as described by Höglund et al. (2007). Every four weeks, 2 × 5 ml blood samples were taken from the coccygeal vein or artery of all animals, using tubes equipped with a cannula (Vacutainer®, Becton Dickinson). Serum was separated to determine the pepsinogen concentration (SPC) according to a micro-method (Charlier et al., 2011), as a measure of damage of the abomasal mucosa.

Results

Pastures

Pasture sward height and chemical composition of the grass were similar in the two enclosures was similar throughout the grazing period (Table 1).

Table 1. *Sward height (cm), dry matter (DM) concentration, energy concentration (ME) and chemical composition of the two pastures. Standard deviation in parenthesis*

	Enclosure 1[1]	**Enclosure 2**
Sward height (cm)	4.4 (2.5)	4.7 cm (2.5)
DM (g/kg)	300 (21)	288 (26)
ME (MJ/kg DM)	10.2 (0.9)	10.3 (1.1)
CP (g/kg DM)	161 (24)	157 (29)
NDF (g/kg DM)	10.2 (0.9)	10.3 (1.1)

[1] Enclosure 1 = Animals treated with anthelmintics (L-group), Enclosure 2 = animals given an oral dose of larvae (H-group).

Automatic weighing stations

The automatic weighing stations worked well throughout the grazing season. The weighing stations are equipped with a computer that register the weight of each animal and sends the information to a software. LiveStock Planner ® is based on mathematical-statistical fit of a biological growth curve (Gompertz, 1832; Brown et al., 1976; Nesetrilova, 2005) of the weight recordings using a least-square method (Baarda, 1968; Rosenholm, 1987). A matrix based technology is used to identify abnormal measurements, data snooping according to Baarda (1968). Thereby registrations of poor quality are identified and excluded (Figure 4). Registrations of poor quality could, for example, be due to the animal passes through the scale too fast or that two animals are on the scale at the same time. On average, five useful weights per week were obtained for each animal which was enough to be able to develop and adapt the algorithm to growing cattle on pasture. In total, 12,592 weights were recorded and of which 5,098 were useful (Table 2).

Table 2. *Number of registered weights in the four different weighing stations used in the experiment*

	Enclosure 1[1]		Enclosure 2	
	Solar powered	Line current	Solar powered	Line current
Registered weights (n)	3005	2223	5681	1683
Wrong weights (n)	1857	1497	3004	1136
Useful weights (n)	1148	726	2677	547
Useful weights (%)	38	33	47	33

[1] Enclosure 1 = Animals treated with anthelmintics (L-group), Enclosure 2 = animals given an oral dose of larvae (H-group).

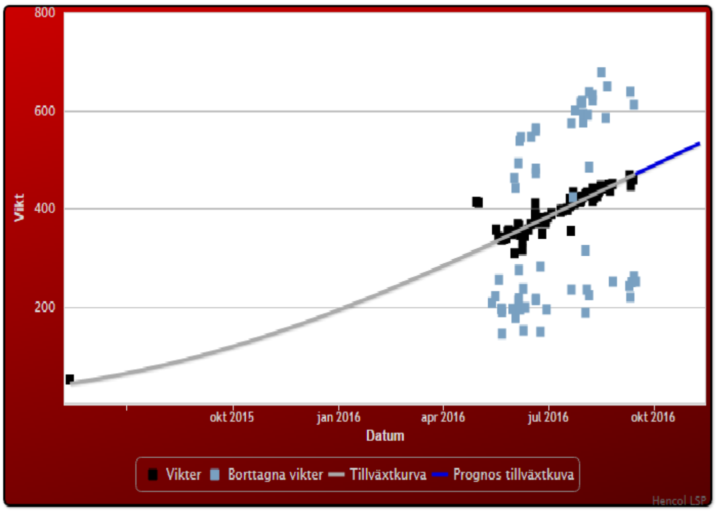

Figure 4. *A growth curve based on registered weights (grey line) and a prognosis (blue line) of future growth generated by the software. Black dots are useful weights and blue dots are sorted out weights.*

The system also shows how many weights per animal that are registered each day (Figure 5), which gives valuable information about how precise the generated growth curve is. This can also be a useful complement to the daily supervision of the animals since one get an indication of both growth rate and motion through the weighing station. However, the weighing stations cannot replace the visual supervision.

There were however some problems with getting the animals to voluntarily pass the scales and to use them as intended, which can be seen in Figure 6. In order to ensure that all animals had access to water, they were driven daily through the one-way gate into the water area (Figure 3).

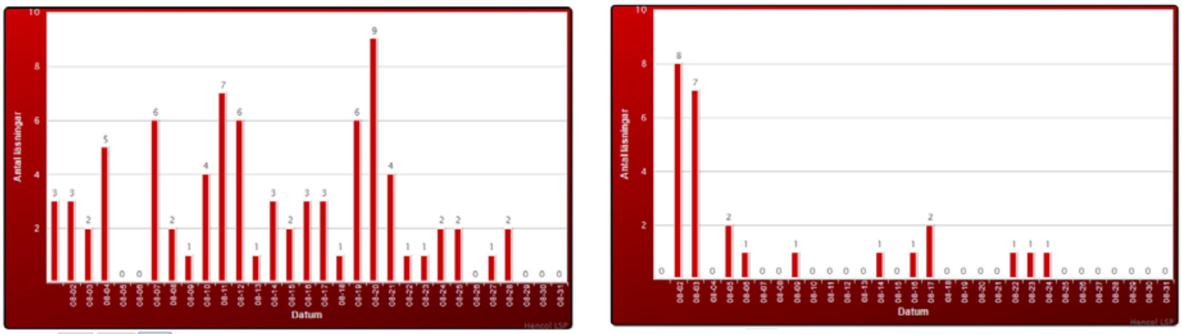

Figure 5*. Two examples of number of weights per day, one animal with many registered weights and one with few registered weights.*

Animal performance

Based on manual weighings, a numerical 26 kg difference in BW was observed between genotypes at the start of the experiment (Figure 6). The animals in both dewormed groups (DL and CL) lost 39 ± 15 kg, while the infected animals lost 41 ±15 (DH) and 42 ±14 kg (CH) during their first two weeks on pasture. All animals then started to gain significantly in BW over time ($p<0.0001$), but the dewormed L group animals of both genotypes (DL and CL) gained approximately 9% more weight than their counterparts in the infected H groups indicating the negative effect of parasite infection on animal performance. Both dewormed groups returned to their starting weights observed at turn-out, approximately after 43 days on pasture, which is in contrast to the infected animals in the H groups (DH and CH) that returned to their initial BW after approximately 58 days on pasture. There was a highly significant ($p=0.0029$) difference in BWG between the two treatments throughout the grazing season but not between the different genotypes (p=0.6830). At housing the BW of the animals of the C genotype in L and H treatments were 426 ±72 kg and 389 ±59 kg, while those of the D genotype in the same treatments were 382 ±75 kg and 365 ± 55 kg, respectively. This implies that there was a significant difference of 17 kg in BW between D animals in the L and the H treatments after the grazing period at housing, while a 37 kg difference between the C animals. The daily BWG after 141 days on pasture in groups DH and DL was 0.43 ± 0.16 kg and 0.59 ± 0.16 kg respectively. The corresponding values in the CH and CL groups were 0.42 ± 0.19 kg and 0.69 ± 0.23 kg, respectively.

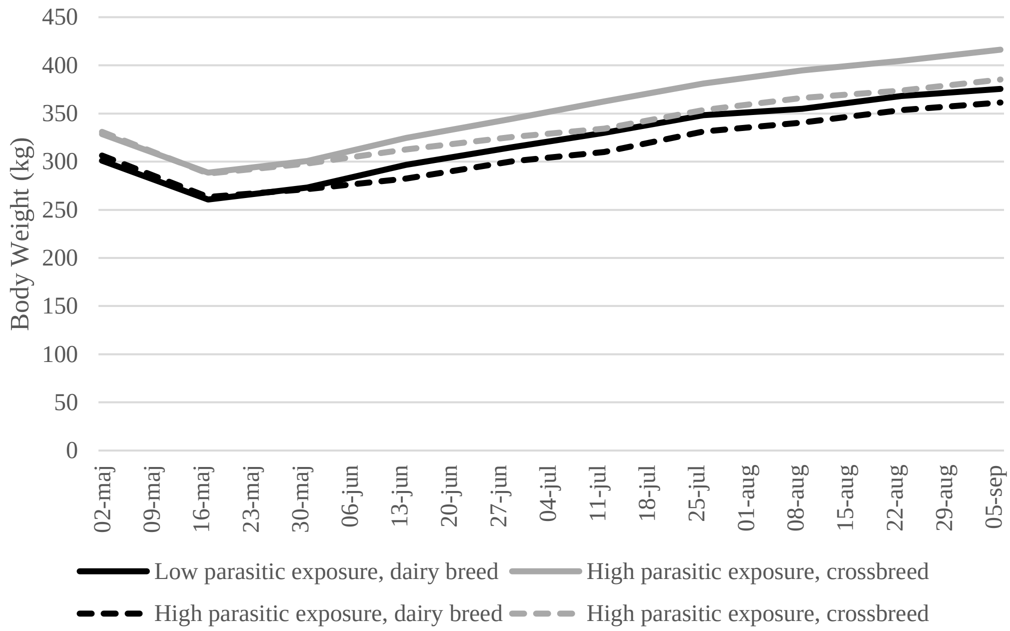

Figure 6. *Weight gain in first season grazing calves of dairy breed and dairy x beef breed with either low or high parasitic exposure based on manual weighings.*

Discussion

Automatic weighing stations

The experiment shows that there is a great potential for using solar powered fully automatic weighing as a way to monitor cattle on pasture, measure growth in these automatic weighing stations, and to early detect if the growth of an animal deviate from the expected growth rate. However, the algorithm needs to be further developed to also include the weight loss normally seen in animals in the beginning of the grazing season (Figure 4). Of all registered weights, about 40 % of them were useful, which was enough to be able to develop and adapt the algorithm to growing cattle on pasture. To get a proper weight, the animal has to stand on the scale for approximately 1.5 sec. In an attempt to stop the animals for a while, we mounted a one-way gate in the front of the weighing station but when the animals got used to the gate they went on without slowing down. Another problem was that the calves went consecutively which quite often led to 1.5 animals on the scale. To prevent the latter, a solution can be to mount a gate also where the animals enter the scale.

In this experiment calves were motivated to pass through the one-way gates in order to get access to water. Even if the summer of 2016 was a quite dry, there were water in ditches etc. and water alone was obviously not enough to get the calves into the smaller enclosure. To increase the motivation to pass the weighing stations, concentrate could be offered but this needs to be tested. Another solution could be to place the weighing stations at a narrow passage in the pasture or one could settle with weight recordings when changing pasture. The latter will, however, not be enough to be able to use the automatic weightings as a tool to detect parasite infections.

The placement of the weighing stations is another issue. When using solar cells to power the scales and the computer it is important that the weighing station is placed in such a way that the sun reaches it even in autumn. A good thing is also to turn off the computer during nighttime. Otherwise, the battery may be drained, which may damage the computer.

In the future, we see a need to be able to send signals and information to, for example a mobile phone, especially about the animal's health and activities. It would also be an advantage to equip the weighing stations with sensors for activity registrations completed with camera and/or video equipment.

Animal performance

In this grazing study we also investigated the effects of parasitism on the performance and resistance in two diverse cattle genotypes with different growth potential. Our initial hypothesis was that crossbred animals may be less resistant to parasite infections and may experience greater penalties in their performance compared to purebred dairy genotypes and the data generated from this study are in support of this hypothesis. Exposure to parasites in the current study impaired calf growth in both genotypes, as shown by the significant differences in BWG between dewormed (L) and experimentally infected (H) animals, a finding in agreement with previous studies with first season grazing dairy calves in Sweden (Dimander et al., 2003; Larsson et al., 2007; Höglund et al., 2013a). Although not significant, the penalty of parasitism (L vs H) in the BW of calves was more pronounced in C (39 kg) than in D (24 kg) calves, indicating that the impact of parasite infection on growth may have been more severe in the crossbreds than in the dairy calves. This observation is in agreement with similar studies in sheep, where genotypes selected for high productivity, were more susceptible to parasites than animals selected less intensively (Amarante et al., 2004; Zaralis et al., 2009). The mechanisms that underline these observations are still under debate; genetics differences (Rauw et al., 1998), nutritional constraints (Coop and Kyriazakis, 1999) or variation in feeding behaviour have all been thought to play a role in this.

From these differences in both growth capacity and susceptibility to parasite infection we can assume that there is a need for different algorithms for different genotypes of cattle. This to ensure that the system detects anomalies in growth rate but without too many false alarms.

Conclusion

There is a great potential for using fully automatic weighing as a way to monitor cattle on pasture, measure growth and to early detect if the growth of an animal deviate from the expected growth rate. However, the algorithm needs to be further developed to also include the weight loss normally seen in animals in the beginning of the grazing season. In this study we also found evidence for differences in parasite resistance and growth performance between two genetically diverse breeds of cattle. To ensure that the system detects anomalies in growth rate we therefore we see a need for different algorithms for different genotypes of cattle.

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