Student Final Report **May 2017**

Cattle helminth infections in England and Wales: An investigation into prevalence, risk factors, attitudes and impacts

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Cattle helminth infections in England and Wales: An investigation into prevalence, risk factors, attitudes and impacts

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CONTENTS

Abstract

In order to address the complexity of cattle helminth infections and control in England and Wales, this work explored the prevalence, risk factors and losses associated with three helminth parasites of economic importance in dairy and beef cattle, namely Ostertagia ostertagi (O. ostertagi), Fasciola hepatica (F. hepatica) and rumen fluke, and engaged with farmers to explore their knowledges, practices and values around prevention and control of cattle helminth infections in this region. This project was based on a mix-methods research (quantitative and qualitative methods) and a multidisciplinary framework that incorporates both veterinary epidemiology and sociology.

The research analyses the cases of dairy and beef cattle in England and Wales by using longitudinal and cross-sectional studies, respectively. For dairy cattle, 43 farms (1,500 heifers) were studied. Data were collected and analysed in relation to: levels of exposure to O. ostertagi and F. hepatica, farmers' practices for helminth control, demographic and management factors associated with young-stock exposure to helminths, production losses due to helminth infections in heifers, and farmers' attitudes. As for beef cattle, data were collected for both single- and poly- infections due to helminths in 974 cattle at slaughter to support: analysis of the prevalence of O. ostertagi, F. hepatica and rumen fluke in cattle, demographic factors associated with infections, and production losses due to helminths in prime beef carcases.

The research confirmed the ubiquity of O. ostertagi infections in cattle in England and Wales and suggested the significant presence of F. hepatica and rumen fluke in the region. Poly-infections due to the three helminths were also very common within the sample analysed. The three parasites were significantly associated with low carcase performances in prime beef cattle. Moreover dairy heifer exposure to O. ostertagi was significantly associated with lower milk production, reproduction and health performances. Results suggest that different practices of grazing management can help farmers controlling dairy heifer exposure to O. ostertagi on pasture, if applied during the first years of grazing, while reducing the use of anthelmintic drugs. Importantly, although dairy farmers tend to overuse anthelmintic drugs, they try to adopt, to some extent, several 'best-practice' recommendations included in COWS guidelines (2010) for cattle helminth control.

The different studies conducted in this project shed light on a series of overlooked epidemiological and behavioural aspects that are critical for cattle helminth control in the UK. Importantly, the project contributes to a better understanding of the complexity that is

inherent to cattle helminth control. By considering both the epidemiology of the infections and broader societal and cultural factors, it offers a comprehensive analysis and a pioneer representation of how the system of cattle helminth control might operate in the UK. The results of this research are extremely valuable to veterinarians, farmers, experts, and policy-makers, who all wish to develop and implement sustainable control of helminth infections in cattle, and will be the subject of several publications.

1. Introduction and objectives

The global food production and consumption system is currently experiencing major structural changes and pressures. Recent projections suggest that the world population will increase to over nine billion people within the next forty years (FAO, 2009). Certain groups of people will become wealthier and most of the world's population will live in urban areas, increasing their demand for livestock products, such as meat and milk (Rushton and Bruce, 2016). Such a trend can create new trade opportunities, especially for cattle farmers (FAO, 2009). At the same time, there is increasing evidence for global warming and the negative effects of production intensification, which has triggered public debate and has motivated the creation of new legislation. New policies aiming to protect both the environment and consumers, especially in relation to food products quality and safety, has been therefore introduced. Consumers' concerns about drug residues and animal welfare have also been responsible for increasing the pressures towards more "ethical", organic and animal-friendly approach to food production (Gasbarre et al., 2001; Waller, 2006; Commission, 2013). To ensure the sustainability of their businesses, cattle farmers have become compelled to improve the efficiency of their production and also to minimise the negative effects of their system intensification, whilst considering competition with other forms of land use, natural resources, biodiversity and infectious and zoonotic diseases (Herrero and Thornton, 2013).

Helminth infections are ubiquitous on cattle farms and represent one of the main concerns for the cattle industry around the world; this is argument is supported by increasing evidence of cattle anthelmintic resistance and failure to control helminth infections in cattle (Waller, 2006). Cattle are infected by a diversity of helminths on pasture, which are known to have a negative impact on their productivity (e.g. feed intake, growth rate, reproduction, milk yield and carcase composition) and welfare (Charlier et al., 2014). Moreover, cattle infected with helminths are known to produce more greenhouse gases (Sargison, 2014). In the UK, O. ostertagi and F. hepatica are recognised as parasites of major importance in terms of their economic impact on cattle production and animal welfare (Skuce et al., 2013). Rumen fluke is another strong candidate in the list of helminths which represent challenges for the sector in the UK (Tilling, 2013). However, because helminth infections are mainly subclinical, their control is often difficult (Charlier et al., 2014). In this context, farmers generally adopt blanket treatment in young-stock to prevent or regain production losses due to these infections (COWS, 2010). This results in increasing problems of helminth resistance to available drugs, making such a practice unsustainable (Vercruysse and Claerebout, 2001; Waller, 2006). Motivated by these concerns, several guidelines for best-practice on cattle helminth control have been published in the past few years. Nonetheless, farmers' have been reluctant to adopt the recommendations put forward by these documents (Heasman et al., 2012).

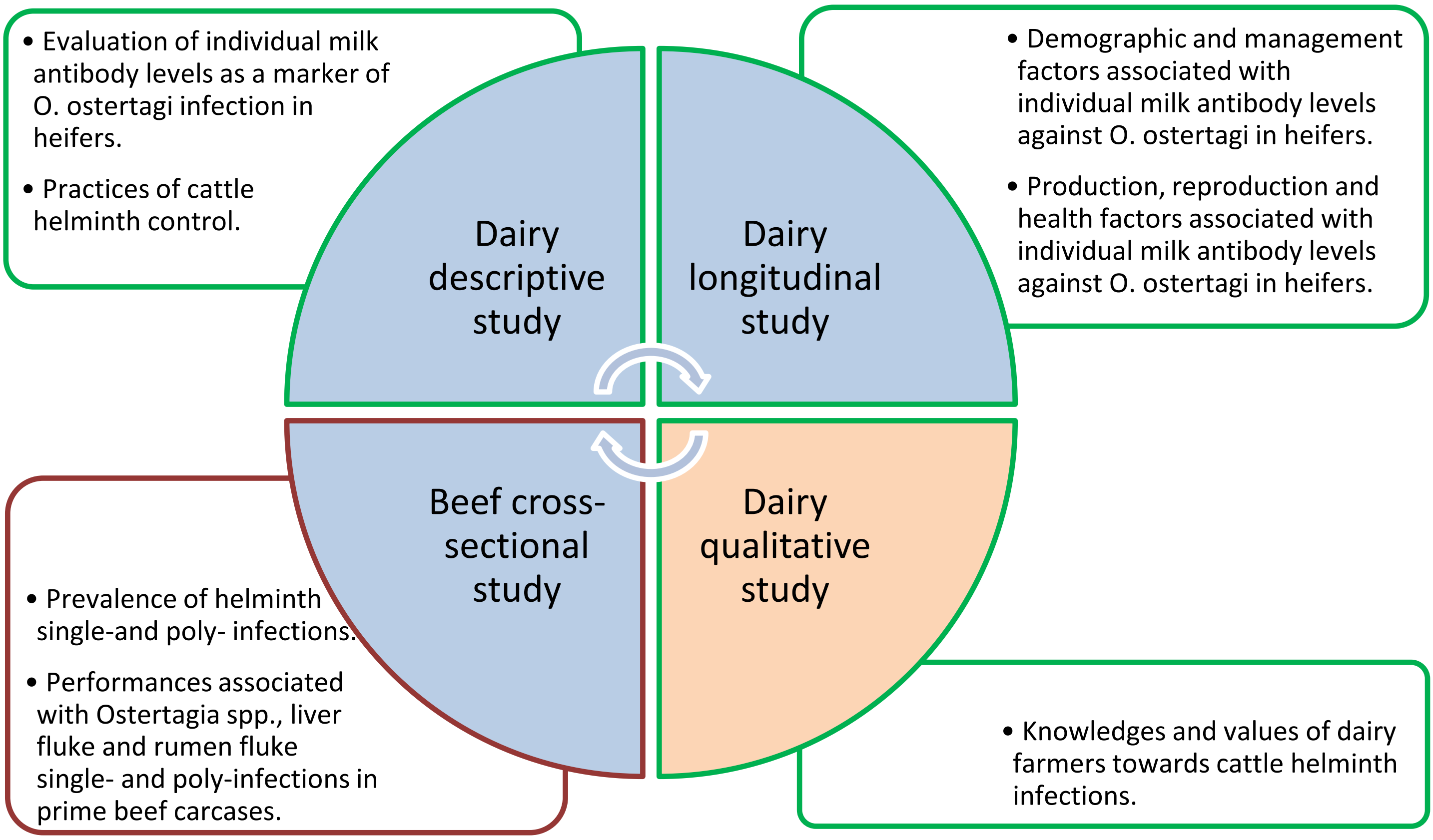
Cattle helminths infections are influenced by the interplay of a wide range of factors. These include not only interactions between different species of parasites, but also climate conditions, management practices, availability of resources, and farmers' attitudes, for which the role of comprehensive and reliable epidemiological information is key (Vercruysse and Claerebout, 2001; Charlier et al., 2015). This is particularly relevant to young-stock, since these are the future of the herd and usually the focus of anthelmintic treatments (COWS, 2010). Estimations of cattle exposure to helminths on pasture are currently scarce in England and Wales, especially for O. ostertagi*,* F. hepatica and rumen fluke. As evidence of this lack of information, no survey on the prevalence of helminths in dairy heifers have been conducted in England since the 1980s (Hong et al., 1981). Moreover, although the identification of risk factors and production losses associated with cattle exposure to O. ostertagi has been the focus of much research, there is a lack of similar research focused on first lactation heifers and prime beef cattle. Besides, the relationship between production losses and helminth infections remains to be clarified in the case of poly-infections. Importantly, while some information on the practices and attitudes of sheep farmers on helminth control is available in England (Morgan et al., 2012), the case of the cattle industry has been so far largely overlooked. However, if guidelines on helminth control are expected to be accepted and adopted on-farm, researchers focused on the topic need to fully understand farmers' behaviour and their contextual challenges (Charlier et al., 2015).

To address the gaps outlined above, this project was based on a mix-methods research (quantitative and qualitative methods) and a multidisciplinary framework that incorporated both veterinary epidemiology and sociology. The research analysed the cases of beef and dairy cattle in England and Wales by using cross-sectional and longitudinal studies, respectively, and focussing on three major helminths in beef and dairy cattle, namely O. ostertagi, F. hepatica and rumen fluke.

2. Materials and methods

The project was organised in two independent studies, a beef study and a dairy study. Figure 1 gives a global overview of the structure of the project and related research questions.

Figure 1. Presentation of the different components of the project



Key – Green, Dairy study; Red, Beef study; Blue, Quantitative; Orange, Qualitative

2.1. Beef study (quantitative)

→ Sample selection and data collection.

Abomasa, reticulorumens and livers from commercial cattle were collected and examined post-mortem quarterly over a twelve-month period between March 2014 and January 2015 in an abattoir slaughtering up to 1,500 cattle per week in the South-West of England. On each visit at slaughter, specific viscera from all cattle were inspected and scored on the slaughter line. The detailed study design and scoring systems are available in (Bellet et al., 2016). Before the commencement of the study, a sample of adult rumen fluke specimens was collected from two animals and was sent for speciation (Moredun Research Institute, UK). Data from the abattoir information management system were used to provide additional information on each animal demographic and production performances, i.e. cold carcase weight (CCW), carcase conformation, fat classification and liver condemnation, using the kill number as the unique identifier.

→ Statistical analysis.

Data were coded, checked and entered into a database (Microsoft Excel 2010). A preliminary descriptive analysis was conducted using STATA 12.1 (STATA Inc., Texas, USA) to summarise the data. Descriptive statistics were conducted to summarise the prevalence of Ostertagia spp., adult rumen fluke and liver fluke infections at farm and cattle levels. This was based, respectively, on the presence in the carcases of abomasal lesions, adult rumen fluke and both lesions and parasite for liver fluke. For each helminth, the carcases were summarised based on the severity scores of the helminths, the season and the category of animal. Where scores were available for all the three helminths, the percentage of co-infected animals was calculated.

Three multinomial logistic regression models (Dohoo et al., 2009) were built (i.e. one for each helminth) to investigate the factors associated with carcase severity scores for helminths. The production losses due to helminth past/current infections in prime beef carcases was estimated using three multilevel linear regression models with the following outcomes: (1) CCW; (2) carcase conformation; and (3) carcase fat classification.

2.2. Dairy study (quantitative and qualitative)

2.2.1. Quantitative study

→ Sample selection.

Forty-three dairy farms, all members of the Quality Milk Management Services' (QMMS) recording scheme (Somerset, England) took part in the dairy study. The average size of the study herds was 150 cows, of which 46 were first lactation heifers. Farm inclusion criteria included: heifers calving all-year-round or at least during two different seasons in a year, heifers being home reared (i.e. not contract reared), farmer compliance on data recording, and farmers agreeing with the study protocol and the sharing of farm's records.

The determination of dairy heifer sample size involved both statistical and non-statistical considerations (e.g. time, budget, and farm recording). These were aligned to the study objectives of identifying the association between individual milk (IM) antibody levels against O. ostertagi in heifers and other collected variables, i.e. demographic, management and production data (Dohoo et al., 2009). It was estimated that around 1,500 heifers had to be sampled and tested for O. ostertagi, i.e. 35 (1,500/43) heifers in each farm. Heifer's IM samples were obtained from samples routinely taken by QMMS from the beginning of March 2014 to the end of March 2015 and stored in freezers. To be included in the study, heifers had (1) to be born on farm; (2) to be sampled between 30 and 90 days in milk (DIM) (Sanchez et al., 2004); (3) to present records on milk yield, fat, protein and somatic cell count (SCC); and (4) not to have started a new grazing season in 2015. If several milk samples were eligible for one heifer, the one with the lowest DIM was included in the study to reduce the complexity of previous exposure to O. ostertagi on pasture. To select the 1,500 heifers, all the records kept by QMMS between March 2014 and March 2015 were extracted from the dairy herd data analysis program TotalVet (QMMS Ltd/SUM-IT Computer Systems). Heifer samples were selected by a stratified random sampling approach, in which two strata were considered and related to the risk factors of heifer exposure to O. ostertagi on pasture: stratum 1, the season (i.e. spring - between April and June; summer - between July and September; autumn - between October and December; and winter - between January and March), and stratum 2, the farm. This approach ensured that the main risk factors of heifer exposure to O. ostertagi were represented in the study sample (Dohoo et al., 2009).

→ Sample testing.

Only IM samples from heifers born after 2010 and having grazed prior to sampling were included in the analysis, which resulted in 1,454 IM samples tested for O. ostertagi. Herd level exposure to O. ostertagi and F. hepatica were also determined by antibody-detection ELISA applied on bulk tank milk (BTM) at the start and the end of the grazing season 2014, in each farm. IM and BTM samples were tested for O. ostertagi using the Svanovir® O. ostertagi ELISA kit from Svanova Ltd. (Sweden). BTM samples were also tested for F. hepatica using the Pourquier® ELISA F. hepatica serum and milk verification test (IDEXX, Montpellier, France) to control for some extent of test cross-reactivity between helminths (Bennema et al., 2009).

→ Data collection.

Individual data on heifer’s management, from birth to sampling, were obtained for a 5-year period between 2010 and 2015, using postal questionnaires (retrospective data), face-to-face and phone interviews (retrospective and prospective data), and farm records (TotalVet). Data cross comparison was conducted with farm records when appropriate (e.g. Huskvac vaccination) to confirm farmers’ declarations. The different variables included: information on farmers’ and farms’ demographic (i.e. geography, system of production, and system of calving), pre-weaned calves’ management, cattle housing and cattle vaccination, as well as information on heifer’s demographic and grazing history, i.e. for each heifer and grazing season: the number and size of pastures grazed, the stocking-rate, the frequency of grass mowing, pasture fertilisation, presence and nature of co-grazing (e.g. sheep, mature cows and young-stock), pasture previous grazing, and individual anthelmintic treatments (e.g. time of treatment, compounds and form of application). More details on the design and tools used to collect the complete history of heifer’s management from birth to sampling are available in (Bellet et al., Submitted).

Individual data on heifer’s production, reproduction and health were also collected over a one year-period from the time of sampling, i.e. between March 2014 and April 2016. Heifer’s individual records at the time of sampling included: season, age, breed, milk yield, fat, protein, DIM, SCC, calving date and status of offspring (i.e. alive or dead). Heifer’s milk yields, protein and fat at day 305 were extracted from TotalVet, if heifers had reached this stage at the end of the study (i.e. April 2016). Interval between heifer’s first and second calving was calculated, if present. Since farmers’ assiduousness to record varied according to farms and variables (e.g. lameness, mastitis, and Johne’s test results), only accurate health variables with a sufficient number of observations were extracted from TotalVet and included in the analysis. This included heifer’s last titre against Johne’s disease in first lactation and heifer’s farm status at the end of study, i.e. present, dead and absent (culled or dead).

→ Statistical analysis.

Computer data entry was done using Microsoft Excel and Access (2013). Data on farm’s and heifer’s demographic, management, production, reproduction and health were coded and checked before being entered into the database.

A descriptive analysis was conducted in STATA 12.1 (STATA Inc., Texas, USA) to summarise the different variables. Moreover, an analysis was conducted to compare IM and BTM ELISA results obtained for each farm for O. ostertagi, expressed as optical density ratio (ODR). Farmers' practices of cattle helminth control were also described.

A multilevel linear model was built to identify the demographic and management factors associated with heifer exposure to O. ostertagi on pasture (expressed as ODR). In addition, three sets of multilevel statistical modelling analysis were conducted to identify: (1) the association between heifer's IM ODR and heifer's milk production at both sampling and day 305; (2) the association between heifer's IM ODR and heifer's health, i.e. levels of milk antibodies against Johne's disease and heifer's farm status at the end of the study (i.e. April 2016); and (3) the association between heifer's IM ODR and heifer's reproduction performances, i.e. offspring's survival at first calving and likelihood to calve for a second time after a first calving.

2.2.2. Qualitative study

The qualitative study aimed to broaden the scope of analysis of farmers' helminth control practices. For that, through in-depth, qualitative interviews with dairy cattle farmers in England, it explored key aspects that have been overlooked in the available literature. These include how farmers build their knowledges and define their practices in relation to cattle helminth infections, and how these intersect with farmers' values and concerns.

Semi-structured face-to-face interviews were conducted with the main manager of the farms selected for the quantitative study. All farmers signed an informed consent form beforehand, agreeing with the terms and conditions of the study. Of the 42 respondents (two farms belonged to the same manager), 36 were male (86%) and 6 were female (14%); 7 (17%) also had sheep on-farm. Interview schedules were pilot-tested to identify questions that could be confusing, any missing topics, and to rephrase any sensitive questions. Interviews lasted on average 35 minutes (from 15 to 90 minutes) and were audio-recorded. Interviews were transcribed by a third party, checked and imported into the software NVivo 11 (QSR, International) for qualitative analysis. A systematic coding process was used to identify emerging themes in the interview transcripts (i.e. thematic analysis) (Coffey and Atkinson, 1996). Through an iterative process, emerging themes and sub-themes were identified and refined until data saturation was achieved (Silverman, 2014).

3. Key findings of the project and discussion

This section provides an overview of the key findings and outcomes of the project. Further details and reflections on cattle helminth control and implications for policy and practice are - or will be – available in corresponding peer-reviewed publications (some of which are present section 5 of this report).

It is important to note that the following observations do not infer a causal relationship between helminth infection/exposure and production and management variables but raise questions about the observed associations. Therefore, the reported associations would need to be confirmed in further intervention studies.

3.1. Evaluation of individual milk antibody levels as a marker of Ostertagia ostertagi infection in heifers

- We observed a high repeatability of the Svanovir® O. ostertagi ELISA kit (pilot study not shown) that supports previous findings of research done with adult cows.
    - ⇨ This kit therefore represents a very good candidate for conducting extensive longitudinal studies of O. ostertagi infections in cattle (i.e. for at least a 2-year period).

- There was a moderate correlation between heifer’s IM and BTM ODR.
    - ⇨ IM ODR values might therefore provide more information about the herd exposure to O. ostertagi than a single BTM sample.

- Several individual parameters, more specifically DIM, milk yield, SCC and breed, were likely confounders in associations of ELISA results with other variables.
    - ⇨ These parameters need therefore to be taken into account before interpreting ODR values from heifer’s IM samples.

3.2. Prevalence of helminth single- and poly- infections in slaughter cattle in England and Wales

- Carcase prevalence of ostertagiasis was 89% (828/933), as opposed to 29% (272/951) and 25% (231/936) for liver and rumen fluke, respectively.

- At farm-level, 97% (149/154), 48% (73/153) and 64% (98/152) of the producers had at least one carcase with signs of ostertagiasis, adult rumen fluke and lesions due to liver fluke, respectively.
  - ⇨ Infections due to Ostertagia spp. seem predominant and ubiquitous among cattle and cattle farms in England and Wales.
  - ⇨ However, liver and rumen fluke should also be viewed as a significant threat for the cattle industry in England and Wales.

- In total, 39% (N=351) of the carcases had signs of co-infections.
  - ⇨ This confirms the need to consider and integrate profiles of poly-parasitism, while making decision on cattle helminth control in England and Wales.

- Although the presence of both fluke species was associated, i.e. only 3% (6/219) and 6% (15/255) of infected animals had single-infection with rumen and liver fluke respectively, only 47% (N=102) of the animals infected with adult rumen fluke had also signs of lesions due to liver fluke.
  - ⇨ Similar environmental requirements and common microclimate and microhabitat shared by the three helminths and their intermediate hosts may explain some of co-infection profiles in cattle, but not entirely (Viney and Graham, 2013).
  - ⇨ Different lymnaeid communities can act as intermediate hosts for the two fluke and, in the UK, snails other than *Galba truncatula* may play an important role as intermediate host (Dreyfuss et al., 2014). Under these circumstances, competition between either helminths or intermediate hosts, especially for food in colonised habitats, can explain an important number of single-infections due to adult rumen fluke (Dreyfuss et al., 2014).
  - ⇨ Cattle anthelmintic treatments or management practices on farms may also generate different patterns of co-infections (Gordon et al., 2013) that would need to be further explored.

3.3. Performances associated with Ostertagia spp., liver fluke and rumen fluke single- and poly-infections in prime beef carcases

- The sole presence of lesions due to liver fluke was significantly associated with lower carcase conformation, i.e. -3.65 points (95% C.I.: -6.98;-0.32) in the numerical scale of carcase conformation, compared to carcases free of the 3 helminths.

- No such association was observed with CCW or fat classification. However, if combined with Ostertagia spp. and rumen fluke, the presence of liver fluke was significantly associated with lower CCW, i.e. -48.28 kg (95% C.I.: -88.35;-8.21), compared to carcases free of the 3 helminths.
    - ⇨ Gastro-intestinal nematodes and liver fluke may negatively affect host performances through different mechanisms (Loyacano et al., 2002).
    - ⇨ If present simultaneously, the resulting effect of the helminths on CCW might be additive (Loyacano et al., 2002).

- Slaughter cattle with single-infection of either ostertagiasis or adult rumen fluke had, on average, significantly lower CCW, i.e. respectively, -30.58 kg (95% C.I.: -50.92;-10.24) and -50.34 kg (95% C.I.: -88.50;-12.18), and lower fat class, i.e. respectively, -3.28 points (95% C.I.: -5.56;-1.00) and -5.49 points (95% C.I.: -10.28;-0.69), than carcases from helminth-free animals.
- Carcases with both lesions due to *Ostertagia spp.* and adult rumen fluke had significantly lower CCW, i.e. -39.99 kg (95% C.I.: -73.09;-6.88), compared to carcases free of the three helminths.
    - ⇨ The current results on the single effect of Ostertagia spp. on CCW and fat classification agree with previous intervention studies on beef cattle (Suarez et al., 1991; Loyacano et al., 2002), but contradict a recent abattoir survey in which no similar association was reported, though there was an effect on conformation (Charlier et al., 2009). It is likely, in this case, that the lower specificity of O. ostertagi ELISA used in the latter study combined with the inclusion of only adult cows and the non-control of other helminth infections in the model, explained such differences.
    - ⇨ These results bring into question the widely held view in Europe that adult rumen fluke are relatively benign and well tolerated by their host, contrary to tropical regions where its high pathogenicity was confirmed (Fuertes et al., 2015).
    - ⇨ Given in the current study there were only a few animals solely infected by rumen fluke, there is a need for further investigations into the pathogenicity of adult rumen fluke in cattle. In addition, what cannot be ascertained in the current study is whether any of the animals that were positive for adult rumen fluke may also have been infected with juvenile fluke in the duodenum; these stages are known to be highly pathogenic when present in large numbers (Zintl et al., 2014).

3.4. Production, reproduction and health factors associated with individual milk antibody levels against O. ostertagi in heifers

- For each 0.1 unit increase in heifer's IM ODR, heifer's milk yield at sampling declined by 0.26 kg (95% C.I.: -0.40;-0.13). No significant association was identified between heifer's IM ODR and heifer milk yield at day 305. After controlling for other variables, there was no significant association between heifer's yields in protein and fat and heifer's IM ODR.
- A 0.1 unit increase in heifer's IM ODR was significantly associated with a 0.48 unit (95% C.I.: 0.16;0.61) increase in heifer's titre for Johne's disease in first lactation.
- Heifer status on-farm was only significantly associated with heifer's IM ODR when comparing the groups of heifers 'present' and 'dead' on-farm at the end of the study (April 2016). After controlling for other variables, a 0.1 unit increase in heifer's IM ODR increased the odds for a heifer to be dead by 1.12 units (95% C.I.: 1.01-1.25).
- After controlling for other variables, the odds for a heifer to have a dead calf at first calving significantly increased by 1.11 units (95% C.I.: 1.03-1.19) for each 0.1 unit increase in heifer's IM ODR.
- After controlling for other variables, the hazard for a heifer to calve for a second time at a time *t* decreased by 0.95 unit (95% C.I.: 0.90- 0.99) for a 0.1 unit in heifer's IM ODR.

3.5. Demographic and management factors associated with individual milk antibody levels against O. ostertagi in heifers

- Regardless of anthelmintic treatments, heifer's IM ODR was significantly positively associated with heifer's length of grazing. Increased heifer's IM ODR was also significantly associated with high stocking rate at first grazing but not at subsequent grazing seasons (i.e. second, third and fourth grazing season). Heifer co-grazing with adult cows for at least 14 days around calving significantly increased heifer's IM ODR.
- After controlling for other variables (including some levels of farm's exposure to F. hepatica), higher frequencies of grass mowing in heifer's pastures and heifer mixed grazing with sheep significantly decreased heifer's IM ODR. Farm's labour and farmer's conscientiousness (e.g. vaccinating and supplementing animal with feed) were also significantly associated with lower IM ODR in heifers.

3.6. Knowledges and values of dairy farmers towards cattle helminth infections

Two main themes emerged from the qualitative study: the first related to farmer's epistemology of helminth infections (i.e. the nature of farmer's knowledge and what they consider as valid knowledge) and the second, to farmers' rationales and practices in helminth control.

- Results suggest that farmers build their knowledge on cattle helminths through interaction with others (e.g. veterinarians and fellow farmers) and by sharing both experiences and knowledge. In this process of knowledge building and knowledge exchange, farmers are proactive and critical assessors with regard to the validity and suitability of that knowledge to their past experience, management and business sustainability.
- Time and financial resources are key determinants of farmers' attitudes towards cattle helminth control. Moreover, farmers mainly use Macrocyclic Lactones and pour-on, advocating their need to use convenient and safe drugs.
- Despite their intentions to do so, farmers often face barriers to implement recommended 'best practice' on cattle helminth control, which lead them to highly rely on anthelmintic drugs.
    - ⇨ Despite their intentions to better control helminths, farmers often face challenges when managing sub-clinical parasite disease and have difficulties in adopting guidelines that usually prove to be inadequate to their farming system.
    - ⇨ Farmers are interested in improving their practices if evidence of the benefits of such control are provided.
    - ⇨ Farmers highly value their expertise and trust their own judgment when making decisions on farm.
    - ⇨ If guidelines are expected to be accepted and adopted on-farm, policy makers need to take into account farmers' perspectives and their contextual challenges. This requires more constructive dialogues with farmers and opportunities for farmers to have a real input in the governance of cattle helminth control in the UK.

4. Concluding remarks and industry messages

Overall, the research has shed light on important epidemiological patterns and key factors that influence the control of cattle helminth infections in England and Wales. This work confirms the ubiquity of O. ostertagi infections and the significant presence of F. hepatica infections, in beef and dairy cattle, in England and Wales. It also suggests that rumen fluke infection is well established and that poly-infections to O. ostertagi, F. hepatica and rumen fluke are very common in cattle in this region. Importantly, this research is the first of its kind investigating the negative effects (1) of several helminth infra-communities on carcase performances in prime-beef cattle and (2) of O. ostertagi exposure on milk production, reproduction and health performances in dairy heifers. Considering that young-stock is the future of beef and dairy herds, the observed associations, if confirmed causal, would justify an urgent need for farmers to implement more effective and strategic control against *O. ostertagi, F. hepatica* and rumen fluke in England and Wales, as well as in the UK more broadly.

The research suggests that there are alternative strategies, potentially more desirable, for helminth control in dairy young-stock that could replace the use of anthelmintic drugs. For example, different types of grazing management practices can help with reducing dairy heifer exposure to *O. ostertagi* on pasture at specific times during their first years of grazing. These include to avoid exposure in the most susceptible periods of heifer's life, i.e. their first season of grazing and their pre-calving period, and to encourage frequent mowing of grass in heifer's pasture. Mixed grazing with sheep might also reduce heifer's exposure to *O. ostertagi*. However, this should be considered in relation with *O. ostertagi* only, since other helminths can be shared between sheep and cattle (e.g. liver fluke). In this context, there is a need to further explore patterns of helminth co-infections in the UK and expand the current research to other contexts of farming and pressures of helminth infections.

Most importantly, if we are to guarantee the transition in management practices and improvements on cattle helminth control in England and Wales, as well as in the UK, there is a need to also ensure and foster understanding between experts and farmers. As suggested by the results of the qualitative study, the tendency of experts to overlook and even neglect farmers' knowledges and the contextual challenges they face, might undermine farmers' trust on expert opinion and might compromise the uptake of expert-based guidelines for cattle helminth control. As a consequence, it is only through constructive dialogues between experts, as those responsible for developing guidelines, and farmers, that opportunities will be created for these actors to improve cattle helminth control in the UK. In this regard, the use of participatory research methods, such as the one included in this project, and other deliberative activities can be very useful. These methods allow different actors to, firstly, bring in their perspectives while evaluating the context of cattle helminth control and, secondly, to foster constructive dialogues while making decisions on it. Conflicting views of different actors could therefore be integrated into decision-making processes so that a 'compromise solution' through mutual agreement can be reached. This way, by taking on board a diversity of concerns and interests, recommendations for best-practice in cattle helminth control are likely to be more adequate, acceptable and lead to more sustainable practices.

5. Current research outputs

The contents of the beef study are published: Bellet, C., Green, M. J., Vickers, M., Forbes, A., Berry, E., Kaler, J. (2016). *Ostertagia spp*., rumen fluke and liver fluke single- and poly-infections in cattle: an abattoir study of prevalence and production impacts in England and Wales. Prev. Vet. Med. 132, 98-106.

The contents of the dairy study related to demographic and management factors associated with heifer's IM ODR are submitted: Bellet, C., Green, M.J., Bradley, A.J., Kaler, J.,. A longitudinal study of gastrointestinal parasites in English dairy farms. Practices and factors associated with first lactation heifer exposure to Ostertagia ostertagi on pasture. J. Dairy Sc. (submitted).

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