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Original Article

Parasite control in organic cattle farming: Management and farmers' perspectives from six European countries

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ABSTRACT

Organic ruminant production is expanding in the EU, but parasite management remains a constant challenge. Mandatory outdoor access for all age groups can increase exposure to pasture borne parasites, whilst restrictions in the prophylactic use of anthelmintics can limit parasite control. The scientific community has been working to deliver effective parasite control strategies and alternative approaches in order to slow down the development of anthelmintic resistance (AR). However, the current parasite control practices and overall awareness with regards to AR and alternative approaches on farms are largely unknown and may be causing a knowledge gap between the scientific and farming communities. Therefore, a structured survey was conducted in six European countries (Switzerland, Germany, Denmark, Netherlands, Lithuania, Sweden) to provide basic data on practices, management and farmers' perspectives for grazing and parasite control (gastrointestinal worms and liver flukes) on organic cattle farms. Overall, 375 surveys were collected (282 dairy and 93 beef farms) in 2015–2016, and analysed descriptively. Additionally, surveys from the 228 dairy farms were assessed using a double-hurdle adoption model to identify the factors involved in the decision to drench against gastrointestinal parasites. Generally, there are prominent differences between countries, with monitoring methods differing especially, which has important implications in terms of knowledge transfer. For example, media warning was the most common method in DE, while antibody testing in bulk tank milk was the common method in NL. In other countries, clinical signs (diarrhoea, hair coat quality, and reduced weight or yield) and liver condemnation data were used frequently. In general, organic farmers from the six participating countries indicated that they would accept alternative approaches despite greater cost and labour. The likelihood of drenching were higher on farms with smaller farm areas, higher number of young stock and total livestock units and farms where faecal egg counts were used to monitor the parasites. In conclusion, it was evident that grazing and parasite management varied between the countries even though they operate under the same basic principles. Parasite management strategies must therefore be country specific and disseminated with appropriate methods.

1. Introduction

Within the EU, the total organically cultivated area has doubled from 2002 to 2015, and the number of certified organic farms increased despite the decreasing total number of agricultural farms within the same period (DG Agriculture and Rural Development, 2016). The trend is also seen at the level of individual EU member states, e.g. Denmark experienced a ten-fold increase in the number of organically reared

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cattle from 1995 to 2017 (Danmarks Statistik, 2018) and the proportion of organic milk delivered was a record high (12%) in the first quarter of 2018 (Larsen, 2018). There has also been a tremendous increase in Sweden where approx. 14% of the total milk production was organic in 2018 (Poole and Ren, 2018). However, despite the perceived benefits of improved animal health and welfare in organic beef and dairy production, there are also some inherent challenges related to the organic standards (Vaarst et al., 2001; Nielsen and Thamsborg, 2005; Sutherland et al., 2013).

Firstly, one of the core principles of organic animal husbandry is that physiological and behavioural needs of the animals are met, and therefore all ruminants in organic systems should have access to roughage daily and grazing throughout the entire grazing season (IFOAM, 2012). This inevitably leads to higher exposure to pasture-borne parasites such as gastrointestinal nematodes (GIN), lungworms, and liver flukes (*Fasciola hepatica*). In Sweden, poor weight gain and diarrhoea in the first grazing season calves, which may be due to parasitic infections, were more frequently reported from organic than conventional herds (Svensson et al., 2000). Similarly, more organic cattle herds were found to be infected with liver flukes as compared to conventional herds according to the Danish meat inspection data from 2011 to 2013 (53.5% and 40.4%, respectively) (Olsen et al., 2015).

In addition, veterinary medicines are considered 'synthetic' in traditional organic terminology and their use in organic livestock production is discouraged by a mandatory, extended (doubled) withdrawal period (IFOAM, 2012). All cattle older than 6 months, regardless of organic or conventional rearing, are required to have outdoor access for at least 2 to 4 months in Sweden, but bulk tank milk antibody levels for brown stomach worm (*Ostertagia ostertagi*) were still higher in organic than in conventional cattle herds in Sweden (Höglund et al., 2010). The authors suggested that this trend was partly due to application of less treatment in organic farms. Despite the general interest in improving the herd health, parasite-related diseases are probably one of the areas where organic farming may fall behind conventional production in terms of health and welfare of the animals (Lund and Algers, 2003).

Therefore, suggestions for integrated parasite control such as reduced stocking rate and grazing management with limited drug use for organic production systems have been recommended by the scientific community (Thamsborg et al., 1999; Thamsborg and Roepstorff, 2003; Waller, 2006). Beyond the higher exposure due to mandatory grazing, the development of anthelmintic resistance in small ruminants and increasingly also in cattle is a growing problem (Demeler et al., 2009; Baiak et al., 2018). Although the use of anthelmintics is discouraged, they are still often used in organic systems and anthelmintic resistance is a problem also for organic farmers (Peña-Espinoza et al., 2014). New strategies which consider the refugia approach to slow down the dynamics of resistance have been developed by scientists in recent years (Charlier et al., 2014). However, technology readiness levels (TRL) of these strategies are still low and implementation of these strategies in reality is questionable due to potential increases in costs and labour. Feasibility in terms of economic and non-monetary aspects is important in decision making in disease prevention, but this has been largely neglected in the current parasite research, especially in organic production. Additionally, it is unknown if the common knowledge among the research community is appropriately transferred to the farmers; there could be a gap between the scientific community and the stakeholders. This study, as part of a European project (CORE Organic funded), therefore tried to address these issues. This particular study aimed; 1) to generate descriptive and quantitative data on organic cattle farming across Europe and their current parasite management strategies, 2) to assess the factors involved in farmers' decision to use anthelmintics, and 3) to determine the farmers' acceptance in implementing alternative/integrated approaches for improved parasite control. Both monetary and non-monetary aspects of farmers' disposition towards the perceived benefits of alternative approaches were assessed.

2. Materials and methods

2.1. Questionnaire

A structured questionnaire was developed in order to collect cross-sectional data on organic cattle farming in six European countries (CH: Switzerland, DE: Germany, DK: Denmark, NL; Netherlands, LT: Lithuania, SE: Sweden). The questionnaire consisted of 11 main questions (Supplementary file 1). Questions 1–3 asked about the basic farm characteristics (years in organic production, number of animals, approximate size and type of land on the farm). Questions 4 and 5 asked about the grazing routines (number of hours grazing in summer and winter, use of pasture management to control GIN and liver flukes). Question 6 asked how the farmers monitored their animals for GIN and liver flukes. Questions regarding anthelmintic treatments were asked in question 7 and 8 (the age groups treated, and treatment frequency and timing for GIN and liver flukes separately). Question 9 asked farmers' disposition towards the rise of anthelmintic resistance (AR) and perceived benefits of alternative approaches, measured on a 5-point Likert response scale (e.g. from strongly agree to strongly disagree; Likert, 1932). Lastly, whether the AR status had been tested and confirmed on the farms was requested in question 10 and 11. The questionnaire was first developed by the authors in English and then translated to the local languages. It was piloted with two cattle farmers by telephone in Switzerland.

2.2. Selection of the farms and interview forms

The aim was to collect a minimum of 40 surveys from each country and assuming an estimated response rate of 30%, at least 140 farms per country would need to be contacted. Each country developed their own selection criteria to survey the most representative study populations according to local differences in e.g. average herd size and total number of organic farms among the participating countries. Each partner in this project had their own network, experience and funds for conducting this interview, and therefore an interview form that was expected to yield the best return rate was chosen for each country. Sampling bias due to a lack of uniform randomisation may be present in some partner countries (DE and NL) and some caution should be paid when comparing the results. The interviews were conducted in 2015–2016. The number of farms, selection criteria and interview forms are summarised in Table 1. A total of 375 surveys were available from six countries: 282 organic dairy farms from CH, DE, DK, LT, NL and SE, as well as 93 organic beef farms from CH, DK, and LT.

2.3. Statistical analysis

All analyses were performed in STATA 15.1 and R (R Core Team, 2017). The answers of each question were tabulated by country and the results are summarised in Tables 1–2 and Figs. 1–6, with most figures shown as proportions. The subtotal of each question may differ from the total number of farms included in the questionnaire in some cases, as not all farms had growing animals or answered the specific questions. The maximum number of missing values was 8. Additionally, for grazing management and monitoring against liver fluke infections (Figs. 2 and 3b), only those who identified liver flukes as a significant problem and answered questions were included in the subtotal. For question 9, Swedish farmers who answered having no opinion towards the statements were excluded from the summary (up to 26 surveys).

To determine the factors associated with the decision to drench, a regression model was developed with the average number of drenches per year per animal as the dependent variable. This model was limited to dairy farms and only developed for GIN treatments, not for flukicide treatments, as few farms used flukicides. Furthermore, as only limited drenching of lactating dairy cows was observed, the analysis of the factors associated with the decision to drench was only undertaken on

Table 1
The number of farms, selection criteria and interview forms in each country (CH = Switzerland, DE = Germany, DK = Denmark, LT = Lithuania, NL = Netherlands, SE = Sweden).

Type	Country	Number of farms	Selection criteria (N = total number of farms that meet selection criteria)	Interview form	Time of interview
Dairy	CH	46	Farms with minimum 5 adult cows and at least 30% young stock were selected (*N* = 1039) and divided into three groups based on herd size (big, intermediate and small), and 50 farms were randomly selected from each group.	Phone	Winter 2015/2016
Dairy	DE	43	Farms in Bavaria region voluntarily enrolled for a study on risk factors for the transmission of *Fasciola hepatica* in organic farms (*N* = 45). All farms had to allow grazing.	Phone	Winter 2015/2016
Dairy	DK	84	A total of 100 farms were randomly selected from a list of all organic dairy farms with minimum 100 animals (*N* = 351).	Phone	Spring 2016
Dairy	LT	42	Farms with a minimum of 5 adult cows (*N* = 391) and 42 farms were randomly chosen.	Phone	Winter 2015/2016
Dairy	NL	24	Farms from another on-farm research project were included as well as respondents to an open invitation.	Interview during farm visit and questionnaire	Winter 2015/2016 and Spring 2016
Dairy	SE	43	A total of 60 organic farms across Sweden were randomly selected from a list provided by the Board of Agriculture.	Phone	August 2016
Beef	CH	33	Farms with minimum 5 adult cows per farm (*N* = 120), 50 farms were randomly selected.	Phone	Winter 2016/17
Beef	DK	36	A total of 60 farms were randomly selected from a list of all organic beef farms with a minimum of 30 animals (*N* = 140).	Phone	Spring 2016
Beef	LT	24	Farms with minimum 5 adult cows (*N* = 148) and 24 farms were randomly chosen.	Phone	Winter 2015/2016

animals being reared as replacements (up to two years of age). The final dataset used for this model consisted of 228 data points after removal of missing values. The dataset excluded answers from SE, as they contained a large number of missing values.

Even though the model data were restricted to young cattle data, the dataset still comprised a large number of observations with no application of drenching, and therefore a standard Poisson regression model was unsuitable. According to Humphreys (2013), the correct choice of estimator depends on the reason for the zeros in the data. There could be three explanations: 1) the zeros represent the true choice of the farmers, 2) the zeros represent either missing or non-response outcomes, or 3) the zeros represent a decision that the farmer had no control over for some reason. The first explanation is the most plausible for our dataset, as missing data were discarded. Additionally, the use of drenches is a widely available method and therefore the decision not to drench was likely to truly reflect the farmers' choice. We also assumed that the decision to drench and the frequency of drenching per year were made simultaneously. Following Humphreys (2013), we thus fitted a Poisson-logit hurdle model. The logit part of the model indicates if drenching is applied and the Poisson part estimates the typical number of drenches per year.

The following 15 variables were hypothesised to have a relationship with drenching and included in the model; total farm area, number of young stock on the farm, total number of animals on the farm, years under organic farming, contact to vet, use own experience, do faecal analysis, signs of diarrhoea, hair coat quality, production loss, application of a low stocking rate, young stock grazes low risk areas (defined 'pastures or land after a previous non-grazing utilisation' e.g. hay or cutting for silage) or new leys in arable rotation (e.g. aftermath), grazing duration for young and growing animals, and the attitude index. The attitude index indicated the overall farmers' willingness and open mindedness to alternative parasite control methods. The index was created using principal component analysis based on six attitude statements corresponding to question 9 in the questionnaire. The variables used were tested for collinearity, with no issues observed. As the number of samples in each country was not directly indicative of the total number of dairy farms per country or in the entire population, the number of samples in each country was weighted in the model. The inverse probability of the selection of a farmer in a given country was used to address the known shortcomings inherent in the sampling approach and more adequately reflect the importance of individual sampling units. Furthermore, we adjusted for clustered standard errors to obtain unbiased results. This specifies that the standard errors allow for correlation within the country groups. Organic farmers in one country follow similar regulations and often share similar values. Therefore, we assumed that observations are independent across clusters (countries), but not necessarily within clusters.

3. Results

3.1. Farm description

The number of farms involved in the study varied between countries from 24 (NL) to 84 (DK). Differences in herd size and production systems were also observed across the different countries. For dairy production, DK organic farms had the largest average herd size, followed by NL. Transhumance (short term/seasonal grazing e.g. mountain grazing, not considered as grazing strategy against parasite infections) was common in CH, while this was uncommon in DE and NL and nonexistent in DK and LT. Data on beef production was available from only three countries (CH, DK, and LT). The average herd size was largest in LT, while DK beef farmers had the largest areas. Average years in organic production varied from 10 to 20 years (LT and NL, respectively) (Table 1).

Table 2
The summary statistics of the farms involved in the study in each participating country (CH = Switzerland, DE = Germany, DK = Denmark, LT = Lithuania, NL = Netherlands, SE = Sweden).

Type	Country	Number of farms	Average number of cows per farm (min-max)	Average years since conversion (min-max)	Average total farm area in ha (min-max)	Trans-humance (% yes)
Dairy	CH	46	25 (5–85)	12 (1 – 22)	27.1 (11–65)	76
Dairy	DE	43	37 (6–93)	17 (0.5–34)[a]	39.1[b]	33
Dairy	DK	84	181 (50–520)	19 (3–26)	248.7 (12–850)	0
Dairy	LT	42	35 (10 – 132)	11 (5–15)	49.9 (7–200)	0
Dairy	NL	24	80 (30–193)	20 (6–35)	67.0 (27–150)	14
Dairy	SE	43	74 (30–400)	15 (4–45)	78.3[b]	NA
Beef	CH	33	16 (0[c]-40)	14 (2–25)	24.8 (4–47)	73
Beef	DK	36	30 (0[c]-160)	19 (6–36)	134.9 (6–1500)	0
Beef	LT	24	59 (11–140)	10 (3–16)	82.2 (23–180)	0

NA: information not available.
[a] Based on 42 farms as 1 missing value.
[b] Estimated value based on average of the sum of the areas used for "permanent pasture" and "arable cropland and permanent pasture and crops".
[c] Some farms only had young stock.

3.2. Grazing management, monitoring and control of GIN and liver flukes

All cattle, regardless of age groups were typically grazed for more than half a day during summer in the six countries, although approximately half of the farms allowed cows to graze only up to 12 h in CH, DE, and DK in summer. In contrast, dairy cows were in general housed during winter. However, beef cattle from approx. half of DK and LT beef farms were also on pasture in winter (Fig. 1). We also asked about grazing management for control of GIN and flukes implemented on the farm. Generally for GIN control, young stock grazing on low risk areas was more commonly implemented in dairy farms, except in SE. Use of lower stocking rate was more common in beef farms. The grazing methods used for control of the liver flukes showed more variations between the countries. Drainage was the most common strategy employed in DE, LT and SE, while it was the least common practice in DK. Fencing around wet areas and moving animals from wet to dry pastures during grazing seasons were commonly practiced in DK (approx. 50% of the farms), while these strategies were uncommon in CH and DE (Fig. 2). The proportions of the farmers who responded that liver fluke was diagnosed on their farm by either laboratory or via slaughterhouse feedback were CH:49%, DE:74%, DK:43%, LT:31%, NL:46%, SE:54% for dairy, and CH:52%, DK:53%, LT:50% for beef.

The methods used to monitor parasite infections on farms differed greatly between the countries. For monitoring of GIN for example, clinical signs (diarrhoea, hair coat quality, and reduced weight or yield) were frequently used in CH and LT, especially by the beef farmers. Media warnings (information farmers can obtain through various media and articles in farmers' magazines on parasite management) was the most common monitoring tool in DE, while veterinary advice/recommendation was the most common in SE. Detection of antibodies was not frequently used, except for NL, where approx. 50% of the farms utilised antibody testing against GIN, fluke and lungworm in bulk tank milk. For liver fluke monitoring, liver condemnation was the most commonly used method in CH, DK, and LT. Media warning was again the most common method in DE, while antibody testing in bulk tank milk was the common method in NL (Fig. 3).

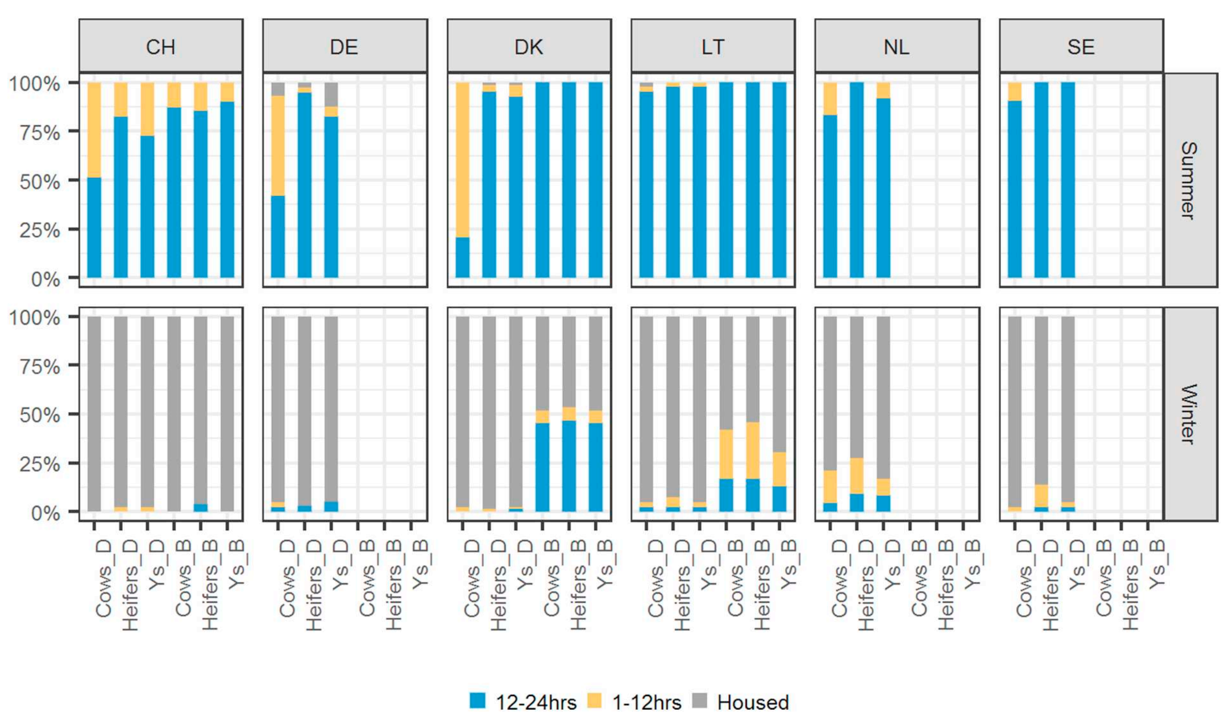

Fig. 1. Grazing time of organic dairy and beef livestock in summer and winter according to age groups in the participating countries (CH = Switzerland, DE = Germany, DK = Denmark, LT = Lithuania, NL = Netherlands, SE = Sweden, D = dairy, B = Beef, Ys = young stock).

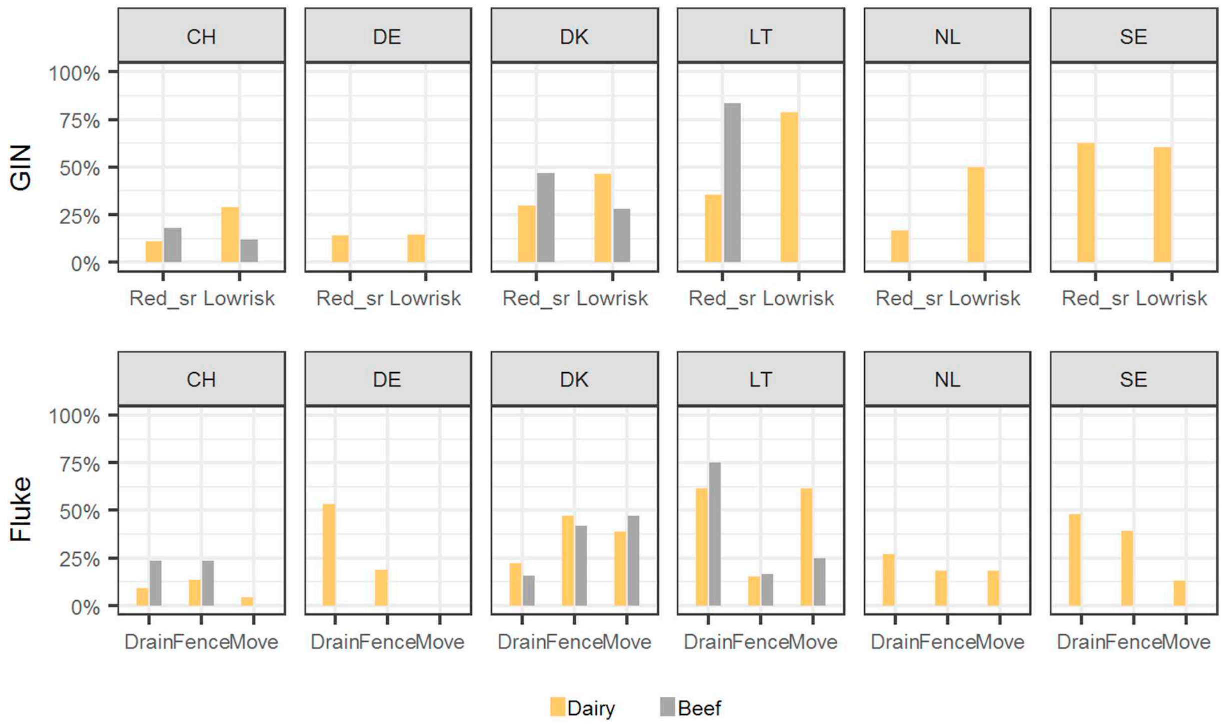

Fig. 2. The proportion of the farms implementing different pasture management to control gastrointestinal nematodes and liver flukes (CH = Switzerland, DE = Germany, DK = Denmark, LT = Lithuania, NL = Netherlands, SE = Sweden, Red_sr = reduced stocking rate, Lowrisk = Young stock grazing in low risk area, Drain = pasture drainage, Fence = fencing out ponds & streams, Move = Moving from wet to dry pastures during grazing season).

For drenching strategies, only the answers concerning GIN are presented since there were few farms treating against liver flukes. In all countries, drenching (yes/no) was more commonly applied to young animals (heifers: 1–2 years of age or young stock: 0–1 year of age) than cows. Group wise treatment was generally more common than selective drenching of individual animals. Drenching of young stock was fairly common (> 50%) in DE, NL, and SE, while drenching itself was uncommon in DK (< 50% farms) (Fig. 4). The average number of drenches per animal per year was under 1 and the number was higher for young stock (heifers and young stock) compared to cows in all countries (Fig. 5).

3.3. Farmers' dispositions towards AR and alternative approaches

The responses to the six statements are summarised in Fig. 6. For statement one (AR is an increasing problem), less than 50% of the organic farmers across six EU countries agreed to the statement overall. However, there was a large difference among the countries. In CH and NL the majority (> 50%) of the farmers thought AR was a problem, but this notion was less in other countries and disagreement was relatively high (> 25%) in DK and SE. When the farmers were asked if they would accept reduced production through less treatments to prevent further AR (statement two), approx. 50% of the farms especially from CH and LT agreed. However, agreement was low (< 25%) and the majority (approx. 50%) was opposed to the statement in DK. Overall, only approx. 25% of the organic farmers believed that the pharmaceutical industry would develop improved treatment or vaccines before AR becomes a problem (statement three). The proportion of the farms who agreed to the statement was highest in Sweden (approx. 50%), while disagreement rate was highest in Switzerland (approx. 50%) compared to other countries. The responses to the last three statements were generally similar. Statement four and five asked if the farmers would accept alternative control methods that may incur greater cost or labour, respectively. More than 50% of the farmers agreed to the statement overall, with agreement generally highest in DE and LT, while the lowest agreement was from SE. Approximately 40% of the Swedish farmers answered that they would not accept alternative methods if they incur greater labour input. Statement six asked about implementation of targeted selective treatment (TST): increased focus on monitoring and treating individual animals is a feasible worm control strategy. Agreement to the statement was high (> 50%) in all six countries.

3.4. Determinants of the decision to drench

The results of the double-hurdle regression model are shown in Table 3. The 'logit' component (factors associated with farmers' decision to treat against GIN) showed that the likelihood of applying treatment was higher if the farmers monitored parasites by FEC, and if the farm had a higher number of young stock and total livestock units. However, the farm area was negatively associated with the application of treatment, i.e. the farms with larger areas were less likely to give treatments. Analysis of the number of given treatments ('Poisson' component), showed that the farms who utilised a reduced stocking rate strategy to control GIN treated animals more frequently. Six other variables were shown to be associated with a reduced number of treatments; farms with more years in organic production, the farmers who were more open-minded regarding alternative control, the decision to drench based on own experience, diarrhoea, or hair coat quality, and the young stock grazing 12 h or less per day compared to > 12 h grazing.

4. Discussions

The present study aimed to obtain an understanding of current pasture and parasite management in organic cattle production systems and to survey farmers' disposition towards AR and alternative GIN control across six different European countries. Although the results were mostly presented as descriptive summaries, similarities and differences in organic production among the countries and production types (beef and dairy) were seen, an important consideration when constructing future studies or recommendations for parasite control in organic production. For example, the scale of organic production was

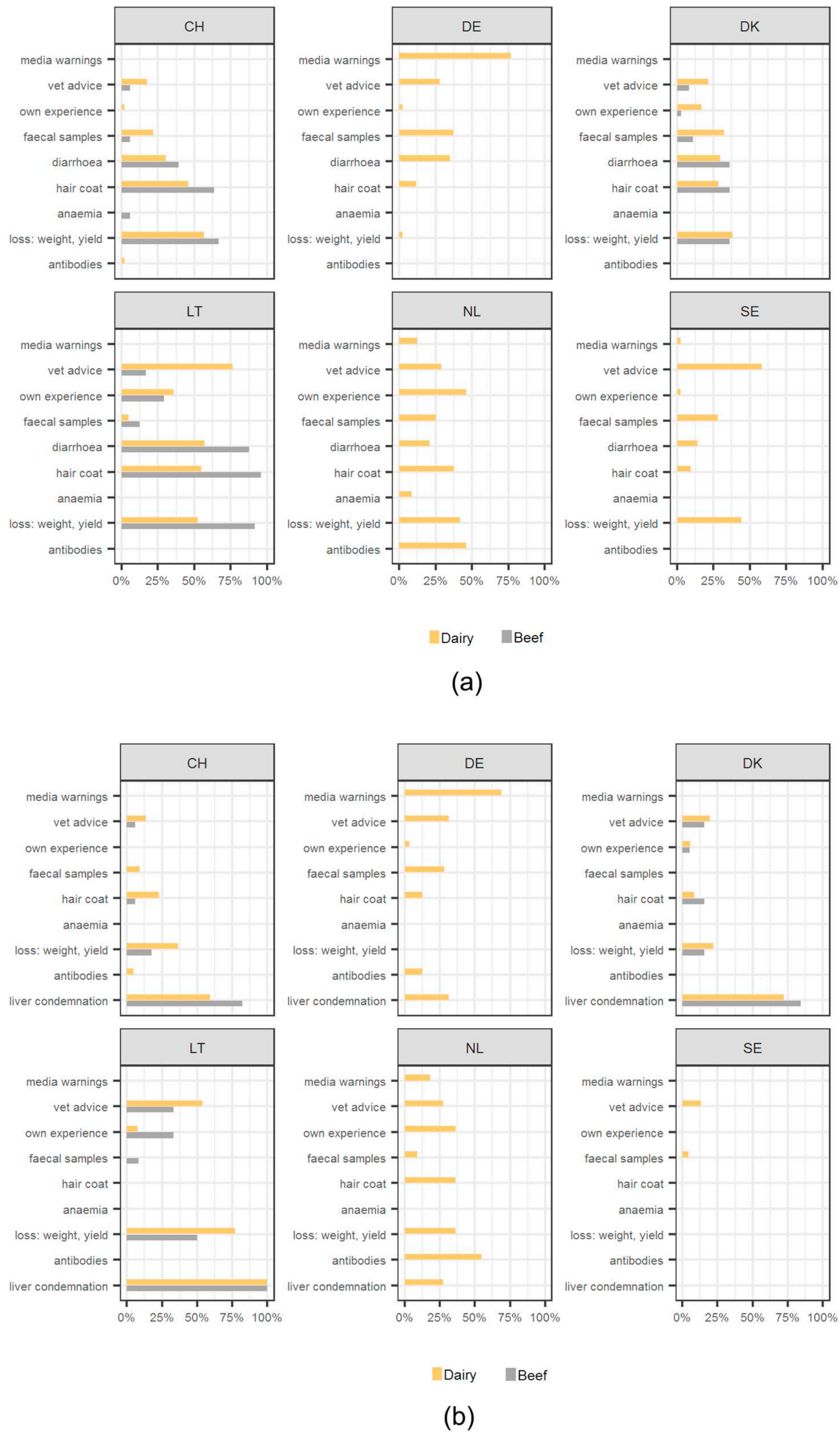

Fig. 3. The proportion of the farms implementing different monitoring methods for a) gastrointestinal nematodes and b) liver flukes (CH = Switzerland, DE = Germany, DK = Denmark, LT = Lithuania, NL = Netherlands, SE = Sweden, D = dairy, B = Beef).

smallest in CH (16 and 25 average number of cows per farm for beef and dairy respectively), whilst on the contrary, the average number of cows on Danish organic dairy farms participating in the study was > 100, comparable to the size of general dairy farms in the country (185 cows per farm) (Danish Agriculture and Food Council, 2018). Organic producers in the EU follow the same basic regulations, therefore it could be hypothesised that they have fairly homogenous grazing management, but the choice of parasite control strategies may differ due to differences in scale of production. In small ruminant productions, it is speculated that targeted treatment (TT: whole flock

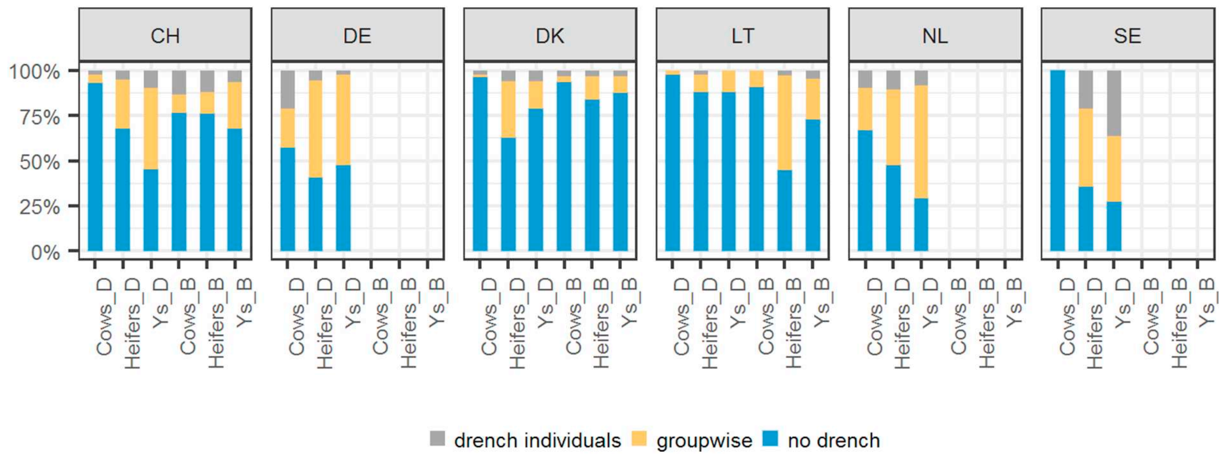

Fig. 4. Drenching strategy used for gastrointestinal nematodes (GIN) according to age groups (CH = Switzerland, DE = Germany, DK = Denmark, LT = Lithuania, NL = Netherlands, SE = Sweden, D = dairy, B = Beef).

treatment if a flock indicator deviates from a certain target) and targeted selective treatment (TST: selective individual animal treatment) are more likely to be adopted by large-scale producers, as these measures may require larger investments in animal handling facilities and performance monitoring systems (Morgan et al., 2013). This might also be true for cattle farms, in that larger farms are more likely to invest in control measures such as fencing and/or drainage on pasture. Likewise, if a farm has a small area available for grazing, movement of animals into different grazing areas and reduction of stocking rate may be difficult. This could be partly the reason for low proportion of the Swiss and German (Bavarian) farms (smallest farm areas) implementing reduced stocking rate, grazing of young stock on low risk areas and moving animals from wet to dry areas during grazing seasons (Fig. 2). Overall, the present study highlights the differences between countries possibly attributed to different scale of productions, as well as regulations and husbandry customs adapted to the local climates.

In general, it seems that the differences between the countries were more prominent than the differences between types of production, although data on beef farms were available from only three countries (CH, DK and LT). The beef farm response were similar to dairy farms in the same country in terms of pasture management, monitoring and drenching strategy of GIN and liver flukes (Figs. 2–4). However, differences between beef and dairy farms were clear in terms of daily grazing time (Fig. 1). In summer, half of the dairy farms in CH and DK allowed cows to graze only half day, while cattle in the majority of the beef farms in these countries grazed all day. Additionally, half of the beef farmers in DK and LT had animals out on pasture during the winter period. It is unknown (but likely) if these animals are offered hay and silage on pasture during winter. For parasite control, differences between half day and all day access to pasture in summer may be small. However, control strategies will differ if animals were on pasture all winter rather than being housed, because animals may continuously be exposed to infective GIN larvae or metacercariae and contaminate the field throughout the winter, assuming unembryonated eggs can survive the winter. This information is important when developing parasite control strategies for beef farmers in DK and LT.

The choice of monitoring methods for parasite infection also differed greatly among the countries (Fig. 3). The reasons are partly due to the availability of e.g. media warnings system and liver condemnation information from the slaughter house. The results show important connotations for the knowledge transfer with regard to parasite control. If, for example, farmers strongly depend on veterinary consultancy such as in SE, then the veterinarians need further education on innovative approaches on parasite control. If on the other hand, the farmers rely more on media warnings such as in DE, then investment in the development of web-based or social media platforms will be a more effective way of communication. To reduce the knowledge gap between the scientific community and farmers, the results of this questionnaire will help to identify the most appropriate communication methods for advisors and the research community to reach the farmers.

A high proportion of the farmers used indicators such as diarrhoea, hair coat quality and weight or yield loss to monitor nematode infection

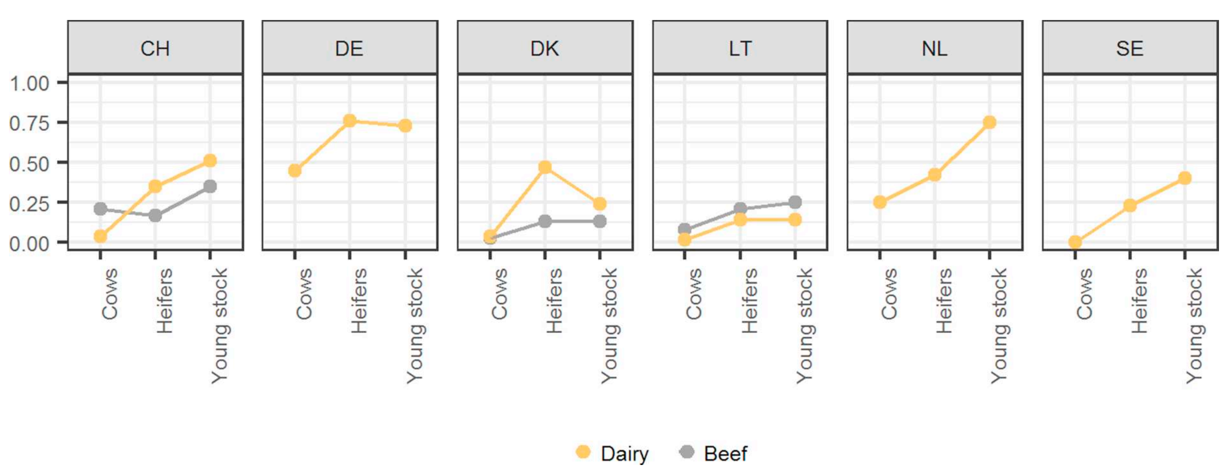

Fig. 5. Average frequency (per animal per year) of treatment against gastrointestinal nematodes (GIN) in organic dairy and beef farms in the participating countries (CH = Switzerland, DE = Germany, DK = Denmark, LT = Lithuania, NL = Netherlands, SE = Sweden).

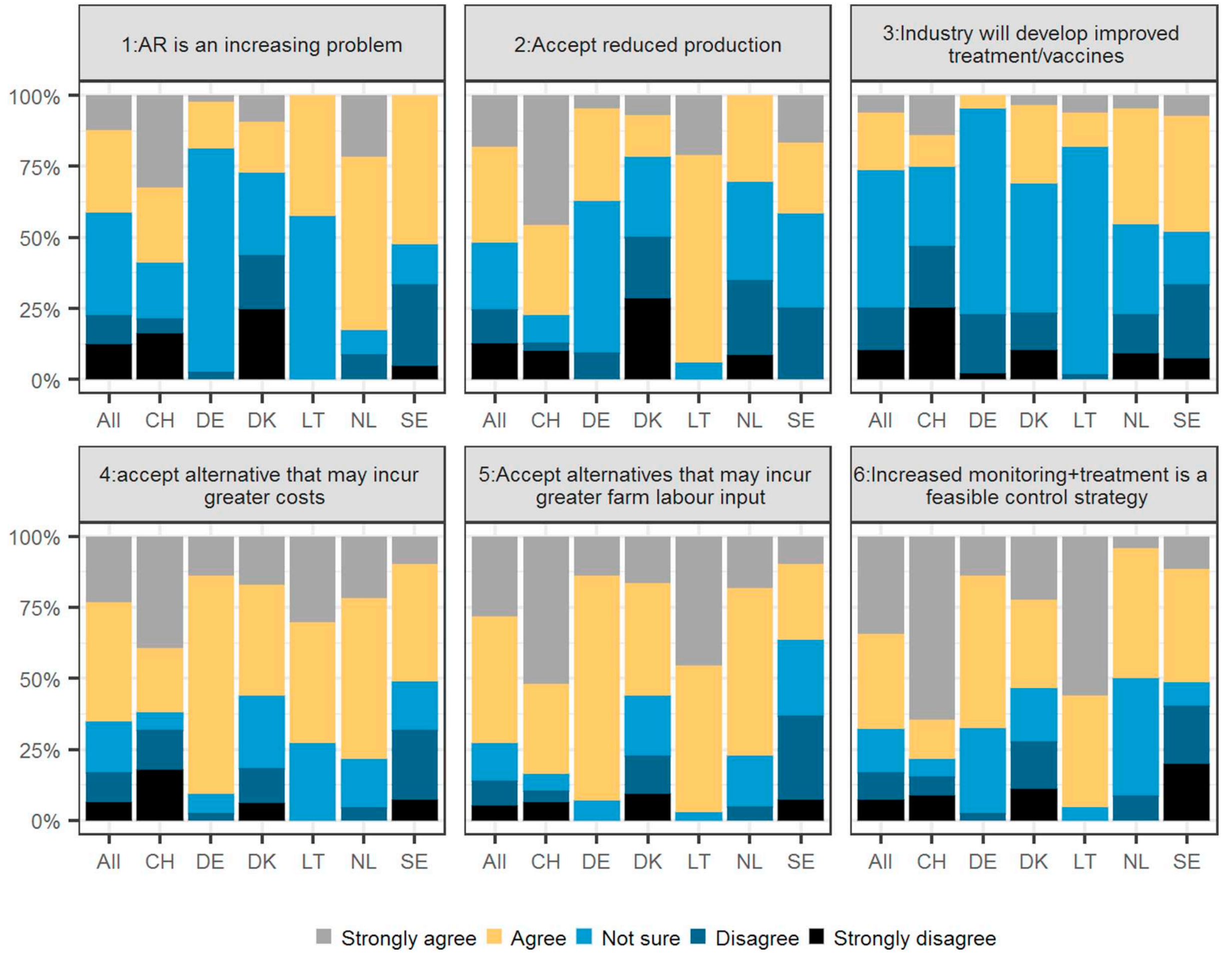

Fig. 6. The results of 5-point Likert-scale questionnaire on the six statements regarding the treatment and anthelmintic resistance (All = all countries, CH = Switzerland, DE = Germany, DK = Denmark, LT = Lithuania, NL = Netherlands, SE = Sweden). The six statements were 1) Anthelmintic resistance (AR) is an increasing problem, 2) To prevent further anthelmintic resistance farmers may have to accept reduced production through less treatments, 3) Industry will develop improved treatments/vaccines before resistance becomes a problem, 4) I would accept alternative control methods that may incur greater costs; e.g. monitoring, products or new equipment, analysis of faecal samples, 5) I would accept alternative control methods that may incur greater on farm labour input; e.g. sample collection, animal monitoring, and 6) increased focus on monitoring and treating individual animals is a feasible worm control strategy.

level. Even though diarrhoea and hair coat quality might be poor clinical signs due to their non-specificity, it may generally show the farmers willingness to look for individual characteristics of their animals, which is an indispensable prerequisite for TST. This is especially the case for small organic farms e.g. in CH, LT or SE, where a technical approach (e.g. automated weighing scales) might not be suitable due to high expenditure and reduced economies of scale. Most farmers across the countries use weight gain or milk loss as a sign to manage nematode infection (Fig. 3). As e.g. weight gain has been shown to be a good indicator for nematode control (Jackson et al., 2017), a TST based on weight gain might be promising in terms of acceptance by cattle farmers. This is supported by the statements of at least 50% or more agreement of farmers to accept innovations that may imply greater labour input.

The proportions of farmers that applied anthelmintics selectively were lower compared to those using group-wise applications (Fig. 4). TST is ideal for prevention of AR, as TST is shown to significantly reduce the number of anthelmintic treatments in calves (Höglund et al., 2013; O'Shaughnessy et al., 2014, 2015), thereby providing refugia. However, the same studies did not provide clear evidence of reduced egg counts and beneficial effect of production levels (Höglund et al., 2013; O'Shaughnessy et al., 2014, 2015; Berk et al., 2016). Technology readiness level of TST is therefore still low, but overall, approx. half of the organic farmers responded that they would accept reduced production levels with less treatments. DK was, however, an exception, where 50% answered that they would not accept reduced production levels when using alternative method of control (Fig. 6-2). This was possibly due to the large-scale production and considerations of financial competitiveness in DK (dairy), but may also reflect differing perceptions of short vs. longer term views on production and effects of AR. Reduction in anthelmintic use in such large farms is most desirable, if AR is to be hindered. It is probably noteworthy that reducing the frequency of treatment may not lead to reduced production by default. However, this statement ("would accept reduced production") was intended for farmers' disposition towards a worst case scenario. Overall, despite the fact that the farmers generally had positive attitudes towards the concept of TST (Fig. 6-6), it is crucial that future studies show that production is not compromised, or at least clearly show the long term financial benefits of using TST. Otherwise TST is unlikely to be widely accepted and TT will remain the principal method of parasites control as suggested by Charlier et al. (2014).

The additional costs and labour input associated with new control strategies may hinder adaptation by the livestock owners (Morgan et al., 2013). Our results show, however, that the majority of the farmers were actually willing to accept alternative methods despite their potentially greater costs and labour input (Fig. 6-4 and 6-5). They were all organic farmers and therefore the results could be more optimistic than the general common view, but we should also consider that there is a risk of a systematic measurement error when these figures are

Table 3
The results of a double-hurdle analysis to determine the factors associated with farmers' decision to treat against gastrointestinal nematode infection in 282 organic dairy farms across five European countries (Switzerland, Germany, Denmark, Lithuania, and Netherlands). Logit refers to qualitative part of the decision (treat or not) and Poisson part determines the number of treatments.

Variable	Logit		Poisson	
	Estimate	SE	Estimate	SE
Constant	0.617	0.769	1.547	0.861
Total farms size (ha)	−1.492**	0.467	−0.0775	0.240
Number of young stock	1.050**	0.330	0.0553	0.060
Total number of animals on farm including beef cattle	< 0.001**	< 0.001	< 0.001	< 0.001
Based on consultation by a vet (Yes = 1)	0.839	0.531	0.201	0.388
Based on own experience (Yes = 1)	−0.787	1.431	−0.634**	0.087
Based on FEC (Yes = 1)	2.140**	0.632	−0.274	0.302
Based on signs of diarrhoea (Yes = 1)	1.449	1.102	−0.150*	0.060
Based on hair coat quality (Yes = 1)	0.962	0.515	−0.870**	0.181
Based on production loss (milk/weight gain) (Yes = 1)	0.290	0.152	−0.228	0.154
Reduced stocking rate (Yes = 1)	0.245	0.737	0.518**	0.153
Young stock grazing low risk areas (Yes = 1)	−0.551	0.293	−0.172	0.116
Grazing duration for heifers (> 1 year of age)	0.013	0.314	−0.122	0.149
Grazing duration for young stock (< 1 year of age)	0.182	0.480	−0.384**	0.091
Years since conversion to organic	0.010	0.010	−0.0131**	0.005
Attitude index[a]	−0.032	0.098	−0.248*	0.124

[a] The attitude index indicates if a farmer is rather open minded or not towards alternative parasite control. The index was calculated by principal component analysis based on the Lickert scale answers given for six statements (Question 9). The statistical significance is indicated as

** $p < .01$.

* $p < .05$.

assessed. It is possible that for example, due to 'social desirability' (Choi and Pak, 2004; Bogner and Landrock, 2015), the respondents answered more positively than their real viewpoint, due to the tendency of an interviewed person to correspond more closely to what society or the investigator expects of them. Bearing this in mind, the willingness to bear greater costs or putting more work into parasite control might be actually lower than indicated by these figures. This conflict is at least true for participants of a questionnaire among Swiss goat owners: even though the respondents affirmed their will to invest time or money for sustainable worm control, they preferred strategies that are little time- or cost-consuming when given the choice (Bollinger et al., 2016). However, even when taking this possibility into account, the results are encouraging for the researchers involved in developing alternative parasite control methods. These may include strategic grazing management, bioactive forages, selective breeding and biological control (Thamsborg and Roepstorff, 2003). Considering that farmers' expectations towards development of vaccine or improved treatments were not very high (Fig. 6-3), they are eager to try new alternatives to anthelmintics to prevent production losses due to parasites.

For the factors associated with decision to drench, FEC was the most influential and significant factor. This was expected since the clinical signs such as hair coat quality and diarrhoea are not specific to parasitic diseases, and FEC is currently the most widely available diagnostic method due to its reliability and relevance for helminth infections (Morgan et al., 2013). Use of FEC was, however, not a significant factor for the number of treatments. The farms with lower stocking rate had a higher drench frequency, which is counter-intuitive to recommendations for a lower stocking rate to reduce infection levels. However, it could be hypothesised that farms with low stocking density may proportionally utilise more permanent pastures and have increased prevalence due to continuous grazing. Drench decision based on own experience and clinical signs such as diarrhoea and hair coat quality were negatively associated with the frequency of drenching, which could be related to financial issues; as the farmers who do not invest in diagnostic methods (e.g. FEC or veterinary consultancy) are also not likely to spend money on frequent treatments due to costs. Overall FEC as a key factor for application of drench (against GIN) is promising for the advisory services and FEC could be even more widely accepted if the method was run cheaper and quicker.

More open-minded and experienced organic farmers were less likely to apply more treatments, which suggest that they may be actively reducing the number of treatments based on the organic principles. Finally, the longer the grazing duration of the young stock, the higher the number of drench numbers. Young stock were generally considered to be more vulnerable to parasitic diseases due to their immunologic naivety (Bellet et al., 2018). It is therefore reasonable to expect higher drenching frequencies if the young stock also experience a longer exposure period.

The interpretation of the results from the present study requires some caution due to the limitations of the survey and sampling design; sampling bias may be present due to a lack of randomisation in some countries. The farmers that are more aware of the parasite problems and control may have agreed to participate in the interviews, which could lead to the results not truly reflecting the issue in the wider organic sector in some participating countries. However, we assume that farmers with either stronger positive or stronger negative views were most willing to participate in the survey, which might mitigate the sampling bias. While it was not possible to fully correct for this possible bias, the variation in the number of surveys per country was however considered in the analysis through the use of sampling weights.

5. Conclusions

This survey in multiple European countries provided detailed information on current practices, management and farmers' perspectives on parasite control in organic cattle farms. There were great variations in herd size between the six countries, probably influencing the general husbandry routines and farmers' attitudes towards parasite control. The differences between the types of productions (beef and dairy) were not as prominent as the differences between the countries. The monitoring methods for parasitic infections also differed among the countries and this highlights the need for dissemination and educational activities to be tailored to the specific country context. At present, group-wise treatments are still the main application method, and more research efforts are needed if TST is to be widely implemented to achieve a reduction in AR. Generally, the organic farmers were positive towards accepting the alternative approaches for parasite control, despite the extra cost and labour input. Overall, the results of the study highlight the differences between farming management between the countries and provide useful information to the scientific community in developing more effective knowledge transfer strategies such as development of media warnings systems or continuing education of veterinarians and the farmers to look for non-invasive indicators. However, further research on-farm is required to identify and clarify the efficacy of these non-invasive indicators, as well as the link between the level of parasitic infections and production losses in organic farms.

Ethics approval

The farmers consented to participate in the study during the interviews.

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Ethical statement

No animals were used in this survey type research. The farmers consented to participate in the study during the interviews.

Declaration of Competing Interest

Authors declare there is no competing interest in relation to the study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vprsr.2019.100329.

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