Veterinary Parasitology 203 (2014) 65–72

Contents lists available at ScienceDirect

Veterinary Parasitology

journal homepage: www.elsevier.com/locate/vetpar

# Prevalence of *Taenia saginata* cysticercosis in French cattle in 2010

Céline Dupuy[a,b], Claire Morlot[c], Emmanuelle Gilot-Fromont[c,d], Michel Mas[c,e], Claude Grandmontagne[c], Pascale Gilli-Dunoyer[f], Emilie Gay[a,*], Marie-Pierre Callait-Cardinal[c,d]

[a] *Unité Epidémiologie, Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (ANSES), 31 avenue Tony Garnier, F-69364 Lyon Cedex 07, France*
[b] *Unité d'épidémiologie animale, UR346, INRA, F-63122 St Genès Champanelle, France*
[c] *VetAgroSup Campus Vétérinaire, Université de Lyon, 1 avenue Bourgelat, F-69280 Marcy l'Etoile, France*
[d] *Université de Lyon, F-69000, Lyon, Université Lyon 1, CNRS, UMR5558, Laboratoire de Biométrie et Biologie Evolutive, Bâtiment Mendel, 43 Bd du 11 novembre 1918, F-69622 Villeurbanne, France*
[e] *ENSV, VetAgroSup, F-69280 Marcy L'Etoile, France*
[f] *Direction générale de l'Alimentation, 251 rue de Vaugirard, F-75732 Paris Cedex 15, France*

ARTICLE INFO

*Article history:*
Received 6 November 2013
Received in revised form 13 February 2014
Accepted 24 February 2014

*Keywords:*
Cysticercosis
Slaughterhouse
Cattle
Prevalence
Meat inspection
*Taenia saginata*

ABSTRACT

Bovine cysticercosis is a foodborne disease caused by the cestode *Taenia saginata* with cattle as the intermediate host and humans as the final host. This disease is responsible for direct financial losses for farmers. It is also economically important because human infestation through raw or undercooked meat consumption can have a negative impact on the confidence the consumer has in the food industry. This study aimed to determine the apparent and true prevalence of bovine cysticercosis in France and describe the locations of identified cysticercosis lesions.

The study sample included 4,564,065 cattle slaughtered in 2010 in France, among which 6491 were detected as harbouring cysticercosis lesions using the current EU meat inspection process. The overall apparent prevalence (including both viable and degenerated cysticerci) was estimated at 0.142% [0.142–0.143]. The true overall prevalence defined as the estimation of the prevalence after taking into account the sensitivity of meat inspection (detection fraction) was 1.23% [0.83–1.93]. The true prevalence of cattle with at least one viable cysticercus was 0.113% [0.076–0.189]. Taking into account both our results and those of a previous study on the prevalence of human cysticercosis in France, we estimated that one carcass could infest an average of 8–20 individuals. The spatial distribution of viable cysticerci showed that the highest apparent prevalence was found in eastern France.

This study, the largest survey ever conducted on bovine cysticercosis in France, indicated a low but spatially heterogeneous prevalence of the parasite among the cattle population. Considering French eating habits, according to which it is not uncommon to consume undercooked meat, the possibility of humans being infested even though viable cysticerci are not detected during meat inspection is high. Increasing the detection sensitivity of meat inspection through the use of a risk-based meat inspection procedure should improve prevention of human infestation.



* Corresponding author. Tel.: +33 04 78 61 44 17.
*E-mail address:* emilie.gay@anses.fr (E. Gay).

http://dx.doi.org/10.1016/j.vetpar.2014.02.054
0304-4017/

## 1. Introduction

Bovine cysticercosis is a foodborne zoonotic disease caused by the cestode *Taenia saginata*. Cattle, the intermediate host, are principally infested by grazing on pasture infested by human faeces containing tapeworm eggs. Pastures can be infested by the accidental overflowing of sewage onto pastures or by the use of sewage sludge for pasture fertilisation in cases where sewage is not treated or if the prescribed period between spreading and grazing is not complied with (Cabaret et al., 2002; Dorny and Praet, 2007; Kyvsgaard et al., 1990). After cattle ingest tapeworm eggs, cysticerci develop in their muscles. Cysticerci first go through a viable stage with a visible single invaginated scolex and then pass into a degenerated stage with the calcification of cysticerci. Humans, the final host, can be infested only by viable cysticerci through the consumption of raw or undercooked meat (Scientific Committee on Veterinary Measures relating to Public Health, 2000). The large tapeworm then thrives in the small intestine. Infested humans are frequently asymptomatic, although gastrointestinal symptoms can be observed (Scientific Committee on Veterinary Measures relating to Public Health, 2000). Infested cattle usually show no clinical signs. *T. saginata* cysticercosis is not a significant public health issue, despite being a zoonotic disease, because of its limited impact on human health. However, this disease is highly troublesome for humans (gastrointestinal symptoms and the disease is surrounded by a taboo because it is falsely associated with poor hygiene). It can therefore have a negative impact on the consumer's confidence in the food industry. Bovine cysticercosis is also responsible for direct financial losses for farmers due to the condemnation or treatment by freezing of carcasses containing parasite lesions (Cabaret et al., 2002).

The prevalence of *T. saginata* taeniasis in humans is difficult to evaluate. This disease is not notifiable in France except in cases of collective food poisoning. It is also underdiagnosed by general practitioners due to sociological reasons (*i.e.* this disease is a taboo subject which explains why patients hesitate to seek medical care). Prevalence in humans can therefore only be estimated using the sales figures for specific drugs (niclosamide) (Scientific Committee on Veterinary Measures relating to Public Health, 2000). In the European Union (EU), the prevalence of human taeniasis ranged from less than 0.01% to 10% depending on the country (Cabaret et al., 2002). In France, the mean annual prevalence of human taeniasis was estimated at 0.11% (French Institute for Public Health Surveillance, 2003).

The surveillance of *T. saginata* is better organised in the animal health sector than in the human health sector due to specific regulations in the former. In the EU, the surveillance of bovine cysticercosis is conducted through the individual mandatory inspection of cattle carcasses. Routine meat inspection includes specific incisions in the predilection sites of cysticerci, *i.e.* mastication muscles and the heart (European Parliament, 2004). According to the official meat inspection figures, the prevalence of bovine cysticercosis in the 1990s was estimated to vary between 0.007% and 6.8% in the different EU countries (Cabaret et al., 2002). In France, Doby et al. (1978) investigated the prevalence of bovine cysticercosis on 2079 cattle slaughtered in the Brittany region, in 1973 and 1974. The apparent prevalence based on traditional meat inspection was less than 1% and increased to 9% when the heart was cut into 2–3 mm-thick slices.

No bovine cysticercosis prevalence studies have been published in France since 1974. The previous studies were conducted at local scale and not throughout the whole country. The use of urban sludge for pasture fertilisation has been regulated in France since 1998 (Ministère de l'agriculture et de la pêche, 1998) and the use of any waste collected during and/or resulting from the various phases of waste-water treatment has been forbidden in compound feeding stuffs since 2000 (Commission of the European Communities, 2000). We may suppose that these regulations have had a positive impact on the prevalence of bovine cysticercosis in France.

The objective of this study was to determine the apparent and true prevalence of bovine cysticercosis in France and describe the locations of cysticercosis lesions identified through the current European meat inspection procedure. The survey was conducted in French cattle slaughterhouses in 2010.

## 2. Materials and methods

### 2.1. Data collection and sample population

A survey was conducted in metropolitan France in 2010 by the French Ministry of Agriculture in all cattle slaughterhouses. Each slaughterhouse was asked to register information on each animal that presented at least one cysticercosis lesion during post-mortem inspection. In France, post-mortem inspection is performed according to current European legislation (European Parliament, 2004). Visual inspection of the heart, tongue, masseter muscles, oesophagus and diaphragm is performed on every carcass, together with one lengthways incision of the heart. Three additional incisions in the masseter muscles are performed for cattle older than 6 weeks. Additional incisions can be made whenever considered necessary by the official inspector (European Parliament, 2004). Information about animal ID, month of slaughter, location of cysticercosis lesions (masseter muscles, heart, inner cheek muscles, tongue, oesophagus, diaphragm and other locations) were recorded. The cysticerci stages for each location were also registered (viable or degenerated). Fully transparent cysticerci with a single visible invaginated scolex were considered as viable; any others, with contents that were cheesy (yellowish and smooth) or calcified (solid and perceptible when cysticerci were sliced) were considered as degenerated, according to the previously established criteria (Kyvsgaard et al., 1990; Minozzo et al., 2002). Generalised cysticercosis cases were defined as animals harbouring cysticerci in at least two different locations (OIE, 2008). No information was recorded about the number of cysticerci per location. Each slaughterhouse provided the data for the first and second semester of 2010 in reports submitted in July 2010 and January 2011 respectively.

The French National Cattle Register (BDNI) was used to extract, for all cattle slaughtered in France in 2010,

the animal's ID, sex, age, breed and the ID of the *département* (French administrative area) where the animal was raised two months prior to slaughter. A database was implemented using Toad for MySQL® to merge data from the survey and the BDNI, as animals were registered in both databases with the same ID. According to zootechnical standards (Barbin et al., 2011) and EU regulations (European Parliament, 2007), the ages of cattle were classified into six levels: <8 months old, 8–24 months old, 2–3.5 years old, 3.5–5 years old, 5–10 years old, and ≥10 years old. Breeds were grouped according to production type as defined by FranceAgriMer (the French National Organisation of Agricultural and Marine Products) into "dairy", "beef" and "mixed" cattle.

All animals that were slaughtered in one of the slaughterhouses that responded to the survey and during the period for which information was registered were included. Animals with missing data regarding sex, age and production type were excluded from the analysis after checking that this removal did not impact apparent prevalence (maximum absolute difference of 0.002% affecting apparent prevalence).

For spatial computation of the prevalence, only animals harbouring viable cysticerci were considered. We judged that it was not possible to determine in which farm an animal harbouring degenerated cysticerci would have been infested. Since viable cysticerci are clearly visible during post-mortem inspection six weeks post-infestation, we hypothesised that the *département* where these animals were raised two months before slaughter was the *département* in which infestation most likely occurred. Calcification begins one month post-infestation in the heart and several months after infestation in the other locations. Calcification is complete nine months post-infestation (Ogunremi and Benjamin, 2010; OIE, 2008). The proportion of animals that moved between *départements* from birth to slaughter, and the distribution of time spent in the last *département* before slaughter were examined. The objective was to evaluate whether the *département* where the animals were living two months prior slaughter was a relevant indicator of the place where the animals became infested.

### 2.2. Data analysis

The representativeness of the sample population was evaluated by comparing the proportion of cattle in the sample population regarding sex, age and production type against the proportion of cattle in the whole population with regard to the same categories. Considering the large amount of data, the use of the Chi-square test was not relevant because of the excess of power. We therefore checked the absence of difference between these proportions by describing the weightings obtained after performing an adjustment by post-stratification. The post-stratification consists in calculating weightings for different strata of the sample population (*e.g.* sex, age and production type) based on known information regarding these strata in the whole population (Little, 1993). The closer these weights are to one, the smaller the difference between the sample and the whole population regarding the distribution of these variables.

Apparent prevalence with a 95% confidence interval [CI] was calculated using data from the sample population (Merrill, 2010). Apparent prevalence was defined as the number of cattle detected as harbouring cysticerci during meat inspection divided by the number of slaughtered cattle. So as to take into account the sensitivity of meat inspection, the true prevalence was calculated by dividing the apparent prevalence by the detection fraction (*i.e.* the proportion of infested animals successfully detected under the current EU meat inspection process). For bovine cysticercosis, the detection fraction was recently estimated by the European Food Safety Authority (EFSA) at 11.5% [7.4–17.1] through a Delfy approach (Dupuy et al., 2012). This approach took into account the variation of sensitivity according to slaughterhouse (meat inspection line speed, level of experience of the official inspectors, *etc.*) through the expert elicitation process.

Multivariate logistic regression analyses were performed to identify which animal characteristics (sex, age, production type) were significantly associated with the presence of cysticercosis lesions. Two models were run: the first using as outcome variable the presence or absence of viable cysticerci and the second using the presence or absence of cysticerci, regardless of their level of development. A combined Sex–age variable was used due to the correlation between age and sex. The modelling selection strategy of Hosmer and Lemeshow was used (Hosmer and Lemeshow, 2000). In the first step, each variable was evaluated separately for statistical significance. Each variable with a $p$-value lower than 0.20 at this univariate step was included in a multivariate model. A backward step-wise selection was performed and non-significant covariates were removed from the model ($p$-value higher than 0.05) to assess confounding effects and obtain the final model.

Apparent prevalence regarding animal characteristics previously identified to be significantly associated with the presence of viable cysticerci or cysticerci regardless of their level of development was calculated. Due to small numbers in some of the categories considered, the exact binomial confidence interval was used.

The estimation of the number of carcasses with viable cysticerci detected during the slaughter process (number of detected carcasses) was calculated by multiplying the apparent prevalence of viable cysticercosis by the total number of cattle slaughtered in 2010 ($n$ = 4,997,846). The estimation of the true number of infested carcasses with viable cysticerci was calculated in the same way using the true prevalence of viable cysticercosis. Carcasses that could infest humans (infested carcasses) were defined as carcasses harbouring viable cysticerci but not detected during the meat inspection process. The number of these carcasses was estimated as the number of true infested carcasses minus the number of detected carcasses. The number of humans that could be infested by an infested carcass was calculated as the number of human cases divided by the number of infested carcasses. By looking at the amount of niclosamide reimbursed by the French social security system, the mean number of annual human cases was estimated by the French Institute for Public Health

**Table 1**
Number of generalised and non-generalised cases of bovine cysticercosis according to the level of cyst development (viable or degenerated).

| | Generalised cysticercosis | | |
|---|---|---|---|
| | Yes | No | Total |
| Viable cysts | 59 | 552 | 611 |
| Degenerated cysts | 177 | 5655 | 5832 |
| Unknown | 48 | 0 | 48 |
| Total | 284 | 6207 | 6491 |

Surveillance to be 64,595 (French Institute for Public Health Surveillance, 2003).

The proportions of cattle with cysticercosis lesions for which the location of the lesion was known were calculated for the major identified locations (combining one location or more) according to age, sex, production type and cysticerci stage. A Chi-square test was performed to compare the proportion of cattle harbouring viable cysticerci with generalised lesions with the proportion of cattle harbouring viable cysticerci without generalised lesions.

Statistical analyses were performed using R software (R Development Core Team, 2010). The apparent prevalence of viable cysticerci by *département* in France in 2010 was mapped to evaluate the spatial distribution of this prevalence using Quantum GIS software (QGIS Development Team, 2012).

## 3. Results

In 2010, 4,997,846 cattle were slaughtered in France in 221 slaughterhouses, 181 of which participated in the study. Among these 181 slaughterhouses, 174 returned both reports and seven only one. Animals with missing data regarding sex, age or production type ($n = 152$) were excluded. The sample population included 4,564,065 animals from 181 slaughterhouses corresponding to 91.3% of the cattle population slaughtered in France in 2010.

The sample population was considered as representative of the French slaughtered population regarding sex, age and production type, as the weightings obtained by post-stratification adjustment ranged from 0.93 to 1.07 (median = 0.99). The weighting distribution being close to 1 means that the two populations were similar. However we compared the prevalence with and without post-stratification adjustment. The maximum absolute difference between apparent prevalence values was 0.003%. It confirmed that our sample population was representative of the whole slaughtered population and did not need post-stratification adjustment.

Post-mortem inspection identified 6491 cattle harbouring at least one cysticercosis lesion. Among these cattle, 5832 (90%) had only degenerated lesions, 611 (9%) had at least one viable cysticercosis lesion and 48 (1%) had lesions without any details about the development stage

**Table 2**
Apparent prevalence (%) of cattle with at least one cysticercus according to sex, age and production type (95% confidence intervals). The estimations were based on the detection of cysticercosis lesions during post-mortem inspection performed on 4,564,065 cattle slaughtered in France in 2010.

| Age | Production type | | |
|---|---|---|---|
| | Dairy | Mixed | Beef |
| Female <8 months old | 0 [0;0.03] | 0 [0;0.02] | 0.01 [0;0.01] |
| Male <8 months old | 0 [0;0] | 0 [0;0.01] | 0 [0;0] |
| Female 8–24 months old | 0.25 [0.12;0.45] | 0.1 [0.01;0.34] | 0.06 [0.04;0.07] |
| Male 8–24 months old | 0.06 [0.04;0.07] | 0.07 [0.05;0.09] | 0.04 [0.04;0.05] |
| Female 2–3.5 years old | 0.27 [0.24;0.31] | 0.32 [0.27;0.39] | 0.28 [0.26;0.30] |
| Male 2–3.5 years old | 0.33 [0.29;0.37] | 0.49 [0.43;0.55] | 0.3 [0.26;0.33] |
| Female 3.5–5 years old | 0.28 [0.25;0.31] | 0.34 [0.29;0.39] | 0.3 [0.28;0.33] |
| Male 3.5–5 years old | 0.32 [0.20;0.49] | 0.51 [0.37;0.69] | 0.33 [0.26;0.41] |
| Female 5–10 years old | 0.21 [0.20;0.23] | 0.25 [0.23;0.28] | 0.28 [0.26;0.30] |
| Male 5–10 years old | 0.84 [0.27;1.96] | 0.54 [0.15;1.37] | 0.15 [0.09;0.22] |
| Female ≥10 years old | 0.19 [0.15;0.24] | 0.18 [0.14;0.24] | 0.21 [0.19;0.23] |
| Male ≥10 years old | 0 [0;33.63] | 4.76 [0.12;23.82] | 0.12 [0.02;0.34] |

**Table 3**
Apparent prevalence (%) of cattle with at least one viable cysticercus according to sex, age and production type (95% confidence intervals). The estimations were based on the detection of cysticercosis lesions during post-mortem inspection performed on 4,564,065 cattle slaughtered in France in 2010.

| Age | Production type | | |
|---|---|---|---|
| | Dairy | Mixed | Beef |
| Female <8 months old | 0 [0;0.03] | 0 [0;0.02] | 0 [0;0] |
| Male <8 months old | 0 [0;0] | 0 [0;0] | 0 [0;0] |
| Female 8–24 months old | 0.05 [0.01;0.18] | 0 [0;0.18] | 0.01 [0;0.02] |
| Male 8–24 months old | 0.01 [0.01;0.02] | 0.02 [0.01;0.03] | 0.01 [0.01;0.01] |
| Female 2–3.5 years old | 0.01 [0.01;0.02] | 0.03 [0.01;0.05] | 0.02 [0.02;0.03] |
| Male 2–3.5 years old | 0.02 [0.02;0.04] | 0.05 [0.04;0.08] | 0.03 [0.02;0.04] |
| Female 3.5–5 years old | 0.02 [0.01;0.03] | 0.03 [0.02;0.05] | 0.03 [0.02;0.03] |
| Male 3.5–5 years old | 0.05 [0.01;0.13] | 0.04 [0.01;0.10] | 0.03 [0.01;0.06] |
| Female 5–10 years old | 0.01 [0.01;0.02] | 0.03 [0.02;0.04] | 0.02 [0.02;0.03] |
| Male 5–10 years old | 0.17 [0;0.94] | 0.13 [0;0.74] | 0.01 [0;0.04] |
| Female ≥10 years old | 0.03 [0.01;0.05] | 0.04 [0.02;0.06] | 0.02 [0.01;0.03] |
| Male ≥10 years old | 0 [0;33.63] | 4.76 [0.12;23.82] | 0.08 [0.01;0.28] |

**Table 4**
Apparent prevalence (%) of cattle with degenerated cysticerci only according to sex, age and production type (95% confidence intervals). The estimations were based on the detection of cysticercosis lesions during post-mortem inspection performed on 4,564,065 cattle slaughtered in France in 2010.

| Age | Production type | | |
|---|---|---|---|
| | Dairy | Mixed | Beef |
| Female <8 months old | 0 [0;0.03] | 0 [0;0.02] | 0 [0;0.01] |
| Male <8 months old | 0 [0;0] | 0 [0;0] | 0 [0;0] |
| Female 8–24 months old | 0.2 [0.09;0.39] | 0.1 [0.01;0.34] | 0.05 [0.04;0.06] |
| Male 8–24 months old | 0.05 [0.04;0.06] | 0.04 [0.03;0.06] | 0.03 [0.03;0.04] |
| Female 2–3.5 years old | 0.26 [0.22;0.30] | 0.29 [0.24;0.35] | 0.25 [0.24;0.27] |
| Male 2–3.5 years old | 0.3 [0.26;0.34] | 0.43 [0.38;0.49] | 0.27 [0.24;0.30] |
| Female 3.5–5 years old | 0.26 [0.23;0.29] | 0.3 [0.26;0.35] | 0.27 [0.25;0.30] |
| Male 3.5–5 years old | 0.27 [0.16;0.43] | 0.48 [0.34;0.65] | 0.3 [0.23;0.38] |
| Female 5–10 years old | 0.2 [0.18;0.21] | 0.22 [0.20;0.25] | 0.25 [0.23;0.27] |
| Male 5–10 years old | 0.68 [0.18;1.72] | 0.4 [0.08;1.17] | 0.13 [0.09;0.20] |
| Female ≥10 years old | 0.16 [0.12;0.21] | 0.15 [0.11;0.20] | 0.19 [0.17;0.21] |
| Male ≥10 years old | 0 [0;33.63] | 0 [0;16.11] | 0.04 [0;0.22] |

of the cysticerci (Table 1). Among the 284 cattle that presented generalised cysticercosis lesions, information about the development stage of the cysticerci was available for 236 animals. Among these cattle, 177 (75%) presented only degenerated cysticerci and 59 (25%) presented viable or viable and degenerated cysticerci. The proportion of viable cysticerci was significantly higher ($p < 0.001$) for cattle harbouring generalised cysticercosis lesions (25%) compared to other infested cattle (552/6207 = 9%) (Table 1).

The overall apparent prevalence of cysticercosis (*i.e.* both viable and degenerated cysticerci) was 0.142% [0.142–0.143]. Using the detection fraction, the true overall prevalence was estimated at 1.23% [0.83–1.93] and the true prevalence of cattle with at least one viable cysticercus was estimated at 0.113% [0.076–0.189].

The true number of carcasses with viable cysticerci was estimated as being between 3887 and 9118, only 665–675 of which would have been detected through the current meat inspection process. The number of carcasses with viable cysticerci that were not detected by the current meat inspection process (infested carcasses) was estimated at between 3212 and 8452 for a one year period. We then calculated that a carcass harbouring viable cysticerci could infest on average between 8 and 20 individuals.

Multivariate logistic regression analyses identified that age-sex and production type were significantly associated with the presence of cysticercosis lesions ($p$ value < 0.05). The apparent prevalence increased with age until the age of 3.5 years old for each type of cyst, sex and production type (Tables 2–4).

An analysis of the movements of cattle with viable cysticerci before slaughter showed that 81% did not change *départements* from birth to slaughter and 18% changed once. Among the cattle that changed *départements* at least once, 63% remained longer than 6 months in the last one. Thus, the use of the parameter concerning the *département* where cattle were located two months before slaughter induced a limited bias for mapping the apparent prevalence of viable cysticerci by *département* (Fig. 1). The *département* where the animal was located two months before slaughter was unknown for 4886 cattle that were excluded from mapping, one of which had viable cysticerci. For each *département*, the proportion of cattle included in the study was at least 19% (median of 93.5%) of the total number of cattle slaughtered from the *département*. We considered that information at *département* level was robust enough for interpretation if the number of cattle was higher than 1000 and the proportion of cattle inspected compared to the whole slaughtered population of the *département* higher than 50%. Three *départements* did not fulfil these conditions and are indicated by a star in Fig. 1. The apparent prevalence of cattle harbouring viable cysticerci by *département* ranged from 0 to 0.112% with a median of 0.01%. *Départements* with apparent prevalence higher than 0.02% were located in eastern France, except for two *départements* in Normandy and one in *Poitou-Charentes* (North West, Fig. 1). No viable cysticerci were detected in 28 *départements*, most of them around the Paris area or bordering the Mediterranean Sea.

The 610 cattle detected as harbouring viable cysticerci originated in 580 farms (one detected animal with missing data). Among these farms, 96.7% ($n = 561$) had only one case detected during the study period, 2.4% ($n = 14$) had two cases detected and a maximum of six cases were detected in one farm.

Among the 6443 cattle for which the location of the cysticercosis lesions was specified, 96.5% had lesions in only one location (Table 5). Through European meat inspection, 62.8% of degenerated cysticercosis lesions were identified in masseter muscles only and 30.6% in the heart only. For cattle with at least one viable cyst, 77.9% of the cysticercosis lesions were in masseter muscles only and 7.4% in the heart only (Table 5). For veal calves (cattle less than 8 months old), 75% of cysticercosis lesions were in the heart only and 3.1% in masseter muscles only. The proportion of cysticerci located in the heart decreased with age whereas the proportion of cysticerci located in the masseter muscles increased with age (Table 5).

## 4. Discussion

This study estimated the prevalence of bovine cysticercosis in France in 2010 based on a survey conducted in all the cattle slaughterhouses in the country with a very high response rate (181/221 slaughterhouses corresponding to 91.3% of the slaughtered cattle). The apparent prevalence of cattle harbouring cysticerci irrespective of their level of development was 0.142% [0.142–0.143]. This is

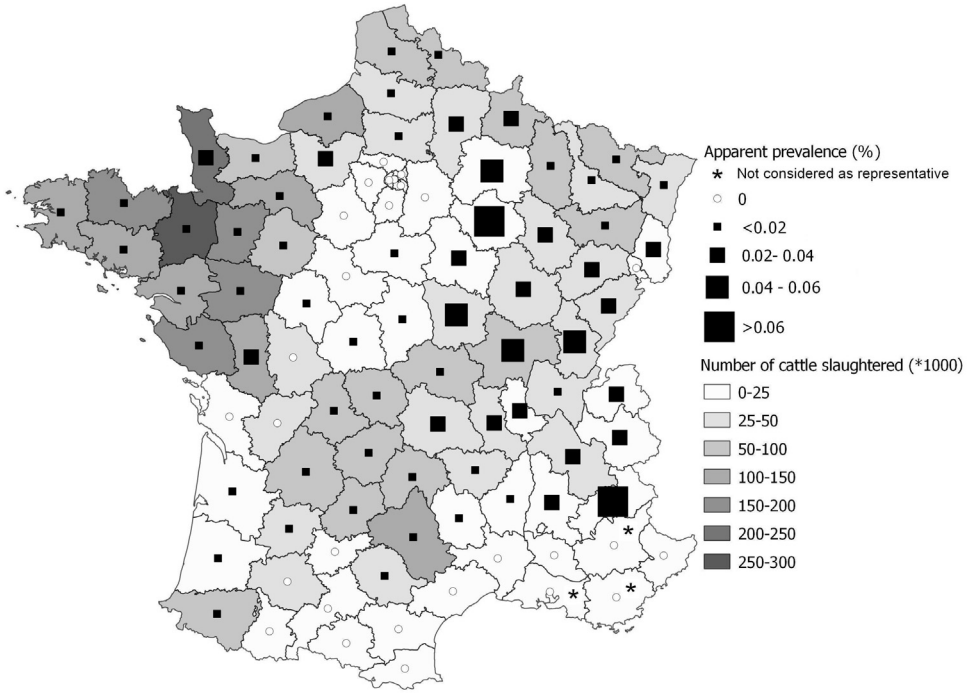


**Fig. 1.** Apparent prevalence of viable cysticerci based on the detection of cysticercosis lesions during post-mortem inspection performed on 4,559,179 cattle slaughtered in France in 2010. The size of black squares indicates prevalence while the level of grey indicates the number of cattle slaughtered in the *département* of their last farm location. Stars denote *départements* where data are not considered as representative.

considerably lower than was observed by Doby et al. (1978) in 1973–1974 in Brittany (*i.e.* 1%). It therefore seems that the situation in France regarding bovine cysticercosis has considerably improved since 1973 but this previous study was performed on a limited number of cattle from a single region of France which makes the comparison difficult. Our results are close to what was observed in other EU countries such as Spain, Italy, Belgium and Denmark in the 1990s (Scientific Committee on Veterinary Measures relating to Public Health, 2000). However, comparison with these results is probably not justified because of the lack of information regarding sample size, sampling methodology, and the diagnostic method used. These studies were mainly published in the native language of the country or based on a personal communication. Furthermore, these results are prevalence estimates performed more than twenty

**Table 5**
Number and proportion (%) of cattle with cysticercosis lesions for which the location of the lesion was known (n = 6437), according to both location of the lesion and age, sex, production type and cysticerci stage. Main locations and totals are in bold font.

| | Masseter only | Heart only | Masseter and heart | Masseter and other | Heart and other | Other only | Total |
|---|---|---|---|---|---|---|---|
| **Cysticerci stages** | | | | | | | |
| Degenerated only | 3658 (62.8) | 1785 (30.6) | 86 (1.5) | 31 (0.5) | 22 (0.4) | 245 (4.2) | 5827 (100) |
| At least one viable cyst | 475 (77.9) | 45 (7.4) | 12 (2.0) | 11 (1.8) | 5 (0.8) | 62 (10.2) | 610 (100) |
| **Age** | | | | | | | |
| [0–8 months old) | 1 (3.1) | 24 (75.0) | 0 (0) | 0 (0) | 4 (12.5) | 3 (9.4) | 32 (100) |
| [8–24 months old) | 248 (52.7) | 176 (37.4) | 10 (2.1) | 6 (1.3) | 3 (0.6) | 28 (5.9) | 471 (100) |
| [2–3.5 years old) | 1337 (61.6) | 669 (30.8) | 27 (1.2) | 14 (0.6) | 6 (0.3) | 118 (5.4) | 2171 (100) |
| [3.5–5 years old) | 836 (63.2) | 383 (29.0) | 24 (1.8) | 7 (0.5) | 4 (0.3) | 68 (5.1) | 1322 (100) |
| [5–10 years old) | 1320 (68.5) | 487 (25.3) | 29 (1.5) | 11 (0.6) | 7 (0.4) | 73 (3.8) | 1927 (100) |
| ≥10 years old | 391 (76.1) | 91 (17.7) | 8 (1.6) | 4 (0.8) | 3 (0.6) | 17 (3.3) | 514 (100) |
| **Sex** | | | | | | | |
| Male | 805 (57.0) | 481 (34.0) | 23 (1.6) | 19 (1.3) | 8 (0.6) | 77 (5.4) | 1413 (100) |
| Female | 3328 (66.2) | 1349 (26.9) | 75 (1.5) | 23 (0.5) | 19 (0.4) | 230 (4.6) | 5024 (100) |
| **Production type** | | | | | | | |
| Dairy | 1046 (59.3) | 603 (34.2) | 24 (1.4) | 9 (0.5) | 7 (0.4) | 74 (4.2) | 1763 (100) |
| Beef | 2327 (65.4) | 960 (27.0) | 57 (1.6) | 24 (0.7) | 15 (0.4) | 177 (5.0) | 3560 (100) |
| Mixed | 760 (68.2) | 267 (24.0) | 17 (1.5) | 9 (0.8) | 5 (0.4) | 56 (5.0) | 1114 (100) |
| Total | 4133 (64.2) | 1830 (28.4) | 98 (1.5) | 42 (0.7) | 27 (0.4) | 307 (4.8) | 6437 (100) |

years ago. Two recent studies conducted using the same meat inspection methodology reported lower prevalence than our results. One in Spain involving 1,565,221 cattle slaughtered from 2005 to 2007 in Catalonia evaluated the prevalence of bovine cysticercosis at 0.018% (Allepuz et al., 2009). The other, in Denmark, estimated a prevalence of 0.009% based on 4,090,661 cattle slaughtered from 2004 to 2011 (Calvo-Artavia et al., 2013). We have no hypothesis that might explain such differences.

This study was based on the results of meat inspection. Previous studies have shown the lack of sensitivity of meat inspection for cysticercus detection, which leads to an underestimation of the number of cattle harbouring cysticerci (Dupuy et al., 2012; Edwards et al., 1997; Eichenberger et al., 2011). In particular, the prevalence of cattle harbouring viable cysticerci is likely to be the most under-estimated. Viable cysticerci are translucent, often pale-pink may therefore be more difficult to detect than degenerated cysticerci, which are white (Dorny and Praet, 2007; Onyango-Abuje et al., 1996). Furthermore, the current meat inspection process requires specifically inspecting the predilection sites of cysticerci (head muscle and heart). This means that cysticerci harboured in cattle only in other locations may not be detected. This lack of sensitivity of the meat inspection process for bovine cysticercosis detection was taken into account in our study by means of the detection fraction for bovine cysticercosis estimated in 2012 by EFSA. This detection fraction (11.5 [7.4–17.1]) was compatible with the sensitivity of meat inspection estimated recently by Eichenberger et al. (2013) (15.6 [10–23]) in dairy cattle using a different approach (*i.e.* serological tests and meat inspection results).

A lack of specificity has also been demonstrated that could, on the contrary, over-estimate the prevalence of this disease and be responsible for unfair financial losses to farmers. This is especially the case for degenerated cysticerci that could be confused with lesions caused by *Sarcocystis* or *Actinobacillus* or with some other deterioration of the meat (Abuseir et al., 2006; Ogunremi et al., 2004). The lack of specificity was not taken into account in the computation of prevalence as it was not possible to estimate it. This did not have any impact in terms of public health since the consequence is over-condemnation or treatment by freezing of infested carcasses.

From this study and previous results, we estimated that a carcass harbouring viable cysticerci could infest between 8 and 20 individuals on average. This is certainly an under-estimation of the actual figures as only carcasses harbouring viable cysticerci were considered as able to infest humans. Some carcasses containing calcified cysticerci might also harbour viable cysticerci but their proportion is unknown. Although the figures used should be considered as rough estimates, this value implies that an average infested carcass may harbour at least 8–20 cysticerci. This value is consistent with previous studies reviewed by Kyvsgaard et al. (1990), which estimated the number of cysticerci per carcass in predilection sites. These studies also suggest high between-carcass variability (from 1 to 30 cysticerci in naturally infested carcasses and from 2 to 2569 in experimentally infested carcasses). We also would expect high variability in the number of individuals infested per carcass both because of the variable cysticerci burden per carcass and because of the possible variability of individual human sensitivity to taeniasis.

The French population is particularly susceptible because of its eating habits, since eating undercooked meat is not uncommon. Consequently, even if the current meat inspection process is a useful tool to guarantee food safety regarding *T. saginata* cysticercosis, there is a clear need to improve detection of this type of infestation in France. The use of communication measures to encourage people to cook beef more does not seem compatible with French gastronomy.

Multiple incisions of the heart (0.5 cm thick) and in the masseter muscles were shown to increase efficiency in detecting cysticerci (Kyvsgaard et al., 1990; Scandrett et al., 2009). For instance, Eichenberger et al. (2011) demonstrated that additional heart incisions had allowed the identification of 29 additional cases over the 20 cases already detected during the standard meat inspection protocol applied to 1088 cattle slaughtered in Switzerland. Increasing the number of incisions in the heart in particular, but also in the masseter muscles, may therefore improve meat inspection sensitivity. However it would not be compatible with routine meat inspection due to the time necessary to perform such incisions. Moreover, such a protocol would result in the systematic condemnation of the heart for aesthetic reasons (high number of incisions in the organ) with a financial impact that remains to be evaluated. The use of serological tests to complement meat inspection for bovine cysticercosis detection could also offer improvement. Antibody-detecting enzyme-linked-immunosorbent assays (ELISA) do not distinguish between viable and degenerated cysticerci. The use of the Enzyme-linked-immunosorbent assay for the detection of circulating antigens (Ag-ELISA) for antigen detection offers the advantage of specifically demonstrating the presence of live cysticerci. But this method is limited by the fact that its sensitivity is high only for cattle harbouring more than 50 viable cysticerci (Dorny et al., 2000). The cost of the analysis as well as the lapse of time for obtaining the test result would have to be taken into account if routine use were to be considered. In any case, no commercial tests are yet available. In the future, these tests as well as additional incisions in the heart could offer improvement if used for a limited number of cattle previously identified as being at risk, based on individual and/or herd-level risk factors.

The present study highlights the fact that some regions in eastern France seemed to have a relatively high prevalence of viable cysticerci. This spatial distribution only took into account cattle harbouring viable cysticerci. It is a conservative estimate of bovine cysticercosis in France because we wanted to use only cattle for which the location of infestation could be considered as sufficiently certain. It would be interesting to find a method that could take into account the uncertainty regarding the farm in which infestation occurred so as to include all cattle harbouring cysticerci irrespective of their level of development.

The vast majority of farms with cattle harbouring viable cysticerci had only one infested animal (96.7% of affected farms). This low number should be interpreted

with caution because the study was conducted over a period of one year which was probably too short for a relevant estimation at farm level.

The proportion of viable cysticerci was significantly higher for cattle harbouring generalised cysticercosis lesions (25%) compared to the other infested cattle (9%). This difference could be explained by the easier detection of viable cysticercosis lesions when there are large numbers of these lesions (*i.e.* generalised cysticercosis).

The main locations of cysticerci were the masseter muscles and the heart. This can be explained by the fact that these locations are known to be predilection sites but also because the inspection is specifically directed at these locations. Only if cysticerci are found in these locations, are further incisions required in other locations such as the diaphragm. In this study we demonstrated that the proportion of cysticerci located in the heart decreased with age whereas the proportion of cysticerci located in the masseter muscles increased with age. Scandrett et al. (2009) demonstrated that the heart was the most reliable site for the detection of cysticerci for at least one year post-infestation. This could partly explain our observations since veal calves, considering their age, can only have been infested in the 8 months preceding slaughter.

This study, the largest survey ever conducted on bovine cysticercosis in France, indicated a low but spatially heterogeneous prevalence of the parasite in the cattle population. We estimated that between 3887 and 9118 carcasses harbour viable cysticerci each year, each carcass potentially infesting 8–20 humans if not detected. Given this potential risk, it would be useful to improve the detection sensitivity of infested carcasses by investigating the use of risk-based meat inspection procedures. Increasing the number of incisions in the heart as well as the use of serological tests as soon as they become available are possible ways for improvement.

## Acknowledgments

The authors wish to thank the French Ministry of Agriculture for funding this study and for having provided access to the data. They would also like to thank Coup de Puce Expansion and Dana Pottratz of Anses for providing the English language editing.

## References

Abuseir, S., Epe, C., Schnieder, T., Klein, G., Kuhne, M., 2006. Visual diagnosis of *Taenia saginata* cysticercosis during meat inspection: is it unequivocal? Parasitol. Res. 99, 405–409.

Allepuz, A., Napp, S., Picado, A., Alba, A., Panades, J., Domingo, M., Casal, J., 2009. Descriptive and spatial epidemiology of bovine cysticercosis in North-Eastern Spain (Catalonia). Vet. Parasitol. 159, 43–48.

Barbin, G., Champion, F., Chaumet, J.M., Chotteau, P., Lelyon, B., Monniot, C., Mottet, A., Perrot, C., Richard, M., You, G., 2011. La production de viande bovine en France. Dossier Economie de l'Elevage 415, 60.

Cabaret, J., Geerts, S., Madeline, M., Ballandonne, C., Barbier, D., 2002. The use of urban sewage sludge on pastures: the cysticercosis threat. Vet. Res. 33, 575–597.

Calvo-Artavia, F.F., Nielsen, L.R., Dahl, J., Clausen, D.M., Alban, L., 2013. Occurrence and factors associated with bovine cysticercosis recorded in cattle at meat inspection in Denmark in 2004–2011. Prev. Vet. Med. 110, 177–182.

Commission of the European Communities, 2000. Commission decision establishing the list of ingredients whose use is prohibited in compound feedingstuffs. In: 2000/258/EC (Official Journal of the Commission of the European Communities, Brussels)., pp. 2.

Doby, J.M., Guillou, L., Robin, L., Gielfrich, G., 1978. Fréquence de la Cysticercose bovine chez le Bétail dans l'Ouest de la France. Médecine et Maladies Infectieuses 8, 334–338.

Dorny, P., Praet, N., 2007. *Taenia saginata* in Europe. Vet. Parasitol. 149, 22–24.

Dorny, P., Vercammen, F., Brandt, J., Vansteenkiste, W., Berkvens, D., Geerts, S., 2000. Sero-epidemiological study of *Taenia saginata* cysticercosis in Belgian cattle. Vet. Parasitol. 88, 43–49.

Dupuy, C., Hendrikx, P., Hardstaff, J., Lindberg, A., 2012. In: EFSA (Ed.), Contribution of meat inspection to animal health surveillance in Bovine animals. European Food Safety Authority, p. 53.

Edwards, D.S., Johnston, A.M., Mead, G.C., 1997. Meat inspection: an overview of present practices and future trends. Vet. J. 154, 135–147.

Eichenberger, R.M., Lewis, F., Gabriel, S., Dorny, P., Torgerson, P.R., Deplazes, P., 2013. Multi-test analysis and model-based estimation of the prevalence of *Taenia saginata* cysticercus infestation in naturally infested dairy cows in the absence of a 'gold standard' reference test. Int. J. Parasitol. 43 (10), 853–859.

Eichenberger, R.M., Stephan, R., Deplazes, P., 2011. Increased sensitivity for the diagnosis of *Taenia saginata cysticercus* infection by additional heart examination compared to the EU-approved routine meat inspection. Food Control 22, 989–992.

European Parliament, 2004. Council Regulation laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. In: 854/2004 (Official Journal of the European Union)., pp. 83–127.

European Parliament, 2007. Council Regulation establishing a common organisation of agricultural markets and on specific provisions for certain agricultural products. In: 1234/2007 (Official Journal of the European Union).

French Institute for Public Health Surveillance, 2003. Morbidité et mortalité dues aux maladies infectieuses d'origine alimentaire en France (INVS)., pp. 192.

Hosmer, D.W., Lemeshow, S., 2000. Applied Logistic Regression, second ed. Wiley J. and Sons, New York, 375 pp.

Kyvsgaard, N.C., Ilsoe, B., Henriksen, S., Nansen, P., 1990. Distribution of *Taenia saginata* cysts in carcases of experimentally infected calves and its significance for routine meat inspection. Res. Vet. Sci. 49, 29–33.

Little, R.J.A., 1993. Post-stratification: a modeler's perspective. J. Am. Statist. Assoc. 88, 2001–2013.

Merrill, R., 2010. Introduction to Epidemiology. Jones and Bartlett Publishers, London, 403 pp.

Ministère de l'agriculture et de la pêche, 1998. Arrêté fixant les prescriptions techniques applicables aux épandages de boues sur les sols agricoles issues du traitment des eaux usées. Ministère de l'agriculture et de la pêche, Paris, France.

Minozzo, J.C., Gusso, R.L.F., de Castro, E.A., Lago, O., Soccol, V.T., 2002. Experimental bovine infection with *Taenia saginata* eggs: recovery rates and cysticerci location. Braz. Arch. Biol. Technol. 45, 451–455.

Ogunremi, O., Benjamin, J., 2010. Development and field evaluation of a new serological test for *Taenia saginata* cysticercosis. Vet. Parasitol. 169, 93–101.

Ogunremi, O., MacDonald, G., Geerts, S., Brandt, J., 2004. Diagnosis of *Taenia saginata* cysticercosis by immunohistochemical test on formalin-fixed and paraffin-embedded bovine lesions. J. Vet. Diagn. Invest. 16, 438–441.

OIE, 2008. Cysticercosis, Manual of Diagnostic Test and Vaccines for Terrestrial Animals. World Health Organisation for Animal Health, Paris, pp. 1216–1226.

Onyango-Abuje, J.A., Nginyi, J.M., Rugutt, M.K., Wright, S.H., Lumumba, P., Hughes, G., Harrison, L.J.S., 1996. Seroepidemiological survey of *Taenia saginata* cysticercosis in Kenya. Vet. Parasitol. 64, 177–185.

QGIS Development Team, 2012. QGIS Geographic Information System (Open Source Geospatial Foundation Project).

R Development Core Team, 2010. R: A Language and Environment for Statistical computing. R Foundation for Statistial Computing, Vienna, Austria.

Scandrett, B., Parker, S., Forbes, L., Gajadhar, A., Dekumyoy, P., Waikagul, J., Haines, D., 2009. Distribution of *Taenia saginata* cysticerci in tissues of experimentally infected cattle. Vet. Parasitol. 164, 223–231.

Scientific Committee on Veterinary Measures relating to Public Health, 2000. Opinion of the Scientific Committee on Veterinary relating to Measures to Public Health on the Control of taeniosis/cysticercosis in man and animals. European Commission, pp. 31.