Assessment of exposure to bovine spongiform encephalopathy in a hypothetical country

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Summary
The authors present a basic quantitative spreadsheet model to evaluate the risk of bovine spongiform encephalopathy (BSE) within a national setting. The model is based on information from BSE risk assessments undertaken in Latin American countries. The analysis focuses on the level of regulatory implementation and its impact over different time periods and estimates the potential impact if one BSE-infected animal is introduced into the production cycle. The information is consolidated so that the results of the evaluation can be presented for a hypothetical country, 'Country X'.
Evaluating the BSE cycle within a country may help in making decisions on where preventive or control measures should be placed and/or enforced. Such an evaluation may also be used as the exposure assessment of a risk assessment, recommended by the World Organisation for Animal Health to determine the BSE risk status of a given country.

Keywords
BSE cycle – Bovine spongiform encephalopathy – Cattle – Exposure assessment – Implementation of laws – Latin America – Risk assessment – Spreadsheet model.

Introduction

The World Organisation for Animal Health (OIE) recommends in its *Terrestrial Animal Health Code* that the risk of bovine spongiform encephalopathy (BSE) within a country should be determined through a risk assessment (20). Such an assessment should be based on both a release assessment and an exposure assessment.

The release assessment evaluates the risk of introducing the BSE agent by importing BSE-infected cattle or BSE-contaminated cattle protein, such as meat-and-bone meal (MBM).

The exposure assessment deals with the risk of recycling the BSE agent by slaughtering BSE-infected cattle and subsequently rendering infectious tissues into MBM, which may, in turn, be fed to cattle. As very low doses of infective agent may infect other cattle (17), and rendering can be taken as a way to reduce but not sterilise BSE-contaminated material (7), the agent can also be amplified (9), as happened during the BSE epidemic in the United Kingdom. It is therefore important not only to prevent the importation of BSE into a country, but also to have measures in place to avoid recycling the BSE agent. An assessment of the exposure risk and BSE cycle within a country may help in deciding where to place or enforce preventive or control measures.

Several countries have already attempted BSE risk assessments (e.g. 10, 11). Heim *et al.* (9) qualitatively describe the variables for determining BSE risk status and give recommendations for BSE risk assessments. A widely used and successful method for establishing a country's likelihood of bovine infection with BSE at any given point in time is the geographical BSE risk (GBR), developed by the Scientific Steering Committee of the European Commission between 1998 and 2003. The GBR was updated in 2007, by the European Food Safety Authority (EFSA), to include estimates of the likely evolution of infection over time (7).

The aim of this work is to provide Veterinary Services with an example of how an exposure assessment can be carried out, and may be used as part of a risk assessment, as recommended by the OIE (20), to determine the BSE risk status of a country.

In a basic model, the potential consequences of one BSE-infected animal entering the production cycle of a country are calculated by taking control measures over time into account. (The term 'animal', used here for brevity and convenience, refers to any BSE-infected bovine animal.)

The focus, however, is not on the time that legislation to prevent BSE was passed (as this might lead to false confidence), but on the actual time that control measures were implemented and the level of their implementation.

The first three cycles of the model therefore happen before, during and after the implementation of legislation. During the first cycle, no measures were taken at all. During the second cycle, legislation had been passed, and there was a partial implementation of control measures. During the third cycle, legislation was enforced far more strictly and the necessary measures had been fully implemented through the Veterinary Services or the corresponding competent authority.

Although a quantitative model was chosen, it must be emphasised that the important focus is not on the model, but on the vast amount of good quality information needed to assess the BSE situation correctly. This information may help a country to decide at what points to take preventive action.

Although this is not demonstrated here, the model could also be used to show the consequences of contaminated MBM or feed reaching the production cycle, instead of infected live cattle.

This report summarises the information from a number of BSE risk assessments undertaken in various Latin American countries. The information and the characteristics of the cattle production systems are presented so that the evaluated countries are not identified and the results are described for hypothetical 'Country X'.

Materials and methods

A model was built to assess the exposure of the domestic cattle production cycle to BSE. Its main purpose was to determine the possibility of one BSE-infected animal being introduced into the cattle production system and infecting other cattle in Country X.

This quantitative, deterministic model was set up as a spreadsheet in Microsoft® Excel 2007, and describes the cattle production cycle in Country X. It contains the main events that may play a role in BSE transmission and lead to recycling and amplification of the BSE agent if it is present in the cattle population. The model examines three phases:

– phase 1: the pathway that may introduce specified risk materials (SRMs) from a BSE-infected animal into cattle feed

– phase 2: the number of calves that could potentially be infected through MBM from one BSE-infected animal, split up among production systems

– phase 3: the complete cycles by combining phases 1 and 2. The impact of control measures over different time periods is also analysed.

Hazard identification and the assumptions used in the model

The hazard in question is the causative agent for BSE, which is widely assumed to be the pathological prion protein (scrapie form) PrP^{Sc} (8, 11).

Since BSE has a long incubation period, averaging approximately five years (2), the BSE cycles in the model were calculated with a time step of five years.

The model assesses the infection potential for cattle only; transmission of the BSE agent to humans or other animals, such as small ruminants, was not considered.

In this model, the brain, spinal cord and distal ileum were considered SRMs in cattle of any age.

Only calves aged less than one year are considered able to be infected by the BSE agent, and only through the feeding of contaminated concentrate. Calf milk replacer was not taken into account.

Contaminated MBM fed to species other than cattle (e.g. pigs or poultry) was not considered to pose a risk for cattle.

However, the risk of cross-contamination during feed production remains if feed mills do not use separate lines. The model assumes a worst-case scenario in which all cattle that enter the BSE cycle are slaughtered in their clinical phase at the height of infectiousness. Cattle that are slaughtered, burned or buried on the farm are assumed to leave the BSE cycle, and therefore are not likely to infect other cattle, as their SRMs would not be rendered.

In the model, all infective tissues of one BSE-infected animal in its clinical phase were considered to account for 4,200 cattle oral infectious doses in 50% of those challenged (CoID$_{50}$). This figure was derived from:

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– an experimental oral challenge study (5), in which one gram of brain from a BSE-infected adult beef cow during the clinical phase was estimated to contain 0.52 to 5 $CoID_{50}$. In that study, the infectivity level of spinal cord was assumed to be 5 $CoID_{50}$ per gram;

– average cattle brain and spinal cord weights of 500 g and 200 g, respectively (5), which resulted in up to 3,500 $CoID_{50}$ from these tissues;

– the brain and spinal cord being estimated to represent 84% of infectivity (3) (Table I).

A worst-case scenario was taken for those parameters for which no information was available. Parameters were used as point estimates or averages, depending on availability.

Table I
Percentage of infectivity of the various tissues in a clinical case of bovine spongiform encephalopathy

| Tissue	Infectivity
Brain	60.2%
Spinal cord	24.1%
Distal ileum	9.6%
Dorsal root ganglia	3.6%
Trigeminal nerve ganglia	2.4%
Tonsil	0%
Total	**~100.0%**

Source: (3)

Results

Phase 1: pathway that may introduce specified risk materials from an animal infected with bovine spongiform encephalopathy into cattle feed

The potential pathway for the introduction of SRMs from one infected animal in Country X is outlined in a scenario tree (Fig. 1). These scenarios reflect the entire production cycle from farm through slaughter and rendering and back to cattle feed.

Data and assumptions about hypothetical Country X are given in italics, to differentiate them from data or assumptions common for all countries. The characteristics of Country X can be found in Table II.

P1: probability that one animal with bovine spongiform encephalopathy is slaughtered at an abattoir

In Country X, around *98% of cattle go to slaughter*. This is a worst-case scenario, as it does not take into account either the detection of BSE-infected cattle with clinical signs before slaughter, nor the age of cattle at slaughter and/or the incubation period.
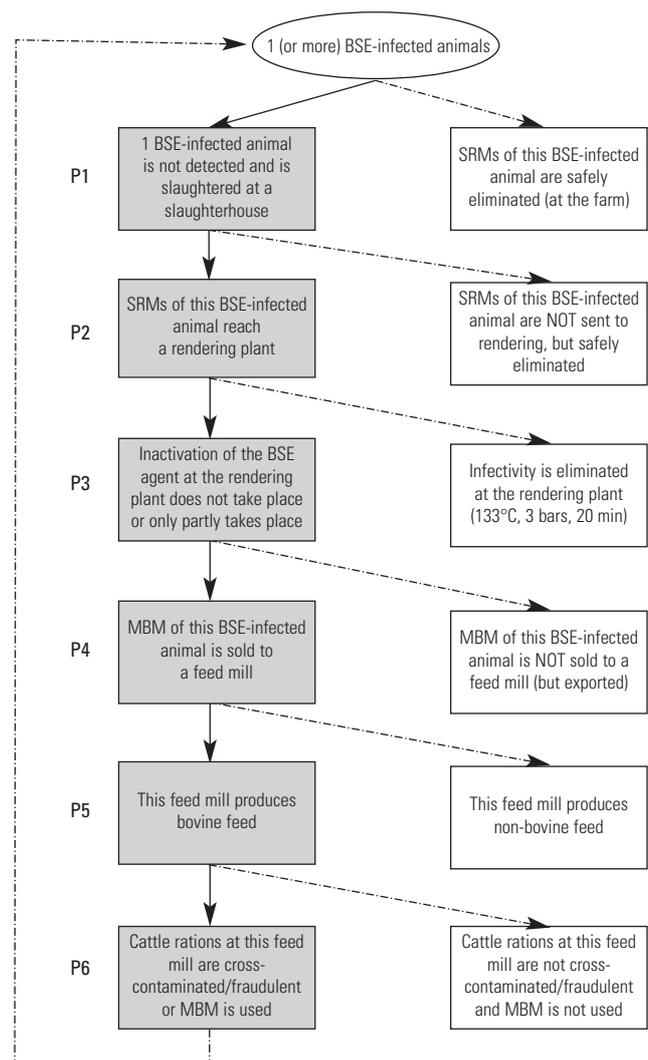
BSE: bovine spongiform encephalopathy
SRMs: specified risk materials
MBM: meat-and-bone meal

Fig. 1
Scenario tree of risk events, which may cause products from an animal infected with bovine spongiform encephalopathy to reach cattle feed
Grey boxes show the risk pathway, while white boxes indicate the absence or elimination of risk

Detection depends on the age of the animal and the clinical signs displayed, as well as on the disease awareness of the farmer and veterinarians on the farm and at the ante-mortem inspection.

The incubation period plays an important role in BSE transmission, as tissue distribution of infectivity varies significantly during this time (2, 14, 18).

Surveillance data and slaughter age could be fitted into the model at this point for a better estimation of this probability.

Table II
Characteristics of Country X before,
during and after the implementation of laws

Characteristic	Before	During	After
Total cattle population (around 80% beef, 20% dairy)	35,000,000	35,000,000	35,000,000
Number of calves	9,000,000	9,000,000	9,000,000
Number of cattle slaughtered at abattoirs without BSE inspection	5,000,000	5,000,000	5,000,000
Percentage of SRMs rendered from abattoirs not inspected for BSE	65%	65%	65%
Number of cattle slaughtered at abattoirs with BSE inspection	4,000,000	4,000,000	4,000,000
Percentage of SRMs rendered from abattoirs with BSE inspection	40%	40%	0%
MBM used for the production of animal feed	95%	95%	95%
Total number of feed plants	700	700	700
Number of bovine feed plants	200	200	200
Total production of feed in an average cattle feed mill in 5 years in tons	63,000	63,000	63,000
Production of cattle feed in an average cattle feed mill in 5 years in tons	25,000	25,000	25,000
Percentage of MBM in cattle feed	10%	1%	0.5%
Percentage of MBM used in feed for other species	5%	5%	5%
Total amount of MBM in a cattle-feed producing plant, in tons	4,400	2,150	2,025
Production of concentrate produced for cattle per year, in tons	1,000,000	1,000,000	1,000,000
Percentage of bovine concentrate fed to calves	45%	45%	45%

BSE: bovine spongiform encephalopathy
SRMs: specified risk materials
MBM: meat-and-bone meal

P1: The probability of this event happening during the three different time periods (before, during and after the legislation was implemented) is presented in Table III.

P2: probability that the specified risk materials from one animal infected with bovine spongiform encephalopathy will reach a rendering plant

Inspection at the slaughterhouse
The type of slaughterhouse inspection for BSE is important, since SRMs are treated in different ways.

In Country X, slaughterhouses can be classified into two types:

– slaughterhouses for export and domestic consumption (these may sell their products abroad and internally, to all regions of the country, and apply strict rules for BSE)

– slaughterhouses and butchers which slaughter only for local consumption (these abattoirs are under less restrictive rules for BSE inspections or may not have them at all. These will be referred to as 'without BSE inspection').

Destination of specified risk materials
Current legislation assumes that these materials are excluded from rendering, but implementation can only be ensured in inspected slaughterhouses.

Slaughterhouses without BSE inspection: in these slaughter facilities, *5,000,000 cattle are slaughtered* per year. Some *65% of the SRMs* from slaughterhouses without BSE inspection *are rendered.*

Slaughterhouses with BSE inspection: in these facilities, *4,000,000 cattle are slaughtered* per year. Before the implementation of legislation:

– *50% of SRMs were sold for human consumption*
– *10% were exported*
– the remainder, *40%, were rendered.*

Since the legislation has been in place, SRMs are removed and incinerated at the slaughterhouse.

The brain, spinal cord and distal ileum from a clinical case of BSE contain around 94% of total infectivity (Table I). Since the destination of tissues other than the 'officially inspected SRM tissues' could not be ascertained, *the rest of the infectivity present in a carcass (6%)* was assumed to go into slaughter wastes and thus to rendering (even those from BSE-inspected slaughterhouses), after the SRMs had been removed.

The total percentage of SRMs entering rendering was calculated as follows. For each type of slaughterhouse and time period, the percentage of SRMs going to rendering was multiplied by the number of cattle slaughtered. The resulting sum (carcasses for rendering) was divided by the total number of cattle slaughtered in Country X per year.

P2: the probability of this event occurring at each time period is presented in Table III.

P3: probability that the bovine spongiform encephalopathy agent is not inactivated

There is little information on the inactivation of the BSE agent during rendering. Taylor *et al.* (16) describe

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Table III

Pathway of risk events for the probability (before, during and after the implementation of legislation) that products from a single animal infected with bovine spongiform encephalopathy will reach bovine feed in Country X

Probability (P)	Steps in the pathway	Probability of this event occurring		
		Before legislation	During legislation	After legislation
P1	1 BSE-infected animal is slaughtered at a slaughterhouse	98%	98%	98%
P2	The SRMs of this BSE-infected animal reach a rendering plant	54%	54%	39%
P3	At the rendering plant, the BSE agent is not inactivated	100%	100%	80%
P4	MBM from one BSE-infected animal is sold to a feed mill	95%	95%	95%
P5	This feed mill produces bovine feed	29%	29%	29%
P6	The use of MBM, cross-contamination or fraud occurs during production of cattle feed	25%	14%	7%
P (overall)	**Probability that SRMs from one BSE-infected animal contaminate cattle feed**	**0.036 (3.6%)**	**0.020 (2.0%)**	**0.006 (0.6%)**

BSE: bovine spongiform encephalopathy
SRMs: specified risk materials
MBM: meat-and-bone meal

experiments on inactivation of the BSE agent through rendering procedures. These showed that not all processes were capable of significantly reducing the BSE agent. They also demonstrated that it was not safe to extrapolate from the pilot study to full-scale procedures, especially in regard to temperature.

Country X now has a law ensuring that rendering is performed to the internationally recognised standards recommended by the OIE, i.e. that rendering is carried out at a temperature of 133°C, with 3 bars of pressure, for 20 minutes, with a maximum particle size of 50 mm (20). Since it is difficult to estimate the reduction in infectivity, a worst-case scenario was applied for the time before and during the implementation of the legislation, assuming that inactivation did not occur. *After the law was enacted, only 20% of the plants implemented the OIE rules.* Thus, reduction of the BSE agent would not occur in 80% of cases.

P3: the probability of this event occurring at each time period is presented in Table III.

P4: probability that meat-and-bone meal from one infected animal is sold to a feed mill

Some 95% of MBM was used to produce animal feed. The rest was exported. Fertiliser containing MBM is also produced, but in such small quantities that it was not considered in this assessment. Imported MBM was not considered either, as the amount was negligible, and most of it derived from low BSE-risk countries.

P4: the probability of this event occurring during the three different time periods is presented in Table III.

P5: probability that bovine feed is produced in a feed plant

Country X has changed its feed bans over the years, with progressive restrictions for ruminant feed. The first ban prohibited the feeding of ruminant MBM to bovines. Later, a ban was placed on feeding animal MBM to ruminants.

The highest risk comes from 'mixed' feed mills, which produce ruminant and other feed in the same plant. Experiences in numerous countries have shown that it is extremely difficult to avoid cross-contamination in feed lines if MBM is used.

In Country X, *200 out of 700 feed plants (29%) produce bovine feed.* Bovine feed is produced in mixed mills, which produce feed for more than one species.

P5: the probability of this event occurring at each time period is presented in Table III.

P6: probability that the use of meat-and-bone meal, cross-contamination or fraud may occur in the production of cattle feed

Before the implementation of legislation

Before the implementation of the ruminant feed ban, it was legal to include MBM in ruminant feed. An average *11%* of cattle feed contained MBM at this time. In addition, a contamination rate of *14%* (as found by the national sampling plan; see below) occurred.

During the implementation of legislation

Since the feed ban, a national sampling programme has been conducted in ruminant feed plants by official

laboratories, to monitor the implementation of laws aimed at avoiding cross-contamination. Feed analyses are carried out by microscopy with a detection limit of 0.1%. The technique was designed to detect:

– MBM

– bone meal

– organ meal

– blood meal

– feather meal

– fish meal

– slaughter residues.

Of the feed examined, *14% was found to test positive* for the presence of the above, assuming 100% sensitivity and specificity for the test. Fraud, which may also occasionally occur, is included in this percentage.

After the implementation of legislation

Half of these mixed plants either stopped using MBM altogether, as they could not avoid cross-contamination, *or started to use separate lines*. This was confirmed by feed analyses, which showed a decrease in positive samples of about 50%, in comparison with those found when analyses were begun. So, as feed mills started to use separate lines or stopped using MBM, *feed contamination* with MBM *was reduced to 7%*.

P6: the probability of this event during each of the three time periods is presented in Table III.

P (overall): overall probability

The overall probability that SRMs from BSE-infected cattle could contaminate a bovine feed batch depends on the timing of their entry into the production cycle. This probability is calculated by multiplying the individual probabilities for each time period. Table III shows the outcomes for the different pathways during the periods analysed: before, during, and after the implementation of the legislation.

Phase 2: the number of cattle in each production system that could potentially be infected through meat-and-bone meal from one infected animal

The outcome of phase 2 is the number of calves that could potentially be infected with the BSE causative agent through concentrates containing contaminated MBM.

This phase is based upon experiences drawn from assessments of Latin American countries.

The assumed values are averages, based on the total feed production in those countries and the number of

feed mills, and are calculated for a five-year period, in accordance with the average incubation time.

It was assumed that *all SRMs from a BSE-infected animal* that had not been detected, removed and destroyed *would go to a rendering plant*, and that MBM containing the BSE agent from this source would be *sold to a feed mill that produced ruminant feed, where cross-contamination would occur* (Fig. 2).

Rendering plants usually receive their products from the same slaughterhouses. The whole batch produced in a rendering plant on one day, or at least the bulk of it, is likely to be sold to a single feed mill.

It was calculated that an *average cattle feed mill produces a total of 63,000 tons of feed in five years*. Of this, *25,000 tons are cattle feed*, the rest is feed for other species.
Different levels of MBM in cattle feed were estimated, to reflect the three different time periods.
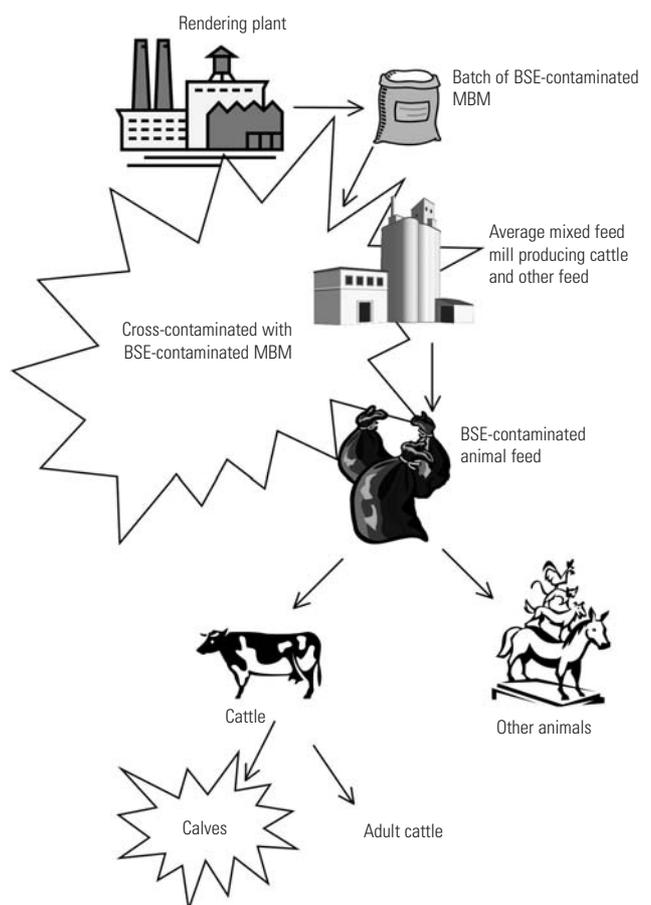
BSE: bovine spongiform encephalopathy
MBM: meat-and-bone meal
Fig. 2
Flow chart for the different steps outlined in phase 2: meat-and-bone meal contaminated with bovine spongiform encephalopathy may cross-contaminate cattle and calf feed in a mixed feed mill

Period before laws were implemented

At this time, MBM could legally be used in ruminant feed. On average, *bovine feed contained 10% MBM.*

Period during the implementation of laws

Feed samples were only sporadically examined during this period, and the possibility that fraud may have occurred during this time cannot be ruled out. *A cross-contamination rate of 1% with MBM was assumed*, which includes the possibility that fraud may have occurred.

Period after laws were implemented

Feed experts from the Ministry of Agriculture of Country X calculated that, if cross-contamination were not avoided, ruminant feed contained, on average, 0.38% MBM. For a conservative estimate, a *cross-contamination rate of 0.5% was assumed.*

The *average amount of MBM used in feed for other species*, based on the availability of MBM and national feed production, was assumed to be 5% at all times.

The total amount of MBM used in an average cattle-feed-producing plant was calculated as follows. First, the average amount of cattle feed produced per bovine feed mill in five years was multiplied by the percentage of MBM in cattle feed as a result of use, cross-contamination or fraud over the three time periods, as described above. Then the amount of feed produced for other species in a bovine feed mill in five years, multiplied by the average 5% of MBM in feed for other species, was added. The result was *4,400 tons* for the 'before' period; *2,150* for the 'during' period; and *2,025* for the period after laws had been implemented.

The infectivity titre of 1 $CoID_{50}$ has a 50% probability of infecting one animal. The amount of SRMs needed to cause infection with BSE is not known. Some studies (17) suggest that it could be anywhere between 100 mg and 1 g. It is also not known whether cattle are infected by a single dose, or multiple doses of infectious material over a period of time. There is no information available on the number of particles of BSE-contaminated MBM that make up 1 $CoID_{50}$; their dispersion in MBM or later in feed. Therefore, it is not possible to estimate the exact number of $CoID_{50}$ per unit of feed.

For this reason, a worst-case scenario was assumed, in which the BSE agent was homogeneously distributed in MBM in units of 1 $CoID_{50}$. In accordance with that assumption, the MBM was assumed to contain 4,200 $CoID_{50}$ from one BSE-infected animal.

The potential amount of $CoID_{50}$ in cattle feed depends on the amount of MBM used for bovine feed (as compared to

MBM used for feed for other species). This amount was calculated for each time period (before, during and after implementation of the feed ban) by multiplying 4,200 $CoID_{50}$ by the amount of MBM in cattle feed used over five years in an average bovine-feed-producing mill. The product was then divided by the estimated total amount of MBM used in the feed mill during the five-year period at each time period examined.

The amount of concentrate fed to calves is important, as it is assumed that most cattle are infected with BSE during their first year of life (1, 15, 19).

Table IV shows the number of calves and the amount of concentrate fed per calf in each production system in Country X. The more intensive the production system is, the more concentrate calves receive. However, for beef calves, the category of intensive production does not exist, as intensive production means that cattle are held in feed lots. This fattening period is only started in the second year of life. *Calves in extensive production do not receive concentrates.*

Table IV
Amount of concentrate fed to calves in their first year of life and number of calves in the various production systems per year

Type of cattle	Production type	Amount of concentrate fed per calf in one year (kg)	Number of calves in one year
Dairy	Intensive dairy system	650	20,000
	Semi-intensive/semi-extensive dairy system	500	840,000
	Extensive dairy system	–	1,140,000
Beef	Semi-intensive/extensive beef system	45	350,000
	Extensive beef system	–	6,650,000
	Total		**9,000,000**

The probability that a calf from a certain type of production system might be infected with BSE depends on the amount of concentrate (containing MBM) fed in this production system. Although calves in intensive dairy production receive the highest amounts of concentrate per animal, the total amount of concentrate fed in this production system is only a small percentage of the total amount of concentrate fed to calves (Table V).

The percentage of bovine *concentrate fed to calves was estimated at 45%.* This was derived from the amount of concentrate fed to calves divided by the *total amount of cattle concentrate produced per year (1,000,000 tons).*

The outcome – that is, the number of calves that could hypothetically become infected through contaminated

Table V
Total amount of concentrate fed to calves in one year, in tons, and distribution of concentrate fed to calves in different production systems

Type of cattle	Production type	Total of concentrate fed in one year (tons)	Concentrate fed (%)
Dairy	Intensive dairy system	13,000	2.9%
	Semi-intensive/semi-extensive dairy system	420,000	93.6%
	Extensive dairy system	–	–
Beef	Semi-intensive/extensive beef system	15,750	3.5%
	Extensive beef system	–	–
	Total	**448,750**	**100.0%**

MBM from one BSE-infected animal introduced into one feed mill – was calculated by multiplying the $CoID_{50}$ by the percentage of concentrate fed to calves, and by the probability of infection from 1 $CoID_{50}$ (i.e. 50%) (Table VI).

Table VI
Hypothetical number of calves infected with bovine spongiform encephalopathy through contaminated feed from one animal in a single feed mill

Time period	Maximum expected number of BSE-infected calves
Before implementation of laws	535
During implementation of laws	110
After implementation of laws	58

BSE: bovine spongiform encephalopathy

Phase 3: complete cycles by combining phases 1 and 2 to analyse the impact of control measures during different time periods

Phase 3 combines the probability that SRMs from a BSE-infected animal will reach a bovine feed batch (phase 1) with the number of calves that could potentially be infected by contaminated feed (phase 2). The outcome of each cycle is the number of potentially infected cattle, which then becomes the input for the next cycle. The calculations are made in five-year steps, since this is the average incubation period.

Phase 3a: cycle before the laws were implemented
The cycle starts with one BSE-infected animal entering the production chain. This animal might be a beef or dairy animal, and it could be either imported or a domestic animal, infected through the consumption of imported MBM.

The outcome of phase 1 is multiplied by the outcome of phase 2 (at the point before laws were implemented), and by the number of infected cattle (i.e one, at this stage). The result is the number of potentially infected cattle from this first BSE case over this five-year period (Table VII).

Phase 3b: cycle during the implementation of the laws

The second cycle is assumed to happen in the five years after the first cycle. The outcome of phase 1 is multiplied by the outcome of phase 2 (at the time when laws were being implemented), and by the number of potentially infected cattle from phase 3a (see Table VII).

Phase 3c: cycle after laws were implemented

The third cycle is envisaged to happen five years after the second cycle. The outcome of phase 1 is multiplied by the outcome of phase 2 (after laws were implemented), and by the number of potentially infected cattle from phase 3b (Table VII).

Phase 3d: future outlook once the laws have been implemented

Similarly, the outcome of phase 1 is multiplied by the outcome of phase 2 (after laws were implemented), and by the number of potentially infected cattle from the previous cycle (see Table VII).

It was assumed that the enforcement of the legislation would remain at this level.

Table VII
Number of cattle entering and leaving the bovine spongiform encephalopathy production cycle at each time period

Phase	Stage of cycle	Cycle	No. of cattle
3a	Start of the cycle	Cycle before the implementation of laws	1
	End of the cycle		19
3b	Start of the cycle	Cycle during the implementation of laws	19
	End of the cycle		42
3c	Start of the cycle	Cycle after the implementation of laws	42
	End of the cycle		14
3d	Start of the cycle	Second cycle after the implementation of laws	14
	End of the cycle		5
	Start of the cycle	Third cycle after the implementation of laws	5
	End of the cycle		2
	Start of the cycle	Fourth cycle after the implementation of laws	2
	End of the cycle		1

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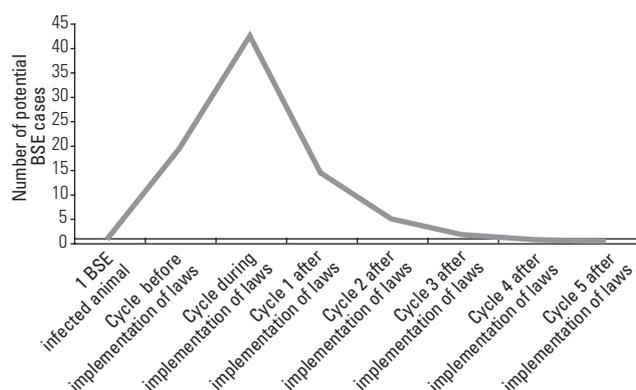
BSE: bovine spongiform encephalopathy

Fig. 3
The course of a hypothetical bovine spongiform encephalopathy epizootic if the same variables in the first cycle after the implementation of legislation are applied throughout the following years
Each cycle represents five years

Figure 3 shows the evolution of the number of BSE cases over time. The epidemic curve would reach 42 cattle at its maximum in a worst-case scenario. The epidemic curve climbs during the first five years, and increases even further during the second five-year cycle. In the following five years, after legislation has been implemented, the number of cases decreases and, after 25 years, there are no more infected cattle. This means that, with these measures in place, a potential epidemic should be brought under control.

Discussion

The characteristic of this exposure assessment is its ability to assess the BSE situation of a country over time. The idea was to create a simple model that can be easily understood and is not a 'black box'. It is meant to guide Veterinary Services through the kind of information that should be collected along the 'BSE chain', and the principal points that need to be included in such an assessment, not to demonstrate a sophisticated mathematical model. To use this model in a real-life situation, it would need to be adapted to the individual situation of a country. It might, for example, be necessary to split the pathway to account for differences in production or slaughtering systems. In addition, it might be necessary to gather more information, e.g. on the way materials are processed at rendering plants, etc. Only then, with further detail, could this model be used as a thorough risk assessment.

Although the probabilities for releasing the BSE agent through imported cattle or cattle products can be calculated, there is usually a high level of uncertainty. Several countries have underestimated the chances

of introducing BSE. It was therefore decided to concentrate on an exposure assessment, since the best way of preventing BSE is to implement risk management measures in good time.

The most labour-intensive task in these assessments was collecting the data. Some of the most valuable outcomes were:

– a better understanding of the destination of cattle products

– data for immediate and future use

– identifying what type of data should be collected in future.

The OIE *Terrestrial Animal Health Code* requires a BSE risk assessment to be updated every year. Once a basic model is set up, it can easily be brought up to date.

The data in the original assessments came from various sources and were not always consistent, as they were not thought to be important at the time. This may lead to certain biases. Over- or underestimations might also occur if numbers are based on a certain year and inferred for all other years. Ideally, the actual numbers should be reflected for all years.

Data gaps, e.g. for the age distribution of cattle or destination of MBM, were handled mainly through worst-case scenarios. This is not a very elegant approach, but it makes calculations easier and adds to the confidence that all eventualities are accounted for.

A deterministic approach was chosen for this model, as many of the data were provided as point estimates. This does not allow for variability and uncertainty.

The data for phase 2 of the model were based on average numbers, derived by dividing the total amount of produced feed by the number of feed mills. The proportion of the production of cattle feed versus other feed was also based on an average feed mill, and should be replaced by more detailed data. The outcomes of this phase are therefore hypothetical, and would need to be validated. A good setting for such a validation might be a country with only a few localised BSE cases, such as Canada or Japan.

Regional differences were not considered in this model, as it was often difficult and time-consuming to gather even basic data. However, this is a very important point, especially since regional circumstances might cause a higher or lower risk than average in a country.

This model could be used to evaluate the situation in different regions by substituting regional data for country data.

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The first cycle of the model begins before the implementation of laws to prevent BSE. The number of BSE-infected cattle would increase if the cycle were started even earlier before the implementation of BSE measures, and decrease if started only after the implementation of these measures. In a real-life situation, the number of cycles should also account for the number of imported cattle and the time of the imports.

The model does not take the effects of the size of the cattle population into account. In its 2007 revision of the GBR methodology, EFSA suggested making an adjustment for countries with large cattle populations, which do not have a very high level of challenge. With an adult cattle population of 10,000,000 or more – as in the case of Country X – it may take longer to reach the same prevalence (7).

One of the assumptions of the model is that cattle enter the cycle at the height of their infectiousness. This worst-case scenario was assumed because there were not enough available data on the age of the cattle at slaughter, in the various production systems. In practice, not all cattle would actually reach the height of infectivity. On the other hand, the latest update of the oral challenge studies reveals that one gram of brain of a BSE-infected animal during its clinical phase might hold between one and 20 CoID$_{50}$, or even more (17).

While the possibility of detecting cattle in their clinical phase is given, especially for dairy and breeding cows, cattle could only be detected during their incubation period by diagnostic testing, a few months before showing clinical signs. If slaughtered before that time, infectious material could reach rendering undetected, in lower doses, and a building BSE epidemic might stay undetected for many years.

Doherr *et al.* (4) modelled the expected number of pre-clinical and clinical cases of BSE in Switzerland. This approach could be adapted to include the age at slaughter in the calculations, but it requires data on slaughter age and production type.

Only the possibility of cattle being infected with BSE while they are calves is considered. Although this might be true for most animals, the possibility of cattle being infected with BSE at a later stage of their lives cannot be ruled out. Calf milk replacer, however, was not taken into account. Although some literature suggests that calf milk replacer produced from BSE-infected tallow might have accounted for some BSE cases (12, 13, 21), an EFSA opinion (6) considers the exposure through tallow as minimal. Here, the authors assumed that calf milk replacer was not a main route of infection.

The model is based on the assumption that one BSE-infected animal entering the production chain infects other cattle. Nevertheless, contaminated MBM in cattle feed, introduced by importation (see P4), may have the same effect.

Imported contaminated MBM from a BSE-infected animal may be an even greater risk than that from a BSE-infected, slaughtered animal, as the slaughtered animal might be detected at ante-mortem inspection and destroyed; its SRMs might be removed and part of the carcass might be rendered. Thus, the calculations could also be started with contaminated MBM instead of one infected animal, shortening the first cycle by starting phase 1 with P4.

Although intensively kept dairy cattle receive more concentrate than cattle from other production systems, they have a lower probability of receiving BSE-contaminated MBM, due to the fact that there are fewer of them.

The estimation of the average amount of concentrate given to calves in each production system is a very rough estimate. It is advisable to cross-check this amount with the amount of concentrate produced by the feed companies.

As it was impossible to estimate the exact amount of MBM used in bovine feed before the feed ban, an average of 10% was assumed. This might be an overestimation.

It was assumed that all infectious material goes from one rendering plant to one feed plant. However, not all the materials from one animal necessarily go to the same place. It is possible that the head and brain of an animal could be sold to a rendering plant directly after slaughter, while the half-carcass, including the spinal cord, is sold to a butcher. From there, it might be sent to a garbage dump or processed for human consumption.

The EFSA opinion on GBR methodology (7) assumes a reduction factor of 1,000 of the BSE agent during rendering, if a process called 'batch pressure cooking' is used and the OIE recommendations (133°C, 3 bars, 20 minutes) are followed (20). As there was very little information available on the sterilisation process in rendering plants in Country X, and the legislation was not well enforced, a reduction factor was not particularly considered.

The risk caused by transporting ingredients containing MBM was not assessed, as only the main routes for infection were examined. However, cross-contamination may not only happen in feed mills, but also during the transportation of feed ingredients.

Cross-feeding means that feed containing MBM, intended for other species, is, intentionally or accidentally, given to ruminants. This may include the feeding of chicken litter to cattle.

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Cross-feeding has not been investigated in this model, as it was assumed that there are very few mixed farms in Country X. However, this may be an important point to investigate in a real-life situation.

Conclusions

The most important factor for a successful assessment is to collect extensive but representative data. The most valuable outcome might be not the final result, but all the knowledge gained in the process.

This exercise suggested a low probability of MBM from BSE-infected cattle being incorporated into bovine feed. However, the introduction of BSE through cattle or contaminated MBM can never be completely ruled out. Should one BSE-infected animal or lot of contaminated MBM have entered bovine feed, BSE could already have been recycled and amplified in Country X.

All complementary measures reduce the probability of amplifying the agent and, eventually, the occurrence of clinical BSE cases. If the appropriate control measures are properly implemented, a potential BSE epidemic in Country X will decline over time. When the first case of BSE is detected in Country X, properly implementing effective control is crucial in stopping the transmission cycle at various levels as quickly as possible. In any case, it would take a few years to eliminate BSE altogether in this country. The introduction of preventive measures for countries at risk, even at a relatively high cost, is good insurance against any future trade losses if BSE does occur.

The main measures to control BSE are SRM removal and destruction and, in particular, the avoidance of bovine proteins in cattle feed.

Proper implementation and enforcement of legislation are crucial in preventing and controlling BSE.

Data must be collected on a regular basis, including data from both active and passive surveillance systems.

This exposure risk assessment, in combination with a risk-based surveillance system, will help in assessing the BSE situation in Country X.

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Évaluation de l'exposition à l'encéphalopathie spongiforme bovine dans un pays hypothétique

S.E. Hutter & U. Kihm

Résumé
Les auteurs présentent un modèle élémentaire de feuille de calcul portant sur des données quantitatives, destiné à évaluer le risque d'encéphalopathie spongiforme bovine (ESB) dans une configuration nationale. Ce modèle a été construit en utilisant les résultats d'évaluations du risque d'ESB conduites dans plusieurs pays d'Amérique latine. L'analyse, basée sur le niveau de mise en œuvre de la réglementation et sur ses effets à différentes périodes, a pour but d'évaluer l'impact potentiel de l'introduction d'un animal atteint d'ESB dans le cycle de production. L'information réunie est intégrée de manière à ce que les résultats de l'évaluation puissent s'appliquer à un pays hypothétique, « pays X ». L'évaluation du cycle de l'ESB au niveau national peut contribuer à la prise de décisions sur les mesures de prévention ou de lutte à mettre en œuvre ou à renforcer. Ces évaluations peuvent également servir à déterminer l'exposition à l'ESB dans le cadre de l'analyse du risque préconisée par l'Organisation mondiale de la santé animale pour déterminer le statut des pays au regard du risque d'ESB.

Mots-clés
Amérique latine – Application de la législation – Bovins – Cycle de l'ESB – Encéphalopathie spongiforme bovine – Évaluation de l'exposition – Évaluation du risque – Feuille de calcul.

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Evaluación del grado de exposición a la encefalopatía espongiforme bovina en un país hipotético

S.E. Hutter & U. Kihm

Resumen

Los autores presentan un modelo cuantitativo básico en hoja de cálculo destinado a evaluar el riesgo de encefalopatía espongiforme bovina (EEB) dentro de un país. El modelo se basa en información procedente de estudios realizados en países latinoamericanos para determinar el riesgo de EEB. El análisis, centrado en el nivel de aplicación de la legislación y su incidencia a lo largo de distintos periodos, sirve para estimar los eventuales efectos que traería consigo la introducción de un bovino infectado en el ciclo de producción. Dado que la información reúne datos de distintos países, cabe decir que los resultados de la evaluación corresponden a un hipotético 'país X'.

El hecho de evaluar el ciclo de la EEB en un país puede ser útil para adoptar decisiones sobre el lugar en que conviene aplicar y/o hacer cumplir medidas preventivas o de control. Además, puede equipararse a la evaluación de la exposición que forma parte del proceso de determinación de riesgos recomendado por la Organización Mundial de Sanidad Animal para determinar el nivel de riesgo de EEB de un país.

Palabras clave

América Latina – Aplicación de las leyes – Bovinos – Ciclo de la EEB – Determinación del riesgo – Encefalopatía espongiforme bovina (EEB) – Evaluación de la exposición – Modelo en hoja de cálculo.

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