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Measuring general animal health status: Development of an animal health barometer

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ABSTRACT

The development of an animal health barometer, an instrument to measure the general health of the Belgian livestock population on a yearly basis and to monitor its evolution over time, is described. The elaboration of a set of 13 animal health indicators (AHIs) as the basis for the animal health barometer is discussed. These indicators were weighted by experts – including scientists, policy makers and agro-industrial representatives – to determine their relative weight in the barometer. The result of the barometer is expressed as a comparison with a previous year. Based on the results of the 13 AHIs, it is concluded that general animal health in Belgium shows a positive evolution since 2008. The animal health barometer provides a composite view of the status of livestock health in Belgium and is a tool to communicate in an intelligible, comprehensible manner on aspects of animal health to consumers and professional stakeholders in the animal production and food chain. Together with the food safety barometer (Baert et al., 2011. Food Res. Int. 44, 940) and the plant health barometer (Wilmart et al., 2014. Eur. J. Plant Pathol. doi: 10.1007/s10658-014-0547-x), the animal health barometer is one of the three instruments to provide a holistic view on the overall status of the safety of the food chain in Belgium.

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1. Introduction

A number of epidemic disease outbreaks that occurred in the European Community in the 1990s and later (e.g. Bovine Spongiform Encephalopathy, Classical Swine Fever, Foot-and-Mouth Disease, Avian Influenza) have shown that ensuring animal health – and by extension food safety and security – can best be achieved by using a farm to fork approach, in which all stakeholders of the food and feed

chain bear their own responsibility for product safety as a whole. In parallel with the steady growth of the European Community and with the increase in animal trade and risk of disease transmission a progressive harmonisation of animal health measures and systems of disease surveillance, diagnosis and control have been put in place (EU Animal Health Strategy 2007–2013).

Animal health and food safety are closely linked as animal diseases transmissible to man (zoonosis) affect public health. Poor hygiene and disease occurrence at the different stages of the animal production chain can affect the quality and the safety of animal products (Singer et al., 2007).

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The safety of the food chain has been reinforced by the general implementation of procedures based on the 'Hazard Analysis and Critical Control Points' (HACCP) principles treated by the General Food Law (Regulation (EC) 178/2002) and the European Hygiene legislation (Regulation (EC) 852/2004). In the various EU Member States competent authorities inspect and audit the implementation of 'Good Agricultural Practices' (GAP) and HACCP based procedures. These procedures are also applicable in the animal production chain and have an indirect effect on animal health as such.

The Belgian Federal Agency for the Safety of the Food Chain (FASFC) was created in 2000 as a response of the government to the dioxin crisis (Royal Decree of 4 February 2000) which had revealed the lack of coordination between different inspection services of the food chain. The expectations regarding the organisation of the food chain control system were clearly defined and were meant to cover the entire food supply chain from farm to fork (starting from the raw materials and the feed to the rearing of food production animals up to their transformation into food), with the objective to protect public health, animal health and plant health.

All respective segments within the food chain bear their own responsibility to ensure that safe food is offered to the consumer, without the hazardous presence of biological, chemical or physical agents. Controls and inspections concerning the sanitary status, hygiene and infrastructure, animal health and welfare and safety of animal products are important tasks performed by the FASFC. The results are published in annual activity reports which can be consulted on the website (<http://www.favv-afsc.fgov.be/rapportsannuels/>). However, these results do not provide a quick general picture of the safety evolution of the food chain. Therefore, the 2009 FASFC business plan mentioned the need to identify a set of indicators to measure and follow-up the safety within the food chain (Houins, 2009). This task was dedicated to the Scientific Committee of the FASFC (an independent scientific consultation body). The idea to develop a barometer to measure the safety of the food chain fits within the context of the prevailing trend towards measurable objectives, performance indicators, assessments, score systems and the like. This idea was also inspired by the introduction of similar notions in other sectors, such as the Belgian Inter-federal Poverty Barometer (2011) and the Belgian sustainability barometer (Sustainable Development Task Force, 2009).

The concept of the measurement of the safety of the food chain and the illustration of the case study of the food safety barometer has been described by Baert et al. (2011, 2012). Next to the food safety barometer two other barometers were developed by the Scientific Committee of the FASFC: the plant health (phytosanitary status) barometer (Wilmart et al., 2014) and the animal health barometer. The present paper describes the development of the latter as a practical tool for measuring and monitoring the general health situation of the national livestock population (14 animal groups or species). Animal health in the context of this paper is considered as the general sanitary status of the animal production chain as observed from

the standpoint of the FASFC which is responsible for the control of the complete food chain from farm to fork.

2. Material and methods

2.1. Objective and scope of the barometer

Animal health, within the framework of the animal health barometer, is defined as the sanitary health status (including infectious diseases and zoonoses but excluding metabolic diseases) of the livestock population (14 animal groups or species including bees and fish but excluding pets and wildlife) including the compliance to standards related to animal husbandry, hygiene and welfare conditions in the primary production. Although most of the data used for the calculation of the animal health barometer are collected by the FASFC during its control and inspection activities, it has to be clear that the concept of animal health is not limited to the aspects that are related to food safety. Nevertheless, the authors are convinced that there is a strong link between animal health and food safety as also mentioned by Singer et al. (2007).

The goal of the animal health barometer is to conduct a measurement of the level of animal health of the national livestock population at the end of a calendar year and to monitor its evolution over time. In the present study, the outcome of the animal health barometer basically relates to the presence of hazards (animal diseases and zoonoses) within the animal production chain affecting the health and well-being of the production animals and posing a threat for the safety of the animal products. It relates also to the existence and functioning of preventive or mitigating systems for limiting the probabilities that such hazards occur or pose a threat to animal and public health. Information about the animal health status is collected yearly via the core activities of the FASFC and external partners.

2.2. Definition and selection of animal health indicators

Numerous controls and inspections are routinely conducted by the FASFC in order to monitor and control animal health and the related activities by the operators. It would be too complex and unworkable to incorporate all the results into the barometer, the more that an overview of most of these data is published in the annual reports of the FASFC (<http://www.favv-afsc.fgov.be/rapportsannuels/>) or other authorities, institutions or organisations. Therefore, it was decided to work with a set of indicators.

An indicator synthesises or simplifies relevant data about the status or evolution of a number of phenomena or symptoms. An indicator can assume either a quantitative or a qualitative (nominal or ordinal) form (Sustainable Development Task Force, 2009). Each indicator provides information about a partial aspect of the animal production chain and the monitoring of each indicator enables to achieve a trend analysis of this particular aspect.

The animal health indicators (AHI) used in the animal health barometer are not performance indicators, in the sense that they are not meant for evaluating the performance level of a certain set of activities neither of the performance of the Veterinary Services as is often done in

a management context where the goals have been clearly set. The AHIs are basically descriptive in nature.

In earlier work on the development of a barometer for the safety of the food chain (Baert et al., 2011) a number of criteria for the selection of indicators were defined. Animal health indicators ideally should respond as much as possible to the following characteristics:

- *Measurability*: indicators should be quantitatively measurable as the objective of the barometer is to follow-up trends over time.
- *Independence*: indicators should be independent. Different indicators should not measure similar aspects of the animal production chain.
- *Reliability*: indicators must be robust, reliable and as much as possible insensitive to bias.
- *Availability*: the data used in the indicator must be readily available in reports, documents or databases.
- *Representative for animal health*: the whole set of indicators must include the various categories of animal health hazards within the scope of the barometer.
- *Unambiguity of formulation*: an unambiguous relationship should exist between the indicator and the overall animal health status as measured in the barometer.
- *Durability*: the indicators have already been measured over a long period of time, and it is expected that they will be further followed up during many years to come.

The food chain encompasses all possible stages of the food supply chain from farm to fork and animal production is an important part of it. Logically, AHIs are chosen at the level of the primary production site (farm level), at the individual animal or herd level and at the level of the slaughterhouse or destruction facility.

AHIs have been selected covering key activities along all the stages of the animal production chain. These activities encompass a considerable production volume, and/or may have a significant impact on the safety of the food chain in general and on animal health more precisely. Key activities are for example: rearing of production animals, milk production, collection of semen, slaughtering, etc.

Based on the above-mentioned criteria, a workgroup of the Scientific Committee of the FASFC has performed a thorough expert evaluation of all possible data providing information about the animal production chain and readily available within the FASFC and other Belgian organisations. The workgroup was composed of scientific risk assessment experts, veterinary animal disease diagnostic experts from the national and regional laboratories and experts representing the livestock sector. Their feedback resulted in the selection of a set of 13 AHIs (Table 1). A detailed technical sheet for each AHI is available on <http://www.favv-afsc.fgov.be/scientificcommittee/advices/.documents/ADVICE09-2011.EN.DOSSIER2009-09bis.appendix1.pdf>.

This set of indicators covers all stages of the entire primary animal production sector (producers, traders, collection centres, transportation, artificial insemination centres, embryo collection teams, slaughterhouses and fish markets) and the 14 animal groups or species (cattle and (veal) calves, pigs, small ruminants, solidungulates, poultry and ratites, cervids, bees, rabbits, farmed game, fish,

molluscs and shellfish). In the selection process of the indicators the Scientific Committee of the FASFC tried to cover the various animal species in accordance with their economic importance in Belgium. Because the databases did not allow to separate mortality data of cattle according to age and holding types (i.e. dairy versus beef holdings) and because adult cattle were already well represented in the animal health barometer (AHI6—notification of bovine abortions and AHI7—milk somatic cell count), it was decided to restrict mortality data of cattle to veal calves. They represent a separate and highly specialised branch of the Belgian cattle industry characterised by few but large holdings (Pardon et al., 2012). Veal calves mortality data are a reliable and useful parameter for the health of the veal calf production.

Some indicators (AHI1, AHI2, AHI4, AHI6) are related to the preventive approach of animal health policy (notification of mandatory notifiable animal infectious diseases, self-checking for the primary animal production sector, traceability and notification of bovine abortions). Prompt notification of regulated animal infectious diseases is crucial for the authority to establish effective control measures without delay in order to prevent the early spread of contagious diseases.

Self-checking refers to the whole range of measures taken by business operators to make sure that the products for which they are responsible meet the requirements laid down in the regulations on the safety and the quality of products under the authority of the FASFC, and on traceability. In the primary production sector, the setting up of a fully operating self-checking system based on the HACCP principles, is not mandatory. Business operators at primary production must, however, comply with good hygiene practices and keep records of certain operations. Several incentives have been put in place in order to encourage primary production operators to install a fully operating self-checking system and have their self-checking system certified. For food business operators (including primary production) with an externally certified self-checking system, FASFC inspection frequencies are reduced as is their annual financial contribution to the FASFC.

Some AHIs (AHI3, AHI4 and AHI5) are related to the production process control (inspection and audits), while others (AHI8 and AHI12) represent observations made by official veterinarians during slaughterhouse inspections. The data for AHI9 (antimicrobial resistance in *Escherichia coli* indicator bacteria) is collected within the framework of the Belgian antimicrobial resistance monitoring program among indicator bacteria of food producing animals.

A specific characteristic of the animal health barometer (compared with the food safety barometer and the plant health barometer) is that some of the data originated from sources external to the FASFC. This is particular the case for indicator AHI7 (milk somatic cell count), for which the data originate from the Walloon Milk Committee and the Flanders Milk Control Centre, as well as for indicators AHI10 (mortality in slaughter pigs) and AHI11 (mortality in small ruminants) for which mortality data are obtained from the rendering company. The data for indicator AHI13 (mortality in veal calves) on the other hand are derived from the

Table 1
Overview of the animal health indicators.

Title	Description	Interpretation
AHI 1: notification of mandatory notifiable animal diseases	The percentage of mandatory notifiable animal diseases that the FASFC has reported in relation to the total number of mandatory notifiable animal diseases ($n = 73$) under the application of chapter III of the Animal Health Law of 24th March 1987	Given that mandatory notification is an inherent part of the preventive approach, and is crucial for the authorities to establish timely control measures preventing the spread of infectious animal diseases, an increase of the indicator is therefore considered as an indication of vigilance and alertness with regard to the safeguarding of animal health and is therefore interpreted as positive
AHI2: self-checking for the primary animal production sector	The percentage of performed key activities using a certified self-checking system in the primary animal production sector, on an annual basis	An increase of the percentage of key activities with a certified self-checking system indirectly leads to a higher confidence level with regard to adequate preventive actions taken in order to ensure overall animal health. An increase of the indicator is therefore interpreted as positive
AHI3: inspections of infrastructure, facilities and hygiene	The percentage of annual inspections with regard to infrastructure, facilities and hygiene that were scored 'favourable' or 'favourable with remarks'	This indicator shows the extent to which the operators meet the legal requirements with regard to infrastructure, facilities and hygiene. An increase of this indicator increases the likelihood of an improvement of animal welfare and health and is therefore perceived as positive
AHI4: traceability inspections	The percentage of annual inspections related to traceability that were scored 'favourable' or 'favourable with remarks'	This indicator measures the extent to which the operators have met the legal requirements concerning traceability. An increase of this indicator indicates a better ability to trace and monitor animals and animal products through the various production, processing and distribution phases and is therefore interpreted as positive
AHI5: animal welfare inspections	The percentage of annual inspections related to animal welfare that were scored 'favourable' or 'favourable with remarks'	This indicator measures the extent to which the operators have met the legal requirements concerning animal welfare. An increase of this indicator indicates an indirect improvement of animal health and is interpreted as positive
AHI6: notification of bovine abortions	The percentage of bovine abortions tested annually in relation to the total number of female cattle aged over 24 months	Bovine abortions may be the result of infectious diseases such as brucellosis, neosporosis, BVD (Bovine Viral Diarrhoea), Q fever, Bluetongue, Schmallenberg virus, etc. This indicator is a surveillance tool of cattle health. An increase of this indicator, i.e. the percentage of pathological examinations performed on aborted tissues, indicates greater awareness of the sector regarding abortion. An increase of the indicator is interpreted as a favourable development of the surveillance of cattle health
AHI7: bulk tank somatic cell count	The percentage of bovine tank milk samples for which the number of cells is below or equal to $400,000 \text{ mL}^{-1}$ annually	An increase of this indicator indicates a better general udder health of the bovine population and implicates fewer cows with (sub)clinical mastitis. An increase of the indicator is interpreted as positive
AHI8: parasitic liver damage in pigs	The annual percentage of healthy pig livers (not condemned) related to the number of slaughter pigs slaughtered in Belgium	An increase of this indicator implicates fewer slaughter pigs with a substantial parasitic infection and indicates an indirect improvement of porcine health. An increase of this indicator is therefore interpreted as positive
AHI9: antimicrobial resistance in <i>E. coli</i> indicator bacteria	The annual percentage of <i>E. coli</i> isolates from live animal sources, collected by the FASFC within the framework of the monitoring of indicator bacteria, which are sensitive to all of the antimicrobials tested	The percentage of <i>E. coli</i> isolates that are sensitive to all types of tested antimicrobials is a measurement of the occurrence of antimicrobial resistance and indirectly the use of antimicrobials. An increase of this indicator, i.e. an increase in the percentage of <i>E. coli</i> isolates sensitive to all types of antimicrobials tested, is a sign of the reduction of antimicrobial resistance and indirectly an improvement of animal health given that there is a reduced need to treat animals. An increase of this indicator is therefore interpreted as positive
AHI10: mortality of slaughter pigs	The annual mortality percentage of fattening pigs compared to the number of slaughtered pigs	This indicator serves as a criterion for the general health of fattening pigs. A reduction of this indicator reflects an improvement in animal health
AHI11: mortality of small ruminants	The annual mortality percentage of small ruminants (sheep and goats) compared to the total number of small ruminants	This indicator serves as a criterion for the general health of small ruminants. A reduction of this indicator reflects an improvement in animal health
AHI12: poultry carcasses declared non-compliant	The annual percentage of poultry carcasses declared non compliant at slaughter	This indicator serves as a criterion for the rejection of poultry carcasses at slaughter for health reasons. A reduction of this indicator reflects an improvement in animal health
AHI13: mortality of veal calves	The annual mortality percentage of veal calves compared to the number of calves reared at veal calf holdings	This indicator serves as a criterion for the general health of veal calves. A reduction of this indicator reflects an improvement in animal health

Table 2

Overview of the number of animal health indicators that are related to the different segments of the animal production chain.

Food chain stage	Number of animal health indicators	AHI
Suppliers	3	AHI 2, 3, 4
Primary animal production	11	AHI1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 13
Processing	6	AHI3, 4, 5, 7, 8, 12
Distribution	2	AHI3, 4
Trade	1	AHI1

Belgian electronic identification and registration system (SANITEL).

The Animal Health Indicator matrix (Table 2) shows the relationship of the different AHIs with the respective stage of the animal production chain, indicating that the whole animal production chain is covered.

2.3. Assigning a weight to each indicator

The concept of measuring 'Animal Health' is not as unambiguous as it seems at first sight: the impact of the various indicators on animal health may be perceived in a different way by different professionals or stakeholders. In order to get a proper insight into the degree of importance attached to certain indicators by the various stakeholders and experts, a weighting of the indicators was performed. This weight is taken into account when the overall value for animal health in the barometer is calculated. A method similar to the one described by Baert et al. (2011) during the development of the food safety barometer has been used.

Each of the 13 AHIs was scored by FASFC risk managers and risk assessors (Scientific Committee) and by stakeholders of the Belgian food chain (agro-industrial sector, consumer organisations and representatives from other competent authorities represented in the Advisory Committee of the FASFC) by means of an electronic survey. The participants got a detailed technical sheet for each AHI and instructions on how to fill in the survey. The survey used the Las Vegas method (Gore, 1987). Responders had to assign 10 points to the AHIs according to their judged importance to animal health. Several points could be assigned to one AHI and each AHI could receive points, however the total sum of all assigned points had to be equal to 10.

The survey was sent to 85 people (34 risk assessors, 12 risk managers and 39 stakeholders). Finally, the mean weight of each AHI was calculated (Table 3).

2.4. Calculation of the animal health barometer

For all 13 AHIs, data were gathered from 2007 to 2012 and the proportional changes between 2 consecutive years were calculated. For AHI9 (antimicrobial resistance in *E. coli* indicator bacteria), only data from 2011 onwards were available. It was decided to neutralise an indicator when its value for a defined year was below 1% to avoid the impact of large fluctuations in percentage change from one year to another that reflect only a limited impact on animal health. Therefore, AHI2 (self-checking for the

primary animal production sector) was neutralised in 2008 and 2009 because the percentage of performed key activities with a certified self checking system was below 1% in 2007 and 2008. It was assumed that the impact on animal health is only very limited if the adoption of this system is restricted to less than 1% of the activities in the animal production chain. On the contrary, this reasoning was not followed for AHI12 (poultry carcasses declared non-compliant) because it was assumed that the percentage of poultry carcasses declared non-compliant is not likely to be higher than 1% of the considered population and small deviations do reflect an important change in the health status of the this population. Also for AHI6 (notification of bovine abortion) a similar reasoning was applied because it was assumed that the percentage of cattle with a notified abortion is low because of several reasons. First of all, Belgium is officially free from brucellosis and abortion storms in cattle have not occurred lately. Second, abortion is often not detected by the farmer especially in the earlier stages of gestation. Indeed, according to Forar et al. (1995) only 20 to 30% of abortions are detected visually. Third, Belgium has an important beef cattle production and abortion may stay undetected in pregnant beef cattle on pasture. Fourth, it has been described that various, often socio-economical reasons play a role in the underreporting of abortion by farmers (Bronner et al., 2014). Finally, cattle owners are traditionally of the opinion that they only have to notify abortion in case of observation of the expulsion of a dead or non-viable foetus during mid- and end-gestation. Therefore, taking all these factors into consideration, the authors postulated that the percentage of cattle with a notified abortion is not likely to be higher than 1% in Belgium, which is in line with the study of Norman et al. (2012) who found an abortion frequency of 1.31% in dairy cattle over 151 days of pregnancy.

Certain AHIs (AHI3, AHI4 and AHI5) are expressed as a percentage of inspections that were scored 'favourable' or 'favourable with remarks'. These indicators show the extent to which the operators have met the legal requirements.

For most indicators an increase was interpreted as an amelioration of the situation. For some indicators related to mortality (AHI10, AHI11 and AHI13) and to percentage of non-compliant carcasses at slaughter (AHI12) a decrease of the indicator reflects an improvement of animal health.

In order to determine the value that reflects the change of the state of animal health, the weighting factor was multiplied with the annual proportional change (two consecutive years) of each AHI and the mean of all these values was calculated. The indicator values are count data and the observed differences between successive years were tested by means of a Poisson regression (StataCorp, 2011), ensuring the validity of the model (i.e. ensuring absence of extra-binomial variability). Values of $p < 0.05$ were considered significant.

3. Results

The individual values for each indicator for a single year, as well as the proportional change between two consecutive years are shown in Table 4. This analysis indicates

Table 3

Overview of the mean weighting score for each indicator and for the different responder groups.

Title	Risk managers (n = 7)	Stakeholders (n = 7)	Risk assessors (n = 20)	Overall (among all responses) n (=34)
AHI 1: notification of mandatory notifiable animal diseases	2.04	2.04	1.76	1.87
AHI2: self-checking for the primary animal production sector	0.74	0.93	1.30	1.11
AHI3: inspections of infrastructure, facilities and hygiene	1.11	2.04	1.56	1.57
AHI4: traceability inspections	1.67	1.49	0.91	1.19
AHI5: animal welfare inspections	0.37	1.30	0.46	0.61
AHI6: notification of bovine abortions	1.67	1.67	0.91	1.22
AHI7: bulk tank somatic cell count	0.74	0.56	0.91	0.80
AHI8: parasitic liver damage in pigs	0.93	0.19	0.33	0.42
AHI9: antimicrobial resistance in <i>E. coli</i> indicator bacteria	1.86	1.49	1.37	1.49
AHI10: mortality of slaughter pigs	0.37	0.56	1.11	0.84
AHI11: mortality of small ruminants	0.19	0.19	0.78	0.54
AHI12: poultry carcasses declared non-compliant	0.93	0.37	0.65	0.65
AHI13: mortality of veal calves	0.37	0.19	0.98	0.69

that overall animal health in Belgium has continuously improved between 2008 and 2012.

As described earlier, a survey was organised amongst stakeholders to obtain a weighting factor for each AHI. In total 34 responses (40% response rate) were obtained of which 7 (21%), 7 (21%) and 20 (59%) were provided by risk managers, stakeholders and risk assessors respectively. Each AHI received a score, meaning that the stakeholders were convinced that every AHI was relevant for the measurement of animal health in the barometer. Based on the answers the mean weight (among all responses) of each AHI was calculated (Tables 3 and 4) indicating their importance assigned by the experts with regard to their contribution in measuring animal health. Table 3 gives an overview of the mean weighting scores for each indicator of the different response groups.

The overall value of the 2008 animal health barometer (2008 versus 2007) was -1.14% . Despite a clear improvement with regard to mortality (AHI10, AHI11 and AHI13) especially in small ruminants after the bluetongue epidemic in 2007, this slight decrease was mainly due to a drop in notification of mandatory notifiable diseases (AHI1).

The overall value of the 2009 animal health barometer (2009 versus 2008) showed a positive result of $+4.65\%$. This was mainly due to a rise in notification of mandatory notifiable diseases (AHI1) and a decrease of mortality in slaughter pigs, small ruminants and veal calves (AHI10, AHI11 and AHI13). On the other hand, there was a clear decrease with regard to vigilance for bovine abortions (AHI6) in 2009.

The overall value of the 2010 animal health barometer (2010 versus 2009) showed a positive evolution of $+16.71\%$. This was mainly the result of an increase of the number of certified self-checking systems in primary animal production (AHI2). Furthermore there was an improved vigilance for bovine abortions (AHI6).

The overall value of the 2011 animal health barometer (2011 versus 2010) amounts $+6.54\%$. This was caused, as in the previous year, by an increase in the number of certified self-checking systems in primary animal production (AHI2) and an increased vigilance of bovine abortions (AHI6). Mortality in slaughter pigs (AHI10) was considerably higher compared to 2010.

Finally, the 2012 animal health barometer (2012 versus 2011) showed an increase of $+14.3\%$. This positive evolution is mainly due to an increase of notification of mandatory notifiable animal diseases (AHI1) and bovine abortions (AHI6). Furthermore, there is a higher number of operators in the animal production chain with a certified self-checking system (AHI2) and there was a lower mortality among slaughter pigs (AHI10).

AHI2 (self-checking for the primary animal production sector) showed a clear positive evolution over the 4 last years, although the results for 2007 and 2008 were neutralised because they were lower than 1%. Between 2007 and 2010, there has been a continuous decrease in swine mortality (AHI10), which was most notable between 2007 and 2008 and between 2008 and 2009. However, in 2011 a slight increase was reported again. The mortality of small ruminants (AHI11) has also decreased substantially, particularly between 2007 and 2008, probably as a result of the compulsory vaccination campaign against bluetongue disease following the epidemic in 2007. However, it appears that the mortality rate in small ruminants is relatively high in relation to other animal species. Between 2009 and 2010 and between 2010 and 2011, there was a substantial increase in the percentage of declared bovine abortions (AHI6). For AHI13, there was a significant increase in the mortality of veal calves between 2009 and 2010 which continued at a lesser extent between 2010 and 2011; while mortality declined significantly between 2008 and 2009.

The yearly result of the barometer is communicated to the public via the annual FASFC report and the website by means of a simplified image of the annual evolution and a spider diagram, which gives a more informative picture of the fluctuations of the individual indicators. An example is given in Fig. 1. The spider diagrams of the different years are available on the website of the FASFC (<http://www.favv-afsc.fgov.be/scientificcommittee/barometer/>).

4. Discussion

The primary goal of the barometer is to conduct a measurement of the national animal health situation on the basis of a set of key indicators that are directly or indirectly related to the monitoring of infectious diseases and to

Table 4

Overview of the results for 2007–2012 of the respective animal health indicators (the number of samples or inspections is shown between brackets) with their annual percentage change (weighted and not weighted).

	Results for 2007	Results for 2008	Results for 2009	Results for 2010	Results for 2011	Results for 2012	% Change (2008/2007) ¹	% Change (2009/2008) ²	% Change (2010/2009) ³
AHI1	16.44%	10.96%	13.70%	9.59%	9.59%	16.44%	-33.33%	25.00%	-30.00%
AHI2	0.17% (63,689)	0.84% (83,968)	6.19% (85,718)	15.09% (88,419)	22.29% (91,992)	23.96% (95,001)	-7	-7	143.78%
AHI3	98.20% (2303)	98.47% (2901)	98.63% (3255)	98.12% (3687)	97.26% (3505)	97.20% (2648)	0.27%	0.16%	-0.52%
AHI4	94.36% (6720)	94.85% (6066)	95.39% (6763)	94.90% (6968)	95.07% (5637)	93.36% (5118)	0.52%	0.57%	-0.51%
AHI5	98.30% (7480)	98.14% (8788)	97.10% (9869)	97.16% (10,744)	97.40% (9836)	97.30% (9203)	-0.16%	-1.06%	0.06%
AHI6	0.27% (1432,543)	0.29% (1437,991)	0.24% (1437,834)	0.46% (1442,392)	0.57% (1423,991)	0.81% (1392,108)	7.41% ⁸	-17.24% ⁸	91.67% ⁸
AHI7	89.14% (544,551)	89.16% (517,648)	88.74% (491,654)	88.77% (464,097)	90.05% (445,856)	89.55% (427,459)	0.02%	-0.47%	0.03%
AHI8	99.20% ⁶ (1307,211)	98.94% (11,574,645)	98.44% (11,678,185)	96.78% (11,969,764)	95.64% (11,800,995)	95.76% (11,724,413)	-0.26%	-0.51%	-1.69%
AHI9	- ⁹	- ⁹	- ⁹	- ⁹	20.92% (765)	19.06% (855)	-	-	-
AHI10	5.03% ⁶ (9500,456)	4.07% (11,171,775)	3.58% (11,285,996)	3.40% (11,688,855)	3.74% (11,579,365)	3.21% (11,479,674)	19.09% ¹⁰	12.04% ¹⁰	5.03% ¹⁰
AHI11	21.54% (267,561)	12.82% (254,003)	11.33% (272,633)	11.27% (260,296)	10.28% (277,078)	10.74% (279,130)	40.48% ¹⁰	11.62% ¹⁰	0.53% ¹⁰
AHI12	0.79% ⁶ (28,894,561)	0.6% (273,426,460)	0.81% (291,838,791)	0.82% (312,527,133)	0.79% (308,809,657)	0.78% (313,096,763)	3.80% ^{10,11}	-6.58% ^{10,11}	-1.23% ^{10,11}
AHI13	5.19% (305,161)	5.23% (312,848)	4.19% (332,643)	5.19% (335,415)	5.35% (326,519)	5.46% (303,356)	-0.77% ¹⁰	19.89% ¹⁰	-23.87% ¹⁰
Global							3.37% ¹²	3.95% ¹²	15.27% ¹³
	% Change (2011/2010) ⁴	% Change (2012/2011) ⁵	Weight factor	Weighted result 2008	Weighted result 2009	Weighted result 2010	Weighted result 2011	Weighted result 2012	
AHI1	0.00%	71.43%	1.87	-62.33%	46.75%	-56.10%	0.00%	133.57%	
AHI2	47.71%	7.49%	1.11	-7	-7	159.60%	52.96%	8.32%	
AHI3	-0.86%	-0.06%	1.57	0.48%	0.22%	-0.83%	-1.34%	-0.10%	
AHI4	0.19%	-1.80%	1.19	0.63%	0.66%	-0.62%	0.23%	-2.14%	
AHI5	0.25%	-0.10%	0.61	-0.09%	-0.65%	0.04%	0.15%	-0.06%	
AHI6	23.91% ⁸	42.11% ⁸	1.22	9.04%	-21.03%	111.83%	29.17%	51.37%	
AHI7	1.44%	-0.56%	0.80	0.02%	-0.38%	0.03%	1.15%	-0.44%	
AHI8	-1.18%	0.13%	0.42	-0.11%	-0.21%	-0.71%	-0.49%	0.05%	
AHI9	-	-8.89%	1.49	-	-	-	-	-13.25%	
AHI10	-10.00% ¹⁰	14.17% ¹⁰	0.84	16.03%	10.11%	4.22%	-8.40%	11.90%	
AHI11	8.78% ¹⁰	-4.47% ¹⁰	0.54	21.86%	6.28%	0.29%	4.74%	-2.42%	
AHI12	3.66% ^{10,11}	1.27% ^{10,11}	0.65	2.47%	-4.28%	-0.80%	2.38%	0.82%	
AHI13	-3.08% ¹⁰	-2.06% ¹⁰	0.69	-0.53%	13.72%	-16.47%	-2.13%	-1.42%	
Global	5.90% ¹³	9.13% ¹⁴	13 ¹⁵	-1.14% ¹²	4.65% ¹²	16.71% ¹³	6.54% ¹³	14.32% ¹⁴	

¹ Percentual change = (2008 result – 2007 result)/2007 result × 100%. Significant changes are indicated in bold = $p < 0.05$, bold italic = $p < 0.01$ and bold underlined = $p < 0.001$.

² Percentual change = (2009 result – 2008 result)/2008 result × 100%. Significant changes are indicated in bold = $p < 0.05$, bold italic = $p < 0.01$ and bold underlined = $p < 0.001$.

³ Percentual change = (2010 result – 2009 result)/2009 result × 100%. Significant changes are indicated in bold = $p < 0.05$, bold italic = $p < 0.01$ and bold underlined = $p < 0.001$.

⁴ Percentual change = (2011 result – 2010 result)/2010 result × 100%. Significant changes are indicated with in bold = $p < 0.05$, bold italic = $p < 0.01$ and bold underlined = $p < 0.001$.

⁵ Percentual change = (2012 result – 2011 result)/2011 result × 100%. Significant changes are indicated in bold = $p < 0.05$, bold italic = $p < 0.01$ and bold underlined = $p < 0.001$.

⁶ Only data collected from November onwards were recorded. The data prior to this date were not deemed reliable as the FASFC was using another database at that time.

⁷ Given that the percentage of the key activities with a certified self-checking system was below 1% in 2007 and 2008, the impact on animal health is only very limited. This indicator is neutralised in the barometer for 2008/2007 and 2009/2008.

⁸ Although the prevalence of this indicator is below 1%, it is taken into account as the percentage of bovine animals that abort is low.

⁹ Result not available yet.

¹⁰ The sign of this indicator was changed since a decrease of this indicator actually shows an improvement in animal health.

¹¹ Although the prevalence of this indicator is below 1%, it is taken into account as the percentage of poultry carcasses declared non-compliant is not likely to be higher than 1%.

¹² Average value of the 11 indicators (excluding AHI2 and AHI9; see⁷ and⁹).

¹³ Average value of the 12 indicators (excluding AHI9, see⁹).

¹⁴ Average value of the 13 indicators.

¹⁵ Sum of all weight factors.

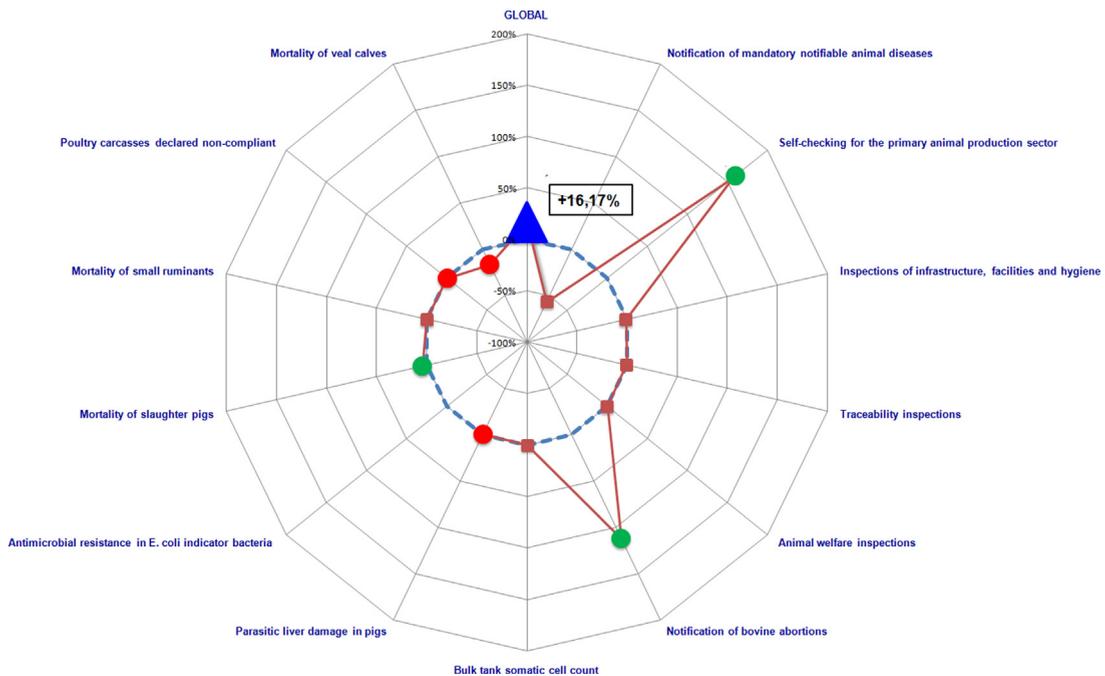


Fig. 1. Spider diagram of the animal health barometer; evolution over the years 2009–2010 (▲: global animal health; dashed line: 0% change; ●: significant change of the animal health indicator ($p < 0.001$); ■: non-significant change of the animal health indicator).

sanitary measures throughout the entire animal production chain. This study aimed to develop a method to estimate the yearly evolution of animal health and eventually to evaluate sanitary measures introduced at a certain moment. The ultimate goal is to introduce a systematic operating procedure based on this “barometer” in order to enable the monitoring of the animal health situation, in an accessible way to a broader public and to observe or analyse trends over the longer term.

This barometer aims at providing a reflection of possible hazards and risks within the animal production chain during a given period. It serves as an instrument for communication, reflection and trend observation with regard to the animal health state, intended both for a broader public and for professional stakeholders in the animal production chain. Therefore, it is not meant to draw up a comprehensive scientific report giving an exact image of the presence and status of all potential hazards within the animal production chain, nor is it intended to carry out any form of risk assessment.

The composition of the set of indicators and the context within they were defined is of major importance. Each indicator has its own strengths and weaknesses, as explained in the technical data sheets (available on internet: <http://www.favv-afsc.fgov.be/scientificcommittee/advice/documents/ADVICE09-2011.EN.DOSSIER2009-09bis.appendix1.pdf>). The composition of this set of indicators may be modified periodically, for instance when it is likely that some indicators are no longer relevant, or when other indicators may better reflect the actual situation as a result of new developments.

The weighting exercise reflects the (subjective) evaluation of participants of the relative importance of the

indicators in the barometer concept. Different considerations (economical or others) may have caused the different interpretation of the weight of individual indicators in the final barometer result according to the respondents position (producer, consumer, risk assessor, risk manager, etc.) and responsibility in the food chain (Table 3). Nevertheless, the final result of the weighting exercise represents the balanced opinion of decision makers, risk assessors and stakeholders of the food chain.

During the weighting exercise AHI1 (notification of mandatory notifiable animal infectious diseases) received the highest weight since many notifiable diseases can cause epidemics which can have a devastating effect on animal health. The list with mandatory notifiable animal diseases currently contains 73 diseases and is adaptable according to epidemiological changes. However, between 2007 and 2012 the list has remained stable. Next, AHI9 (antimicrobial resistance in *E. coli* indicator bacteria) received also a high weight indicating that antimicrobial resistance in (intensive) animal production is generally accepted as an important concern in society because of its negative repercussion on public health. This growing public concern regarding antimicrobial resistance has also been demonstrated by an Eurobarometer consumer survey (Eurobarometer, 2010). Also, indicators concerning inspections of infrastructure, facilities and hygiene (AHI3) and traceability (AHI4) received elevated weight factors indicating they were deemed important indicators for maintaining animal health. On the other hand, inspections of animal welfare (AHI5) received only a low weight (<1). Furthermore, AHI6 (notification of bovine abortions) was considered to be an important indicator as monitoring of bovine abortions is crucial in the surveillance of many

transmissible diseases in cattle. The last indicator with a weight factor above 1 is AH12 regarding self-checking systems. On the contrary, indicators which reflect mortality (AH10, AH11, AH13), slaughterhouse inspections (AH8, AH12) and milk somatic cell count (AH17) were considered slightly less important indicators for animal health (weight factor <1).

With regard to the reporting of mandatory notifiable animal diseases (AH1) and notification of bovine abortions (AH16), it is clear that an increased notification does not only result from an increased occurrence of animal diseases but may also result from a higher degree of alertness of livestock farmers and veterinary field workers (e.g. following one or a few rapidly contained outbreaks of a (new) disease), leading to a higher degree of vigilance. Given that mandatory notification is an inherent part of the preventative approach, and is also essential for preventing the spread of animal diseases, an increase of the number of reported cases was therefore considered in this context as an indication of a substantial degree of vigilance with regard to the safeguarding of animal health and is therefore interpreted as a favourable element. Each individual notification to the FASFC gives rise to a risk management action directed towards a verification of the situation and if necessary the control of the disease or infection. Furthermore, an increased surveillance or notification can also be the result of a stimulation campaign of the authorities and therefore does not necessarily reflect a real shift in disease occurrence but is rather to be considered as a higher safeguarding of animal health. The latter phenomena have played a pivotal role for the animal health barometer in the last years, especially for AH16 (notification of bovine abortions) after the installation of the 'abortion protocol' by the government which encourages farmers to notify abortions and provide abortive tissues for laboratory analysis (without supplementary costs). The increase in the notification of bovine abortions from 2010 onward is due to the installation of this 'abortion protocol'. Also, the amount of disease surveillance is not only driven by disease occurrence but also by other factors such as government budgets, political choices, trade agreements, etc. Finally, disease surveillance 'as such' cannot only be regarded as negative in the framework of an animal health measurement tool such as the barometer because disease surveillance also leads to early detection and rapid management actions following an outbreak in order to limit the spread of a disease (pro-active policy). Indeed, the monitoring of bovine abortions has proven to be a valuable asset in the early detection of some recent disease outbreaks (e.g. brucellosis, Schmallenberg virus, bluetongue virus, etc.).

Therefore, it was decided that a rise of the disease surveillance and notification indicators (AH1 and AH16) under the current Belgian circumstances has to be interpreted as a favourable evolution in the context of the animal health barometer as it gives an indication of vigilance and awareness of the professionals in the field and provides useful information to the authorities allowing to take the necessary control or communication measurements.

As for the presence of a certified self-checking system (AH12), it should be noted that the operators may

freely choose whether or not they want to have their self-checking system certified. Attention should however be drawn to the fact that in case no certified self-checking system for a key activity is present, this does not mean that the self-checking system is absent or malfunctioning. The point is that an independently certified self-checking system provides added value and adds to the confidence as to the foundations and functioning of such system. An increase of the percentage of key activities with a certified self-checking system thus indirectly leads to a higher confidence level with regard to adequate preventive actions taken in order to ensure overall animal health.

As regards the results of the inspections (AH3, AH4, AH5), any changes that may be made to the evaluation system from time to time (e.g. new checklists, different action limits or tolerance levels) must be taken into account. This may result in year-to-year differences with regard to the detection of non-conformities. It is, however, recommended that, in the event of significant changes to the evaluation system, both the sector and the authorities make great efforts in raising awareness, informing and assisting the concerned operators, with a view to apply and limit the non-conformities to a new evaluation system. This is why, for some indicators, one must also take into account the fact that some inspections may have been aimed at high-risk production sites, as a result of which some degree of bias is likely. This is, however, a systematic bias that is inherent to the development of a risk-based control program which is within the mandate of the FASFC.

Indicators AH7 to AH13 relate to certain observations in the animal population, on the animal products and on carcasses, and concern animal health both directly and indirectly. Indicators AH10, AH11 and AH13 relate to the mortality within a population and are general indicators, but they are nevertheless informative as regards the health of the productive livestock population.

During the period 2007–2011 Belgium was faced with a number of disease outbreaks of (re)emerging diseases (e.g. bluetongue, brucellosis, Schmallenbergvirus). The impact of these outbreaks on the animal health barometer was relatively limited. The bluetongue epidemic caused an elevated mortality among small ruminants in 2007. In 2008, however, partly due to the vaccination campaign, this mortality rate decreased. The outbreak of brucellosis in 2010 was quickly under control, but was accompanied with an increased vigilance with regard to abortion, which had a positive effect on the animal health barometer. The outbreak of Schmallenbergvirus occurred late in 2011. This disease is not a mandatory notifiable disease and is not accompanied with an increased mortality. Therefore, there was hardly any impact on the animal health barometer, except for an increase in the number of reported abortions.

It should be noted that for certain indicators (e.g. AH7, AH8, AH12) the determination of the statistical significance is based on a large number of observations which means that small variations in a particular indicator may give rise to significant differences that may not necessarily be of biological significance. Determining an appropriate minimal level for a difference to be considered significant is currently the subject of a research effort. Several indicators show high level of conformity (AH3, AH4, AH5, AH8),

leaving less space for improvement. On the other hand, for several indicators only moderate results can be observed and for them an increase can be expected in the future.

Based on the present animal health barometers, overall animal health in Belgium appears to show a positive evolution. However, the real meaning of this evolution has to be assessed over the long term. Given the limited number of calculated barometers up till now, a thorough trend analysis has not yet been executed but should be highly informative in a future evaluation process of the animal health barometer concept.

Furthermore this barometer, or a similar concept thereof, can form the basis for a benchmarking system to compare countries or geographical regions or to develop a European animal health barometer. However, it is clear that this concept of animal health barometer and the outcome needs follow-up in the future.

5. Conclusion

The animal health barometer is an instrument providing a general picture of livestock animal health in Belgium. It is a tool for easy communication and for reflection on the evolution of animal health. Together with the food safety barometer and the plant health barometer, those three instruments provide a holistic view on the overall status of the safety of the food chain in Belgium.

Based on 13 animal health indicators, it has been found that animal health in Belgium shows a positive evolution, the real meaning of which must be assessed over the long term.

This instrument or a similar concept thereof can also be developed in other countries provided that results of an animal health control plan are available.

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