



Measuring the safety of the food chain in Belgium: Development of a barometer

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ABSTRACT

This paper describes the development of a concept to measure the safety of the food chain in Belgium based on the 'Pressure–State–Response' model. The actual measurement tool or barometer consists of a measurement of the 'State' based on a set of indicators. The present paper discusses the elaboration of a set of 30 food safety indicators (FSIs) as the basis of the food safety barometer. These indicators were weighted by expert opinion in order to determine their relative weight to be considered in the barometer. Food safety was reflected in a composite and agreed upon set of indicators related to i) the compliance to action limits/criteria for selected chemical and microbial hazards, ii) the implementation of preventive and control measures to mitigate food safety throughout the food chain from farm to fork and iii) the reported number of foodborne outbreaks and reported cases of some selected zoonotic agents (*Salmonella* sp. and *Listeria monocytogenes*). As food safety remains an abstract term and no quantitative value could be attributed (also due to lack of quantitative food safety objectives), the option was taken to document the status of food safety in a relative manner by comparing the results of the set of indicators of the current year with the previous year. By comparing the years 2007, 2008 and 2009 it was concluded that the status of the global food safety in Belgium was high and an upward trend could be observed. Statistical analysis on each of the individual indicators was performed, however since at present a restricted data set is available (2009 versus 2008 and 2008 versus 2007) no trend analysis could yet be performed. The barometer provides a helicopter view of the status of food safety in Belgium and is a tool to communicate in an intelligible, comprehensible manner on aspects of food safety to consumers and other stakeholders in the food chain. The methodology and results of the survey for the 'Pressure' and 'Response' collection from the Belgian stakeholders in the food chain will be discussed in another manuscript.

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1. Introduction

The last decade, major reforms concerning the management of the safety of the food chain, were implemented on European and national level (e.g. EU regulation 178/2002 also referred to as the General Food Law, establishment of EFSA, re-organization of several national food agencies). These reforms have demanded great efforts from the stakeholders of the food chain (e.g. public authorities, the agro-food industry, farmers, ...). In Belgium, the Advisory Committee of the FASFC (the Belgian Federal Agency of the Safety of the Food Chain), in

which all stakeholders of the food chain are represented, raised the question to measure the impact of the current FASFC food safety policy. Moreover, the 2009–2011 business plan of the FASFC mentions the need to identify a set of indicators to measure and follow-up the safety within the food chain (Houins, 2009).

To our knowledge, measuring food safety has been limited up till now to company level in order to evaluate food safety management system performances (Jacxsens et al., 2009; Jacxsens et al., 2010; Luning et al., 2011), and has not been applied to the complete food chain at country level. A report on healthy diet and safe food was issued in 2006 by RIVM in the Netherlands on request of the Ministry of Health, Welfare and Sport (Kreijl, van Knaap, & Raaij, 2006). It is a valuable comprehensive report which offers an overview of knowledge at the time concerning the effects of diet and foods upon health but does not respond to the question raised by FASFC to develop a tool, a barometer, to measure the safety of the food chain on a yearly basis and to enable trend analysis.

Abbreviations: FASFC, Belgian Federal Agency of the Safety of the Food Chain; FSI, Food Safety Indicator; PSR, Pressure–State–Response.

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The idea to develop a barometer should be situated within the context of the prevailing trend towards identifying measurable objectives, indicators, assessments, score systems and the like (Kaplan, 2001; Dess & Robinson, 1984; Saraph, Benson, & Schroeder, 1989). This idea is also inspired by the introduction of similar notions in other social domains, such as social welfare (the Belgian inter-federal poverty barometer—State Secretary for fight against poverty, FPS Social integration, FPS Social security, & FPS Economy, 2009) and environment (the durability barometer—Task force durable development, 2009). The barometer to be developed is not an instrument to assess the performance of the competent authorities in general, neither of the FASFC in particular. The barometer should enable to communicate in an intelligible, comprehensible manner on the safety of the food chain in Belgium to stakeholders in the food chain (farmers, processors, distribution) and in particular to consumers and trade partners.

In agreement with the core competence of the FASFC it was decided that nutritional aspects of food and feed (energy intake, nutritional composition, balanced dietary pattern) and general quality aspects of food (e.g. organoleptic qualities, ease of use) are not taken into consideration in the development of the barometer, this in contrast with the 2006 issued RIVM report “our food, our health” which has a wider scope to public health issues related to food consumption (Kreijl et al., 2006). As a consequence, the barometer presented in this study is limited to aspects relating to the presence and control of chemical, physical, and microbiological hazards within the food chain from farm to fork.

Since no tools were described in scientific literature to address this question raised by FASFC and its stakeholders, the Scientific Committee of the FASFC, (an independent scientific consultation body), has elaborated an advice on this topic (Scientific Committee, 2010), describing the concept of a tool to measure safety in the food chain. The particular case study of the food safety barometer is being elaborated in the present manuscript.

2. Materials and methods

2.1. Scope of the barometer: defining the “food chain”, the “safety of the food chain” and “food safety” and measuring food safety

As internationally validated definitions lacked, the first and crucial step in the development of the barometer was to make up solid definitions of ‘food chain’ and ‘safety of the food chain’ and to determine the scope of this barometer. Table 1 gives an overview of the elaborated definitions. The scope of the food safety barometer is limited to aspects relating to the chemical, physical and microbiological hazards within the food chain.

Food safety still maintains a vaguely defined term, perceived differently according to the individual or stakeholder and his particular background knowledge or experience. In addition no specific, quantitative objectives were available concerning food safety or particular aspects (hazards) being part of food safety. As such it was not possible to measure performance of food safety or food safety as a concept in an absolute value on a gradual scale. The business plan 2009–2011 of the FASFC (Houins, 2009) does mention however it aims for a safer food chain. Therefore, it was decided to measure the status of the safety of the food chain on a yearly basis using a set of indicators and to compare the results with previous years. The FASFC is responsible for laying down, implementing and enforcing measures related to the analysis and the management of risks and bases its policy on knowledge and scientific advice but also seeks to be well accepted by the operators and recognised by society. As such also in the concept of the barometer it was the aim to develop a composite and agreed upon tool to measure the safety of the food chain that may serve to

Table 1

Overview of the used definitions (Based on European Parliament & Council, 2002).

Definition
The ‘ <i>Food chain</i> ’ is any and all possible stages that are proceeded <ul style="list-style-type: none"> ○ during the course of breeding and rearing of animals and growing of crops, starting from the biological material and all necessary raw materials, ○ during the course of production of foodstuffs and feed, from the stage of production up to the stage of consumption.
<i>Safety of the food chain</i> is the general sanitary status of the food chain with regard to biological, chemical or physical hazards (including animal and plant/crop health), for which all respective links within the food chain bear their own responsibility, ensuring that safe food can be offered to the consumer. In this respect plant and animal health are not limited to the aspects that are related to human health.
<i>Food safety</i> is defined as the condition of the foodstuffs in all stages of production, processing and distribution, required to guarantee protection of consumer’s health, also taking into account normal circumstances of use and information available for the foodstuffs concerned. Food safety thus means the absence of biological, chemical or physical agents (hazards) in concentrations/quantities that can cause adverse health effects.

communicate on the status of food safety to the broad public and stakeholders in the food chain.

The initiative for development of this barometer was taken by the Scientific Committee of the FASFC but by exchange and feedback obtained by the risk managers of the FASFC and the stakeholders of the food chain (represented in the Advisory Committee of the FASFC) in the development of the barometer, also the expectations of the society as a whole towards the safety of the food chain were taken into account and reflected in the set of indicators defined.

2.2. Adoption of a concept: the Pressure–State–Response (PSR) concept and its application to the food chain

The Pressure–State–Response (PSR) concept was selected as a starting point for establishing the research model. The PSR concept was used in the 1980s by the OECD for the classification of environmental indicators into three different categories: Pressure, State, and Response (Van Gerven, Block, Geens, Cornelis, & Vandecasteele, 2007; OECD framework for environmental indicators, 2010). The PSR concept is based on the principle of causal relationship, occurring when activities or incidents exert a pressure on a system, thereby causing a change in the state of the system. Society reacts to these changes and will ultimately have to take decisions (response) (OECD framework for environmental indicators, 2010).

Pressure is exerted by numerous general forces, processes or mechanisms operating within society (e.g.: globalisation, demographic changes, new technologies, climate change, economic crisis, new consumption patterns, ...). These pressures have an impact on the food chain and may possibly modify its state or in other words its safety. The pressure on the food chain involves economical, sociological, technological and environmental factors and international requirements. These factors are often referred to as belonging to the so-called ‘PEST’, PESTLE (Political, Economic, Social, Technological, Legal, Environmental) or STEEP (Social, Technological, Economic, Ecological and Political) framework, a denomination that is frequently used in management circles (Carruthers, 2009; Value based management, 2010). Mapping the pressures that act on the food chain at the present moment will assist in understanding the context in which stakeholders in the food chain have to act and thus reveal the drivers or bottlenecks that may have impact on the status of the safety of the food chain in the (near) future.

The *State* is a measure for the safety of the food chain at the end of a determined period (e.g. one year). In the present application it was decided to basically relate the status of the safety of the food chain to the presence of hazards within the food chain and the implementation

of a systematic approach for limiting the presence or governing the exposure to unacceptable levels of such hazards, and only to lesser degree the possible impact of these hazards on public health and on animal and plant health. Information about the state is systematically and consistently being collected in Belgium via the core activity of the FASFC, namely the control of the food chain by audits and inspections of operators and analyses of products.

Response refers to the preventive and corrective measures that are taken by the respective stakeholders within the food chain to react to the pressure on the food chain, as well as to the overall safety status of the latter in order to maintain or improve its safety. 'Response' indicators refer to individual or collective actions or reactions, aimed at mitigating, correcting or preventing negative consequences in case that changes occur within the food chain. Actions may be of a technological nature, or of a more policy-oriented or social nature. Policy-level actions typically involve the elaboration of rules and legislation. Social actions rather relate to initiatives taken by society itself, such as: quality labels, consumption of biologically grown products. It follows that response actions are situated at the various levels within the food chain, namely the operator and/or sector levels, the consumer (organization) level, and the competent authorities, scientific advisory bodies and institutions, and so on.

2.3. Developing a measurement instrument for pressure, state and response

In 2009, a workshop was organized by the Scientific Committee of the FASFC for various stakeholders of the Belgian food chain to collect their input on how to develop a measurement tool for the safety of the food chain. At the workshop, the Pressure–State–Response model was presented and several examples of indicators were discussed. The discussions during the workshop led to the conclusion that the final barometer should only consist of the state, and that pressure and response must be used to further interpret the 'State' within a broader societal context.

Under the competence of the FASFC three subcategories contributing to the safety of the food chain can be distinguished, namely food safety, animal health (including control on animal diseases e.g. brucellosis, Q-fever, blue tongue, etc.) and plant health (including plant quarantine organisms e.g. *Ralstonia solanacearum*, *Phytophthora ramorum*, etc.). Because of their specific nature, and in view of a clear communication to their respective stakeholders involved, a separate measurement tool, a separate barometer, is designed for each of them. Nevertheless, the pressure and response that influences the state of these three aspects of the food chain is similar and is thus taken up as one. In order to illustrate the developed methodology to construct a barometer (State), this paper presents in the next section the elaboration of the food safety barometer. At present also the elaboration of a barometer for the two other subcategories contributing to the safety of the food chain, namely animal health and plant health, is under construction by the Scientific Committee of the FASFC using a similar approach.

For the 'Pressure' and 'Response', a methodology for collection of information on perceived pressures by the stakeholders and their reaction (response) was developed. Further details on the elaboration of the 'Pressure' and 'Response' collection from the Belgian stakeholders in the food chain with regard to the safety of the food chain and the discussion of the results concerning this survey is the subject of another manuscript.

2.4. Identification of indicators

Yearly numerous analyses of food and feed products and inspection activities are being conducted by the FASFC, in order to monitor the safety of the food chain. It would be too complex and

unworkable to incorporate the results of all these controls and inspections into the barometer, the more that an overview of most of these measurement data is publicly available in the annual reports of the FASFC (FASFC, 2007; FASFC, 2008; FASFC, 2009). Therefore, it was chosen to work with a set of indicators. An indicator is a measure for rendering and analyzing certain problems or issues. It is a tool that is intended for communication and support in the decision making process (Task force durable development, 2009). Since no concrete, measurable quantitative objectives concerning food safety and the safety of the food chain have been laid down, it was not possible to define indicators providing information on the level of gained result. Therefore, the indicators are basically descriptive in nature. Each indicator provides information about a partial aspect of the status of the food safety and the monitoring of each indicator enables to achieve a trend analysis of this particular aspect.

The following criteria have been established for the careful selection of considered indicators:

- *Measurability*: The actual goal of measurement of the state is to find out whether overall food safety (or in due time animal health or plant health) has improved, deteriorated or remained the same with time. For this reason quantitatively measurable indicators were selected in order to be able to follow-up evolutionary trends in time.
- *Independence*: indicators should be independent and should not measure the same aspect of food safety.
- *Reliability*: indicators must be relatively insensitive to bias.
- *Availability*: the data used in the indicator must at all times be easily available in reports, documents or databases. Only results that were collected in the context of the FASFC control program are used for product control purposes.
- *Being representative for food safety (or in due time animal health or plant health)*: The whole set of indicators must include the various categories of food safety hazards.
- *Being representative for the food chain*: The whole set of indicators must be representative for the various aspects of the food chain and its stakeholders.
- *Unambiguity of formulation*: an unambiguous relationship should exist between an increase or decrease of the indicator on the one hand, and an improvement of the overall food safety (or in due time and/or animal and plant health status) on the other hand.
- *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.

As a whole, across all FSIs, the set of indicators measures and reflects the different aspects of the food safety situation and covers:

- the entire food chain, including suppliers, primary production, processing, distribution, storage and transport by third parties, as well as services and wagework;
- both the Belgian food production chain, the intra-Community (within EU 27) trade and import from third countries to Belgium;
- plant and animal production;
- product control (biological and chemical hazards);
- process control (inspections/audits);
- the preventive approach (self checking systems based on good working practices and HACCP (Hazard Analysis Critical Control Points), obligation to report and traceability);
- human health when there is a direct link with food safety (Since, the toxicological effects of chemical hazards in the food chain are mainly chronic, it is difficult to make the link between food safety and for example the number of people that have cancer due to the occurrence of a carcinogen in foods. Therefore, the indicators related to human health are limited to biological hazards, since their effect on human health is more acute).

2.5. Assigning a weight to each indicator

Since individual indicators have a different (perceived) effect on food safety, it was decided to assign a weight to each FSI by expert opinion. This weight is taken into account when the overall value for food safety is calculated. Therefore the list of 30 FSIs was scored by the stakeholders of the Belgian food chain (FASFC risk managers, the FASFC Advisory Committee—including representatives from the industry associations, as well as from other competent authorities and consumer organizations in Belgium—and the FASFC Scientific Committee) by assigning 20 points to the FSIs following the Las Vegas method (Gore, 1987). The points had to be divided among the 30 FSIs, taking into account their judged importance to food safety. The points had to be allocated as full units, so it was not allowed to allocate half points. Several points could be assigned to one FSI and several FSIs could receive points, however the total sum of all assigned points had to be equal to 20.

2.6. Calculation of the food safety barometer

For all 30 FSIs, data were gathered for the years 2007, 2008 and 2009 and the percentual change between 2 consecutive years was calculated. Most FSIs are expressed as a percentage of conform samples or as a percentage of inspections that turned out to be 'OK' or 'OK with minor remarks'. For these indicators, the percentual change for the year 2008 and 2009 has been calculated, as compared to the previous year. For some indicators another calculation method was used as they are expressed in a different way (FSIs 28, 29 and 30 e.g. the number of reported cases of salmonellosis per 100,000 inhabitants, ...). For these indicators, the data for 2005, 2006 and 2007 were used to calculate an average value for these years, to which the results for 2008 were subsequently compared. For the comparison with 2009, the average of 2006, 2007 and 2008 was used. In this way it was avoided that, for these low-count indicators, an incidental rise or drop in a large population might entail excessive deviations of the barometer. For the same reason, namely avoiding large deviations that reflect a limited impact on the food safety, FSI 2 to 5 (self checking) were neutralized in the barometer when the percentage of performed key activities with a validated self checking system for that year was below 1%, since the impact on food safety is only very limited if the adoption of this system is restricted to less than 1% of these activities in the food chain.

In order to calculate the value that reflects the change of the state of the food safety, the weighting factor was multiplied with the percentual change of the FSI and the mean of all these values was calculated. Next, using a Poisson regression (STATA CORP., 2009), it was checked for each indicator whether the observed changes of the indicator values from one year to the previous year were to be considered as incidental or statistically significant ($p < 0.001$).

3. Results

The state of the food safety was measured using a set of 30 different food safety indicators (FSIs). Table 2 gives an overview of the selected FSIs and a detailed technical data sheet for each FSI is available on internet (http://www.favv-afsc.fgov.be/scientificcommittee/advices/_documents/Advice28-2010-Annex3-TechnicaldatasheetFoodSafetyستاteindicators.pdf). Table 3 shows for each food chain segment the number of FSIs that are related to that segment. For all 30 FSIs data were gathered for the years 2007, 2008 and 2009 and the individual values for each indicator for a single year as well as the percentual change between 2 consecutive years can be noticed in Table 4.

In order to assign a weight to each of the indicators as to its (perceived) contribution to food safety, an inquiry survey was performed among the stakeholders in the Belgian food chain. In total 40 responses were obtained (response rate 59%) of which 10 (25%), 18 (45%) and 12 (30%) were filled in by the FASFC risk

managers, the FASFC Advisory Committee and the FASFC Scientific Committee respectively. It was interesting to note that every FSI was scored, meaning that the stakeholders were convinced that every suggested FSI was important for the measurement of food safety. Based on the answers the mean weight of each FSI was calculated. Table 4 shows the mean weight factor of each FSI showing their importance assigned by the experts to contribute in measuring food safety. Inspections regarding self checking (FSI 6) received the most points. It is remarkable, that the 3 indicators concerning inspections (FSI 6, 7 and 8) ended up within the 4 indicators with the highest weight, indicating that inspections are perceived by all stakeholders to be an important tool to measure food safety. Concerning the analysis of products, FSI 19 (residues from pesticides in vegetables and fruit of Belgian origin), FSI 13 (substances with an anabolic action, unauthorized substances and veterinary drugs for cows and pigs) and FSI 17 (residues from pesticides in vegetables and fruit originating from other EU-countries and third countries) had the highest weight. Concerning the biological hazards, the occurrence of illness due to these hazards (FSI 28, 29 and 30) was considered to be more important (weight factor > 1) compared to the occurrence of these hazards in products (weight factor < 1). Other FSIs that received a weight higher than 1 were FSI 1 (compulsory notification with regard to food safety) and FSI 4 (self checking systems in the transformation sector). The lowest weight was given to several indicators concerning chemical and biological hazards in the food chain, namely FSI 14 (sulfite in minced meat), FSI 10 (acrylamide), FSI 23 (*Salmonella* sp. in layer hens), FSI 22 (*Salmonella* sp. in meat pigs), FSI 18 (forbidden colorants) and FSI 16 (mercury in mollusks, crustaceans and fish).

For the overall food safety barometer, taking into account the weighing factors assigned to each indicator by expert opinion, a change of +0.11% was observed for 2008 compared to 2007 (based on 28 indicators as shown in Table 4). A change of +11.26% was observed for 2009 compared to 2008 (based on 29 indicators as shown in Table 4). However, when only the same 28 indicators are included as for the previous food safety barometer (2008 versus 2007) a change of 2.37% was calculated.

The overall value of +0.11% for the first food safety barometer (2008 versus 2007) is mainly the result of the increase of the number of validated self checking systems in primary production (FSI 3) and the poor results for inspections regarding self checking (FSI 6) and inspections of infrastructure, installations and hygiene (FSI 7). The diminution for these latter two indicators related to inspections was due to the implementation of a new evaluation system since September 2007. This system is based on the use of a checklist, by which a fixed appraisal is made, using points for each item to be inspected. This new evaluation method is more stringent and partly accounts for the divergences between 2008 and 2007. The fact that controls were aimed at establishments where non-conformities had already been reported (systematic risk-based re-inspection) may also be part of the explanation.

The overall value of the second food safety barometer (2009 versus 2008) showed a change of +11.26%, although the change was limited to 2.37% when the same 28 indicators were used as for the previous barometer (2008 versus 2007). This indicates that the value for 2009 versus 2008 was caused by the strong increase (260%) of validated self checking systems in the transformation sector (FSI 4), the latter indicator not being included in first food safety barometer (2008 versus 2007) as in 2007 the number of activities that were complying to these newly introduced system of validated self-checking systems was still below the threshold value of 1%. As the system of validated self-checking systems (a voluntary system, but with a financial incentive) is still only recently penetrating the food chain and gradually been taken up by the operators in the food chain, this also clarifies the large gain that was obtained in the year 2009 versus 2008 for the indicators relating to the self-checking systems.

Table 2
Overview of the food safety indicators.

Name of FSI	Definition
FSI1: Compulsory notification ¹ with regard to food safety	The number of notifications received by the FASFC for each year. This indicator does not relate to the notifications concerning animal diseases, plant diseases or harmful organisms, as long as they do not have an impact on food safety.
FSI2: Self checking ² systems in the supply sector for primary production	The percentage of performed key activities ³ using a validated self checking system in the supply sector for primary production, on an annual basis.
FSI3: Self checking systems in the primary production sector	The percentage of performed key activities using a validated self checking system in the primary production sector, on an annual basis.
FSI4: Self checking systems in the transformation sector	The percentage of performed key activities using a validated self checking system in the transformation sector, on an annual basis.
FSI5: Self checking systems in the community kitchen sector	The percentage of performed key activities using a validated self checking system in the community kitchen sector, on an annual basis.
FSI6: Inspections regarding self checking throughout the food chain	The percentage of inspections with regard to self checking that turned out to be OK or 'OK with minor remarks'. These inspections are done in primary vegetable production intended for human consumption, as well as in slaughterhouses, processing, dairy farms, egg packaging plants, hotel and catering industry, community kitchens and wholesale and retail. This indicator does not include the phytosanitary inspections, because they are irrelevant to food safety.
FSI7: Inspections of infrastructure, installations and hygiene in the sectors of distribution, hotels and catering and community kitchens	The percentage of inspections with regard to infrastructure, installations, and hygiene in the hotel and catering industry, in community kitchens and in wholesale and retail businesses that turned out to be OK or 'OK with minor remarks'.
FSI8: Inspections regarding traceability within the food chain	The percentage of inspections regarding traceability that turned out to be OK or 'OK with minor remarks'. These inspections are conducted at the level of the suppliers to primary production (fertilizers, soil conditioners, growing substrates, purification sludge and animal fodders), as well as at the level of primary vegetable production intended for human consumption and animal primary production (cow farms, pig farms, farms having sheep, goat and deer-like animals, layer hen farms, poultry farms, hatcheries), slaughterhouses, traders and collecting centers (for the identification and registration of animals), transport (identification and registration of animals), processing, and, finally, wholesale and retail.
FSI9: Residues from pesticides in vegetables and fruit of Belgian origin	The percentage of samples of vegetables and fruit of Belgian origin that were tested for residues from pesticides and that were conform.
FSI10: Acrylamide	The percentage of samples that were tested for acrylamide and that were conform.
FSI11: Lead and cadmium in vegetables and fruit	The percentage of samples of vegetables and fruit that were tested for the presence of lead and cadmium and that were conform.
FSI12: Aflatoxin en deoxynivalenol	The percentage of samples of foodstuffs in distribution that were tested for aflatoxin B ₁ , B ₂ , G ₁ and G ₂ and deoxynivalenol (DON) and that were conform.
FSI13: Substances with an anabolic action, unauthorized substances and veterinary drugs for cows and pigs	The percentage of samples/animals that were tested for substances with an anabolic action and on the presence of unauthorized substances (Group A: stilbene, and its derivatives, salts and esters; antithyrogenic substances; steroids; resorcylic adic lactones (including zeranol); β-agonists; substances that listed in Annex IV of the Regulation (EEC) n° 2377/90) and veterinary drugs (group B1 (antibacterial substances, including sulfonamides and quinolones) and group B2 (anti-worm products; vermicide products; anticoccidia, including nitro-imidazoles; carbamates and pyrethroids; tranquilizers; non-steroidal anti-inflammatory pharmaceuticals; other substances with a pharmacological action) that are used on cows and pigs, within the scope of the control program and that were conform.
FSI14: Sulfito in minced meat	The percentage of samples of minced meat that were tested for sulfito in the distribution sector and that were conform.
FSI15: Dioxins and dioxin-like PCBs in dairy products and eggs	The percentage of samples of dairy products and eggs that were tested for dioxins and dioxin-like PCBs and that were conform.
FSI16: Mercury in mollusks, crustaceans and fish	The percentage of samples of mollusks, crustaceans and fish that were tested for the presence of mercury and that were conform.
FSI17: Residues from pesticides in vegetables and fruit originating from other EU-countries and third countries	The percentage of samples of vegetables and fruit originating from other EU-countries and third countries that were tested for the presence of pesticides and that were conform.
FSI18: Forbidden colorants	The percentage of samples that were tested for forbidden colorants and that were conform.
FSI19: Chemical and microbiological hazards in imported animal products intended for human consumption	The percentage of samples of animal products intended for human consumption that was taken in border inspection stations and that were tested within the context of the control plan and that were conform.
FSI20: Dioxins and dioxin-like PCBs in animal fodders	The percentage of samples of animal fodders (raw materials, mixed fodders, premixtures and additives) that were tested for dioxins and dioxin-like PCBs and that were conform.
FSI21: Contact materials	The percentage of samples of contact materials per year that were conform.
FSI22: <i>Salmonella</i> sp. in meat pigs	The number of meat pig farms that were labelled as a risk farm for <i>Salmonella</i> sp. per year. This indicator includes both the newly labelled risk farms within a given year and the farms of which the risk status is being extended for another year.
FSI23: <i>Salmonella</i> sp. in layer hens	The percentage of negative flocks of layer hens (breeding and production) for <i>Salmonella</i> sp. per year.
FSI24: <i>Salmonella</i> sp. in poultry and pigs	The percentage of samples, taken on poultry and pigs at the level of slaughterhouses and meat cutting plants, that were tested for <i>Salmonella</i> sp. and that were conform. Accordingly, this indicator relates to the analysis of carcasses and cut meat of poultry and pigs, collected in slaughterhouses and meat cutting plants.
FSI25: <i>E. coli</i> in carcasses and cut meat	The percentage of samples taken in slaughterhouses and meat cutting plants that were tested for <i>E. coli</i> . and that were conform. Accordingly, this indicator includes samples of carcasses from layer hens and broilers, as well as cutted pork and beef meat.
FSI26: <i>E. coli</i> in foodstuffs	The percentage of samples of foodstuffs taken in dairy farms, the processing sector (with the exception of slaughterhouses and meat cutting plants) and the distribution sector that were tested for <i>E. Coli</i> and that were conform.
FSI27: <i>Listeria monocytogenes</i> in foodstuffs	The percentage of samples of foodstuffs taken in dairy farms, the processing sector and the distribution sector that were tested for <i>Listeria monocytogenes</i> and that were conform.
FSI28: Foodborne outbreak	The number of reported individuals affected by a foodborne outbreak, per year and per 100,000 inhabitants.

Table 2 (continued)

Name of FSI	Definition
FSI29: Salmonellosis in humans	The number of reported cases of human salmonellosis (the number of humane <i>Salmonella</i> germs received by the National Reference Centre for <i>Salmonella</i> and <i>Shigella</i>), per year and per 100,000 inhabitants.
FSI30: Listeriosis in humans	The number of reported cases of listeriosis per year and per 100,000 inhabitants.

¹ Compulsory notification: any operator shall promptly inform the FASFC when he is of the opinion or has reason to believe, that a product he has imported, produced, reared, grown, processed, manufactured or distributed may be injurious to the health of humans, animals or plants (FASFC, 2003).

² 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 concerning food safety;
- meet the requirements laid down in the regulations concerning the quality of products under the authority of the FASFC;
- meet the requirements laid down in the regulations concerning traceability. Self-checking implies that the requirements have to be met at all stages of production, processing and distribution of products. All business operators (except those of the primary sector) with activities in the food chain must introduce, implement and sustain a self-checking system. (FASFC, 2003).

³ Key activity: an activity that is part of the food chain and represents a considerable production volume, and/or may have a considerable impact on the food chain safety because of the nature of the activity.

The overall results of the food safety barometer measures the sum %-change across all indicators, thus in 30 dimensions. The interpretation and relevance of such an overall result lies especially in its simplicity as a communication tool on the status of food safety towards the general public and the stakeholders. It is more important to monitor the evolution of the individual indicators from one year to the next year. Statistical analysis was performed for each indicator to distinguish significant changes from one year to the previous year (2008 versus 2007 and 2009 versus 2008). A one by one comparison of the separate indicators showed several significant differences as shown in Table 4. A visual representation of the observed percentage changes from one year over the previous year for each of the 30 indicators (with indication of the significance of the result) is also shown in Fig. 1. These spider webs enable to obtain a helicopter view of the status of food safety reflected by the 30 indicators for the current established food safety barometers (2009 versus 2008 and 2008 versus 2007). Over the two food safety barometers it can be noted, there was two times a significant increase ($p < 0.001$) of the percentage of performed key activities with a validated self checking system in the primary production (FSI 3). However, also over the two years a significant decrease was perceived for FSI 6 (Inspections regarding self checking) ($p < 0.001$), thus in the percentage of 'favourable' inspections (incl. 'favourable with minor remarks'). This may be attributed to an important extent due to the start of the evaluation of the content of the systems instead of just checking whether they are present.

The percentage of meat pig farms without risk status for *Salmonella* sp. (FSI 22) showed a significant decrease ($p < 0.001$) in 2008, when compared to 2007 but FSI 22 showed a significant increase ($p < 0.001$) in 2009, when compared to 2008. Concerning the indicators dealing with *E. coli* as hygiene indicator as for FSI 26 (*E. coli* in foodstuffs), a significant increase ($p = 0.007$) of the percentage of conform samples has been noticed in the first food safety barometer (97.80% in 2008, compared to 95.51% in 2007) whereas for FSI 25 (*E. coli* in carcasses and cut meat), a significant decrease ($p < 0.001$) was observed in 2009, compared to 2008.

The number of persons affected by a foodborne outbreak per 100,000 inhabitants (FSI 28) was significantly greater ($p = 0.004$) in 2008 when compared to the average value for 2005, 2006 and 2007 but was significantly lower ($p = 0.001$) in 2009 when compared to the average value for 2006, 2007 and 2008. On the other hand, salmonellosis in humans (FSI 29) showed a significant decrease ($p = 0.001$) in both current established food safety barometers.

However, data gathered with this concept of the food safety barometer are currently limited. As at present for each of the indicators only values for three years are available a trend analysis is not yet possible, but will be conducted in the future.

4. Discussion

The use of indicators has become popular in the last decades in different fields, either in order to try to measure the performance of systems or policy actions or as a communication tool. The current food safety barometer is to serve primarily as a communication tool to stakeholders and in particular consumers and trade partners. Food safety was reflected in a composite agreed upon set of indicators related to i) the compliance to action limits/criteria for selected chemical and microbial hazards, ii) the implementation of preventive and control measures to mitigate food safety throughout the food chain from farm to fork and iii) the reported number of foodborne outbreaks and some selected zoonotic agents (*Salmonella* sp. and *Listeria monocytogenes*). As food safety remains an abstract term and no quantitative value could be attributed (also due to lack of quantitative set objectives), the option was taken to document change of the status of food safety in a relative manner by comparing the results of the set of indicators of the current year with the previous year.

During the selection process of the indicators, special attention was given to the availability and accessibility of data. It is important in the concept of a barometer, that the selected indicators are stable in time, meaning that they have been measured over a long enough period in the past and that it is expected that this will be further continued in the future. Consistent and uniform registration and documentation in preferably one common database for all aspects of food safety (from farm to fork) is a prerequisite to set up the current tool to measure food safety. It is foreseen that the composition of the set of indicators may evolve with time, whenever individual indicators are not longer relevant, or whenever new indicators appear to better reflect the actual situation as a result of new developments in the food chain.

Food safety, as became clear by the selection of relevant indicators, is a complex concept to measure. Thirty indicators were necessary to

Table 3

Overview of the number of Food Safety Indicators (FSIs) that are related to the different segments of the food chain.

Food chain segment	Number of FSIs
Suppliers	7
Primary vegetable production	10
Primary animal production	14
Processing	15
Distribution	12
Consumer	3
Import	8
Storage and transport by third parties	7
Services and wagework	2

Table 4
Overview of the results for 2007, 2008 and 2009 of the respective Food Safety Indicators (the number of samples or inspections is shown between brackets) with their change during time (weighted and not weighted).

FSI	Result 2007	Result 2008	Result 2009	Change in 2008 compared to 2007 ²	Change in 2009 compared to 2008 ³	Weight factor	Weighted result 2008	Weighted result 2009
1	357	390	367	9.24%	-5.90%	1.16	10.75%	-6.86%
2	43.57% (1065) ¹	53.33% (1065)	68.28% (1195)	22.41	28.03%***	0.9	20.17%	25.23%
3	6.25% (84,303)	11.73% (92,399)	21.45% (93,285)	87.78%***	82.93%***	0.71	62.54%	59.09%
4	0.61% (16,754)	1.76% (17,888)	5.69% (16,163)	185.53% ⁶	223.91%***	1.16	215.68% ⁶	260.30%
5	0.01% (20,972)	0.11% (21,635)	0.36% (20,640)	643.17% ⁶	237.25% ⁶	0.79	506.50% ⁶	186.83% ⁶
6	73.10% (5693)	62.16% (7068)	55.62% (12,169)	-14.97%***	-10.51%***	2.06	-30.87%	-21.68%
7	77.77% (14,910)	56.01% (12,492)	56.03% (20,392)	-27.98%***	0.03%	1.88	-52.46%	0.06%
8	93.87% (11,856)	94.70% (13,713)	95.31% (15,767)	0.88%*	0.65%*	1.65	1.46%	1.07%
9	94.20% (889)	96.30% (538)	95.54% (763)	2.23%	-0.79%	0.98	2.17%	-0.77%
10	91.57% (178)	89.01% (182)	91.92% (198)	-2.80%	3.27%	0.41	-1.15%	1.35%
11	100.00% (374)	100.00% (397)	100.00% (130)	0.00%	0.00%	0.75	0.00%	0.00%
12	99.33% (297)	99.72% (406)	99.69% (318)	0.39%	-0.03%	0.9	0.35%	-0.03%
13	99.81% (10,945)	99.86% (11,624)	99.86% (10,773)	0.05%	0.00%	1.5	0.08%	0.00%
14	94.00% (480)	91.10% (936)	93.30% (1804)	-3.09%	2.41%	0.38	-1.16%	0.91%
15	99.51% (838)	99.15% (470)	100.00% (1366)	-0.36%	0.86%*	0.98	-0.35%	0.84%
16	100.00% (153)	100.00% (212)	100.00% (41)	0.00%	0.00%	0.53	0.00%	0.00%
17	91.20% (770)	92.30% (862)	93.06% (1009)	1.21%	0.83%	1.39	1.67%	1.15%
18	100.00% (228)	100.00% (246)	100.00% (157)	0.00%	0.00%	0.53	0.00%	0.00%
19	99.30% (1248)	99.00% (1586)	96.81% (940)	-0.30%	-2.21%***	1.73	-0.52%	-3.82%
20	99.20% (1441)	100.00% (1264)	100.00% (1266)	0.81%*	0.00%	0.94	0.76%	0.00%
21	95.72% (397)	95.83% (719)	96.20% (815)	0.11%	0.38%	0.64	0.07%	0.24%
22	96.15% (6978)	93.50% (6658)	95.07% (6395)	-2.75%***	1.69%***	0.49	-1.34%	0.82%
23	94.66% (487)	91.83% (942)	94.36% (1046)	-3.00%	2.76%*	0.49	-1.46%	1.35%
24	86.62% (1248)	89.75% (1256)	86.54% (2258)	3.62%*	-3.58%*	0.98	3.52%	-3.49%
25	93.88% (1066)	95.04% (1164)	88.01% (1109)	1.24%	-7.40%***	0.68	0.83%	-4.99%
26	95.51% (732)	97.80% (1095)	97.75% (2446)	2.40%**	-0.05%	0.71	1.71%	-0.04%
27	98.16% (1872)	98.20% (5055)	97.71% (3362)	0.04%	-0.50%	0.9	0.04%	-0.45%
28	8.63	9.37	7.94	-14.50% ^{4, 7**}	14.32% ^{5, 7**}	1.46	-21.20%	20.94%
29	37.55	36.97	29.84	7.33% ^{4, 7**}	18.37% ^{5, 7***}	1.28	9.35%	23.42%
30	0.54	0.60	0.74	-1.75% ^{4, 7}	-25.73% ^{5, 7}	1.09	-1.90%	-27.98%
Global				2.44% ⁸	11.16% ⁹	30 ¹⁰	0.11% ⁸	11.26% ⁹

¹ As the database of the operators and their activities was only completed in the course of 2007, there is a certain degree of uncertainty as to the number of key activities performed in the animal fodder sector for the year 2007. As a consequence, the number of key activities performed in 2008 was used as a basis for the calculation of the indicator for 2007.

² Percentual change = (result 2008 - result 2007).100%/result 2007. Significant changes are indicated with * (* = p < 0.05, ** = p < 0.01, *** = p < 0.001).

³ Percentual change = (result 2009 - result 2008).100%/result 2008. Significant changes are indicated with * (* = p < 0.05, ** = p < 0.01, *** = p < 0.001).

⁴ Instead of using the value of 2007, the average value for the years 2005, 2006 and 2007 was used.

⁵ Instead of using the value of 2008, the average value for the years 2006, 2007 and 2008 was used.

⁶ As the percentage of performed key activities with a validated self checking system for the year is below 1%, the impact on food safety is only very limited. Therefore, this indicator has been neutralized.

⁷ The sign of this indicator was changed, because a decrease of this indicator actually shows an improvement of food safety.

⁸ Average value for the 28 indicators.

⁹ Average value for the 29 indicators.

¹⁰ Sum of all weight factors.

cover the full farm to fork concept of food safety and to include the various categories of hazards and aspects of product control, process control and public health impact. However, this set of indicators can not by itself encompass all aspects or features of food safety. It is evident that each indicator has its own strengths and weaknesses, as explained in the technical data sheets which can be consulted at http://www.favv-afsc.fgov.be/scientificcommittee/advice/_documents/Advice28-2010-Annex3-TechnicaldatasheetFoodSafetystateindicators.pdf. In this respect, it is important to take into account the context in which the indicators were defined. The interpretation of certain groups of indicators can be further explained in a generic way.

For example, FSI 1 is the number of mandatory notifications with regard to food safety meaning that any operator has promptly to inform the FASFC when he is of the opinion or has reason to believe, that an imported, produced, reared, grown, processed, manufactured or distributed product may be harmful to the health of humans, animals or plants (FASFC, 2003). It is obvious that an increase of the number of notifications may occur due to new incidents (national or abroad), or as a result of a higher degree of alertness (whether or not stimulated by information campaigns), leading to a greater vigilance with regard to hazards and risks. However, as mandatory notification is inherent to a preventive policy strategy, and is also essential for preventing hazardous foodstuffs from entering the food chain, it is concluded that an increase in the number of notifications signifies that

there is a substantial degree of vigilance with regard to the safeguarding of the food chain.

FSI 2 to 5 are defined as the percentage of performed key activities covered by a validated self checking system, on an annual basis in a specific sector. A key activity is an activity within the food chain representing a considerable production volume, and/or may have a considerable impact on the safety of the food chain because of the nature of the activity. A systematic approach to self checking was introduced in Belgium in 2003 and refers to the whole range of measures taken by business operators to make sure that their products:

- meet the requirements laid down in the regulations concerning food safety;
- meet the requirements laid down in the regulations concerning the quality of products under the authority of the FASFC;
- meet the requirements laid down in the regulations concerning traceability.

Self checking implies that the requirements have to be met at all stages of production, processing and distribution of products. All business operators (except those of the primary sector) with activities in the food chain must introduce, implement and sustain a self checking system (FASFC, 2003). Concerning these FSIs, it needs to be mentioned that the operators may deliberately choose whether or not they want to have their self checking system validated. One must

however note that, in case a key activity doesn't have a validated self checking system, this does not mean that the self checking system is absent or malfunctioning. The point is that an independently validated self checking system gives a surplus 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 validated self checking system thus indirectly leads to a higher confidence level with regard to adequate preventive actions taken in order to ensure overall food safety. Furthermore, recent literature indicates that a well functioning self checking system is generally reflected in a better performance of food safety (Noble, Griffiths, Thompson, & Maclaurin, 2009; Jacxsens et al., 2010; Sampers et al., 2010).

As for the results of inspections in food companies (FSI 6 to 8) and analyses of food products (FSI 9 to 27), one must take into account

that changes may occur in the evaluation system from time to time (e.g. introduction of new checklists, modified action limits or tolerance levels). This may result in year-to-year differences with regard to the detection of non-conformities. It is however recommended that, in case of significant changes to the evaluation system, both the sector and the authorities make strong efforts to sensitize, inform and assist the operators concerned in order to limit the non-conformities even with a new evaluation system. One must also take into account that some inspections or controls may have been focused on high-risk companies, products or countries of origin, and cause in this way some degree of bias. However, this is a systematic bias, which is intrinsic to the development of a risk-based control program. On the other hand, in defining the indicators related to product control, it was decided, as much as possible, to only include the results of the risk

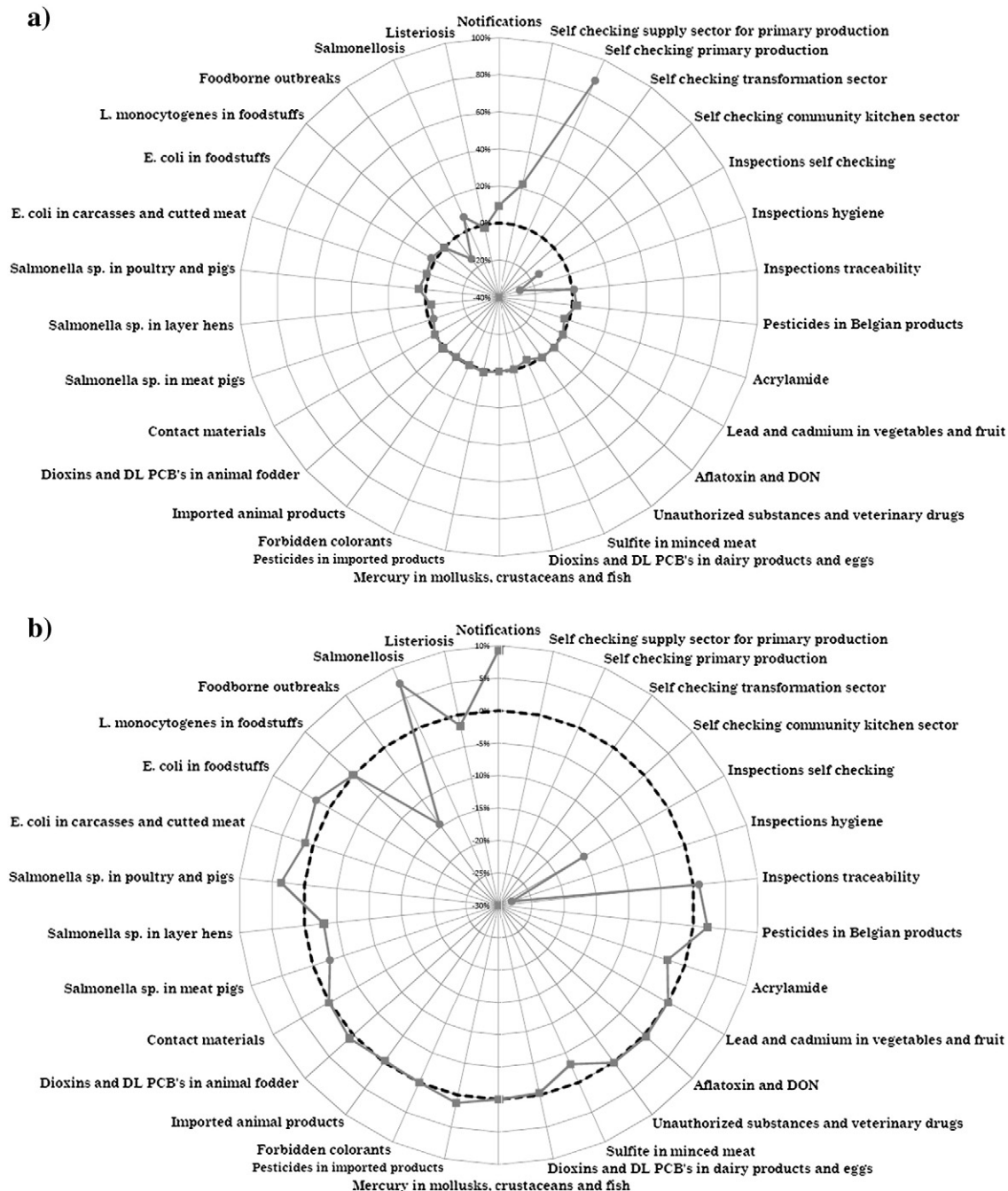
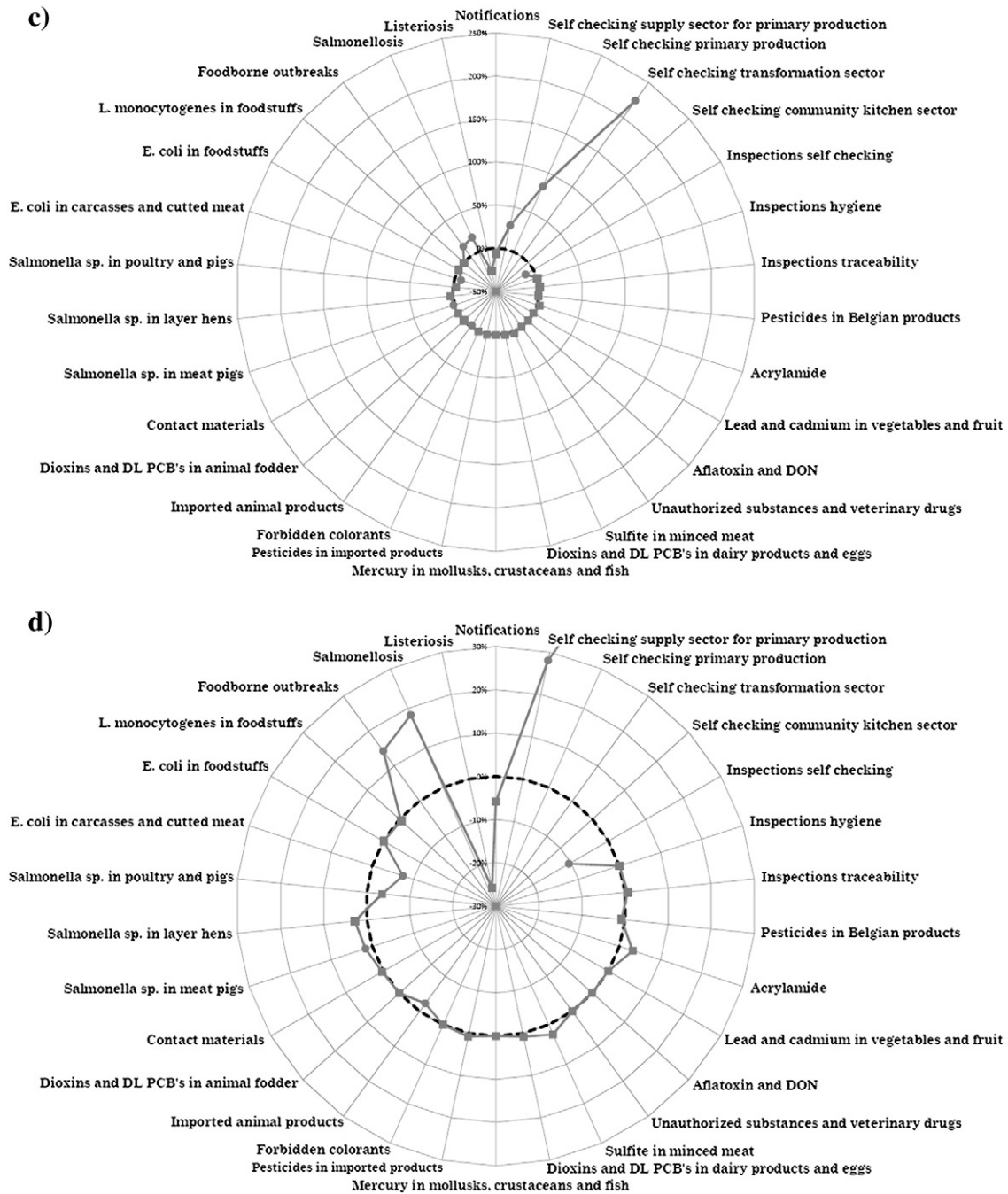


Fig. 1. Visual representation of the food safety barometer (A: 2008 versus 2007; B: 2008 versus 2007-detail; C: 2009 versus 2008; D: 2009 versus 2008-detail). ●: significant change of the food safety ($p < 0.01$); ■: non-significant change of the food safety; dashed line: 0% change.



based control program of the FASFC, with the exclusion of analysis results from samples that were taken following complaints or incidents.

The indicators relating to samplings and analyses of food, feed and animals (FSI 9 to 27) were defined on the basis of the percentage of established conformities of the considered hazard (compliance to the legal level, criterion or action limit). However, the unconformity in relation to these indicators does not necessarily represent a direct and significant risk to public health. In order to assess the risk for public health, a risk assessment should be conducted, taking into account the amount of exposure of the consumers to the chemical or microbiological hazards via consumption of these products as part of their diet, as well as the effect of this exposure on public health warranting the knowledge of the dose–response relationship. These types of risk-assessments take up considerable time and resources and don't fall

under the scope of this food safety barometer that warrants a yearly and timely monitoring of food safety status. However, these risk assessments are undertaken for particular hazards or commodities by working groups of Scientific Committees or research projects using the available FASFC monitoring data (e.g. Uyttendaele et al., 2006; Baert et al., 2007; Uyttendaele et al., 2009; Claeys et al., 2010; Claeys et al., 2011). These risk assessments are complementary to the food safety barometer. Within the framework of the barometer, the presence of non-conform samples for certain indicators thus must be interpreted as an indication that good working practices were insufficiently implemented, as a result of which the predefined levels, criteria or action limits have not been met (resulting in a possible negative impact on food safety as should become clear from follow-up risk assessments). Accordingly, an increase of the indicator, namely an increase of the percentage of conform samples, will above all reflect a

better mastering of good working practices and preventive actions, which also indirectly (or in some cases also directly) is an indication of the fact that the overall food safety situation has improved.

FSI 28 to 30 measure the food safety at the level of public health, namely the number of persons involved in food borne outbreaks or reported cases of selected zoonotic agents. It is generally known, that underreporting is inherent to this indicator (Martinez et al., 2008). However, this underreporting occurs systematic in nature and unless the human surveillance system for infectious diseases and/or food borne outbreaks changes considerably is assumed to be constant over the years. Therefore in the comparison of one year to another as is the case in the present study, this indicator can be considered to be reliable for reflecting the evolution of the reported number of selected food borne infections and intoxications in humans.

Although the impact of the food safety policy is often measured in terms of effects on consumer's health, more in particular with regard to (preferably) decrease of reported foodborne diseases caused by zoonotic agents, it was decided to include this aspect only as one of the indicators (FSI 28 to 30) in the overall measure of food safety in the current food safety barometer. Many other indicators were included which measure the presence of hazards and its associated control measures rather in the farm to fork continuum itself at the level of the potential introduction and mitigation in the food chain. The latter shows a more direct and measurable relationship with the food safety policy that is being implemented, while the relationship of public health with overall food safety is less direct and more biased by a large number of other variables (e.g. an inadequate efficiency of the reporting systems used for the determination of the total disease burden, insufficient clarity as to whether or not the reported disease cases are food borne, confounding effects of changing consumption pattern, travel etc.) and information available restricted to biological hazards. In addition, the General Food Law (EU Regulation 178/2002) introduced in the EU the keynote that the responsibility for putting safe food on the market, is primary the responsibility of the food business operators, advocated an integrated approach from farm to fork to achieve this and put forward the precautionary approach and alert systems. This is also reflected in the barometer by composing a set of food safety indicators targeting all stages in the food chain and both including product analysis and inspections on one hand and preventive systems such as self checking, notifications and traceability on the other hand.

Several indicators showed high levels of conformity (>95%) indicating that food safety is on a high level in Belgium. However, for the inspections of infrastructure, installations and hygiene (FSI 7) and inspections regarding self checking systems (FSI 6) moderate results were observed, leaving some space for improvement in the future. Also for the validated self checking systems (FSI 2 to 5), which were introduced some years ago, an increase can be expected in the future.

Since the impact of each indicator on food safety is perceived different by various individuals, it was decided to perform a weighing of the indicators by consulting the various stakeholders in the food chain including scientists of various food science disciplines, the FASFC risk managers and representatives of the agro-food industry associations, consumers and other competent authorities in the Belgian food chain. It was confirmed that all selected indicators contributed to the measurement of food safety. Weighing of the indicators using the Las Vegas methodology resulted in a science-based, broadly accepted, balanced barometer for the FASFC to use in its task to communicate on food safety to society. It is clear that the weight assigned to the separate indicators is based on expert opinion and not on risk assessment which was out of the scope of the development of the barometer. For now, the current food safety barometer enables to have a helicopter view on the status of food safety and its various aspects by means of the selected indicators. Still it is clear that the current food safety barometer is only one way of

communication on food safety in the tool box available. The food safety barometer is complementary to the communication established by the yearly report with full description of all activities of the FASFC (e.g. FASFC, 2009) and other publications available on the agency's website (including also the advices of the Scientific Committee of the FASFC on defined topics).

The barometer may in due time not only be an accessible ease to use communication tool but on the long term, when more experience has been gained with the concept of the current food safety barometer and data have been gathered over multiple years, also evolve to a management tool. It is clear that this concept of food safety barometer and outcome needs follow-up in the future. The set of 30 indicators allows to observe trends with regard to historical evolutions of the food safety for a certain country or geographic region. In the present study statistical analysis on each of the individual indicators was performed but as only data for 2009 versus 2008 and 2008 versus 2007 are available for now no conclusions can be drawn yet. However, further data collection in coming years may serve to set a baseline of food safety and the formulation of objectives for particular indicators. Nevertheless, the status of food safety is expected to change continuously, impacted by the other two aspects in the OECD Pressure–State–Response model.

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