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Advice from the Director of the Office for Risk Assessment & Research

Advice on the risks in the egg supply chain

It is my distinct pleasure to present you with the risk assessment of the egg supply chain as drawn up by my Office. In supplement to the risk assessment for the poultry meat supply chain, this present document contains a collection of the international scientific literature on the food safety and animal welfare of poultry that produces eggs. We have assessed the relevance of the various potential hazards to humans and animals for the Dutch egg supply chain and assessed the applicable risks. We included information available from the Netherlands Food Safety and Consumer Product Safety Authority (NVWA) itself, as well as from other knowledge institutes and other sources.

The NVWA is permanently committed providing more risk-oriented and knowledge-driven monitoring, in furtherance to the recommendation formulated by the Dutch Safety Board in relation to the ‘horse meat scandal’ (*Risks in the meat supply chain*, 26 March 2014; Dutch Safety Board (OVV, 2014), which is directed at your role, as Inspector-General of the NVWA:

‘Identify the risks that exist in vulnerable stages of the chain and define priorities.’

In 2014, partly in response to this recommendation, the Office for Risk Assessment & Research (BuRO) launched its project to draft risk assessments for the production supply chains that encompass virtually the entire domain of the NVWA. The project entailed a cyclical process to be repeated every four years. These risk assessments, in conjunction with information on monitoring, compliance and fraud (the comprehensive supply chain analysis), provide an essential basis for effective risk-oriented and knowledge driven oversight.

In the risk assessments for the red meat and dairy supply chains, I previously noted that the levels of food safety and animal welfare in the Netherlands are high, but that further improvements could nonetheless be made. The same applies to the egg supply chain. Hazards to animals and humans are introduced chiefly at the start of the poultry chain and their effects have an impact in subsequent links in the chain. A very limited set of food safety and animal welfare indicators implemented at these later stages, however, may encourage improvements in the preceding stages in the chain.

As such, the recommendations not only focus on identifying the risks present in the egg supply chain, as requested by the Dutch Safety Board, but also focus on the recommendations of the Board itself to ensure that:

'*binding agreements are made with private parties in order to achieve structural improvement of the level of food safety*'

where it should be ensured that

'*companies [call] each other to account regarding high-risk behaviour, such as unsanitary slaughtering or illegal practices. Companies should inform one another, and the NVWA, of any high-risk behaviour taking place at other companies*'

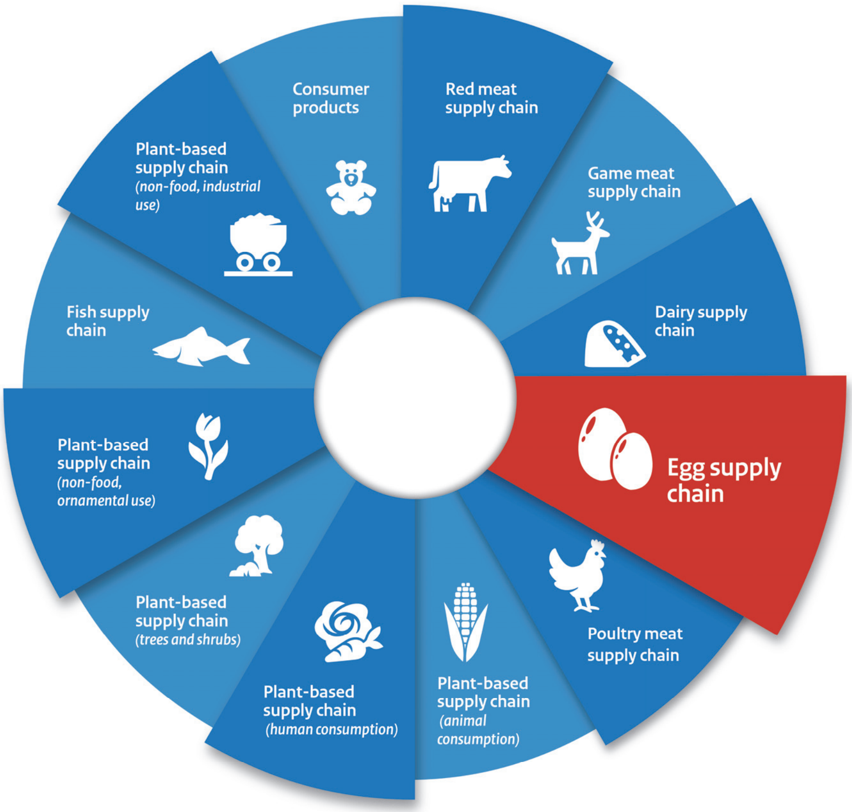
and, in addition, that

'*the traceability of products should improve and the performance of individual companies in the field of food safety should become more transparent to consumers.*'

Utrecht, February 2018

Yours sincerely,

Prof. Antoon Opperhuizen
Director of the Office for Risk Assessment & Research



Introduction

Before you is the comprehensive risk assessment of the Dutch egg supply chain, prepared by the Office for Risk Assessment & Research (*Bureau Risicobeoordeling & onderzoek*, BuRO) of the Netherlands Food and Consumer Product Safety Authority (*Nederlandse Voedsel- en Warenautoriteit*, NVWA). In this document, the BuRO has carried out an assessment of the food safety risks of Dutch eggs and egg products as well as the animal welfare risks for Dutch poultry. The risk assessment for the egg supply chain is largely similar to the comprehensive risk assessment for the poultry meat supply chain, which was published virtually simultaneously.

In the Netherlands, over 10 billion eggs are produced each year by nearly 1,000 poultry farms. In addition, over 2 billion eggs are imported into the Netherlands and incorporated into the egg supply chain (egg collectors, packing stations and egg processing sector). The Netherlands is a major net exporter of eggs and egg products, which means that food safety risks extend beyond Dutch consumers. Conversely, the estimated disease burden in the Netherlands is caused by eggs that cannot be definitively traced back to Dutch poultry farms. A Dutch person will consume at least 80 eggs a year (RIVM, food consumption survey) and the equivalent of approximately 100 eggs as an ingredient of composite products.

Table 1.
Size of the egg sector

Size of egg sector	Number
End layer poultry farms	964
Collectors	17
Packing stations	108
Wholesalers	121
Egg product producers	20
Egg product traders	16
Total	1246

(Source: MANCP, 2015)

A number of types of risks have not been include in the scope of this assessment. The risks relating to importing eggs, for example, have not been included. The risks to nature and the environment as a result of manure, air pollution, the spread of zoonoses and chemicals, such as veterinary drugs into the environment, have likewise not been included in this risk assessment.

Antibiotics resistance of a number of the bacteria that may be found in the egg supply chain, such as multi-resistant Staphylococcus aureus (MRSA) and extended-spectrum beta-lactamase (ESBL)-producing bacteria, is similarly not addressed in this assessment. In the risk assessment for the poultry meat chain, however, the risks of antibiotic use are examined.

Dutch eggs are primarily produced by chickens. Eggs from other birds, such as quail, duck, ostrich, and goose, are consumed relatively little in our country by comparison – generally only by a limited group of enthusiasts. These eggs are mainly imported from other European countries. As such, and for both reasons, these poultry species will not be discussed in this assessment. The risk assessment is limited to the production of the chicken egg as a shell egg or table egg and as a raw material for egg products in the food industry. The products for which eggs, egg yolk or egg white are an ingredient (such as in composite products) have likewise not been included. BuRO will, however, be focusing on those aspects in the next edition of this supply chain risk assessment.

The present risk assessment will examine the animal welfare risks of laying hens, from the farm to the transport of spent laying hens and parent stock to the slaughterhouse. At the stage of the farm, additional attention is focused on the dangers of red poultry mite and histomoniasis in poultry. The former, in particular, gained notoriety in the summer of 2017 through the non-authorised use of the pesticide fipronil in the egg production sector. Due to the possible use of agents used to combat red poultry mite by back yard poultry farmers, this assessment will also focus on this sector with its regular customers. The issue of red poultry mite, histomonas and the (illegal) control of these parasites is not solely confined to the Netherlands. Other, chiefly tropical, countries also experience major problems in relation to parasites that are being combated.

The animal welfare considerations from arrival at the slaughterhouse have already been outlined in the comprehensive risk assessment for the poultry meat supply chain.

The risk assessment is BuRO's advisory report to the Inspector-General of the NVWA. What follows is the research method used, an extensive outline of the risk assessment, the findings and recommendations and the consulted literature. The advisory report includes annexes containing further substantiation of the risk assessment.

Questions to be addressed
The Office for Risk Assessment & Research (BuRO) formulated the following questions for its investigation of the risks in the egg supply chain:

'*What are the most significant risks to food safety and animal welfare in the various stages of the egg supply chain?*'

'*How could further risk reduction be achieved?*'

Approach
As the basis for this risk assessment, BuRO prepared an extensive hazard identification and characterisation for the food safety of eggs and egg products and for the welfare of the poultry in the egg supply chain.

The 'Microbiology' assessment is largely based on the literature reviews entitled *Microbiologische risicobeoordeling eierketens* ('Microbiological risk assessment of the egg supply chains') published by the Netherlands National Institute for Public Health and the Environment (RIVM) and *Beoordeling verlenging 'ten minste houdbaar tot' (THT)-termijn van eieren* ('Assessment regarding the extension of the "best before" dates for eggs') carried out by the Front Office for Food and Products Safety of the RIVM. For the risk assessment relating to chemical and physical risks, this document made use of the report entitled *Chemical and physical hazards in the egg production chain in the Netherlands* published by Wageningen RIKILT (van der Fels-Klerx et al., 2017). For the risk assessment relating to animal welfare, BuRO made use of the report entitled *Risicoanalyse dierenwelzijn eierketen* ('Risk assessment of animal welfare in the egg supply chain') published by Wageningen Livestock Research (WLR; Visser et al., 2015). In addition, BuRO made use of '*Desk research gevarenanalyse diergezondheid-Eierketen*' ('Desk research for hazard assessment regarding egg supply chain animal welfare') (Swanenburg et al., 2015*)* published by Wageningen BioVeterinary Research.

The Office for Risk Assessment & Research (BuRO) conducted an extensive literature review in relation to each aspect covered by the risk assessment, in which the recent reports of the European Food Safety Authority (EFSA) in particular played a key guiding role. In addition, BuRO has made use of the data available at the NVWA on the presence of food safety and animal welfare hazards in the egg supply chain as much as possible.

A multidisciplinary team at BuRO created the draft report, which was put to external experts for review in several segments. The departments of the NVWA were asked to provide any additions and to check for any inaccuracies.

BuRO has presented the preliminary findings and recommendations of the risk assessment to the IG and the directors of the NVWA in order to enable them to formulate a comprehensive risk assessment and a management response in a timely fashion. The findings and recommendations were subsequently presented to the relevant policy departments of the Ministries of Agriculture, Nature and Food Quality (LNV, formerly Economic Affairs) and Health, Welfare and Sport (VWS). On 29 December 2017, the final draft of the advisory report was made available to the Inspector General of the NVWA for the formal inspection prior to publication, as well as to the policy departments of LNV and VWS.

The methodology of the risk assessment for the egg supply chain is largely based on the methodology of the Codex Alimentarius and on the working methods of the EFSA, and is in line with the systematic risk assessment procedure stated in

Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety, which consists of the following four stages.

1. Hazard identification: the threats to food safety and animal welfare described in international scientific literature;
2. Hazard characterisation: the relevance of the food-safety and animal-welfare threats to the Dutch egg supply chain. Not everything that is described in the international literature is relevant to Dutch circumstances.
3. Exposure assessment: the probability of the occurrence of these hazards. In relation to food safety, this is the extent to which potential disease-causing agents (components of egg, micro-organisms, chemicals and physical particles) that actually occur in Dutch products. For animal welfare, this is the occurrence of circumstances, situations and practices that affect and impair the welfare of egg-producing animals.
4. Risk assessment: the overall assessment of the nature and severity of each threat, and the likelihood/prevalence thereof in the Netherlands.

These facets are discussed below with regard to A) Food Safety and B) Animal Welfare.

BuRO has not assessed each and every aspects relating to food safety and animal welfare in the egg supply chain. For an explanation of the scope, assessment methods, risk terminology and approach, please see Appendix 1 (in Dutch only).

Food safety risk assessment

Allergy
Foodstuffs can cause food allergies in people that are susceptible, with eggs belonging to the category of foodstuffs that can cause the most serious allergies. Food allergies result in a significant disease burden (expressed in lost years of healthy life or DALYs[1]) and substantial costs may be associated with food-induced allergic reactions (Patel et al., 2011, Janssen en Ezendam, 2012). EFSA has described published cases of food-related anaphylactic reactions in children in four different countries (United Kingdom, the United States, Sweden and Germany). A total of 31 deaths and 132 life-threatening reactions were reported. Two of the cases with a fatal outcome (a 3-month-old child and a 2-year-old child) related to egg allergies (EFSA, 2014b).

People who suffer from egg allergies are frequently also allergic to the eggs of other birds (Langeland, 1983). Hypersensitivity to egg white is the second-most common type of food allergy. Symptoms of food allergies will usually surface at a young age, in infants, and will generally go away within a few years. Food allergies that develop later will generally be permanent (Health Council of the Netherlands, 2007). For egg allergies it is the case that approximately 70% of children will no longer suffer from any symptoms once they are sixteen or older. Boiled eggs are tolerated much easier than raw eggs (Hasan et al., 2013).

The RIVM has found no evidence to support the assertion that egg food allergies have increased in 1-year-old Dutch children between 1992 and 2003 (Ezendam et al., 2008). Of the 1-year-old children that were examined, 2 to 5% was sensitised to eggs. In this study, none of the children tested positive for IgE, an egg allergy indicator, in their blood at 8 years of age. Between 1995 and 2007, the number of

[1] DALY is disability-adjusted life year.

people that was allergic to eggs in the Netherlands did not increase (Ezendam et al., 2009).

Eggs are processed in a large number of foodstuffs, including bread, ice cream, biscuits and pastas. The following labelling information may point to the presence of egg: albumin, avidin, conalbumin (ovotransferrin), egg yolk, egg powder, egg white, phosphatidylserine, phospholipids, globulin, lecithin (E322), lipovitellin, livetin, lysozyme (E1105), ovalbumin, ovoglobulin, ovomucin, ovomucoid, ovosucrol, ovotransferrin, phosvitin (Dutch Food Allergy Foundation).

Allergens may be denatured, hydrolysed and aggregated or bound to other foodstuffs after the original foods have been processed. All this, however, has no marked effect on the allergenicity (EFSA, 2014; Netting et al., 2015). Nevertheless, someone who tolerates egg when cooked may have a reaction to raw egg. There are more (severe) reactions to egg white than to egg yolk. For that reason, allergic reactions to the Gal d2-Gal d4 components, which are heat sensitive, are chiefly associated with the intake of raw eggs. The principal allergen in eggs, ovomucoid, however, is heat stable.

In 1995, the FAO identified eight food groups, including eggs, as the most common causes of food allergies relevant to public health worldwide. Regulation EU No. 1169/2011 included these allergens in Annex II which consists of a list of substances or foodstuffs that cause allergies or intolerances and that must be listed on the label. Eggs and egg-based products are included on the list. As of 13 December 2014, allergen information must also be available and presented for non-prepacked food.

Exposure to micro-organisms
According to the expert estimates of the RIVM, eggs and egg products are responsible for roughly 4% of the food-related disease burden in the Netherlands. To humans, *Salmonella*[2] is the principal pathogen associated with eggs and egg products. The most common serotype is *S.* Enteritidis, followed by *S.* Typhimurium. The egg supply chain significantly contributes to the total burden of human *Salmonella* infections.
It is estimated that roughly 1/5 of all humane *Salmonella* infections in the Netherlands are egg related. Depending on the estimation method, this figure relates to 4,000 - 10,000 new cases of disease per year: 100 - 300 DALYs (Bolder et al., 2015).

Mengen et al. estimate the disease burden of *Campylobacter* to lie at 43 DALYs. However, despite the fact that *Campylobacter*, similarly to *Salmonella*, is frequently found in poultry, the pathogen rarely occurs in egg content or on egg shells. In addition, *Campylobacter* cannot survive for longer than 16 hours in a dry environment (EFSA, 2014a). This means that further research is required to establish the attribution of *Campylobacter* to the disease burden related to the egg supply chain. At present, no single, clear infection route can be indicated based on the scientific literature.

The remaining disease burden attributed to the egg supply chain, however to a far lesser degree, relates to Staphylococcus aureus toxin (22 DALYs), Clostridium perfringens toxin (14 DALYs), Listeria monocytogenes (6 DALYs), Norovirus (6 DALYs) and Bacillus cereus toxin (4 DALYs).

Attribution estimates can be made more accurately once whole genome sequencing (WGS) is applied more routinely as the typing method. At present, it is

[2] Where this risk assessment refers to *Salmonella* , this refers to zoonotic *Salmonella*.

unclear what contribution the 10 billion eggs that are produced in the Netherlands make to the disease burden and what share is caused by the roughly 2 billion eggs that are imported.

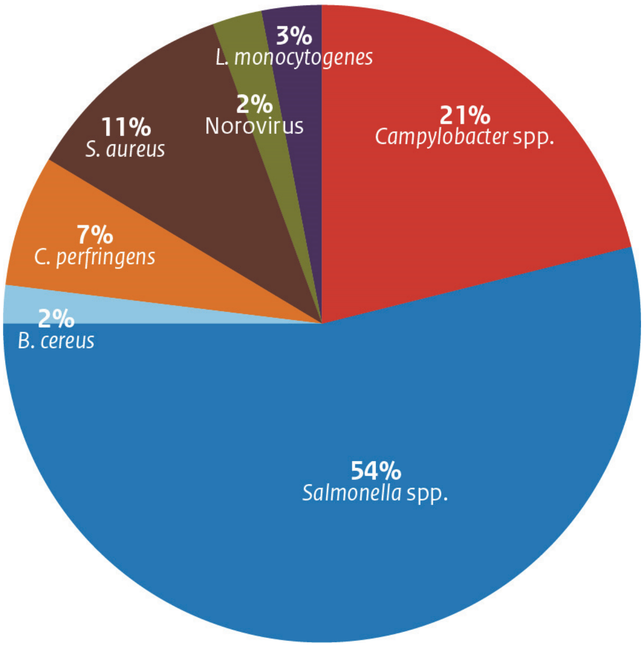


Figure 1.
Expert estimates of the distribution of the disease burden (% of the number of DALYs) caused by eggs and egg products according to agent in the Netherlands, 2015 (Source: Mangen et al., 2017).

In addition, the majority of this total of 12 billion eggs is subsequently exported. As a result of the Netherlands' egg exports, the largest share of the true disease burden may potentially be manifesting itself abroad. Conversely, imports of eggs from abroad may be causing a share of the disease burden in the Netherlands. The estimate for burden of disease in the Netherlands of the RIVM relates to the national consumption of just under 3 billion eggs per year.

Harmful micro-organisms may be introduced at various links in the Dutch egg supply chain. The introduction of *Salmonella* chiefly takes place during the farm phase, both at breeding and egg-producing poultry farms. The other micro-organisms are primarily introduced in the subsequent phases.

The egg supply chain can be divided up into two distinct sub-chains. The largest sub-chain is that of eggs for human consumption (table eggs, 75% of all eggs). The chain of egg products (25% of all eggs) exists as a parallel sub-chain.

EFSA considers *S.* Enteritidis as the only pathogen that currently poses a significant risk to egg-related disease burden in the European Union (EU) (EFSA, 2014a). As such, hereafter the assessment will only examine *Salmonella*.

Exposure to *Salmonella*

The risk of a *Salmonella* infection being introduced into eggs in the supply chain depends on a variety of factors in the chain. The following section will set out the key risk factors for each link in the chain, as well as discuss options and opportunities to control those risks.

Primary phase

During the primary phase on the farm, there are two possible routes along which *Salmonella* may contaminate eggs: vertical and horizontal contamination. In vertical or ovarian transmission, the pathogen is transferred to the offspring (in breeding animals) and to table eggs (in laying hens). It is through the reproductive of a (laying) hen infected with *Salmonella* that the egg content and/or egg shell will become infected. *Salmonella* bacteria that are taken in orally through poultry feed, water or the environment can subsequently colonise in the intestines and thereafter lead to infections of various organs, including the reproductive organs. This vertical transmission is considered to be the most significant infection route for an egg infected with *S.* Enteritidis.

In the horizontal transmission route, an egg is contaminated with *Salmonella* via the egg shell either through the intestines or the environment (nesting material and faeces) during or after laying. These infections can subsequently penetrate the egg. Contamination of the egg content via the shell is no a unique trait of *S.* Enteritidis – other *Salmonella* serotypes are also able to penetrate the egg shell.

The risk of introduction of *Salmonella* in a flock of chickens through the environment can be significantly reduced by putting hygiene measures in place, enforcing biosecurity[3] procedures and cleaning and disinfecting the housing pens before new flocks enter the pens. It is, however, difficult to control *Salmonella* entirely, given that the pathogen is able to survive in the environment of a housing unit for a long time. The levels of *Salmonella* in housing units that have been cleaned are usually very low and are difficult to detect. The presence of *Salmonella* in poultry flocks is regarded as the most significant risk factor for the presence of *Salmonella* in (meat and) eggs, and, consequently, as a risk to public health. For that reason, various control programmes have been in place in the Netherlands since 1997 to reduce of the number of *Salmonella* infections in poultry and to limit the spread of *Salmonella* to the subsequent links in the chain. As of 2008, EU rules and regulations have been in force which oblige the Member States to draw up a control programme for *Salmonella*. Hygiene measures and cleaning and disinfection of buildings, alongside monitoring, the exchange of monitoring results, vaccination and the implementation of measures in relation to infected poultry, constitute the basic principles of the control approach to *Salmonella*, followed by / in conjunction with the channelling of the eggs infected with *Salmonella* in the secondary phase.

The scientific literature does not offer a clear answer as of whether there are (significant) differences in the prevalence of *Salmonella* in chickens (and their eggs) that are able to range freely and chickens (and their eggs) that are housed indoors.

The control approach in the laying hen sector has led to a visible decrease in the number of infected flocks of laying hens since 1998. As such, the Netherlands is in compliance with the EU target (maximum of 2%). Although the number of patients with salmonellosis attributable to laying hens and eggs has more than

[3] *Biosecurity* is defined as the preventive measures that are put in place to reduce the risk of the introduction and spread of infectious diseases.

halved over the past 15 years, there are infected eggs still on the consumer market (0.0078%, see Annex 3).
As of 2013, the decrease in human cases of disease that are attributable to the egg poultry sector has abated (figure 2).

Despite that table eggs come from flocks with a negative *Salmonella* status, these flocks may have been infected in the period between two samples carried out under the monitoring programme (15 weeks). In addition, a flock may have been infected for the entire period. Both situations may result in infected eggs having entered the market. Increasing the frequency of sampling will likewise increase the probability of a positive finding through the sampling process. This would limit the potential introduction of infected eggs onto the consumption market.

The sampling that must be carried out for the *Salmonella* monitoring programme is carried out by poultry farmers themselves. Following a report of an infected flock at the NVWA, the NWVA will conduct an investigation; the organisation may only impose measures on the farmers based on official samples. For the duration of the investigation, the supply of eggs to the consumer market will be halted. Any flock that has been found to be infected by the farmer and is given suspect status, will only be able to be declared infected following confirmation of the positive test result by the NVWA. In roughly half of all cases, the investigation will confirm the suspicion. In 2016, this figure related to 42% of breeding flocks and 58% of laying hen flocks.

Salmonella is not spread homogeneously within a flock nor is it over time, which may result in *Salmonella* present in the flock no longer being able to be identified through the investigation. An end poultry farm with a housing pen that has mistakenly been declared free of *Salmonella* may potentially supply eggs to the market that are infected with *Salmonella*.

Depending on the serotype and the type of farm, appropriate interventions are prescribed for a given type of *Salmonella* infection. At breeding farms, the animals of flocks that have tested positive are culled (<14 weeks) or prematurely slaughtered. Hatching eggs are destroyed or channelled to the egg processing sector where they must undergo sufficient microbial count reduction treatment (heat treatment). Animals of laying hen flocks that have tested positive are not culled but are slaughtered at the end of the laying period. The eggs of the contaminated flock are channelled to the egg processing sector where they must undergo sufficient heat treatment.

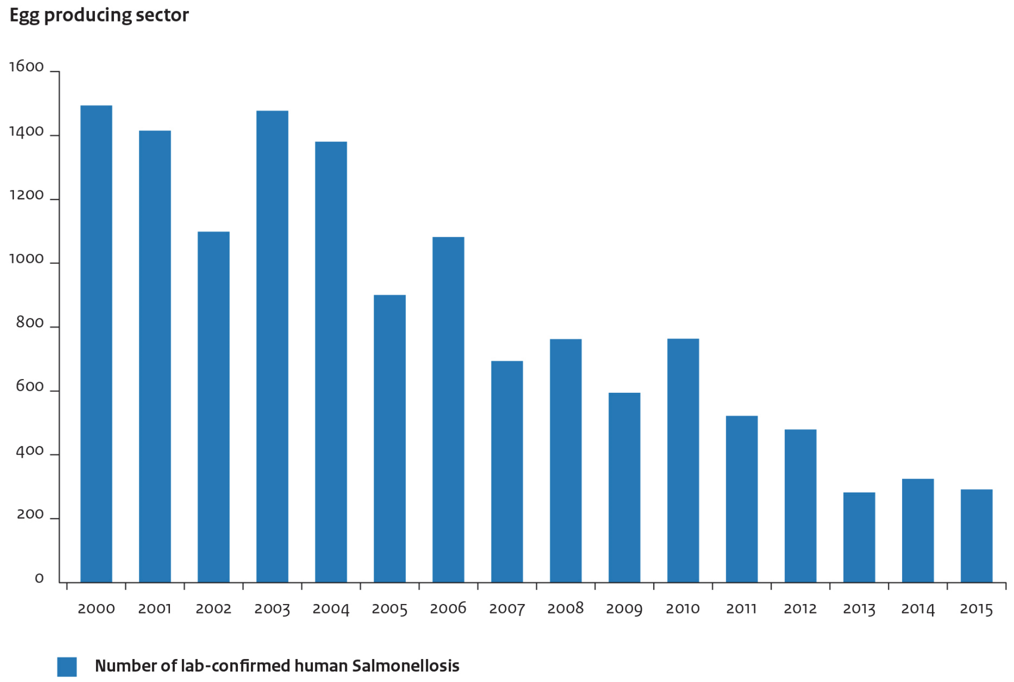


Figure 2.
Estimated contribution of the egg producing sector to the salmonellosis isolates confirmed by human laboratory (2000-2015) (based on Uiterwijk et al., 2016).

All hens at a farm that has been declared contaminated with *Salmonella* must be vaccinated against *S.* Enteritidis. Only once there are no more *S.* Enteritidis-positive flocks on a farm, will vaccination for supplied flocks of laying hens no longer be required. Vaccines against *S.* Enteritidis (and *S.* Typhimurium, however, do not provide full protection, despite significantly reduced colonisation in hens and/or excretion compared to non-vaccinated hens (Desin et al., 2013).

Adequate measures to prevent cross contamination between (infected) flocks and eggs are not always taken after detection of *Salmonella* in a flock. The literature has shown that the infrastructure of the facility in which the eggs are sorted is a crucial source of cross contamination. This is due to the continuous use of the facilities due to the presence of various pens at the farm, which are not always vacant at the same time and, as such, are rarely cleaned and disinfected (Bolder et al., 2017; Dewaele et al., 2012).

Secondary phase
During the collection, sorting, packing and transport of eggs, the eggs may become contaminated on the exterior by contaminated materials (for example, due to traditional egg trays, which at present have been replaced on a large-scale) or equipment. Eggs may also incur cracks and damage, making them an additional risk factor, due to the fact that the natural bacterial barrier has been removed. These eggs and visibly soiled eggs, alongside the eggs from flocks already infected with *Salmonella*, constitute a health risk and for that reason are sorted separately from the eggs that meet the specifications of table eggs that fall within Category A. The former eggs are channelled into the egg processing sector as Category B eggs. It is crucial that this is carried out in a correct and diligent manner. Category B eggs have a lower market value than Category A eggs.

The breaking of externally contaminated eggs and contaminated equipment may result in further infections in the egg product sector. During the industrial processing of contaminated eggs during the production of egg products, either a pasteurisation step is carried out or the eggs are cooked. For eggs of *Salmonella*-positive flocks, this step meets the requirement stipulated by Regulation (EC) No.1237/2007 whereby such eggs must undergo a treatment for the destruction of *S.* Enteritidis and *S.* Typhimurium. Pasteurisation is a critical process: if temperatures are too low and/or the heating period is too short, this will result in too little bacterial reduction, whereas the liquid egg product may solidify at a temperature that is too high. Despite pasteurisation, *Salmonella* can still be found in egg products. Of the egg product samples that were analysed for the period of 2013 to 2016, 0.45% appeared to contain *Salmonella*, including as a result of ineffective pasteurisation (NCAE 2013; 2014; 2015; 2017). As such, egg products contribute to the risk of consumers becoming infected with *Salmonella*.

Tertiary phase
Salmonella that is present in an egg is able to grow during the storage period prior to consumption. This also applies to *Salmonella* that is present on the egg shell and is able to penetrate the egg through the shell. Further growth of *Salmonella* in the egg is able to take place if nutrients from the egg yolk become available in the egg white or *Salmonella* is able to compromise the egg yolk. In addition, the temperature must be high enough to be able to facilitate growth. This former only occurs if the vitellin membrane around the egg yolk becomes permeable. In the event of unrefrigerated storage / storage at room temperature (18 ºC), this will occur after 21 days on average. Growth is only possible in eggs from 10 ºC and above. No further growth can occur below 7 ºC. Degradation of the vitellin membrane is delayed during refrigerated storage, with the membrane only degrading after 62 days at 7 ºC. Refrigeration slows the growth of *Salmonella*.

Under EU law, eggs may be stored unrefrigerated until the sale to the end user, at which the recommended sell-by date is set at 21 after laying. Thereafter the egg will have an additional week until the 'best before' period has expired. Consumers are advised to store the egg in refrigerated conditions. The retail storage period and temperature until sale to the consumer corresponds to the average estimated time that elapses until the vitellin membrane becomes permeable. If consumers subsequently store the egg in the refrigerator, this will delay or prevent the growth of any *Salmonella* that is present.

Outside the EU, the requirements that are in place for table eggs may differ from those within the EU. As such, producers may deviate from the EU requirements subject to certain conditions, such as a longer best before period than 28 days for eggs that are exported. This can only be achieved without additional risk up to 70 days after laying if the eggs are stored below 7 ºC as soon as possible after laying.

As such, the risk to consumers is partly determined by the extent to which they themselves have an awareness of how to handle foodstuffs. The use of eggs when preparing foods for which insufficient or no heating is applied in the preparation phase constitutes the most significant risk factor. In addition, recontamination or cross contamination may occur in the kitchen through the kitchen utensils (such as via a fork) that have also been used for raw egg or by way of the consumer's hands which may have been contaminated through the egg shell. For that reason, correct kitchen and personal hygiene (handwashing) are essential.

In the past, major *Salmonella* outbreaks chiefly occurred in the preparation of dishes such as bavarois and mayonnaise which use raw eggs in the industrial kitchens of hospitals and nursing homes in particular. The key factor in this instance is the industrial scale of the cooking in these settings. A single infected egg may contaminate the entire dish and cause illness in a large number of people. Dishes are also often prepared some time in advance, giving *Salmonella* the opportunity to multiply rapidly during the storage period prior to consumption. The current hygiene codes, such as the hygiene code for the hotel and catering industry (KHN, 2016) prescribe the heating of egg dishes up to 75 ºC at the centre and the use of pasteurised eggs or egg products in dishes that are not subsequently (adequately) heated.

In the Netherlands, as of the past few years, eggs may be donated to the food bank (*Voedselbank*) after the date of sale but within the stipulated statutory best before period (NVWA, 2015c). This has resulted in a situation in which the date of sale (21 days) is made equal to the best before date of 28 days. Most eggs in the Netherlands are consumed within 2 to 3 weeks, whereas in the case of donation to the food bank, this will only be the case after 3 weeks. Given that in retail, eggs are stored unrefrigerated until the sell-by date, the risk of re-growth of a possible *Salmonella* infection is slightly higher. The risk to consumers, however, only increases in the case of eggs being consumed raw or partially cooked.

Exposure to chemical hazards
Chemicals in can end up in foodstuffs inadvertently, as may be the case for environmental contaminants (such as dioxins, heavy metals) or contaminants that are used during production and processing operations (such as residues of cleaning agents). In addition, chemicals may be deliberately added during the production of foodstuffs, such as preservatives. Although foodstuffs of animal origin will also contain residues of veterinary drugs, such as antimicrobial agents, this risk appears to be low from the egg production sector.

Exposure to physical hazards
There are no physical hazards that are due to the presence of particles in the eggs. Nevertheless, in principle, particles of the equipment that is used may end up in foodstuffs during the production of egg products. Such threats, however, are not specific to the egg supply chain. In addition, ignorance, incompetence or fraud on the part of producers or traders may result in unsafe situations.

Risk assessment for chemicals
The key sources for the chemical contamination of eggs are located at the poultry farm. The intake of chemicals by laying hens may lead to the presence of substances in the eggs. These substances may be the result of contaminated animal feed, feed additives or from medication. Contaminated land for free ranging poultry may also be a source, due to the fact that laying hens may pick up the soil (and insects) during their scratching activities. Other potential sources of exposure for the laying hens include the use of cleaning agents and disinfectants and the fumigation of housing units and the use of pesticides in units whilst the laying hens are present (van der Fels et al., 2017).

The housing system in which laying hens are kept (cage, barn, free range, or organic farm) plays a role in the exposure of laying hens to chemical contaminants.

Both the natural toxins and the environmental contaminants are a very low risk to the food safety of eggs and egg products. Mycotoxins (toxins produced by fungi on grain) and plant toxins (toxins produced by plants) virtually do not end up in the eggs, given that there is hardly any transmission from the chicken to the eggs. Approved pesticides have not been found in Dutch eggs and as such do not constitute a risk.

The various environmental contaminants (such as persistent organic compounds and heavy metals) are present in eggs, however in low concentrations. Calculations of the intake of these substances by humans from foods show that for all these substances it can be said that eggs do not, or hardly, contribute to the total intake of those substances. The values do not exceed any toxicological thresholds.

Sporadic concentrations around or above the legal standard (Maximum Residue Limit, MRL) of the now-banned pesticide DDT, which is still present everywhere in the environment, are still found in eggs. The risk to the food safety of eggs is considered to be very low, given that there is no chronic exposure in play.

Dioxins and dioxin-like PCBs are a group of environmental contaminants that deserve particular attention. Eggs from laying hens that have outdoor access may have relatively high concentrations of these chemicals. Measurements show that dioxin levels in eggs from organic and free-range chickens in general are higher than in eggs from chickens reared in cage systems, where the Maximum Levels for eggs are exceeded in some cases. The main source of these increase levels is contaminated soil in the outdoor area, which can almost always be traced back to former furnaces or the re-use of old building materials in or around the outdoor area. Once this source has been removed, the dioxin levels in the eggs seem to decrease significantly. The dioxin concentrations in the (commercial) eggs of free range chickens have decreased in recent years due to the control system that was introduced by the sector itself. Eggs of hens held by backyard poultry farmers occasionally also contain (overly) high concentrations of dioxins and dioxin-like PCBs, for which contaminated soil is yet again the source of the contamination. In these circumstances, regular buyers of eggs from these backyard poultry farms may be exposed to an elevated health risk, due to their long-term consumption of potentially contaminated eggs. Given the low degree to which maximum levels are exceeded, the risk to food safety is considered to be very low.

Looking at the total intake of dioxins and dioxin-like PCBs from foods, these levels remain below the (net) maximum health limit. Commercial eggs make a relatively small contribution (approx. 5%) to the total dioxin intake through foods.

Dioxins in eggs should remain a concern and the control of concentrations of these substances in eggs remains necessary, with the focus on the eggs of free-range chickens and hens held by backyard farmers.

Only a limited number of veterinary drugs are authorised for laying hens of which the most widely used are antibiotics and coccidiostats. Residues of veterinary drugs are, however, virtually never found in eggs above the legal MRL standards. There are strict rules for the use of veterinary drugs in laying hens (application, waiting period).

Cleaning agents and disinfectants
Cleaning agents and disinfectants (biocides) are used at various instances in all links of the poultry and egg supply chain, such as in the disinfection tubs when entering the housing unit, mandatory cleaning and disinfection of the pens, transport trolleys and crates in which live poultry is transported. Biocides may only be put on the market following authorisation by the Dutch Board for the Authorisation of Plant Protection Products and Biocides (Ctgb).

There is no insight into the use of cleaning agents, disinfectants (and other biocides) due to the lack of systematic records in the chain and the lack of insights into turnover figures of disinfectants and biocides.

The food safety and health risks of disinfectants cannot be assessed due to the lack of insight into both the use and the potential residues in animal products.

Banned agents: fipronil
In the summer of 2017, it was revealed that a significant number of professional laying hen farms had made use of the agent known as fipronil, which is a banned agent used against red poultry mite in poultry sheds (BuRO 2017a; 2017b; 2017c; 2017d). This illegal use resulted in the contamination of roughly 20% of the eggs at that time. The acute and semi-chronic public health risks to consumers were low, however the large-scale contamination undermined the system of laws and regulations intended to safeguard food safety.

As a result of this incident, a review was carried out of the potential use and the associated risks of banned agents used against pests or diseases, such as for red poultry mite and histomonas in particular, in the poultry sector. A selection of banned agents of which it was estimated that they could be used as an illegal alternative to red poultry mite yielded 35 active ingredients. For histomonas this resulted in a list of 4 active ingredients (see Annex 4).

At the end of August, EFSA requested that the Member States carry out a voluntary, additional screening for the presence of residues of illegal agents during the months of September and October. They were asked to analyse a representative number of samples without further instructions.

In addition to the professional poultry farm sector, there are also private poultry farms (less than 250 chickens and/or breeders of special poultry, and the petting zoos and care farms). There is a realistic chance that these poultry farmers may use agents that would normally be used to prevent fleas and ticks in dogs, cats and other companion animals against red poultry mite in their poultry. This admission does not take into account the possible consumption of the companion animals and, as such, no withdrawal period was derived for food safety reasons. This implies that the used of these drugs in the private poultry farming sector may potentially result in elevated health risks for (regular) customers of poultry meat and eggs from this sector.

Other chemicals
In addition, there are many other chemicals that may end up in egg products inadvertently, such as chemicals from inks, adhesives, and packaging materials. There is no accurate data available on which chemicals are concerned, which precludes any assessment of the food safety risks involved.

Finally, there are a number of food additives and process additives that are deliberately added during the processing of eggs. These chemicals are all regulated and when used correctly do not pose a risk to the food safety of egg products. The same is true for the dye known as canthaxanthin (a carotenoid pigment), which is occasionally added to the feed of chickens to make the egg yolks take on a darker colour.

Measured data on chemicals in Dutch eggs
Measurements of chemicals in the egg supply chain for the most part are carried out on eggs and rarely on egg products. Veterinary drugs are identified most frequently by far, though rarely do any amounts exceed prescribed levels.

When screening for banned substances, chemicals with a relatively high impact (as demonstrated by the risk assessment) will be given priority for a screening of the presence of residues in eggs and/or meat, with chemicals with the most significant probability of leaving 'a detectable residue in eggs or meat' during use in the production phase having the highest priority. During screenings of eggs and/or meat to confirm or exclude possible illegal use, the various (sub-chains and poultry species must be taken into account, in addition to whether such use relates to backyard poultry farming (including petting zoos and care farms).

The design of a potential screening should be in line with the methods of the regular surveillance programme for farm animals or the regular sampling procedures of the National Residue Monitoring Plan. The National Residue Monitoring Plan largely consists of random sampling.

The storage of the results of the analyses is geared toward whether or not the maximum levels have been exceeded or not (National Residue Monitoring Plan, NCAE (Netherlands Supervisory Authority for Eggs) database, and parts of the KAP database), where the concentrations measured are not always listed (in full). This means that a proper risk assessment is not possible. The available data, however, indicates that the chemical risks for food safety in the egg-producing sector are very low.

Research into 'unknown' chemicals and situations only actually takes place if there are clear signs that a production process or a contaminant may potentially lead to contamination.

Food Safety Risk Assessment: Summary

Chicken egg allergies primarily occur in children and may have serious consequences. In later life, these allergies will take on milder forms or will even disappear. People suffering from allergies stand to benefit a great deal from accurate food labelling.

A specific microbiological public health threat is caused by the infection of eggs and egg products with *S.* Enteritidis and *S.* Typhimurium. Infections of eggs chiefly occur on the farm during the primary phase. Measures aimed at the prevention and control of *Salmonella* (infections) during the primary phase, such as mandatory monitoring and mandatory vaccination of flocks at farms that have tested positive, in conjunction with the channelling of eggs of laying hen flocks that have test positive, have led to fewer contaminated eggs penetrating the consumption market in recent years. During the same period, the estimated number of human cases of salmonellosis in the Netherlands has also seen a considerable decrease.

At present, however, limited contamination of eggs still takes place and the disease burden attributed to this contamination should not yet be ignored. Further reduction of contamination on the farm may help reduce that disease burden. Eggs of *Salmonella*-positive flocks are channelled into the egg processing sector where heat treatment is mandatory (cooking or pasteurisation). The pasteurisation process, however, does not always offer a full guarantee of the sufficient limitation of the degree of contamination to prevent disease in consumers. This is chiefly true for cases in which the eggs have been very heavily contaminated prior to pasteurisation.

The level of food safety could be increased even further if every case of human *Salmonella* infection could be traced back to infected egg or egg products and subsequently back to the farm. This would allow the risks to be reduced from the shelf all the way back to the farm.

The physical and chemical food safety risks of eggs and egg products (or in the entire egg supply chain) are considered to be very low. The risks posed by dioxins and dioxin-like PCBs in eggs laid by hens with outdoor access are also judged to be very low, despite the health standards established by law being exceeded on occasion. The risks of chemicals from packaging materials and residues of cleaning agents and disinfectants cannot be assessed due to a lack of data.

Chemical data is insufficiently stored and accessible in order to be used for monitoring duties and/or risk assessments.

B Animal welfare risk assessment

Throughout their lives, animals experience distress as a result of exposure to a large number of hazards, which can broadly be categorised into hazards as a result of the hereditary characteristics of the animal (as a result of breeding policy), housing and care in the broadest sense of the word (management, stockmanship, appropriate handling), external facilities, means of transport and environmental conditions (such as weather conditions and pathogens). The distress that they experience as a result is discussed in terms of the animals' key needs: a sufficient and appropriate diet, adequate housing and the ability to express other normal behaviours (Welfare Quality criteria).

This risk assessment will also make use of foreign data to indicate where improvements can be made in the Netherlands in terms of animal welfare issues. BuRO, however, wishes to emphasise that this does not mean that the risks to animal welfare are greater in the Netherlands than abroad. On the contrary: BuRO is aware that in a great many countries were poultry is reared and kept the risks to animal welfare are often far greater than in the Netherlands.[4]

In order to be able to assess the welfare of chickens or other poultry, their natural, physiological needs should be known. The chicken and its ilk are omnivorous by nature (feeding on both vegetable and animal materials by nature) and will spend over 80 - 90% of their time during the day scratching / foraging. The chicken and its conspecifics naturally inhabit wooded areas where they are able to find shelter and protection against any natural predators and where they are able to withdraw to the safety of a branch at night to rest. In addition, the birds will have a dust bath every other day, lasting roughly half an hour.

If these animals are unable to fulfil their natural needs, they will often develop deviant and/or stereotypical behaviour, such as the picking of other objects or those who share their pen (feather pecking), which may progress into forms of cannibalism. Feather picking, in essence, is an adjusted type of foraging behaviour.

Table 2.
Key pillars of animal welfare based on the principles and criteria of Welfare Quality.

Pillars of welfare based on Welfare Quality			
Appropriate nutrition	**Suitable housing**	**Optimal health**	**Normal behaviour**
• Absence of prolonged hunger • Absence of prolonged thirst	• Comfort when resting • Temperature comfort • Ease of movement	• Absence of injuries • Absence of disease • Absence of pain due to stock management procedures	• Expression of social behaviour • Expression of other species-specific behaviour • Quality of human-animal relationship • Positive emotional state

[4] This risk assessment will not address the animal welfare risks for animals that are kept in domestic, non-professional settings. The threshold for domestic, backyard poultry keepers is 250 animals or less for the Identification & Registration regulations, animal production rights as in the European approach to Salmonella and *Campylobacter*.

Various types of animal welfare risks are recorded at the farm. Other findings were derived from the inspections at the slaughterhouse. The WLR identified over 30 potential animal welfare issues in the production phase of the laying hen, some of which had a limited impact, such as the inoculation of animals, the sexing process, fear of humans and weak animals.

Of the welfare problems with a moderate impact, the discomfort is chiefly caused by restricted feed and water intake, social stress and smothering.

Animal welfare problems with a serious or significant impact on the animals include: keel bone fractures, feather pecking, limited behavioural repertoire, (endo)parasitic infestations, (non-)infectious, mild and severe respiratory diseases, (non-)infectious gastrointestinal diseases, burnout, aftereffects of beak trimming and major injuries.

The severity of the animal welfare impairment of the hazards listed above is not simple to determine. In addition, the threats and the resulting effects are highly varied in nature. BuRO has asked experts to estimate the severity of each threat on a scale of 1 (low harm) to 7 (severe harm), see Annex 5.

General animal welfare problems in the entire live phase of live laying hens

These animal welfare concerns are manifestations of the animal as a response to exposure to one or more hazards. Often the issues will be multifactorial in nature and can affect one another or even reinforce one another in various ways.

Risk is determined by the severity of the impact and the probability of the harmful effect actually occurring. In addition to the assessment of the severity and duration of the welfare problems, Visser et al. (2015) also described the degree of prevalence based on the scientific literature (table 3).

The following animal welfare problems are described in the literature, with data often being based on a limited number of farms. The poultry farming sector retains a great deal of management data, whether or not pursuant to a requirement under the Animals Act. The Food Chain Information form must be completed for the meat inspection during the slaughter process, which list mortality in the first week of life and the cumulative daily mortality. Slaughter findings during the inspection are recorded in the Poultry administration database of the NVWA (also known as Pladmin) and may contribute to gaining and idea of the health situations at the holding of origin.

The principal hazards in the hatchery phase are largely similar to those of the meat supply chain and relate to the duration of the 'hatching process' of the chicks, the delayed access to water and feed and the movement and handling that take place on the farm. A matter specifically relevant to the egg supply chain is that the animals undergo more handling at the farm such as sexing, vaccination(s) and beak trimming. The process of sorting into 1st and 2nd-choice chicks, as well as the killing of superfluous (2nd-choice) chicks, is similar to the meat supply chain.

On-farm hatching, though increasingly more widely used on broiler farms, is not an alternative for the laying hen sector due to issues such as sexing. Instead of on-farm hatching, farms are experimenting with the concept of hatch care (RDA, 2016), where the chicks hatch in a separate facility and where they already have access to feed and water at the hatchery.

Due to the specific breeding practices for the volume and quality of eggs, there is virtually no application for hatched cockerels, resulting in over 40 million day-old chicks being killed by gassing in the Netherlands each year (Jochemsen, 2010; Woelders, 2012). Killing these day-old chicks can be seen as an animal welfare issue or as an ethical issue (Bruijnis et al., 2015). A portion of the day-old chicks that are killed are used to feed zoo animals. There is broad consensus both in the industry and in the government that only female embryos should be incubated and hatched. In recent decades, there has been extensive research worldwide dedicated to robust and efficient methods to determine the sex of chickens early on in the hatching egg.

Table 3.
Key animal welfare problems based on impact and degree of prevalence in the successive stages of the egg supply chain (based on Visser et al., 2015).

Hatchery	Rearing	Laying			Transport
		Enriched cage	**Barn (aviary)**	**Free range – organic**	
Reduced feed/ water	Feather pecking	Keel bone fracture	Keel bone fracture	Keel bone fracture	Wing fractures/ dislocations
Disturbed rest	Ectoparasitic	Feather pecking	Feather pecking	Feather pecking	Major injuries
Weak animals	Beak trimming (after-effect); except organic		Endoparasitic	Endoparasitic	Reduced water/feed intake
Killing of day-old chicks	Smothering (except in enriched cage)	Limited behavioural repertoire			Hypothermia
		Ectoparasitic	Ectoparasitic	Ectoparasitic	Hyperthermia
	Fear of humans (least for enriched cage)	Burning out	Burning out	Burning out (lower than cage/barn)	
	Limited behavioural repertoire (chiefly in enriched cage; absent in organic farming)		Smothering	Smothering	
		Mortality	Mortality	Mortality (including predation)	Mortality
			Social stress	Social stress	

During the hatching process a distinction would be able to be made between hens and cockerels, which would make the killing of day-old chicks redundant. It is chiefly methods that determine the sex based on hormone analyses in the 10-15-day period within the hatching process that seem to be effective on a small scale but are not yet suitable for large-scale application.

More generally, there are few key figures available at BuRO to allow a comprehensive assessment, quantification and comparison of the animal welfare risks. Making the key figures available in a uniform fashion per hatchery and per breed would contribute to increasing quality awareness at hatcheries and to better choices for customers and for the regulator. The key figures that are crucial for the assessment of animal welfare at the hatchery are: the hatching rate of the egg, the average weight of chicks at a certain age, the ratio of first and second-choice chicks, the percentage of chicks killed at the hatchery, and the mortality rate in the first week of life. In order to facilitate a chain-oriented assessment and to safeguard animal welfare, it is essential that this information be available at the level of the flock, so that it can be aggregated to the level of the chain.

Keel bone fractures
Keel bone fractures are often the result of accidents in the laying pen or housing, with animals bumping into the structures present. The presence of perches leads to more keel bone fractures. Perches adjusted to incorrect heights, sub-optimal

distances between levels and an overly low level of light are risk factors for keel bone fractures. Optimal housing / pen infrastructure, in conjunction with a higher level of light and a decrease in the distress of a flock, will lead to a reduction in keel bone fractures (Visser et al., 2015). Tarlton links the prevalence of keel bone fractures to modern housing systems that give chickens more space to roam. In the traditional cage system, there were no or very few keel bone fractures (Tarlton, 2014).

Moulting
Poultry moulting is a natural phenomenon that is normally induced by factors such as a shorter length of the day and less feed supply. In the laying hen farming sector worldwide, the moulting process is used to extend the actual laying period of the hens, so that new animals need not be added to the flock (table 4). It is primarily an economically driven consideration. Moulting may be induced in various ways, such as through temporary deprivation or restriction of water and feed (forced moulting) or milder variations of these methods. Forced moulting is banned in the Netherlands, with only the milder methods of inducing moulting in poultry being permitted.
During the moulting process, which may last a number of weeks, the animals will lose 25% of their body weight. For a large portion of the moulting animals, this process will extend their lifespan; some of the animals, however, will not survive the process. Accurate data on this issue is not available.

Table 4.
Application of moulting practices per housing system; data from 2013 (Landman & van Eck, 2015).

Housing system	Number of farms	Length of laying period (in days)	% of moulting applied
Cage	74	591	60
Barn (aviary)	700	540	50
Free range	235	482	30
Organic	140	437	0

Nutrition and health
It is chiefly highly productive hens and hens that begin the laying period prematurely and/or with insufficient body weight that are more likely to end up in a negative energy balance, subsequently lose weight and eventually die during the laying period. This is known as wearing out or burning out. Hens that are free to range are more at risk of getting worn out. By allowing animals gain a sufficient amount of weight during the rearing period before the start of laying and providing appropriate nutrition, the burning out of hens can be controlled.

Feather pecking, partly in relation to the forthcoming ban on beak trimming
Feather pecking is unwanted harmful behaviour in poultry that can degenerate into cannibalism. It is a multifactorial problem. To date, beak trimming is a poultry management process that has been widely used, however which may be banned in the Netherlands as of 1 September 2018. Certain breeds or laying hen hybrids (genotype/heredity) are more prone to feather picking – as are frightened animals. Group size and stock density play a key role, in addition to the nature of the litter, the forage quality, absence of diversionary materials, etc.

The likelihood of feather pecking may be reduced through various flock management measures. The most success can be achieved by these measures already being in place during the rearing process and if the rearing process is effectively coordinated with the laying. The use of outdoor access can reduce the incidence of feather pecking.

Limited behavioural repertoire
Due to the fact that laying hens are housed in an environment that is dull and low on stimuli, the animals are restricted in terms of their behavioural repertoire. Similarly, animals that are keep in an overly high stock density are not able to express their full behavioural repertoire. This can be prevented by enriching the environment of the animals and reducing the stock density. In order to meet the requirements of laying hens' behavioural needs, such as eating and foraging, exploring and resting, in general, the minimal furnishing elements are cited, such as litter, laying nests, perches and sufficient space for each animal. Competition for scarce resources, such as nests, nipple drinkers, feeding space, total are per hen and perches, may lead to more aggression and stress in a direct way, but may indirectly also lead to cannibalism (cloaca pecking; Riber, 2014).

Smothering
Both during the rearing period and the laying period, hens may crawl on top of one another in a heap, whereby the hens at the bottom die by suffocation. This phenomenon is known as smothering and may result in dozens of animals dying within a short period of time. In some flocks, this may result in a 5 - 10% loss. Occasionally, smothering will have a direct cause, such as a ray of sunshine on an area of litter, but often there will be no discernible cause. During the rearing process in non-cage systems, it is vital that the farmer should not remain standing still in one place in the barn for too long, as this may attract hens to that person, who will subsequently spontaneously crawl onto one another in a heap. During the laying period, smothering may also occur in corners where hens often tend to lay their eggs. These corners are best shielded or made unattractive to the hens. Nevertheless, some flocks exhibit this behaviour to a high degree for reasons that are unclear and it is the farmer's job to exercise constant vigilance and remove the animals from one another as quickly as possible. The behaviour primarily occurs in non-cage systems, however also occurs in cages for large groups of hens.

Predation
Predation is the catching and killing of animals by predators or birds of prey. This problem only applies to animals that are kept in an uncovered outdoor area, such as free range and organic animals and may lead to hens experiencing fear and pain as a result. In 2015, the Louis Bolk Institute conducted a study of losses of chickens held for commercial purposes as a result of birds of prey (Bestman, 2016) for the period of July to November 2015. The study used observations during 90-minute periods, as well as a camera assembly at 1 site. The records of the farms with an average size of 19,000 animals, losses due to disease appeared to amount to 7%, with 1% of losses due to predators based on retrieved remains and 3% of losses due to predators based on counts at the slaughterhouse (missed animals). The damage done by birds of prey (varying between 70 to 160 animals per year per farm) was greater than that done by foxes (ranging between 2 to 52 dead animals per year per farm). The presence of trees did not provide sufficient protection.

Microbiological risks
The hazards to the welfare of poultry in the primary phase are largely microbiological in nature, relating to the various germs that may affect the animals' health, such as bacteria, viruses and parasites.

Parasitic infections
Endoparasitic infections are caused by the presence of parasites in the intestines, for example, resulting in damage to the intestinal epithelium. Problems involving endoparasites primarily occur at farms at which the animals may come into contact with their own faeces and run the risk of becoming contaminated. The

most significant problems occur at farms outdoor areas, due to the difficulty of keeping the environment free of worm eggs, for example. The main endoparasitic diseases are coccidiosis and histomoniasis.

Ectoparasites include lice, fleas and mites and live off dander and cause irritation and itching and/or suck blood. Key source of ectoparasitic infections include trees (with wild birds) in the immediate vicinity of the housing unit, introduction into the housing unit through infected crates, egg trays, soiled equipment, visitors, pests, introduction into the unit through ventilation air, infected rearing animals and insufficient cleaning practices in the housing.

- Red poultry mite and histomonas
Parasitic infections such as red poultry mite (bird mite) and histomonas are a persistent problem in the poultry industry. For decades that have been successfully controlled using a range of pesticides. In the past 15 to 20 years, various authorised pesticides and veterinary drugs have been withdrawn from the market due to public health risks to humans due to residues in meat or eggs or due to adverse affects on the environment (such as adverse effects on bees and fish). In addition, changing housing conditions of poultry (increase in barn size and free-range capabilities) and more focus on the needs of the animals to increase animal welfare, and climatic changes make it difficult to control red poultry mite (Pritchard, 2015). Furthermore, there is a lack of new drugs that have been submitted for registration. In 2005, the Farm Animal Welfare Advisory Council (FAWAC) in Northern Ireland highlighted the problems of both histomonas as red poultry mite as the 2 most significant problems in poultry for which insufficient veterinary drugs were available (FAWAC, 2005).

Both red poultry mite and histomonas occur in various links of the egg and poultry meat supply chains (laying hens, rearing flocks, parent flocks) in various poultry breeds as well in the backyard poultry farming sector. Both diseases are parasitic infections.

- Red poultry mite
Red poultry mite, Dermanyssus gallinae, also known as redblood mite, is an ectoparasite in poultry, which feeds primarily at night. Most of the time, the parasite spends its time hiding in secluded places in the housing unit and pens, such as the cracks in perches or the floor or in laying cabinets. The highest numbers of red poultry mite occur during warm and humid seasons.

Red poultry mite is the main ectoparasite in laying hens all across Europe. It is estimated that in the Netherlands over 90% of farms are afflicted by red poultry to a greater or lesser extent. Across Europe, this percentages ranges between 50 and 90%.

Red poultry mite cause itching and irritation in animals, which leads to unrest in the housing unit. The 2 to 5-day period that the parasite will spend sucking blood may lead to anaemia in the animal, which adversely affects their health.
In recent years, there have been an increasing number of indications that red poultry mite is also able to act as a vector of bacterial and viral diseases, such as *Salmonella* and *Campylobacter*, with Avian Influenza also potentially being able to be transferred from animal to animal by the red poultry mite.

- Histomonas
Histomoniasis is a poultry disease that is caused by the parasite Histomonas meleagridis. The roundworm heterakis gallinarum is an intermediate host and plays a key role in the transmission. Not all the various poultry species are equally sensitive to histomonas. In turkeys, the disease is often acute and has a high

mortality rate (ranging between 10-70% in outbreaks), whereas in chickens the disease has more of a chronic effect. It is chiefly in broiler parent stock that chronic problems will occur with secondary bacterial infections, whereas in laying hens elevated mortality and a decrease in egg production have been reported (Hess, 2015).

The Animal Health Service (GD) in the Netherlands indicates that in recent years more cases of histomonas have been identified in laying hens, with most cases in organic laying hens. This is most likely related to the increased occurrence of (round) worm infections in animals that range outdoors (GD, 2017).

Histomoniasis is an 'old' poultry disease that has been effectively controlled for decades as a result of effective veterinary drugs. The ban on these drugs at the beginnings of the 2000s, however, has led to a resurgence of histomoniasis.

Health and use of veterinary drugs
In laying hens, bacterial and viral infections are a principal cause of disease and cause of death. Within the context of reducing the use of antibiotics, in recent years veterinarians have been required to report any visits to farms at which an antimicrobial agent was prescribed, as well as the indication for its use (IKB-CRA database).

The use of antibiotics in the laying hen poultry sector is far less than in the broiler sector. The problems of the use of antibiotics in the poultry sector are described in greater detail in the *Risk assessment for the poultry meat supply chain*.

Different types of housing systems
Apart from the microbiological risks, there are many threats to the welfare of animals through the lack of physical opportunities for the animals to satisfy their behavioural needs. These physical threats to animal welfare are caused by various factors, such as housing, climate control, the design of the pens, the quality of the litter and feed. (Surgical) procedures on and injuries to the animal will also affect and threaten animal welfare. During transport from the farm and during the slaughter phase, key hazards consist of the catching process, the quality of the means of transport, climate conditions, the absence of water and feed and the facilities at the slaughterhouse.

The same types of threats may occur in various links of the egg supply chain, however the estimated severity of the threat may vary for each specific link.

Various types of housing systems for laying hens are popular in the Netherlands. The key difference between the systems in terms of the animal welfare component are:
- The size of the group in relation to social behaviour, for example (very restricted in cage system; no maximum flock size in barn system; maximum group size for free-range and organic hens).
- The type of housing, including space to scratch and range, adequate enrichment material, perches, access to natural light or length of light-dark interval.
- The quality of the feed or opportunity to forage.
- The availability of a free range outdoor area with requirements for vegetation and shelter.

The enriched cage system has the disadvantage that it limits hens' expression of natural behaviour such as foraging and scratching. At the same time, this system entails health benefits for the animals, such as fewer diseases, fewer injuries and less social stress.

The barn farm is characterised by the fact that allows more expression of natural behaviour, however entails a broader range of welfare issues with a serious impact, such as keel bone fractures, endo and ectoparasitic infections, the wearing out of animals and social stress in animals.
Free-range systems provide animals with more opportunities to satisfy their natural behaviour, but entail additional risks such as parasitic infections that are more difficult to control, a risk of fear of and predation by birds of prey and higher mortality due to both health problems and the increased occurrence of smothering (hens heaping onto one another) and avian influenza.

The social perception of sound animal welfare amongst other things is based on animals' needs to be outdoors. For that reason, free-range and organic systems are automatically rated higher by the organisations that are concerned with improving animal welfare. A recent survey showed that many Dutch consumers feel that animal welfare is guaranteed the most on backyard poultry farms, such as petting zoos and care farms and at people's homes, followed by free-range hens and barn and organic chickens. There are no consumers that feel that animal welfare is best guaranteed in cage systems. The same applies to poultry farming. Free-range hens are rated higher and the products of such hens can be sold at a higher price. The housing requirements require free access to an outdoor area for a minimum number of hours each day for a longer period of time, however there are no requirements regarding the actual use of the outdoor area.

A study from Switzerland, published in 2014, however, shows that there is an inverse relationship between the use of the outdoor area and the size of the flock (Gebhardt-Henrich, 2014). The larger the flock, the fewer animals will make use of the outdoor area in relative terms. There are also indications that poor usage of the outdoor area regularly takes place in the Netherlands, particularly in cases where insufficient vegetation and shelter is present. Insufficient usage of the outdoor area in conjunction with the adverse health and welfare aspects of free range facilities present results in an overestimation of the welfare benefits of individual farms.

No single system is perfect; each system has multiple weaknesses with specific problems. To quote Weeks (2014):
'*Good stock carers and managers achieve good welfare and production in all systems*'.

Mortality as an animal welfare indicator
Mortality is referred to as an 'iceberg' indicator, as it is the result of a collection of health and welfare concerns. Frequently identified concerns include daily mortality, mortality in the first week of life and cumulative mortality, which relate to animals dying as a result of animal health and animal welfare concerns, and to animals that are (or must be) selected for culling on a daily basis by the farmer in order to prevent any further discomfort (killing at the farm). Any unforeseeable increase in daily, weekly, cumulative mortality, selection and disease may reflect a problem with regard to animal welfare (OIE, 2015). The converse is not necessarily the case: in flocks (or at farms) with low mortality, serious animal welfare issues may still occur, such as mental concerns in the form of fear, stress and disturbed rest or insufficient ability to express natural behaviours or normal behaviour such as foraging and scratching.

In the literature, the mortality rate in laying hens ranges between an average of 4% up to over 15%, expressed as cumulative mortality and as an average for a housing system per year[5]. Worldwide, mortality for (enriched) cage and barn (aviary) systems ranges between 4 - 10% and in free-range systems it ranges between 8 and 15%.

A recent Dutch study on the sustainability of the housing systems (van Asselt, 2015) uses mortality figures (from age> 20 weeks) from the period of 2010: enriched cage 8%, barn 10%, free range 12% and organic 15%. It is primarily in the free-range systems that the distribution is very large with outliers exceeding 25% mortality per flock.

The large distribution in losses between flocks and categories means that health and welfare gains can be made, first of all, by providing insight into loss figures (benchmarking) in order to subsequently use those figures more actively for the management of the farm and for risk-based monitoring, such as for the exceeding of standards.

Table 5.
Cumulative mortality in laying hens in the Netherlands per housing system per laying period (Agrovision data; Leenstra, 2014; updated 18 April 2016).

Average cumulative mortality (M) and number of farms (N)								
	Enriched cage		Barn (aviary)		Free range		Organic	
	N	M (%)	N	M (%)	N	M (%)	N	M (%)
2009	62	9,2	132	11,2	38	11,9	14	15,4
2010	94	8,4	154	11,1	59	13,3	23	20,9
2011	62	10,2	190	8,8	54	11,6	29	13,1
2012	22	10,2	225	10	62	10,9	42	9,1
2013	11	8,8	174	9	49	9,7	42	7,9
2014	20	8,6	195	9,2	46	8,9	39	8,8

A multiyear comparison of the cumulative mortality per housing system in the Netherlands (table 5) shows that 6 to 8 years ago the mortality rate in barn, free-range and organic farming was higher than in enriched cage farming. In recent years, the cumulative mortality rate has levelled and is currently at the level of mortality of enriched cage farming. In an European study on organic poultry farming systems, poultry farmers and researchers jointly found (Leenstra, 2014) that a learning effect takes place in poultry farmers who switch to free-range systems. In this comparison of cumulative mortality, it should be noted that this relates to cumulative mortality per laying period. Due to the longer laying period of animals that are kept indoors, mortality per unit of time is relatively lower.

In Europe, there is no system that allows animal welfare to be mapped out in a uniform way, which precludes a comparison with other countries.

- Death on arrival at slaughterhouse

In the Netherlands, slaughtered laying hens and parent stock come chiefly from the Netherlands however also occasionally come from surrounding countries. The vast majority of Dutch animals are slaughtered in Belgium.
A significant proportion of all spent laying hens undergo long journeys to various countries (House of Representatives, Parliamentary Questions 2016Z06134)

The hazards are the same as cited in the risk assessment for the poultry meat supply chain, however differ in terms of frequency and impact. At the end of the production cycle, laying birds are in a worse condition, often suffering from

[5] An average annual mortality would be the fairest measure of comparison instead of cumulative mortality per laying period that is used most often.

osteoporosis and with their plumage in a poor condition. As a consequence, they run a higher risk of incurring catching injuries. In addition, the animals are more sensitive to changes in temperature during transport.

Hyper and hypothermia chiefly occur during journeys subjected to extreme weather conditions in combination with the sub-optimal design the means of transport: use of tarpaulin covers, insufficient ventilation between crates. Extreme weather conditions are relatively uncommon in the Netherlands, however are more likely to occur during prolonged, cross-border transport, which will lead to various types of discomfort compounding one another.

Discomfort as a result of reduced intake of feed and water is the most significant type during long journeys. It should be noted that the legal standard applies to the net transport time of animals and that this standard does not, or insufficiently, takes into account the duration of the catching process and loading of the animals at the farm of origin and any waiting times that occur after arrival at the slaughterhouse. In the Netherlands, the rule is that animals that have endured a long journey will be slaughtered as a matter of priority in order to avoid the otherwise mandatory access to water and feed.

Crucial and available indicators with regard to physical discomfort during transport include death on arrival (DOA) and injury. Death on arrival as an indicator is currently available in the form of average mortality per slaughterhouse (per year), including as the percentage of flocks that exceed the signalling standard of 0.5% DOA (Annex 5). In international terms (EFSA, 2011), average death on arrival varies considerably with outliers of 0.85% chiefly relating to spent laying hens.

The average death of spent laying hens on arrival at the slaughterhouse in the Netherlands between 2014 and 2016 (NVWA data; Pladmin) is between 0.15 and 0.17%. The latter only relates to animals that are slaughtered in the Netherlands (approximately 20%). Unfortunately, no data is available on the spent laying hens that are slaughtered in slaughterhouses abroad and have occasionally undergone very long journeys (please see the Risk assessment for the poultry meat supply chain, 2017).

In addition to the average death on arrival, a record is also made of whether a flock falls within the established signalling standard of 0.5% DOA. The DOA percentages at the slaughterhouse vary significantly between the various countries of origin of the animals. The most extreme discrepancy is for the spent laying hens from France and broiler from Denmark (Risk assessment for the poultry meat supply chain). For spent laying hens that were delivered from France in 2015 and slaughtered in the Netherlands, an excess figure was measured in more than 25% of the flocks, compared to an average of 3.8% for Dutch flocks.

Summary of animal welfare risk assessment

The hazards to animal welfare on the farm are caused by a number of factors including access to and the quality of water, feed and the housing (pens, facilities, layout, litter, climate control, light regime), resulting in animals not being able to adequately satisfy their behavioural needs. In addition, management and breeding policy play a role in this regard.

On the farm, laying hens may be exposed to microbiological hazards such as bacteria, viruses and parasites. The extent to which this occurs is partly related to the housing and living conditions listed above. Hygiene at the farm, however, is also a crucial factor affecting the development of microbiological infections.

All housing systems for laying birds have advantages and disadvantages in relation to risks. There are no indications that there are differences between the housing systems in terms of prevalence of *Salmonella*. The systems with outdoor access have a higher (but still low) risk of contamination with dioxins and PCBs of the eggs that do not constitute a threat to animal welfare, but do lead to increase exposure of consumers.

For animal welfare, it is true that hens in the enriched cage system are less able to exhibit their natural behaviour and satisfy their behavioural needs.

In barn systems and free range, outdoor systems, there is a degree of mortality as a result of smothering (clambering on top of one another in panic) and a higher prevalence of endo and ectoparasitic infections.

On free-range farms, including organic farms, there is an additional risk of predation and of the introduction of infectious diseases such as the pathogen Avian Influenza.

The shift in the last 10 to 15 years, from chiefly cage system to more barn and free-range systems had resulted in other types of welfare problems. On the one hand this has led to farming in which animals are able to exhibit more natural behaviour and on the other hand it has led to more health problems and higher mortality. There are no objective criteria to compare the animal welfare in the various housing systems. None of the systems is optimal. Loss (cumulative mortality) is currently the most significant and broadly available indicator on hand. A few years ago, the cumulative mortality of laying hens in the Netherlands was highest in housing systems with a free-range outdoor area, however at present is level with the indoor housing systems. There are still significant differences between farms, which indicates that improvements in animal welfare can still be achieved.

There is no comprehensive overview of the key figures within layer poultry farming (or the egg supply chain), which effective precludes broad-spectrum risk-based monitoring. Further digital unlocking of data by the NVWA, systematic data analysis, specific inclusion of the 'intermediate segment breed' in the databases, linking external data such as IKV-IKB and improved of the inspection process for potential animal welfare indicators at the slaughterhouse are all key factors and will contribute to improved transparency in the supply chain. Ideally, the effects of international transport (DOA and injury) should be exchanged on an international level, to allow the effects of such transport to be quantified better and the information to be used for risk-based monitoring.

Findings of the risk assessment for the egg supply chain

1
Food safety risks and the associated disease burden in the egg supply chain is primarily determined by *Salmonella*. A minor disease burden is caused by other pathogens that are generally introduced onto the eggs or egg products through unsanitary procedures at later preparation and processing phases in the chain, rather than at the farm. Based on the scientific literature, no single infection route can be designated for the disease burden which the RIVM attributes to *Campylobacter* in the egg supply chain.

2
Starting in 1998, the number of laying hen flocks infected with *S.* Enteritidis and *S.* Typhimurium has clearly decreased. In the same period, the number of cases of salmonellosis related to eggs has also dropped. Nevertheless, that decrease has stagnated in recent years. Infected eggs and egg products still find their way onto the consumer market (approximately 1 in 1360).

3
Salmonella is chiefly introduced into the egg supply chain during the primary phase, namely on the farm. The most significant health benefits may be gained through interventions in this phase. Increasing the frequency of sampling will likewise increase the probability of a positive finding through the sampling process. This would limit the potential introduction of infected eggs onto the consumption market.

4
The shared implementation of the mandatory National Control Programme for *Salmonella* with the private sector is a vulnerable element in the control of the risks of *Salmonella*.

5
Other vulnerable elements with regard to the control of the risks of *Salmonella* include ineffective pasteurisation and subsequent contamination of egg products in the processing of eggs into raw materials for foodstuffs.

6
Eggs that are put on the market in the EU, including (re-)export and export products, must comply with EU rules and regulations, unless the country of destination outside of the EU has determined otherwise.

7
In the Netherlands, eggs are stored at room temperature until the sale date up to 21 days after laying. Growth of *S.* Enteritidis in an egg under these conditions will only occur after that period. For that reason, the consumers are currently advised to store eggs in refrigerated conditions up to 7 ºC after purchase, which prevents the growth of *Salmonella*. There is a slightly elevated risk of salmonellosis in relation to the consumption of unrefrigerated eggs after the sell-by date. Provided the eggs are stored below 7 ºC as soon as possible after laying, the risk of salmonellosis will not increase for a period of 70 days.

8
A disease burden should also be expected in recipient countries as a result of the re-export and export of a large proportion of the eggs.

9
The physical and chemical food safety risks in the egg supply chain are considered to be low. Although a very low risk exists, the risk of dioxins and dioxin-like PCBs in eggs of free-range chickens constitutes an exception. The National Control Plan for chemical risks is very limited with regard to the egg sector and focuses primarily on known contaminants and veterinary drugs.

10
There is chance that banned agents are being used to combat red poultry mite, given the widespread problem of this pest among laying hens, in conjunction with the limited availability of effective drugs for the prevention and treatment thereof. The likelihood that the banned drugs are also used to combat histomonas is lower, despite there also being no available drugs for that purpose, given that histomonas outbreaks in the primary sector occur infrequently. The use of these banned drugs goes to undermine the system which guarantees food safety and results in a potentially increased food safety risk.

11
Consumers that regularly purchase eggs from the same private poultry holder run a higher food safety risk if these eggs are contaminated with dioxins or unauthorised pesticides or drugs.

12
Egg white allergies chiefly occur in small children and may lead to severe reactions. Persons that suffer from such allergies only benefit from avoiding taking in egg whites.

13
Genetics, housing, stock management, health and transport cause various (serious) welfare risk in the primary and secondary phases. These risks consist of a physical component (such as disease and keel bone fractures) and/or a mental component (such as stress due to fear or frustration). The key animal welfare risks with a major welfare impact and that occur frequently include: parasitic infections, keel bone fractures, limited behavioural repertoire and feather pecking.

14
Many welfare and health risks are multifactorial in nature, with the underlying factors affecting one another. As such, there are no simple solutions to individual risks. Feather pecking is a key example where aspects such as genotype, fear, insufficient diversionary material and high stock density are key factors.

15
The forthcoming ban on beak trimming was impelled from an animal welfare point of view, however, it may potentially result in an increase in feather pecking. This may lead to an increase in cannibalism and higher mortality. The envisaged welfare gains (avoiding surgical procedures) will depend entirely on the extent to which poultry farmers are able to adapt their management (as well as other factors, such as housing) to the new circumstances.

16
All four poultry housing systems in the egg supply chain lead to animal welfare risks, with a different emphasis on certain aspects:
- in the enriched cage system, hens are less able to satisfy their behavioural needs and exhibit their natural behaviour;
- in barn systems and free range, outdoor systems, there is a degree of mortality as a result of smothering (clambering on top of one another in panic) and a higher prevalence of endo and ectoparasitic infections;

- on free-range farms, including organic farms, there is an additional risk of predation and of the introduction of infectious diseases such as the pathogen Avian Influenza.

17
There are no objective criteria to compare the animal welfare in the various housing systems. None of the systems is optimal. Loss (cumulative mortality) is currently the most significant and broadly available indicator on hand.

18
At present, cumulative mortality is measured to assess health and welfare on the farm. An elevated mortality rate means poorer animal health and impairment of animal welfare; however, a low mortality rate does not necessarily mean that there is no impairment of animal welfare. Gains in the field of animal welfare can be made by gaining insight into the causes and by driving lower mortality in all phases of life of laying hens in all poultry farming housing systems. The use of animal welfare indicators at the level of the farm and flock are crucial in this regard.

19
The catching of animals prior to, as well as, the (long-distance) transport of spent laying hens and parent stock for slaughter is a key welfare risk of which the welfare burden is difficult to determine, given that most such animals are slaughtered abroad.

Advice following the risk assessment for the egg supply chain

1
Businesses should be encouraged to implement at least a limited set of food safety indicators (*Salmonella*) as well as for animal welfare at flock level (mortality, death on arrival) in order to initiate improvements in the chain. The NVWA should also use this set of indicators in order to provide risk-oriented monitoring of the chain.

2
Continuous and strict monitoring practices should take place to ensure the effectiveness of the pasteurisation process of eggs.

3
In the primary and secondary phase, stricter monitoring should be in place regarding:

- the private sector component of the National Control Programme for *Salmonella*;
- the prevention of cross-contamination with *Salmonella*;
- the sorting/channelling of cracked and soiled eggs that have been infected with *Salmonella* to the egg product sector;
- the hygiene and safeguarding of the pasteurisation in egg processing companies;
- eggs and egg products in the commercial chain.

4
The NVWA should ensure the export of eggs is carried out in compliance with the law: (re-)exported eggs must meet the requirements in place in the EU, unless the country of destination outside the EU has determined otherwise.

5
The NVWA should ensure that the consumer advice with regard to storing eggs in refrigerated conditions after purchase is conveyed more effectively.

6
Eggs should regularly be tested for non-authorised drugs that may potentially have been used for the prevention or treatment of red poultry mite or histomonas. These chemicals should be defined and selected based on a systematic food safety risk assessment and this assessment should be updated periodically.

7
A communication strategy should be designed with regard to the food safety risks of eggs from backyard poultry farmers based on the NVWA risk communication strategy.

8
The NVWA should ensure that the data of microbiological and chemical analyses in egg supply chains, for which there is a basis by law, is effectively and transparently organised, including Dutch data distribution to EFSA. This should be done in a way that makes data accessible to assessors and regulators, preferably in a centralised database, such as exists for *Salmonella*.

9
The animal welfare monitoring in the primary phase should at least be organised to focus on the key indicators of cumulative mortality and monitoring transport for death on arrival. This monitoring should not only use data on the averages of various flocks at farm level, but should also use data at flock level. Where

possible, this monitoring should be supplemented with information from robust animal welfare indicators such as open fractures and other injuries. The NVWA should also use this set of indicators itself to provide risk-based supervision.

10
At a national and EU level, the NVWA should advocate in favour of reducing long-distance transport of poultry. More stringent requirements should be put in place with regard to conditions during transport, chiefly in relation to climate control and the reduction of stress due to limited water intake by poultry.

11
At the European level, the NVWA should advocate in favour of the registration and reporting of animal welfare indicators, such as cumulative mortality and death of poultry on arrival, by analogy with the registrations in the area of food safety.

12
The NVWA should advocate in favour of there being sufficient focus on information provision and knowledge sharing regarding the correlation between animal welfare, food safety and sound economic business operations in order to achieve improvements in all these areas. This should take place preferably in partnership with all the actors in the sector.

13
A communication strategy should be designed for the animal welfare risks of laying hens in the egg production sector, taking into account the social sensitivity of the issue, based on the NVWA risk communication strategy. This strategy should involve the sharing of the information on animal welfare indicators for all the various types of laying hen farms.

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