



Killing for purposes other than slaughter: poultry

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Killing for purposes other than slaughter: poultry

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Abstract

Poultry of different ages may have to be killed on-farm for purposes other than slaughter (in which slaughtering is defined as being for human consumption) either individually or on a large scale (e.g. because unproductive, for disease control, etc.). The processes of on-farm killing that were assessed are handling and stunning and/or killing methods (including restraint). The latter were grouped into four categories: electrical methods, modified atmosphere, mechanical methods and lethal injection. In total, 29 hazards were identified and characterised, most of these regard stunning and/or killing. Staff were identified as origin for 26 hazards and 24 hazards were attributed to lack of appropriate skill sets needed to perform tasks or due to fatigue. Specific hazards were identified for day-old chicks killed via maceration. Corrective and preventive measures were assessed: measures to correct hazards were identified for 13 hazards, and management showed to have a crucial role in prevention. Eight welfare consequences, the birds can be exposed to during on-farm killing, were identified: not dead, consciousness, heat stress, cold stress, pain, fear, distress and respiratory distress. Welfare consequences and relevant animal-based measures were described. Outcome tables linking hazards, welfare consequences, animal-based measures, origins, preventive and corrective measures were developed for each process. Mitigation measures to minimise welfare consequences were also proposed.

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Keywords: poultry, on-farm killing, hazards, animal welfare consequences, ABMs, preventive/corrective measures

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Summary

In 2009, the European Union (EU) adopted Council Regulation (EC) No. 1099/2009 'on the protection of animals at the time of killing', which was prepared on the basis of two Scientific Opinions adopted by the European Food Safety Authority (EFSA) in 2004 and 2006. Successively (in 2012, 2013, 2014, 2015 and 2017), EFSA produced other Scientific Opinions related to this subject.

In parallel, since 2005, the World Organisation for Animal Health (OIE) has developed in its Terrestrial Animal Health Code over two chapters: (i) Slaughter of animals (Chapter 7.5); and (ii) Killing of animals for disease control purposes (Chapter 7.6). OIE has created an ad hoc Working Group (WG) to revise these two chapters.

Against this background, the European Commission requested EFSA to write a Scientific Opinion providing an independent view on the killing of domestic birds for purposes other than slaughter, which includes: (i) large-scale killings outside slaughterhouses for depopulation to control diseases and for other similar situations, like environmental contamination, disaster management, etc.; and (ii) on-farm killing of unproductive animals.

With specific reference to handling, restraint, stunning/killing, and unacceptable methods, procedures or practices on welfare grounds, EFSA was asked to: identify the animal welfare hazards and their possible origins in terms of facilities/equipment and staff (Term of Reference (ToR) 1); define qualitative or measurable criteria to assess performance on animal welfare (animal-based measures (ABMs)) (ToR2); provide preventive and corrective measures (structural or managerial) to address the hazards identified (ToR3); and point out specific hazards related to species or types of animals (e.g. young ones, etc.; ToR4). In addition, the European Commission asked EFSA also to provide measures to mitigate the welfare consequences that can be caused by the identified hazards.

This Scientific Opinion aims at updating the above-reported EFSA outputs by reviewing the most recent scientific publications and providing the European Commission with a sound scientific basis for future discussions at international level on the welfare of animals in the context of killing for purposes other than slaughter (in which slaughtering is defined as being for human consumption).

The animal species that are considered in this assessment are the ones that pertain to the category of 'poultry' as defined by the OIE that can be put in crates and containers, such as chickens, turkeys, quails, ducks and geese and game birds. It does not concern ratites, which are free moving animals.

The mandate also requested a list of unacceptable methods, procedures or practices that need to be analysed in terms of the above welfare aspects. Methods, procedures or practices cannot be subjected to a risk assessment procedure if there is no published scientific evidence related to these. In the light of this, Chapters 7.5.10 and 7.6 of the OIE Terrestrial Animal Health Code (World Organisation for Animal Health, 2018) list principles and practices considered to be unacceptable, and the Panel has no scientific arguments to disagree with these statements.

Council Regulation (EC) No. 1099/2009 defines 'killing' as 'any intentional induced process which causes the death of an animal'; and the 'related operations' are 'operations that take place in the context and at the location where the animals are killed'. This Opinion concerns the killing of poultry for purposes other than slaughter (in which slaughtering is defined as being for human consumption), which does not involve slaughterhouses (so-called on-farm killing) and the related operations, which here are called 'processes'.

To address the mandate, two main approaches have been used to develop this Opinion: (i) literature search; followed by (ii) expert opinion through Working Group (WG) discussion. Two literature searches have been carried out to identify peer-reviewed scientific evidence providing information on the aspects requested by the ToRs (i.e. description of the processes, identification of welfare hazards, origin, preventive and corrective measures, welfare consequences and related ABMs) on the topic of 'killing of poultry for purposes other than slaughter (on-farm killing of poultry)'.

From the available literature and their own knowledge, the WG experts identified the processes that should be included in the assessment and produced a list containing the possible welfare hazards characterising each process related to on-farm killing of poultry. To address the ToRs, experts identified the origin of each hazard (ToR1) and related preventive and corrective measures (ToR3), along with the possible welfare consequences of the hazards and relevant ABMs (ToR2). Measures to mitigate the welfare consequences were also considered. Specific hazards were identified for day-old chicks killed via maceration (ToR4). In addition, uncertainty analysis on the hazard identification has been also carried out and it was limited to the quantification of the probability of false-negative or false-positive hazards.

The processes assessed in this Opinion are handling and stunning/killing methods. The description of the restraint, when it is needed, has been included in the assessment of the relevant stunning/killing method.

As this Opinion will be used by the European Commission to address the OIE standards, more stunning/killing methods than those reported in Council Regulation (EC) No. 1099/2009 have been considered. However, among the methods that world-wide are used for on-farm killing, the following criteria have been applied for the selection of stunning/killing methods to include in this assessment: (i) all methods with described technical specifications known by the experts and not only the methods described in Council Regulation (EC) No. 1099/2009; (ii) methods currently used for stunning/killing of birds, and those which are still under development but are likely to become commercially applicable; and (iii) methods for which the welfare aspects (in terms of welfare hazards, welfare consequences, ABMs, preventive and corrective measures) are described sufficiently in the scientific literature. Applying these criteria, some methods that may be applied world-wide have not been included in the current assessment.

The stunning and/or killing methods that have been identified as relevant for poultry can be grouped in four categories: (1) electrical; (2) mechanical; (3) modified atmospheres; and (4) lethal injection.

Electrical methods include waterbath, head-only and head to body. Head only is a simple (reversible) stunning method that does not lead to death; therefore, it needs to be followed by a killing method. Modified atmosphere methods include whole house gassing, whole house gassing with gas-filled foam, gas mixtures in containers, low atmospheric pressure stunning (LAPS). Mechanical methods include captive bolt, percussive blow to the head, maceration of day-old chicks, cervical dislocation, neck cutting, decapitation and brain piercing. Some of these can be used as stunning and killing methods; whereas cervical dislocation, decapitation and piercing devices are considered pure killing methods and, therefore, they need to be applied on unconscious animals. Lethal injection is the intravenous injection of a lethal dose of anaesthetic drugs that cause rapid loss of consciousness followed by death; it should be administered strictly following the manufacturer's instructions on dose, route and rate of administration.

In this Opinion, for each process related to on-farm killing, a description on how it is technically and practically carried out and how the birds are kept (e.g. if still in containers or in a restraint device) is provided. In addition, for each process, a list of the main hazards that can occur and the relevant welfare consequences that the hazards can cause, is reported. In some specific cases ABMs are also provided as examples.

To answer ToR1, in total, 29 welfare-related hazards have been identified during on-farm killing of poultry. All the processes described in this Opinion have hazards; about the stunning/killing methods, some methods present hazards related to the restraint of birds (i.e. electrical and mechanical methods, lethal injection) other methods to the induction phase to unconsciousness (modified atmosphere methods).

Some of these hazards are common to different processes (e.g. inversion) or stunning/killing methods (e.g. manual restraint). Hazards linked to failure in provoking death are the most represented ones. Some hazards are inherent to the stunning/killing method and cannot be avoided (e.g. shackling in waterbath), other hazards originate from suboptimal application of the method, mainly due to unskilled staff (e.g. rough handling, use of wrong parameters e.g. for electrical methods). In fact, most of the hazards (26) had staff as origin and 24 hazards could be attributed to lack of appropriate skill sets needed to perform tasks or due to fatigue.

The uncertainty analysis on the set of hazards for each process provided in this Opinion revealed that the experts were 90–95% certain that they identified the main and most common welfare hazards considered in this assessment according to the three criteria described in the Interpretation of ToRs. However, when considering a global perspective (due to the lack of documented evidence on all possible variations in the processes and methods being practised on a world-wide scale), the experts were 95–99% certain that at least one welfare hazard is missing. On the possible inclusion of false-positive hazards, the experts were 95–99% certain that all listed hazards exist during on-farm killing of poultry. This certainty applies to all processes described in this Opinion except the hazard 'expansion of gases in the body cavity' during stunning/killing with LAPS, in which the lack of field experience and of scientific data reduces the level of certainty to 33–66%.

The mandate also asked to define qualitative or measurable (quantitative) criteria to assess performance (i.e. consequences) on animal welfare (ABMs; ToR2); this ToR has been addressed by identifying the negative consequences on the welfare (so-called welfare consequences) occurring to

the birds due to the identified hazards and the relevant ABMs that can be used to assess qualitatively or quantitatively these welfare consequences. Eight welfare consequences have been identified in the context of on-farm killing of poultry: not dead (after application of killing method), consciousness (after application of killing method), heat stress, cold stress, pain, fear, distress and respiratory distress. Birds experience these welfare consequences only when they are conscious.

Animal welfare consequences can be the result of single or several hazards. The combination of hazards would lead to a cumulative effect on the welfare consequences (e.g. pain due to injury caused by rough handling during catching will lead to more severe pain during shackling).

List and definitions of ABMs to be used for assessing the welfare consequences have been provided in this Opinion. However, under certain circumstances, not all the ABMs can be used because of low feasibility. Even if welfare consequences cannot be assessed during on-farm killing of poultry, it does not imply they do not exist. In fact, if the hazard is present, it should be assumed that also the related welfare consequences are experienced by the birds.

In response to ToR3, the preventive and corrective measures for the identified hazards have been identified and described. Some of these are specific for a hazard, others can apply to multiple hazards (e.g. staff training and rotation). For most of the hazards (23), preventive measures can be put in place and management showed to have a crucial role in prevention. Corrective measures were identified for 13 hazards; when they are not available or feasible to put in place, actions to mitigate the welfare consequences caused by the identified hazards should be put in place.

Finally, outcome tables linking all the mentioned aspects requested by the ToRs (identification of welfare hazards, origin, preventive and corrective measures, welfare consequences and related ABMs) have been produced for each process of on-farm killing of poultry to provide an overall outcome, in which all retrieved information is presented concisely. Conclusions and recommendations of this Scientific Opinion are mainly based on the outcome tables.

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1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

1.1.1. Background

The European Union adopted in 2009 Council Regulation (EC) No. 1099/2009¹ on the protection of animals at the time of killing. This piece of legislation was prepared on the basis of two EFSA Opinions respectively adopted in 2004² and 2006³. The EFSA provided additional Opinions related to this subject in 2012⁴, 2013^{5,6,7,8,9,10}, 2014^{11,12}, 2015¹³ and 2017^{14,15}.

In parallel, since 2005, the World Organisation for Animal Health (OIE) has developed in its Terrestrial Animal Health Code two chapters covering a similar scope:

- Slaughter of animals (Chapter 7.5).
- Killing of animals for disease control purposes (Chapter 7.6).

The chapter on the slaughter of animals covers the following species: cattle, buffalo, bison, sheep, goats, camelids, deer, horses, pigs, ratites, rabbits and poultry (domestic birds as defined by the OIE).

The OIE has created an ad hoc WG with the view to revise the two chapters.

Against this background, the Commission would like to request the EFSA to review the scientific publications provided and possibly other sources to provide a sound scientific basis for future discussions at international level on the welfare of animals in the context of slaughter (i.e. killing animals for human consumption) or other types of killing (killing for other purposes than slaughter).

1.1.2. Terms of Reference

The Commission therefore considers it opportune to request EFSA to give an independent view on the killing of animals for purposes other than slaughter:

- free moving animals (cattle, buffalo, bison, sheep, goats, camelids, deer, horses, pigs, ratites);
- animals transported in crates or containers (i.e. rabbits and domestic birds).

The request focuses on the cases of large-scale killings that take place for depopulation for disease control purposes and for other similar situations (environmental contamination, disaster management, etc.) outside slaughterhouses.

The request also considers in a separate section the killing of unproductive animals that might be practised on-farm (day-old chicks, piglets, pullets, etc.).

The request includes the following issues:

- handling
- restraint
- stunning/killing
- unacceptable methods, procedures or practices on welfare grounds.

¹ OJ L 303, 18 November 2009, p. 1.

² The welfare aspects of the main systems of stunning and killing the main commercial species of animals. EFSA Journal 2004; 45:1–29.

³ The welfare aspects of the main systems of stunning and killing applied to commercially farmed deer, goats, rabbits, ostriches, ducks, geese and quail. EFSA Journal 2006;326:1–18.

⁴ Electrical requirements for waterbath equipment applicable for poultry. EFSA Journal 2012;10(6):2757.

⁵ Electrical parameters for the stunning of lambs and kid goats. EFSA Journal 2013;11(6):3249.

⁶ Monitoring procedures at slaughterhouses for bovines. EFSA Journal 2013;11(12):3460.

⁷ Monitoring procedures at slaughterhouses for pigs. EFSA Journal 2013;11(12):3523.

⁸ Monitoring procedures at slaughterhouses for poultry. EFSA Journal 2013;11(12):3521.

⁹ Monitoring procedures at slaughterhouses for sheep and goats. EFSA Journal 2013;11(12):3522.

¹⁰ The use of carbon dioxide for stunning rabbits. EFSA Journal 2013;11(6):3250.

¹¹ The use of low atmosphere pressure system (LAPS) for stunning poultry. EFSA Journal 2014;12(1):3488.

¹² Electrical requirements for poultry waterbath stunning equipment. EFSA Journal 2014;12(7):3745.

¹³ The scientific assessment of studies on electrical parameters for stunning of small ruminants (ovine and caprine species). EFSA Journal 2015;13(2):4023.

¹⁴ The low atmospheric pressure system for stunning broiler chickens. EFSA Journal 2017;15(12):5056.

¹⁵ The animal welfare aspects in respect of the slaughter or killing of pregnant livestock animals (cattle, pigs, sheep, goats, horses). EFSA Journal 2017;15(5):4782.

For each process or issue in each category (i.e. free moving, in crates or containers), the EFSA will:

- ToR1: Identify the animal welfare hazards and their possible origins (facilities/equipment, staff);
- ToR2: Define qualitative or measurable criteria to assess performance on animal welfare (animal-based measures);
- ToR3: Provide preventive and corrective measures to address the hazards identified (through structural or managerial measures);
- ToR4: Point out specific hazards related to species or types of animals (young, with horns, etc.).

1.2. Interpretation of the Terms of Reference

This Scientific Opinion concerns the killing for purposes other than slaughter of poultry [as defined by the World Organisation for Animal Health (OIE, 2018)]¹⁶ that can be put in crates and containers, such as chickens, turkeys, quails, ducks and geese, and game birds, whereas it will not concern ratites, which are free moving animals that will be treated in another Scientific Opinion.

The European Commission asked EFSA to provide an independent view on the killing of poultry for purposes other than slaughter that takes place involving: (i) large-scale killings on-farm (depopulation for disease control purposes and for other similar situations such as: environmental contamination, disaster management, etc.); and (ii) killing on-farm of unproductive animals. The latter can occur for health, welfare or economic reasons and can be split in two subcategories: (a) large-scale killing of unproductive birds; and (b) individual killing of unproductive, unhealthy or injured birds. For each of these scenarios, several welfare aspects need to be analysed (including e.g. welfare hazards, welfare consequences and preventive/corrective measures).

This Opinion will use definitions related to the killing of poultry provided by Council Regulation (EC) No. 1099/2009 of 24 September 2009¹⁷ on the protection of animals at the time of killing, and that entered into force in January 2013. The Regulation defines 'killing' as any intentional induced process that causes the death of an animal; and the 'related operations' are operations that take place in the context and at the location where the animals are killed. In the context of this Opinion, related operations are called 'processes'.

The processes that will be assessed in this Opinion are: (1) handling; and (2) stunning/killing methods.

The stunning/killing methods that have been identified as relevant for poultry and they can be grouped in four categories: (1) electrical; (2) mechanical; (3) modified atmospheres; and (4) lethal injection.

The assessment of the relevant stunning/killing method will include a description of the restraint when it is needed.

Due to the diversity of available stunning/killing methods, in this Opinion the assessment of hazards, welfare consequences, related animal-based measures (ABMs) and mitigation measures, hazard's origin of hazards and preventive/corrective actions will be considered separately for each method.

The mandate requests EFSA to identify hazards at different stages (processes) of killing for purposes other than slaughter and their relevant origins in terms of equipment/facilities or staff (ToR1). This Opinion will report the hazards that can occur during killing of poultry for purposes other than slaughter (in which slaughtering is defined as being for human consumption) and that does not involve slaughterhouses (so-called on-farm killing). In this context, 'facilities' has not been recognised as a possible origin category for the hazards, therefore only staff and equipment have been considered as origins.

The on-farm killing can be performed using several stunning/killing methods, some of which are specific to on-farm killing while others are commonly practised in slaughterhouses (for slaughter) but also applicable during on-farm killing. For stunning/killing methods that can be used for slaughtering and also for on-farm killing, some hazards may occur in the two scenarios (slaughtering and on-farm killing; e.g. 'shackling' for waterbath), whereas some other hazards may not apply to the context of on-farm killing (e.g. hazards related to the facilities in the slaughter plant, such as: 'drops, curves and inclination of shackle line' for waterbath; for details see EFSA AHAW Panel, 2019).

¹⁶ POULTRY definition by OIE: means all domesticated birds, including backyard poultry, used for the production of meat or eggs for consumption, for the production of other commercial products, for restocking supplies of game, or for breeding these categories of birds, as well as fighting cocks used for any purpose. Birds that are kept in captivity for any reason other than those reasons referred to in the preceding paragraph, including those that are kept for shows, races, exhibitions, competitions or for breeding or selling these categories of birds as well as pet birds, are not considered to be poultry. (Glossary of the 2018 © OIE – Terrestrial Animal Health Code – 10 August 2018.)

¹⁷ Council Regulation (EC) No. 1099/2009 of 24 September 2009 on the protection of animals at the time of killing. OJ L 303, 18 November 2009, pp. 1–30.

Additionally, the mandate does not specify the level of detail to be considered for the definition of 'hazard'. One hazard could be subdivided into multiple ones depending on the chosen level of detail. For example, the hazard 'inappropriate electrical parameters' for electrical stunning/killing methods, could be further subdivided into 'wrong choice of electrical parameters or equipment', 'poor or lack of calibration', 'voltage/current applied is too low', 'frequency applied is too high for the amount of current delivered'. For this Opinion, it was agreed to define hazards by a broad level of detail ('inappropriate electrical parameters' in the example above). Birds experience welfare consequences due to presence of hazards only when they are conscious.

The mandate also asks to define qualitative or measurable (quantitative) criteria to assess performance (i.e. consequences) on animal welfare (ABMs; ToR2); this ToR has been addressed by identifying the negative consequences on the welfare (so-called welfare consequences) occurring to the birds due to the identified hazards and the relevant ABMs that can be used to assess qualitatively or quantitatively these welfare consequences. In some circumstances, it might be that no ABMs exist or are not feasible to use in the context of on-farm killing of birds; in these cases, emphasis to the relevant available measures to prevent the hazards or to mitigate the welfare consequences will be given.

In this Opinion, in the description of the processes, the relevant welfare consequences that the birds can experience when exposed to hazards will be reported. The mandate does not request the ranking of the identified hazards in terms of severity, magnitude and frequency of the welfare consequences that they can cause.

The description of preventive and corrective measures for the identified hazards will be structured in two main categories: (i) structural and (ii) managerial (ToR3). When corrective measures for the hazards are not available or feasible to put in place, actions to mitigate the welfare consequences caused by the identified hazards will be discussed. In addition, it will be assessed whether specific categories or species of poultry might be subjected to specific hazards (ToR4).

In response to an additional request from the EC, measures to mitigate the welfare consequences will also be described under ToR2.

As this Opinion will be used by the European Commission to address the OIE standards, it will consider more stunning/killing methods than those reported in Council Regulation (EC) No. 1099/2009.

Among the methods that world-wide are used for on-farm killing, EFSA has applied the following criteria for the selection of stunning/killing methods to include in this assessment: (i) all methods with described technical specifications known by the experts and not only the method described in Council Regulation (EC) No. 1099/2009; (ii) methods currently used for stunning/killing of birds, and those that are still under development but are likely to become commercially applicable; and (iii) methods for which the welfare aspects (in terms of welfare hazards, welfare consequences, ABMs, preventive and corrective measures) are described sufficiently in the scientific literature.

Applying these criteria will result in not including nor describing in this Opinion some practices that may be applied world-wide.

The mandate also requests a list of unacceptable methods, procedures or practices that needs to be analysed in terms of the above welfare aspects. The Panel considers that there are two problems with this request. First, the question of what practices are 'acceptable' or 'unacceptable' cannot be answered by a scientific risk assessment, but it involves e.g. ethical and socioeconomic considerations that need to be weighed by the risk managers. Second, methods, procedures or practices cannot be subjected to a risk assessment procedure if there is no published scientific evidence related to these. In the light of this, Chapters 7.5.10 and 7.6 of the OIE Terrestrial Animal Health Code (OIE, 2018) list principles and practices that are considered to be unacceptable, and the Panel has no scientific arguments to disagree with these statements.

2. Data and methodologies

2.1. Data

2.1.1. Data from literature

Information from the papers selected as relevant from the literature searches described in Section 2.2.1 and from additional literature identified by the WG experts was used for a narrative description and assessment to address ToR1 to ToR4 (see relevant sections in the chapter on Assessment).

2.1.2. Data from expert opinion

The data obtained from the literature were complemented by the WG experts' opinion to identify the origins of hazards, welfare consequences, ABMs and hazard preventive, and corrective measures relevant for the current assessment.

2.2. Methodologies

To address the questions formulated by European Commission in ToR1 to ToR4, two main approaches were used to develop this Opinion: (i) literature search; followed by (ii) expert opinion through WG discussion. These methodologies were used to address the mandate extensively (see relevant sections in the chapter on Assessment) and also in a concise way with development of outcome tables (see Section 2.2.2.1).

The general principle adopted in the preparation of this Opinion was that relevant reference(s) would be cited in the text when published scientific literature is available, and expert opinion would be used when no published scientific literature is available or to complete the results retrieves.

2.2.1. Literature searches

Two literature searches (LS) were carried out to identify peer-reviewed scientific evidence providing information on the aspects requested by the ToRs (i.e. description of the processes, identification of welfare hazards, origin, preventive and corrective measures, welfare consequences and related ABMs) on the topic of 'killing of poultry for purposes other than slaughter (on-farm killing of poultry)': (1) the first search (Search 1) was a broad literature search under the framework of 'welfare of poultry at slaughter and killing' (for details; see Appendix A of EFSA AHAW Panel, 2019). For the current Opinion, the publications obtained from this first search were screened for their relevance to the context of 'on-farm killing of poultry' and assessed: 21 papers resulted pertaining to on-farm killing of poultry; and (2) a second literature search (Search 2) aimed specifically at retrieving additional publications relevant to on-farm killing of poultry. From this search, five additional relevant papers resulted.

Full details of the Search 2 protocol, strategies and results are provided in Appendix A to this Opinion.

In addition, the reference list of relevant review articles and key reports was checked for further relevant articles and experts were invited to propose any additional relevant publications.

2.2.2. Expert opinion through Working Group discussion

The WG experts firstly described the processes of killing and specifically that stunning/killing methods should be considered for the current assessment.

The experts then produced, from the available literature and their own knowledge, a list containing the possible welfare hazards characterising each process related to on-farm killing of poultry. To address the ToRs, experts then identified the origin of each hazard (ToR1) and related preventive and corrective measures (ToR3), along with the possible welfare consequences of the hazards and relevant ABMs (ToR2). Measures to mitigate the welfare consequences were also considered.

ToR1 of the mandate asks to identify the origins of the hazards in terms of staff or facilities/equipment. When discussing the origins, it was agreed that in the on-farm killing context, the term 'facilities' has not been recognised as a possible origin category for the hazards. Therefore, only staff and equipment have been considered as origins. Moreover, it was considered necessary to explain the origins further by detailing what actions from the staff or features from equipment can cause the hazard. Therefore, for each 'origin category' (staff or equipment), relevant 'origin specifications' have been identified by expert opinion.

2.2.2.1. Development of outcome tables to answer the ToRs

A conceptual model has been developed following EFSA's Guidance on risk assessment in animal welfare (EFSA AHAW Panel, 2012a) that shows the interrelationships between aspects corresponding to the different ToRs (see Figure 1), and the main results of the current assessment have been summarised in tables (so-called outcome tables, see Section 3.10).

The outcome tables link all the mentioned aspects requested by ToR1, ToR2 and ToR3 of the mandate and were produced to provide an overall outcome for each process of on-farm killing of poultry, in which all retrieved information is presented concisely (see description of the structure below

and, for details, Tables 8–20). Conclusions and recommendations of this Scientific Opinion are mainly based on the outcome tables.

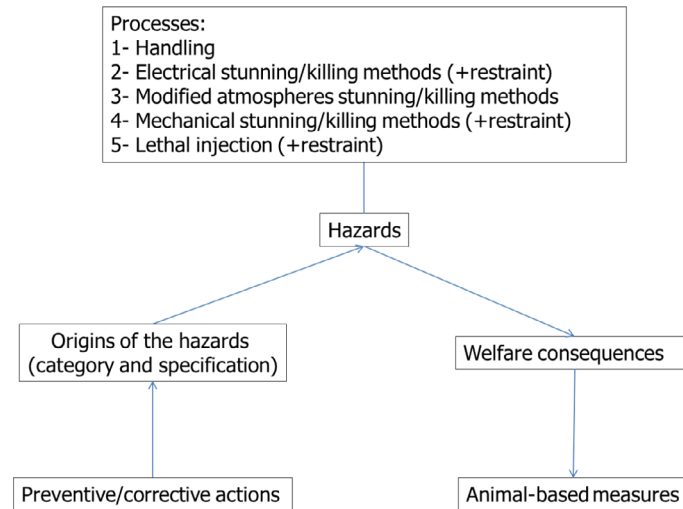


Figure 1: Conceptual model reproducing interrelationships between the aspects corresponding to the different ToRs

Description of the structure of the outcome tables

The outcome tables have the following structure and the following terminology should be referred to:

- 'OUTCOME TABLE': Each table represents the summarised information for the processes described in the assessment (see Sections 3.3 and 3.4).
- Column 'HAZARD': in each table, the first column reports all hazards pertaining to the specific process related to on-farm killing of poultry; the number of the section in which each hazard is described in detail is reported in brackets.
- 'ROW': For each hazard, the individual row represents the summarised information relevant to the aspects analysed for that hazard. Therefore, it links among an identified hazard, the relevant welfare consequences, origin(s) of hazards and preventive and corrective measures (see example in Figure 2).
- Column 'WELFARE CONSEQUENCES OCCURRING TO THE BIRDS DUE TO THE HAZARD': in which the welfare consequences on the birds due to the mentioned hazards are listed.
- Column 'HAZARD ORIGIN': this contains the information related to the main origins of the hazard; for on-farm killing it can be staff or equipment related. Hazards can have more than one origin.
- Column 'HAZARD ORIGIN SPECIFICATION': this further specifies the origin of the hazard. This information is needed to understand and choose among the available preventive and corrective measures.
- Column 'PREVENTIVE MEASURE(S) OF THE HAZARD': depending on the origin(s) of the hazard, several measures are proposed to prevent the hazard. They are also aspects for implementing standard operating procedures (SOP).
- Column 'CORRECTIVE MEASURE(S) OF THE HAZARD': practical actions/measures for correcting the identified hazards are proposed. These actions may relate to the identified origin of the hazards.
- Row 'ANIMAL-BASED MEASURES': list of the feasible measures to be performed on the birds to assess the welfare consequences of a hazard.

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) for the hazard (implementation of SOP)	Corrective measure(s) for the hazard
(Number of section)					
ABMs: (to assess the identified welfare consequences)					

Figure 2: Structure of outcome table (for details on the data, see Tables 8–20)

2.2.3. Uncertainty analysis

The outcome tables include qualitative information on the hazards and related aspects identified through the methodologies explained in Section 2.2.

When considering the outcome tables, uncertainty exists at two levels: (i) related to the completeness of the information presented in the table, namely to the number of rows within a table (i.e. hazard identification); and (ii) related to the information presented within a row of the table (i.e. completeness of hazard origins, preventive and corrective measures on the one side, and welfare consequences and ABMs on the other side).

However, owing to the limited time available to develop this Scientific Opinion, there will not be an uncertainty analysis for the latter level, but only for the first level, i.e. for the hazard identification.

In such a process of hazard identification, uncertainties may result in false-negative or false-positive hazard identifications:

- Incompleteness (false negative): Some welfare-related hazards may be missed in the identification process and so would be considered non-existent or not relevant.
- Misclassified (false positive): Some welfare-related hazards may be wrongly included in the list of hazards of an outcome table without being a relevant hazard.

Incompleteness (false negatives) can lead to under-estimation of the hazards with the potential to cause (negative) welfare consequences.

The uncertainty analysis was limited to the quantification of the probability of false-negative or false-positive hazards. False-negative hazards can relate to: (i) the situation under assessment, i.e. limited to the on-farm killing practices considered in this assessment according to the three criteria described in the Interpretation of ToRs (see Section 1.2); or (ii) the global situation i.e. including all possible variations to the on-farm killing practices that are employed in the world, and that might be unknown to the experts of the WG. The Panel agreed it was relevant to distinguish the false-negative hazard identification analysis for these two cases.

For false-negative hazard identification, the experts elicited the probability that at least one hazard was missed in the outcome table. For false-positive hazard identification, the experts elicited the probability that each hazard included in the outcome table was correctly included.

For the elicitation the experts used the approximate probability scale (see Table 1) proposed in the EFSA Uncertainty Guidance (EFSA, 2019). Individual answers were then discussed, and a consensus judgement was obtained.

A qualitative translation of the outcome of the uncertainty assessment was also derived (e.g. 'extremely unlikely' for an uncertainty of 1–5%: see Table 1).

Table 1: Approximate probability scale (see EFSA, 2019, Table 4)

Probability term	Subjective probability range	Additional options	
Almost certain	99–100%	More likely than not: >50%	Unable to give any probability: range is 0–100% Report as 'inconclusive' cannot conclude, or 'unknown'
Extremely likely	95–99%		
Very likely	90–95%		
Likely	66–90%		

Probability term	Subjective probability range	Additional options	
About as likely as not	33–66%		
Unlikely	10–33%		
Very unlikely	5–10%		
Extremely unlikely	1–5%		
Almost impossible	0–1%		

3. Assessment

3.1. Introduction

Section 3.2 provides an overview of the practices that can be performed on-farm in the context of killing of birds for purposes other than slaughter (on-farm killing). The following sections (Sections 3.3 and 3.4) describe in detail the processes related to on-farm killing, and are structured in two sections: (i) process description, with information on how they are technically and practically carried out and how the birds are kept (e.g. if still in containers or in a restraint device); and (ii) a section on hazards and welfare consequences in which, to explain the impact of each process on birds' welfare, a list of the main hazards that can occur in the process and the relevant welfare consequences that the hazards can cause, is provided. In some specific cases ABMs are also provided as examples.

Section 3.5 deals with the unacceptability on welfare grounds of methods, procedures or practices.

The details of the hazard's characterisation and origins (ToR1) and the description of hazard's preventive and corrective measures (ToR3) are discussed in Section 3.6; the description of the welfare consequences, the related ABMs (ToR2) and of the measures to mitigate the welfare consequences is provided in Section 3.7. The preventive measures (ToR3) that are considered general and applicable to several hazards and processes are presented in Section 3.8. Specific hazards related to animal categories (i.e. day-old chicks) (ToR4) are reported in Section 3.9.

Finally, outcome tables linking the above-mentioned aspects requested by the ToRs of the mandate are reported in Section 3.10.

3.2. Description of on-farm killing practices

3.2.1. Introduction

Killing of animals for purposes other than slaughter could be due to different reasons such as the culling of injured and sick individuals, needs associated with stock management, or emergency killing for disease control, management of natural disasters or other emergencies including those related to animal welfare. The methods used to cull small numbers of animals on farm are diverse and they may differ from those applied on a large scale, e.g. for depopulation.

According to the mandate, the current assessment should be focus on two scenarios: (1) large-scale killing that takes place in case of depopulation for disease control purposes and for other similar situations; and (2) the killing of unproductive or surplus animals that might be practised on farm. This second scenario can be split in two categories: (i) large-scale killing of unproductive animals; and (ii) individual killing of unproductive, unhealthy or injured birds.

3.2.2. Large-scale killing

Large scale cannot simply be defined by setting a limit at a certain number of birds, as the concept should be viewed not only in terms of absolute numbers but also in relation to the total number of birds in the flock and at the farm. The assumption is that a group, a considerable proportion of the birds, are involved: not just a few individuals.

The expression 'large-scale killing' is not used for small non-commercial entities (backyard or hobby flocks), even in cases in which all birds in a flock are killed. In contrast to depopulation, large-scale killing does not necessarily – but commonly does – involve the entire flock; the main difference relates to the context in relation to the reason for the killing. In relation to poultry, the expression 'large scale' is commonly not used for groups or flocks of less than approximately 500 birds, but this is not a fixed, pre-defined number.

This practice takes place in case of depopulation¹⁸ for disease control purposes (Raj et al., 2006; Berg, 2009a; Gerritzen and Raj, 2009) and for other similar situations (environmental contamination, natural disaster management such as earthquake, floods, etc.; Raj, 2008; Thornber et al., 2014) outside slaughterhouses under the supervision of the competent authority. Large-scale killing for disease control involves the killing of all birds in at least one given biosecurity-based compartment, such as a poultry house, where a disease has been diagnosed or is suspected or the empty a zone if there are difficulties in controlling the disease. More often, and depending on the nature of the disease, it involves the killing of all birds at the premises involved, i.e. possibly in several compartments or houses at the same farm (Berg, 2009a) or at several farms in an area (with the aim of 'stamping out' the disease), for example if a case of highly pathogenic avian influenza (HPAI) was detected (EFSA, 2004, 2008). Furthermore, the activity may involve pre-emptive killing of poultry at adjacent farms and farms with known or suspected contact, direct or indirect, with the infected premises (Berg, 2012). In relation to a serious disease outbreak, various other restrictions may be imposed regionally, such as a stand-still prohibiting live poultry transport and feed transports. Already within a few days, such restrictions may lead to poultry welfare problems related to overstocking or feed shortage, and birds may then have to be killed on-farm to prevent further suffering (Raj, 2008; Berg, 2012). In emergencies other than disease outbreaks, these may be linked e.g. to various types of disasters such as flooding or wildfires, but also chemical environmental contamination or nuclear power plant accidents. In practice, it is rarely possible to evacuate the birds from large-scale commercial poultry farms and, if producer and staff have to be evacuated for human health reasons, the birds may be left behind. In such cases, especially if evacuation is expected to be long-lasting and the birds will run out of feed, water and be without supervision for an extended period of time, killing of the flocks is a preferred alternative from an animal welfare perspective. The same applies if the disaster itself will affect the birds in a way that will make their meat or eggs unsuitable for human consumption. In summary, depopulation can be defined as the process of killing animals for public health, animal health, animal welfare or environmental reasons and, in the EU, according to Council Regulation (EC) No. 1099/2009, it should be carried out under the supervision of the competent authority. Depopulation is usually large scale when commercial flocks are involved, but can also be small scale, if the farm is small or for backyard flocks. Large-scale killing and depopulation can be applied to any type of poultry of any age. It has been suggested that welfare of animals can be greatly improved if the facilities take into consideration, at the time of design and construction stages, the various needs for depopulation (Gavinelli et al., 2014).

3.2.3. Killing of unproductive or surplus animals

This practice can be split in subcategories (see also Table 2).

3.2.3.1. Large-scale killing of unproductive animals

This practice relates, for example, to the killing of end-of-lay hens (Berg et al., 2014), surplus male broiler breeders or male day-old layer chicks. The latter category includes male day-old layer chicks or surplus male day-old breeder chicks, when animals are hatched on the farm. Otherwise, it is performed in the hatchery itself.

For end-of-lay hens, slaughter is not always an option, depending on the geographical location of the farm in relation to the nearest available laying hen slaughterhouse, and on the costs and work involved in catching, crating, transporting and slaughtering birds with a very limited economic value. There are also egg producers that choose on-farm killing of the end-of-lay hens for animal welfare reasons, to spare the birds the stress of being caught (depending on the method), crated and transported. Furthermore, there are cases in which the end-of-lay hens are deemed unfit for transport due to poor plumage condition, poor skeletal condition or are unlikely to be accepted for human consumption due to underlying infections and that may not be affecting the birds but are considered problematic for meat quality or consumer health (e.g. *Salmonella* contamination). If the meat from these birds is not acceptable for human consumption, the birds should not be sent to a slaughterhouse, but instead be killed on the farm. Large-scale killing of unproductive birds at end of lay predominantly refers to end-of-lay hens after egg production, but can in some cases also involve end-of-lay breeding poultry of any species, for example,

¹⁸ Council Regulation (EC) No. 1099/2009, defines 'depopulation' as the process of killing animals for public health, animal health, animal welfare or environmental reasons under the supervision of the competent authority.

end-of-lay broiler breeders, laying hen breeders or turkey breeders, although these categories are more often sent for slaughter, when there is market demand.

A separate case relates to male broiler breeders during the production cycle, in which natural mating predominantly occurs and the proportion of males to females will usually be deliberately decreased with time. This means that healthy male birds will routinely be killed during the production cycle. It can be debated if the killing of surplus male broiler breeders during the production cycle is truly 'large scale' as it only involves a few per cent of the birds in a given shed, but as the birds are neither sick nor injured they may still be included in this category.

3.2.3.2. Individual killing

On any farm, individual birds may become sick or injured. This covers for example production-related diseases, metabolic diseases, infectious diseases, health issues emanating from behavioural problems such as injurious pecking, or injuries caused by accidents. In commercial large-scale poultry production, single or low numbers of sick or injured birds are often not attended by a veterinarian and not treated individually. Instead, they are killed to prevent further suffering, and to avoid the possible costs related to the keeping of low producing/non-producing birds (Berg, 2009b). For animal welfare reasons, such birds should be killed and not left to die slowly while remaining in the flock. Hence, it is of utmost importance that the producer or staff routinely, preferably twice daily, inspect the flock to identify and kill such birds. The producer and stockpersons at a farm are responsible for ensuring that birds that are suffering from injury or disease, when treatment is not an option, are humanely killed. According to the EU Broiler Directive (2007/43/EC)¹⁹, broiler keepers are obliged to participate in specific training, including emergency killing and culling. Individual killing on-farm can be applied to any type of poultry of any age.

It is hence important to differentiate between 'on-farm killing' of poultry in general, which can be carried out for a number of different reasons as described above and relate to single or multiple birds or the entire flock (unproductive or surplus birds, disease control, disaster management, animal welfare reasons) and 'emergency killing'. Emergency killing is always urgent, and it is related to single or multiple birds or the entire flock. The term 'emergency killing', as used in Council Regulation (EC) No. 1099/2009, means the killing of animals that are injured or have a disease associated with acute pain or suffering, and when there is no other practical possibility to alleviate this pain or suffering. In this case, the killing needs to be provoked immediately. In contrast, the term 'depopulation' is used for describing a planned process of killing animals for public health, animal health, animal welfare or environmental reasons under the supervision of the competent authority (as described in Council Regulation (EC) No. 1099/2009), and should refer to the killing of an entire flock – or several flocks – at the same or adjacent premises of birds.

All the methods presented in Table 2 are applicable for emergency killing of individual birds. However, cartridge powered captive bolts are the most feasible option in this context, owing to the portability of equipment and ease of use, especially in large/heavy birds like broiler breeders, turkeys, ducks and geese. Manual or mechanical cervical dislocation by stretching, or percussive blow to the head can also be used if appropriate to the bird type. Electrical and controlled atmosphere stunning/killing methods are usually not used for emergency killing, for practical reasons (lack of equipment, need of skilled personnel, etc.).

Poultry are usually kept in large groups in closed, controlled housing systems. An important reason for killing poultry on-farm is related to problems with the general fitness of individuals. In commercial flocks, single birds are rarely treated or placed in separate sick pens. Instead, birds that are not fit to follow the routines in the large flocks (sick or injured) are usually removed and killed. Birds that are not apparently sick but are growing considerably slower than the remaining flock (with poor growth rate, often referred to as runts) will also be culled. The reason for this is twofold: as feed and water lines are gradually elevated to fit the size of the birds, the runts may experience difficulties reaching these resources and so suffer from prolonged thirst and hunger and even die from it. Second, these very small birds are usually not accepted by the slaughterhouse, even if they survived the last journey, as the stunning and processing equipment does not fit these. Council Regulation (EC) No. 1099/2009 clearly states that birds that are likely to miss the waterbath stunners, which is the most common method used throughout the world, should not be shackled, but instead killed humanely, preferably on

¹⁹ Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production. OJ L 182, 12 July 2007, pp. 19–28.

the farm before transport. In addition, birds that are not fit for transport (Council Regulation (EC) No. 1/2005²⁰) should be killed humanely on the farm to avoid unnecessary suffering during transport.

Domestic birds are killed on the farm during production for several reasons, including economic ones. For example, newly hatched chicks derive nutrients from their yolk sacks for survival for the first few days of life (up to 72 h after hatching) and may not survive if they do not begin to eat and drink before this source is depleted. Broiler farmers therefore routinely monitor the flock and they recognise the chicks' viability from their growth and activity patterns. Chicks showing signs of poor health or welfare or viability are usually killed, this is commonly known as 'culling' and this is a continuous operation throughout the production cycle in a flock.

Poultry are killed regularly for various reasons that lead to poor welfare, most notably, those severely injured due to feather pecking or cannibalism, which is most commonly seen in laying hens. Also, in turkeys, including breeding stock, injurious pecking can be a reason for on-farm killing. In any type of poultry, severe injuries caused by other birds or by interactions with equipment are a cause for killing to avoid further suffering. The same applies to obviously sick or moribund poultry of any type, regardless of the underlying cause or signs, as a clear diagnosis is often not made.

One major reason for killing broilers on farm is associated with leg disorders. Leg disorders may begin to develop in the flock as early as 14 days of age and worsen very rapidly during 25–45 days of age. It is a common practice in the industry to kill broilers showing signs of severe lameness, i.e. birds being unable to walk or having great difficulties in walking or sustained standing, due to the fact that these birds will be suffering severe pain and they would, as a result of their increasing immobility, be deprived of access to feed and water (EFSA AHAW Panel, 2012b).

Table 2: Stunning/killing methods used on-farm and approved for poultry under Council Regulation (EC) No. 1099/2009 as described in this Scientific Opinion for depopulation and individual killing of animals, with indication of the purpose of killing (see Section 3.2)

Method	Purpose of on-farm killing	
	Large-scale killing	Individual killing
Electrical		
Waterbath	Yes	No
Head only	Yes	Yes
Head to body	Yes	Yes
Modified atmospheres		
Whole house gassing	Yes	No
Whole house gassing with gas-filled foam	Yes	No
Gas mixtures in containers	Yes	Yes
Low atmospheric pressure ^(a)	Yes	No
Mechanical		
Captive bolt	Yes	Yes
Percussive blow to the head ^(b)	Yes	Yes
Cervical dislocation ^(b)	Yes	Yes
Maceration ^(c)	Yes	No
Lethal injection	Yes	Yes

(a): Low atmospheric pressure stunning/killing (LAPS) has not been evaluated.

(b): Certain conditions apply to percussive blow to the head and cervical dislocation and these are presented under the relevant sections (Sections 3.4.4.2 and 3.4.4.4).

(c): Maceration is permitted only for day-old chicks (for details, see Section 3.4.4.3).

²⁰ Council Regulation (EC) No. 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No. 1255/97. OJ L 3, 5 January 2005, pp. 1–44.

3.3. Handling of the birds

3.3.1. General principles

Although domestication and subsequent genetic selection of poultry have reduced the magnitude of their fear responses, poultry still perceive humans as predators (Gerritzen and Raj, 2009). Response to handling may vary between flocks and farms based on the animal species, the rearing system and the amount and nature of previous interactions with stockpersons.

Housing systems used to rear domestic birds vary widely according to the species (e.g. broiler vs layer hens) stage of production (e.g. chick brooder vs pullets and broilers on deep litter vs laying hens in barns or cages), size of the farming operation (number of birds at each stage) and the farming/housing system (e.g. indoor vs free range) and country/geographical location in the world. It is therefore inevitable that the nature of hazards and the magnitude of animal welfare consequences would vary according to these factors during the life of the birds and when handled for any purpose, including killing.

In addition, the method of killing to be employed will also determine the nature of hazards and the number of birds exposed to these.

3.3.2. Process description

Handling consists in removing birds from their rearing environment; depending of the housing systems and the method of killing, the scenarios that it could occur are:

- Absence of bird handling and minimum movement (e.g. in the cases of whole house gassing).
- Manual handling:
 - e.g. for electrical waterbath or gassing in containers, birds are manually caught by their legs, inverted and carried up to three birds in each hand of the operator to the point of killing on distances that can be long;
 - e.g. for containerised gassing, birds are caught by their legs, inverted and placed rapidly in containers and moved in containers to the point of killing either inside or outside the building.

Movement of birds may involve passing these from operator to operator several times, each acting as trigger for wing flapping. For example, the catcher would pass the birds to the carrier who would pass these on to the loader to put these into containers (Tinker et al., 2004). When birds are killed outside the house, operators catching birds inside the house may hand these over to a different operator to carry these to the point of killing or hand these over to operators performing restraint of individual birds (e.g. shackling or placing inverted in cones).

Lighting intensity during rearing, breed and strain of birds, age at sexual maturity, age at depopulation, weight and catching method might impact bird reactivity and affect welfare outcomes (EFSA, 2004).

Among all domestic birds considered in this Opinion, laying hens are the most vulnerable to suffer injuries due to reduced bone strength related to osteoporosis in end of lay (Gregory and Wilkins, 1989).

Diverse types of containers are used for moving birds and hazards may vary according accordingly. When housed in cages, the type of cage can influence handling conditions and laying hens welfare:

- Battery cages are widely used outside the EU for layer hens and they are arranged in tiered rows along the length of the house with passageways between these. Up to six hens may be kept in each cage and removing these through a narrow cage opening and carrying inverted birds, up to three in each hand, along the narrow passageways impose high welfare risks (Tinker et al., 2004), especially broken bones (Gregory et al., 1993).
- Enriched cages are now compulsory in the EU, but the design and layout of facilities (presence of nest boxes and perches) and colony size (up to 60–80 birds) are significant factors to be considered during catching and handling. There are at least two types of cage-free systems used for layer hens: those with flat floor and those with up to four tiers of perches (known as aviaries). Some design and layout of perches may affect the practicability of catching and handling the birds (Gregory et al., 1990; Knowles and Wilkins, 1998; Leyendecker et al., 2005).

Birds kept under extensive or free-range housing systems may be prone to flight, and therefore they are more difficult to be caught. In addition, feeder and water troughs in the houses will have to be raised or moved out of the way just before the commencement of catching and moving birds. The total duration of deprivation of food and water would vary at least according to the number of birds in the house, number of available operators and their skill levels, chosen method of killing and available resources. Division of large flocks of birds into smaller groups of more manageable size would be helpful to minimise the duration of the catching and then of the food and water deprivation.

3.3.3. Related hazards and welfare consequences

Even if birds are handled to be killed, during this process good animal welfare should be ensured through prevention of the hazards and mitigation of the welfare consequences.

The hazards identified during this process are: 'People entering the house', 'Rough handling of the birds', 'Inversion', 'Manual restraint' and 'Unexpected loud noise'. These hazards can cause pain, fear and distress, as welfare consequences to the birds. Birds can experience pain and fear due to the exposure to the hazards related to handling at all stages of the killing on-farm.

The hazards identified during 'handling', the relevant welfare consequences and related ABMs, origins of hazards, preventive and corrective measures are reported in Table 8.

3.4. Stunning/killing methods for poultry

3.4.1. Introduction on stunning/killing methods and related restraint

According to Council Regulation (EC) No. 1099/2009, 'stunning' means any intentionally induced process that causes loss of consciousness and sensibility without pain, including any process resulting in instantaneous death. Birds subjected to reversible (simple) stunning methods should be killed by using another method (e.g. cervical dislocation).

The list of methods used for on-farm killing with indication whether they are stunning or/and killing methods is reported in Table 3. This list is based on the understanding that methods used for slaughter (see e.g. Raj, 2004) can also be used for on-farm killing and the knowledge of the WG experts as the most frequently used methods for on-farm killing. However, it might not be exhaustive in a world-wide context.

Each method will be also described in detail in the following section (see below).

According to Council Regulation (EC) No. 1099/2009, 'restraint' means the application to an animal of any procedure designed to restrict its movements sparing any avoidable pain, fear or agitation to facilitate effective stunning and killing.

Restraint is a pre-requisite to killing birds and using mechanical or electrical methods. Individual birds may be restrained manually or in a metal cone or shackle (e.g. for electrical waterbath stunning/killing). For mechanical methods, manual restraint may be applied by one operator holding an individual bird by the legs, while the other operator performs shooting with a captive bolt gun. Details on specific ways for restraining birds will be provided in the relevant stunning/killing method section below.

Table 3: List of the main methods used for on-farm killing with indication whether they are stunning or/and killing methods^(a)

Method	Stunning	Killing
Electrical		
Waterbath	Yes	Yes
Head only	Yes	No
Head to body	Yes	Yes
Modified atmospheres		
Whole house gassing	Yes	Yes
Whole house gassing with gas-filled foam	Yes	Yes
Gas mixtures in containers	Yes	Yes
Low atmospheric pressure	Yes	Yes

Method	Stunning	Killing
Mechanical		
Captive bolt	Yes	Yes
Percussive blow to the head	Yes	Yes
Cervical dislocation	No	Yes
Maceration	No	Yes
Lethal injection	Yes	Yes

(a): Specific parameters required to achieving stunning and killing are described in the section of each method (Sections 3.4.2.1 to 3.4.5).

Exposure of birds to modified atmospheres, electrocution using waterbath, killing by using mechanical methods and lethal injection are practised widely and each method has animal welfare advantages and disadvantages (see reviews by Gerritzen and Lambooij, 2004; Raj et al., 2006; Gerritzen and Gibson, 2016). Some methods can be applied *in situ* to kill an entire house of birds (e.g. whole house gassing) or in batches outside the house (e.g. containerised gassing), whereas some methods could only be applied to individual birds (e.g. captive bolt stunning). Due to this, the hazards and animal welfare outcomes also vary. Birds subjected to reversible stunning methods (e.g. head-only electrical stunning) must be killed by a killing method (e.g. cervical dislocation, neck cutting).

For all methods, it is important to ensure that all birds are dead before carcass disposal (e.g. transport to the rendering plant, buried, etc.). If some birds are not dead, a back-up killing method should be applied. Failure to induce cardiac arrest can be recognised from the presence of at least one potential sign of life as described in EFSA AHAW Panel (2013) (presence of muscle tone, breathing, eye reflexes and absence of dilated pupils). Induction of cardiac arrest produces relaxed carcasses that can be recognised from drooping wings and dilated pupil. All these aspects should be included in an SOP.

3.4.2. Electrical methods

Three electrical stunning/killing methods exist: (i) waterbath; (ii) head only; and (iii) head to body. Waterbath stunning is the only electrical method that has been used for killing big batches of poultry on-farm for disease control. However, head-only electrical stunning can be used if the equipment is available (e.g. used for on-farm slaughter for human consumption; see EFSA AHAW Panel, 2019). Neck cutting (or another killing method, e.g. cervical dislocation) is mandatory in birds subjected to effective head-only electrical stunning and in birds exposed to waterbath stunning with current parameters that do not guarantee cardiac arrest at stunning in all the birds.

3.4.2.1. Waterbath

Process description

This method involves manually catching and moving birds outside their house and hanging the birds on a moving shackle line that carries birds through an electrified water bath (see Figure 3).

This method can be used for large-scale killing, but not for individual killing (see Table 2); it is a stunning and, if applied with certain parameters, a killing method for poultry (see Table 3).

Electrocution using a waterbath stunner requires shackling birds and the shackle size should be appropriate to the size of the birds. In this sense, the width of the metal shackles should be enough to provide good electrical contact without causing excessive compression of the legs.

Electrocution (leading to onset of death) using electrical waterbath stunners supplied with a 50 Hz sine wave alternating current (AC) has been used (Gerritzen and Lambooij, 2004). The electrical water bath stunner may contain many birds at the same time and, as birds enter and leave a stunner supplied with a constant voltage, they form a continuously changing resistance (Sparrey et al., 1992, 1993). Under this situation, according to Ohm's law, each bird will receive a current inversely proportional to the electrical resistance or impedance of the birds. The effective electrical impedance can vary between chickens, usually between 1,000 and 2,600 Ohms in broilers and 1,900 and 7,000 Ohms in layer hens (Schutt-Abraham et al., 1987; Schutt-Abraham and Wormuth, 1991). In this situation, birds with high electrical resistance would not receive a minimum current necessary to die. The minimum current necessary to induce cardiac arrest in a water bath varies according to the species, among other factors such as depth of immersion, cleanliness of shackles and tightness of contact between the legs and metal shackle.



Figure 3: Illustration of waterbath stunner that can be used for on farm killing of poultry. Source: kindly provided by Berg C

Council Regulation (EC) No. 1099/2009 stipulates certain minimum currents for stunning poultry with a waterbath (see EFSA AHAW Panel, 2019, Table 2).

However, for on-farm killing, these minimum currents should be delivered using electrical waterbath stunners supplied with 50 Hz sine wave AC, which is more effective in inducing cardiac ventricular fibrillation at stunning leading to death. The duration of exposure to current should be at least four s. However, some birds in a multiple bird waterbath stunner may not receive sufficient current to suffer cardiac ventricular fibrillation, and therefore, neck cutting or cervical dislocation at the exit of the stunner is an option to ensure death.

The Humane Slaughter Association (HSA, 2017a) in the UK recommends in their guidelines for on-farm killing for disease control purposes using the minimum current of 400 mA and waveform of 50 Hz (AC) to induce effective cardiac arrest (killing) in chicken, guinea fowl, duck and geese. Lower currents have been shown to be effective in inducing cardiac arrest in chickens (Gregory and Wotton, 1990; Gregory et al., 1995). However, these studies involved an individual bird waterbath in laboratory situation. For overcoming the complexity of the on-farm killing situation and considering the use of multiple bird waterbath, the EFSA AHAW Panel agrees with the position of HSA to recommend the use of a minimum current of 400 mA to ensure that 100% of birds are effectively killed.

Related hazards and welfare consequences

The hazards identified during this process are: 'Inversion', 'Shackling', 'Inappropriate shackling', 'Pre-stun shocks', 'Poor electrical contact', 'Inappropriate electrical parameters', which can cause the following welfare consequences to the birds: 'Not dead', 'Consciousness'²¹ or 'Pain' and 'Fear'.

The hazards identified for electrical waterbath stunning/killing, with relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 9.

3.4.2.2. Head only

Process description

This method is applied to birds individually restrained manually, in a cone or – less common in on-farm situations – in shackles (Figure 4). However, it can be used also for large-scale killing (see Table 2).

This method produces reversible stunning in birds and is hence used for stunning before applying other killing methods (see Table 3) such as bleeding or cervical dislocation. In theory, it could be

²¹ In the stunning/killing context, the lack of unconsciousness (i.e. consciousness) is a welfare issue (negative welfare consequence) as it allows birds to feel fear, pain and distress during the killing procedure (see Section 3.7).

combined with a second current application to induce cardiac fibrillation, but this is not applied in practice to the knowledge of the EFSA WG experts.

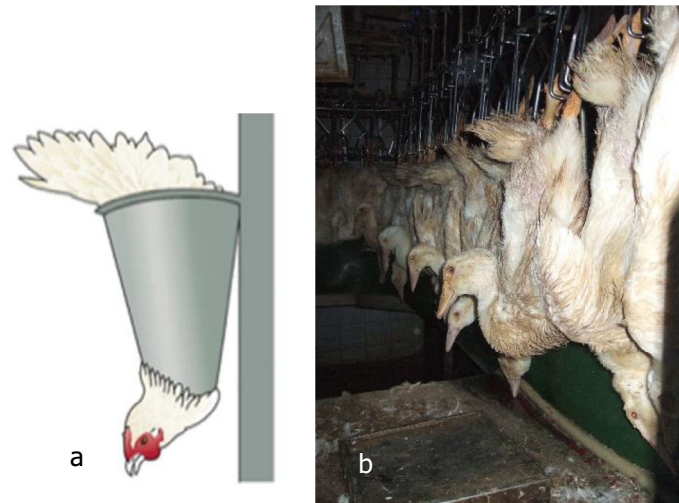


Figure 4: Birds restrained in (a) a cone, or (b) in shackles. Source: (a) European Commission (2018a); (b) kindly provided by Raj ABM

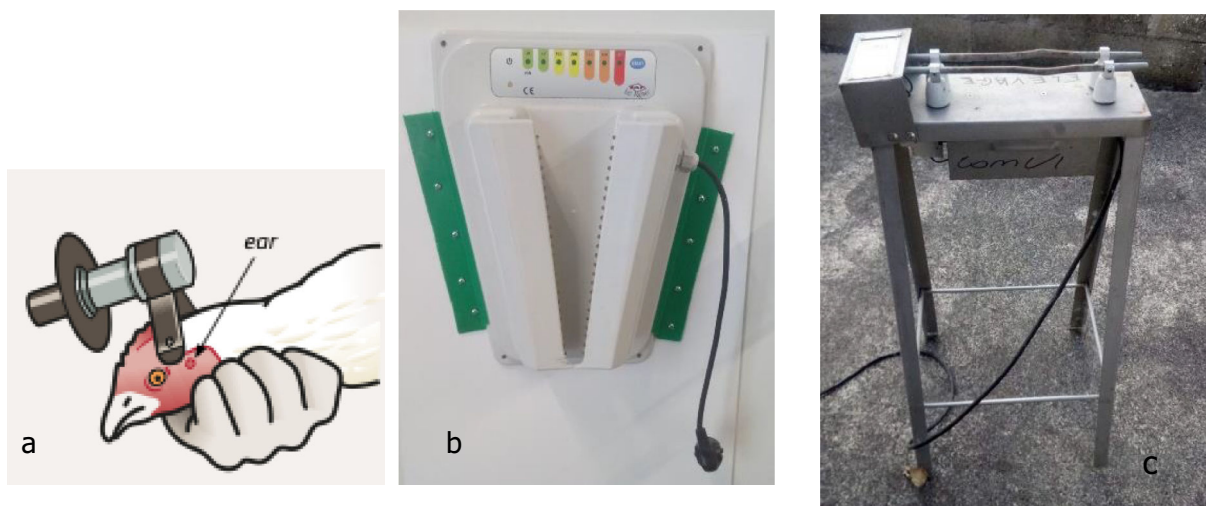


Figure 5: (a–c) Examples of devices used for on-farm head-only electrical stunning. Source: (a) European Commission (2018b); (b and c) Anses

Head-only electrical stunning is based on the principle that passage of an electric current of sufficient magnitude (through the brain of the bird should induce generalised epilepsy, rendering these temporarily and reversibly unconscious). Head-only electrical stunning is applied using two electrodes on either side of the bird's head, such that they span the brain (Figure 4). Birds can be restrained either manually or placed in a cone before stunning.

According to the current Council Regulation (EC) No. 1099/2009, the minimum electrical currents for head-only electrical stunning are 240 mA for hens and broiler chickens, and 400 mA for turkeys. A minimum current of 600 mA delivered using a 50 Hz sine wave AC is recommended for ducks (EFSA, 2006).

The exposure time should be long enough to ensure that birds show proper signs of unconsciousness, usually indicated by tonic seizure activity (rigidly extended legs).

Ideally, head-only electrical stunning should be performed using a constant current source and the minimum current should be applied for at least 4 s. However, most of the head-only electrical stunning equipment used around the world is supplied with a constant voltage and in some countries, this is

limited to 110 volts for operators' health and safety reasons. Such a low voltage may not be sufficient to deliver the minimum currents necessary to induce immediate loss of consciousness, especially when the electrical resistance in the pathway is too high, for example in waterfowl (ducks and geese).

To ensure that proper and reliable stunning is achieved, the legislative requirements mentioned above should be complied with. This includes the requirement for a visible amp meter. Furthermore, it is crucial that the bird's head is correctly positioned in the equipment for a sufficient period of time (minimum 4 s). In addition to this, the electrodes must be cleaned from burnt feather debris at regular intervals, to facilitate good electrical contact.

Head-only electrical stunning is a reversible stunning method and therefore a killing method (e.g. cervical dislocation or bleeding) should be applied. It is important to ensure that all birds are unconscious before applying the killing method. Signs of consciousness are the presence of wing flapping, breathing, eye reflexes, spontaneous swallowing and head shaking. Death should be confirmed before carcass disposal (EFSA AHAW Panel, 2013).

Related hazards and welfare consequences

The hazards identified during this process are: 'Manual restraint', 'Inversion', 'Poor electrical contact', 'Too short exposure time', 'Inappropriate electrical parameters', or 'Prolonged stun to stick interval', which can cause the following welfare consequences to the birds: 'Consciousness', 'Pain' and 'Fear'.

The hazards identified in cases of 'Head-only electrical stunning', relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 10.

3.4.2.3. Head to body

Process description

This method can be used for large-scale killing and for individual killing (see Table 2); it is a stunning and killing method for poultry (see Table 3).

Head-to-body electrocution using dry electrodes is a method to induce immediate unconsciousness followed or accompanied by cardiac fibrillation resulting in death. Birds can be restrained in a cone or on shackles to apply electrodes that span the brain and the heart. When electrodes will not span the brain and heart at the same time a current should be applied to the brain first to render the bird unconscious before an electrical current is applied to the body. A current of sufficient magnitude (400 mA; HSA, 2017a) delivered using AC with a frequency of 50 Hz should be applied long enough to ensure death. Minimal exposure time should be 4 s. This method is comparable with the electrical waterbath method (see Section 3.4.4.1) with the difference that birds are killed individually. A device used for head-to-body electrical killing is reported in Figure 6.



Figure 6: Head-to-body electrical killing device. Source: Top-equipment B.V.

Related hazards and welfare consequences

The hazards identified during this process are: 'Inversion', 'Shackling', 'Inappropriate shackling', 'Poor electrical contact', 'Too short exposure time' and 'Inappropriate electrical parameters', which can cause the following welfare consequences to the birds: 'Not dead', 'Consciousness', 'Pain' and 'Fear'.

The hazards identified for 'head-to-body killing method', relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 11.

3.4.3. Modified atmosphere methods

Four main modified atmosphere methods exist: (i) whole house gassing, (ii) gas-filled foam, (iii) gassing in containers, and (iv) LAP. All of these can be used as stunning and killing methods, and with appropriate settings.

3.4.3.1. Whole house gassing

Process description

This method can be used for large-scale killing, but not for individual killing (see Table 2); it is a stunning and killing method for poultry (see Table 3).

In recent years, whole house gassing using carbon dioxide has been applied on a large scale especially for the control of HPAI. The advantages of different gases and gas mixtures as well as the different gassing methods have been reviewed previously (Gerritzen, 2006; Gerritzen et al., 2006; Raj et al., 2006; Raj, 2008; Sparks et al., 2010; McKeegan et al., 2011). The main advantages of whole house gassing are that no handling of birds is required, the method can be fast, has the potential to kill birds in very large numbers (all in the barn at the same time), and there is almost no contact of humans with infected birds and materials, which improves biosecurity. From an animal welfare point of view, the main advantage is that animals are killed in their housing facilities without being separated from their companions or being handled, moved or restrained.

From literature reviews cited just above, it appears that carbon dioxide is the most appropriate gas to use for whole house gassing. Carbon dioxide is widely available in large amounts and, due to its chemical properties, it is a gas that can be distributed and maintained in a closable building. The negative effect (aversive reactions), seen in birds that are rapidly or instantly exposed to high carbon dioxide concentrations when conscious, does not appear in this case. This is because during whole house gassing procedures carbon dioxide will increase gradually, hence inducing unconsciousness before animals are exposed to the high levels of carbon dioxide causing aversion (Gerritzen et al., 2007). Other options for whole house gassing are carbon monoxide and nitrogen. The use of carbon monoxide must be discouraged because it is potentially dangerous when applied under on-farm situations that are difficult to control. This is the case, for example, of whole house gassing, when absolute sealing can be difficult to achieve (Gerritzen et al., 2006). The use of nitrogen to create an anoxic situation as an alternative to carbon dioxide is not suitable for whole house gassing because it dissolves in the air very rapidly. Furthermore, poultry buildings cannot generally be sealed to an extent to create an atmosphere with less than 2–4% of oxygen, which is necessary for efficient killing of the birds.

The disadvantage of whole house gassing is that the procedure is less controllable. The buildings need to be closable and sealable to a large extent, but there will always be a certain leakage of gas. Therefore, it is very important to measure gas concentrations (or for nitrogen: measure residual oxygen) at critical points throughout the whole building during processing. After venting out the gas, the effectiveness of the gassing procedure should be checked. Birds, if any, that survived the procedure should be rendered unconscious and killed as soon as possible. How to kill survivors depends on the number of birds: small numbers can be killed by lethal injection, and cervical dislocation when unconscious. For larger numbers of birds, containerised gassing or re-gassing the whole building can be considered.

During whole house gassing the carbon dioxide concentration is gradually increased from 0% to at least 45% in the air, well above the level of the upper row or platform level birds' heads. The time taken to reach this lethal level of carbon dioxide will vary according to several factors, for example the size of the house (cubic space to be filled), injection rate or the extent of sealing and leakage from the houses. The turbulence created by gas injection lasts several minutes. Although research has shown that chickens die within 2–3 min when exposed individually to 45% carbon dioxide in air, the house is usually left undisturbed for longer than 20 min for the denser-than-air gas to settle from the floor level and upwards, and the birds to die due to the inhalation of the gas. The gas is then emptied by

opening the doors/switching on the ventilation systems and further gas evacuation time lets solid carbon dioxide (dry ice), if any, vaporise.

The gas is injected from a tank on a lorry by one or more injection points into the shed from where it distributes. The way carbon dioxide is administered to a poultry house strongly influences possible animal welfare risks (Raj, 2008).

Carbon dioxide can be injected into a poultry house in liquid form, from which it will immediately vaporise inside the house due to the higher temperature in the house. In this situation, when using a single injection point, gas concentration will not increase simultaneously through the whole building and implies that not all animals will be affected by the gas at the same time. Birds in the vicinity of the gas entry point will be instantly exposed to relatively high carbon dioxide concentrations, whereas those remaining away from the gas inlet will be exposed to rising concentrations of carbon dioxide somewhat later. A negative aspect of this method is that the temperature around the birds can drop below freezing (e.g. -80°C) (Sparks et al., 2010) and remain at that level for several minutes. However, Sparks et al. (2010) argued that birds would be rendered unconscious due to increasing concentrations of the gas before such a low temperature is reached inside the house.

However, we do recommend not to use direct injection of liquid gas in the barn.

Freezing of gas regulator and frosting of delivery systems during containerised gassing with a mixture of 80% argon and 20% CO_2 can happen as well (Raj et al., 2008a). A proportion of liquid carbon dioxide injected into the house will also turn to solid carbon dioxide (dry ice) and accumulate in small pockets when the liquid falls to the ground. Therefore, conscious birds can suffer from extreme cold or freezing. If carbon dioxide is injected under pressure at multiple injection points the temperature drop may not be more than $10\text{--}15^{\circ}\text{C}$. High pressure multi-injection point leads to a gradual increase of the carbon dioxide concentration in the whole building, which will decrease the risk of exposure of conscious birds to high carbon dioxide concentrations.

Recently, a method of pre-heating the liquid carbon dioxide up to a temperature of $15\text{--}25^{\circ}\text{C}$ has been applied. An advantage of this method is that the carbon dioxide is converted into the gas phase before entering the building. This furthermore implies that the temperature in the poultry house will not drop out of the thermal comfort zone and that the gas will distribute very evenly through the building. A disadvantage of this method is the larger amount of equipment and investment that is required.

The ventilation system needs to be switched off during killing of birds in houses using gas, just before the injection of gas. Ventilation shutdown should not be used as a killing method and prolonged periods of ventilation shutdown before injection of gas can lead to heat stress.

For whole house gassing, it is important to ensure that all birds are dead before evacuating these from the barn, since gas can be delivered again if there is failure involving large quantities of birds.

Related hazards and welfare consequences

The hazards identified during this process are: 'Unexpected loud noise', 'Too high temperature', 'Too low temperature', 'Too short exposure time', 'Too low gas concentration', 'Jet stream of gas at bird level', which can cause the following welfare consequences to the birds: 'Not dead', 'Consciousness', 'Pain', 'Fear' and 'Respiratory distress'.

The hazards identified for 'whole house gassing', relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 12.

3.4.3.2. Whole house gassing with gas-filled foam

Process description

This method involves administration of gas-filled foam into the house to create an atmosphere depleted of oxygen to stun and kill the birds. This method can be used for large-scale killing but not for individual killing (see Table 2); it is a stunning and killing method (Table 3).

Gas foam bubbles can be filled using 100% nitrogen gas that results in a strong anoxic atmosphere. Due to the very low residual oxygen concentration ($< 1\%$) birds will be rendered unconscious very rapidly and die very quick after losing consciousness (McKeegan et al., 2013). Similarly, foam created using 100% CO_2 has also been tested for killing poultry in houses (Gerritzen and Sparrey, 2008; Turner et al., 2012; Gurung et al., 2018a)

Foam with an expansion ratio²² between 250:1 and 350:1 appeared to be the optimum compromise between foam stability, water content, bubble size and wetness, so that the airways are

²² Expansion is the ratio between the foam volume obtained and the volume of the foaming solution used (Wu et al., 2015).

not blocked and suffocation does not occur. Large bubble size (higher than 10 mm diameter) helps to deliver more gas above the bird's heads level in the house (see Figure 7). With the combination of this expansion ratio and large bubble size dry foam can be created preventing the occlusion of trachea or drowning of the birds due to high water content (Gerritzen and Sparrey, 2008; Raj et al., 2008b; McKeegan et al., 2013; Gerritzen and Gibson, 2016).

When the bubbles bust (due to contact with the surface or the animals) and release the gas, birds are exposed to anoxic atmosphere that induce unconsciousness and death. The movement of the birds will help the busting of the bubbles.

The nitrogen released from the bubbles can then mix with air resulting in increases in the oxygen levels and birds surviving the treatment. Therefore, the foam production capacity is required to be much larger than the rates of breakdown of bubbles and dilution of the gas and that may not be possible in large poultry houses.

Gas-filled foam can be applied in open buildings that are not suitable for whole house gassing. The foam will not easily penetrate through mesh wire cages and fences therefore the method is not applicable in some aviary systems and in systems using cages. Research has shown that high expansion nitrogen foam is effective in killing different poultry species (chickens, turkey and ducks) (Gerritzen et al., 2010).

In the USA, air filled high-density foam with high water content (firefighting foam) has been tested and conditionally approved by the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) for use with floor-reared poultry. A blanket of high-density foam is created and spread to cover all the birds. The dense foam blocks the airways resulting in death by suffocation (Benson et al., 2007). In general, death due to drowning in fluids or suffocation by occlusion of the airways is not accepted as a humane method for killing animals, including poultry.



Figure 7: Gas-filled high expansion foam. Source: Livetec systems UK

Related hazards and welfare consequences

The hazards identified during this process are: 'Unexpected loud noise', 'Too short exposure time', 'Too small bubble size' and 'Low foam production rate', which can cause the following welfare consequences to the birds: 'Not dead', 'Consciousness', 'Pain', 'Fear' and 'Respiratory distress'.

The hazards identified for 'whole house gassing with gas-filled foam', relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 13.

3.4.3.3. Gas mixtures in containers

Process description

Killing of birds with gas mixtures outside the house is performed using different gas mixtures and equipment, such as: (i) gassing in containers; (ii) containerised gassing systems; and (iii) exposure of birds in containers to high expansion foam created using gas mixtures. These methods can be used for large-scale killing and for individual killing (see Table 2); they are stunning and killing methods for poultry (see Table 3).

Gassing in containers

This method is the exposure of batches of birds to high concentrations of carbon dioxide (CO₂) or a mixture of inert gases and CO₂, contained in waste bins, skips or bags. Equipment for killing of individual turkeys on farm has been developed.²³

In this method, birds are manually caught and carried by their legs out of the house in small batches and dropped into the container connected to gas cylinders (see Figure 8). The time and distance birds are carried depend on the location of the gas containers on the premises and on the type and size of the housings. The time to onset of death in birds is related to the concentration of the gas and the duration of the exposure, i.e. lower concentration requires longer exposure (Raj and Gregory, 1990a,b). Each batch of birds dropped in the containers (one layer) should be allowed sufficient time to die before adding the next batch of birds (Webster and Collett, 2012). For example, cessation of wing flapping and of visible movements in birds can be used as a proxy to ascertain death, or at least unconsciousness (Raj and Gregory, 1990b). Throwing batches of live birds into containers filled with a gas mixture could seriously compromise their welfare due to the small size of the hole through which batches (handful) of birds will have to be applied. Some birds dropped into the container may die as a result of compression and suffocation caused by more birds being dropped into the container without a sufficient interval between two consequent batches of birds. In addition, each batch of birds dropped into the container will displace equal volume of gas into the atmosphere, which will lead to fluctuating concentrations.



Figure 8: Equipment used for gassing in containers. Source: kindly provided by Raj ABM

Containerised gassing systems

This is the exposure of birds in transport containers to gas mixtures.

It is thought that stress on birds associated with live bird handling associated with the methods described above could be eliminated or minimised by crating these immediately after catching and then exposing the crate full of birds to a gas mixture. A containerised gas killing system known to exist in Europe involves loading crates or modules full of birds into a gas-tight metal container fitted with a gas delivery system fitted at the bottom and gas sampling/monitoring tubes fitted at the top, closing the doors and delivering the gas mixture until the desired concentrations are attained (see Figure 9), maintaining the gas concentrations until all the birds are dead, opening the doors to expel the gas, removing the crates and confirming death of all birds before carcass disposal.

Practical experience indicated that a residual oxygen (O₂) of 5% by volume or less created using a mixture of 80% by volume of argon and 20% by volume of carbon dioxide will cause death in pheasants, quails, chickens and turkeys within 2 min. Ducks and geese require residual O₂ of 2% by volume or less to cause death within 2 min of exposure to this gas mixture (Raj et al., 2008a).

²³ https://www.poultryworld.net/Health/Articles/2019/4/Gas-stunning-for-small-poultry-operations-445944E/?cmpid=NLC|pigprogress|2019-09-26|Gas_stunning_for_small_poultry_operations



Figure 9: A containerised gassing system. Source: kindly provided by Raj ABM

Exposure of birds in containers to high expansion foam created using gas mixtures

The equipment used in this method is similar to the one described in the previous section (exposure of birds in containers to gas mixtures), but the gas mixture, usually nitrogen, is administered as high expansion foam. Birds are placed in a container and the container is filled with a large flow of high expansion gas-filled foam. The flow of foam should be large enough to keep the birds covered during wing flapping or convulsions that will occur due to rapid induction of the anoxic situation.

Related hazards and welfare consequences

The hazards identified during 'gas mixtures in containers stunning and killing' are: 'Too low temperature', 'Inhalation of high CO₂ concentration', 'Overloading', 'Too short exposure time' and 'Too low gas concentration', which can cause the following welfare consequences to the birds: 'Not dead', 'Consciousness', 'Pain', 'Fear' and 'Respiratory distress'.

The hazards identified in this process, relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 14.

3.4.3.4. Low atmospheric pressure stunning/killing (LAPS)

Process description

This method can be used for large-scale killing, but not for individual killing (see Table 2); it is a stunning and killing method for poultry (see Table 3).

In this method, broilers are placed in containers into the decompression chamber and are exposed to gradual decompression with a reduction of available oxygen to less than 5% (Martin et al., 2016a,b, c; Holloway and Pritchard, 2017). This method was found to be acceptable based on the published scientific evidence only for broiler chickens up to 4 kg live weight. During the first phase, the decompression rate must not be greater than equivalent to a reduction in pressure from standard sea level atmospheric pressure of 760 Torr to 250 Torr for at least 50 s. During a second phase, a minimum standard sea level atmospheric pressure of 160 Torr should be reached within the following 210 s. The pressure time curve should be adjusted to ensure that all birds are irreversibly stunned and killed within the cycle time (EFSA AHAW Panel, 2017).

A mobile LAPS system is available and can be used for on-farm killing (Figure 10).



Figure 10: Mobile LAPS system. Source: Technocatch LLC, USA

Related hazards and welfare consequences

The hazards identified during this process are: 'Too fast decompression', 'Expansion gases in the body cavity' and 'Too short exposure time', which can cause the following welfare consequences to the birds: 'Not dead', 'Consciousness', 'Pain' and 'Respiratory distress'.

The hazards identified for 'LAPS', relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 15.

3.4.3.5. Modified atmospheres for day-old chicks

Process description

Modified atmosphere methods are used for day-old chicks for large-scale killing, but not for individual killing (see Table 2), as stunning and killing methods (see Table 3).

Exposure to high concentrations of carbon dioxide (at least 75% by volume in air), inert gases such as argon or nitrogen containing less than 2% residual oxygen or a mixture of inert gases and carbon dioxide is routinely used to kill unwanted day-old chicks in hatcheries (Raj and Whittington, 1995; HSA, 2001; AVMA, 2016). The duration of exposure to gas mixtures required to kill chicks varies according to the species and concentrations of carbon dioxide or residual oxygen levels. The HSA Guidelines recommend the exposure times reported in Table 4 to 90% carbon dioxide in air or inert gases with less than 2% residual oxygen.

Table 4: Exposure times recommended for different species of day-old poultry when exposed to 90% carbon dioxide in air or inert gases with less than 2% residual oxygen (HSA, 2001)

Species	Time
Chicks	3 min
Turkey poults: sickly, injured or deformed	3 min
Turkey poults: healthy	5 min
Ducklings and goslings	5 min

On-farm killing of chicks with this method involves their exposure to gas mixtures contained in bins or large skips. Under this situation, batches of chicks will be added to containers prefilled with a chosen gas mixture. It is important to ensure that each batch of chicks is allowed sufficient exposure time to die before adding the next batch in another layer. Chicks contained in trays or crates may also be lowered into the containers filled with gas mixtures. In this situation, it is important to ensure that a layer of chicks is evenly distributed and all of these exposed to the gas mixture.

More recently, exposure of chicks to LAP has been evaluated and reported to be a suitable method (Gurung et al., 2018b). In this study, preliminary trials showed that a negative air pressure of 15.3 kPa (1 kPa = 7.5 Torr) would result in 100% mortality and, therefore, the experimental chicks were

subjected to a reduction in chamber pressure from 100.12 kPa to 15.3 kPa over 80 s and then held in the chamber for 5 min, resulting in death.

When day-old chicks are killed with a modified atmosphere method, it is important to ensure that birds are not showing any sign of life before adding the subsequent batch of chicks.

Related hazards and welfare consequences

The hazards identified during 'Gas mixtures in containers' and 'LAPS' for day-old chicks, relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures, are the same that apply to the adults of the same species, and, therefore, are reported in Tables 14 and 15.

3.4.4. Mechanical methods

The main mechanical stunning/killing methods usable on-farm are: (i) captive bolt; (ii) percussive blow; (iii) cervical dislocation; (iv) neck cutting; and (v) maceration. The first four methods can be only applied to individual animals for individual stunning/killing. Therefore, the main preventive action consists of training the staff in how these methods should be applied manually.

Mechanical methods can be used as stunning and killing methods, whereas some of these are only killing methods.

Martin et al. (2019) examined three novel mechanical killing devices: Modified Armadillo (MARM; a brain piercing device), Modified Rabbit Zinger (MZIN; a penetrating captive bolt device originally designed to kill rabbits; 6 mm bolt diameter, 2.5–3.5 cm penetration depth), a novel mechanical cervical dislocation device (NMCD; a mechanical method that closely resembled the manual cervical dislocation (MCD) technique); and the traditional MCD method (carried out according to HSA Guidelines). The four killing methods were tested on 230 (layer hens and broiler) chickens. Post-mortem examination was carried out immediately after confirmation of death in all the birds to establish treatment-specific post-mortem lesions. The percentage for successfully causing death (defined as only one application attempt with no signs of recovery) in birds was MCD = 100.0%, NMCD = 96.0%, MZIN = 75.0% and MARM 48.7%. The authors could not report whether the methods produced immediate unconsciousness because the objective of the study was to investigate these as killing methods and ascertain the incidence of death.

3.4.4.1. Captive bolt

Process description

This method can be used for both large-scale killing and individual killing (see Table 2). It requires individual handling of the birds and restraint for correct application. Handling of live birds may cause fear in and carries a risk of painful injuries to the birds. It was used in the UK during an outbreak of low pathogenic avian influenza to kill birds in small farms and before the arrival of containerised gassing equipment in large farms. Captive bolt is stipulated in Council Regulation (EC) No. 1099/2009 as a reversible (simple) stunning method (see Table 3) that should be followed by a killing process (e.g. cervical dislocation) to ensure death. However, scientific evidence has demonstrated that if captive bolt is properly applied in poultry, stunning is already enough to kill the animal (Raj and O'Callaghan, 2001; Erasmus et al., 2010a,b; Gibson et al., 2018). It has been suggested that the appropriate specifications for captive bolt stunning of broilers are a minimum of 6 mm bolt diameter driven at an air pressure of 827 kPa to a penetration depth of 10 mm (Raj and O'Callaghan, 2001). Other authors concluded that the use of captive bolts in turkeys, ducks and geese is effective in inducing death, when properly applied involving similar parameters as in broilers (Erasmus et al., 2010a,b; Sparrey et al., 2014; Gibson et al., 2018). In any case, death should be confirmed after shooting with the captive bolt gun to eliminate the risk of birds surviving due to human error or equipment failure, and, if animals are not dead, a back-up killing method should be applied.

Captive bolts can either be penetrative or non-penetrative and powered by cartridge, compressed air or spring loaded. An operator performing shooting with captive bolt must restrain the head by gently holding the beak with one hand and placing the gun on the bird's head with the other hand (European Commission, 2017, 2018b) (Figure 11). Manual restraint may be applied by one operator holding the individual bird by the legs, while the other operator performs shooting with a captive bolt gun. Captive bolt guns should be placed firmly and perpendicularly on the parietal bones of restrained birds before being fired. Shooting of birds with both types of captive bolts leads to severe damage to skull bones and the bolt diameter and penetration depth are sufficient to cause damage to the brainstem, leading to irreversible loss of consciousness and death.

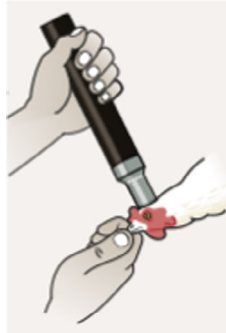


Figure 11: Restraint and application of captive bolt stunning. Source: European Commission (2018b)

Erasmus et al. (2010a,b) assessed the effectiveness of a commercially manufactured (Zephyr), pneumatically operated (airline pressure of 758–827 kPa) non-penetrating captive bolt (25 mm diameter, 17 mm protrusion beyond the barrel) for on-farm euthanasia of turkeys and compared this with blunt force trauma, MCD and mechanical cervical dislocation (crushing of the neck) using a burdizzo. The results indicated that the Zephyr, discharged twice in immediate succession, and blunt trauma (single hit) were similarly effective at consistently causing immediate insensibility. Conversely, neither method of cervical dislocation caused immediate insensibility. Several studies have shown that cervical dislocation induced by neck crushing or brain piercing does not lead to immediate loss of consciousness and therefore should not be used on conscious birds (Erasmus et al., 2010b; Martin et al., 2016d, 2018a). It is recommended that birds are restrained in a bleeding cone, to contain wing flapping.

The power of the cartridge, compressed air line pressure or spring should be appropriate for the species and size of birds. Damp cartridges will fail to stun the birds effectively. Operator fatigue and overheating of the gun due to repeated firing can all lead to poor welfare. There should be sufficient bolt guns such that they can cool between operations, and they should be cleaned and maintained according to manufacturer's instruction.

The diameter and strength and penetration depth of the gun are important parameters to ensure efficacy of the stun. Martin et al. (2019) evaluated a captive bolt device with 6 mm diameter, penetration depth of 2.5–3.5 mm and delivering an impact of energy of 11.87 J and reported only 75% success in causing death in chickens. If the bolt is too narrow (less than 6 mm), or the velocity is too low, there will not be enough energy transfer to the head to induce effective stunning (Raj and O'Callaghan, 2001; EFSA, 2004; Karger, 1995; Gibson et al., 2018; Woolcott et al., 2018a).

There are spring-operated captive bolt guns on the market that are specifically designed for stunning and killing poultry such as ducks, geese and turkeys up to 16 kg.²⁴

In the spring-loaded captive bolt, when the bolt remains extended, it can be used to swiftly destroy the brain immediately, provided the captive bolt first rendered the bird unconscious. Figure 12 provides an example of a spring-loaded captive bolt.



Figure 12: Example of a spring-loaded captive bolt. Source: kindly provided by Velarde A.

²⁴ <https://www.msschippers.com/dick-captive-bolt-gun-for-small-animals-3409913.html>

Related hazards and welfare consequences

The hazards identified for the 'captive bolt' are: 'Manual restraint', 'Inversion', 'Incorrect shooting position' and 'Incorrect captive bolt parameters', which can cause the following welfare consequences to the birds: 'Not dead', 'Consciousness', 'Pain' and 'Fear'.

The hazards identified during this process, relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 16.

3.4.4.2. Percussive blow to the head

Process description

This method can be used for large-scale killing (with the limitations reported below) and individual application (see Table 2) and it is a stunning and killing method in poultry (Table 3).

It is performed by holding a bird by its legs, placing its head on a hard surface and delivering a blow to the back of the head with a hard object (European Commission, 2018b). The percussive blow delivered, using a metal pipe, bat or a solid wooden stick, to the head with sufficient force and accuracy will lead to brain concussion and death.

Electroencephalographic (EEG) data showed that the blunt trauma induced by a single, sufficiently strong hit placed in the fronto-parietal region of the head of broilers, broiler breeders and turkeys weighing up to 16 kg led to a reduction or loss of the auditory evoked potentials (AEPs) in all groups of birds, suggestive of unconsciousness (Cors et al., 2015).

This method has been reported by Erasmus et al. (2010a,b) to be effective when performed by a trained operator. However, it is doubtful whether a percussive blow delivered to a bird held up-side-down by its legs, without resting its head on a hard surface, would be consistently effective.

Considering that the application of this method is entirely manual and prone to error, a percussive blow might be used only when no other stunning/killing method is available and, if it is used according to Council Regulation (EC) No. 1099/2009, it can be performed only on 70 birds per person per day, to avoid errors due to operator fatigue.

Related hazards and welfare consequences

The hazards identified during this process are: 'Manual restraint', 'Inversion' and 'Incorrect application', which can cause the following welfare consequences to the birds: 'Not dead', 'Consciousness', 'Pain' and 'Fear'.

The hazards identified at 'Percussive blow to the head', relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 19.

3.4.4.3. Maceration of day-old chicks²⁵

Process description

According to Council Regulation (EC) No. 1099/2009, this method can only be used for chicks up to 72 h post-hatch and for egg embryos. It is used only for large-scale killing (see Table 2) and as a killing method only (see Table 3).

Council Regulation (EC) No. 1099/2009 stipulates that maceration should result in instantaneous maceration and death of the chicks and embryos (unhatched eggs). The apparatus should contain rapidly rotating, mechanically operated blades. The capacity of the apparatus should be sufficient to ensure that all chicks are killed instantaneously, even if they are handled in a large number. Mechanical destruction of chicks should result in slurry, rather than recognisable body parts such as internal organs, legs, wings and heads, to ensure chicks that were truly macerated (HSA, 2005). Garden shredders should not be used.

When day-old chicks are killed with maceration method it is important to ensure that the speed of the equipment is appropriate for the batch size and that chicks are dead when they come out of the machine.

Related hazards and welfare consequences

The hazards identified during this process are: 'Slow rotation of blades or rollers', 'Overloading' and 'Rollers set too wide', which can cause the following welfare consequences to the birds: 'Not dead', 'Consciousness', 'Distress', 'Pain' and 'Fear'.

²⁵ 'Day-old chicks' include chicks up to 72 h of age.

The hazards identified for 'Maceration', relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 19.

3.4.4.4. Killing (and non-stunning) mechanical methods

When a simple stunning method is applied, or if birds are not being killed after the application of other methods, one of the following methods should be immediately applied to kill the unconscious animals.

Cervical dislocation following stunning

Process description

Cervical dislocation can be performed manually or mechanically:

- MCD is applicable only in birds weighing up to 3 kg. Neck or cervical dislocation, by stretching and twisting, should always result in the separation of spinal cord from the brain (AVMA, 2013; European Commission, 2018b; Woolcott et al., 2018b), in one continuous movement (HSA, 2004) (see Figure 12).
- However, it has been demonstrated that MCD even with separation of the spinal cord fails to produce immediate loss of consciousness or signs of brain concussion in all the birds tested in the study, but only in some of these; and it was concluded that birds may die due to asphyxiation (Gregory and Wotton, 1990).
- According to Council Regulation (EC) No. 1099/2009, MCD can be performed only in 70 birds per person per day, to avoid errors due to operator fatigue. However, Martin et al. (2018b) evaluated MCD in broilers, laying hens and turkeys using 12 male stockworkers and each person killed 100 birds at a fixed rate with each method. In this study, evaluation reflexes and behavioural measures indicated that cervical dislocation caused rapid loss of brain function. Importantly, there was no evidence of reduced performance with time/bird number up to 100 birds with either method. Therefore, the authors argued that neck dislocation has an important advantage in that it can be performed immediately with no equipment, and therefore this may make it preferable in some situations.



Figure 13: Illustration of manual cervical dislocation by pulling (1) and twisting (2) of the head dorsally in one continuous motion. Source: European Commission (2018b)

- Mechanical cervical dislocation can be used in birds up to 5 kg. Mechanical devices dislocate by stretching or crushing. The equipment used for cervical dislocation by stretching typically consists of a restraining cone mounted on a tripod with a neck clamp fixed to a pivot below

the cone. The bird is restrained head down in the cone and the neck placed into the clamp so that it rests just behind the head. It is essential that the bird is held firmly in the cone before applying the neck clamp. Pulling down by the neck of a bird that is too small for the device will simply pull the bird down through the cone until it is wedged and fail to dislocate the neck (Sparrey et al., 2014). The concerns presented under the MCD by stretching would apply to the mechanical application.

- Mechanical cervical dislocation by crushing at the first cervical vertebra with a pair of pliers such as 'Semark pliers' or the 'Burdizzo' has been used as cervical dislocation. Neck crushing does not sever the common carotid arteries and does not reduce its diameter. Therefore, it does not cause cerebral ischaemia and hence loss of consciousness. If the spinal cord is severed without stopping blood supply to the brain, it results in death from asphyxia (Gregory and Wotton, 1990; Martin et al., 2017). Similar conclusions were reached in studies in different species of poultry (Erasmus et al., 2010a,b,c; Sparrey et al., 2014; Martin et al., 2016d, 2018a).

On the basis of evidence presented above, cervical dislocation by stretching (manual and mechanical) does not always lead to immediate loss of consciousness in all the birds (EFSA, 2004). Considering this issue, some EU countries (e.g. Sweden) apply national legislation requesting that birds are properly stunned before being killed by neck dislocation. Therefore, it is suggested here to use cervical dislocation to kill unconscious animals (see Table 3). This method can be used for large-scale killing and individual application (see Table 2). Cervical dislocation by crushing should not be used under any circumstances.

Related hazards and welfare consequences

The hazards identified during this process are: 'Manual restraint', 'Inversion', that can cause 'pain' and 'fear' only if there is failure of the stunning method applied and recovery of consciousness; 'Incorrect application' may also occur and cause 'Not dead' and 'Consciousness' leading to 'Pain' and 'Fear'.

The hazards identified during 'cervical dislocation', relevant welfare consequences and related ABMs, origin of hazards, preventive and corrective measures are reported in Table 18.

Neck cutting (bleeding) following stunning

This process consists in severance of both carotid arteries, leading to death, through loss of blood.

As neck cutting should be avoided for biosecurity reasons during on-farm killing, cervical dislocation or other non-blood-effusive methods should be preferred for killing after application of the simple stunning method.

The hazards identified during this process are: 'Prolonged stun-to-neck-cut interval', 'Incomplete sectioning of carotids' and 'Entering the scalding tank alive'. These hazards can cause 'Consciousness' leading to 'Pain' and 'Fear'. The birds that are ineffectively stunned or those recovering consciousness can be exposed to pain also due to 'Neck cutting', and also 'Repeated cuts' and 'Stimulation of the wound'. These birds will also experience 'Fear' when 'Bled to death'. Proper stunned animals do not experience the above-reported negative welfare consequences during bleeding.

For details on the hazards identified for 'neck cutting' relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures see EFSA AHAW Panel (2019) (Table 20 on 'Bleeding following stunning').

Decapitation following stunning

Decapitation is not in the list of the stunning methods provided in the Council Regulation (EC) 1099/2009. In the USA, it has been reported as not commonly employed in the commercial slaughter of food animals, but often used for on-the-farm slaughter (AVMA, 2016).

This practice involves separation of the head from the body, by severing the neck, close to the head (Close et al., 1996) causing death through anoxia of the central nervous system and blood loss. It is performed in one cut by using a purpose-built mechanical device with a sharp blade, i.e. guillotine. The blade should be accurately placed high on the neck, ideally at the level of the first vertebra and be able to sever the entire head without needing more than one blow. Birds must be restrained to prevent these from moving away from the blade.

Research has shown that there is brain activity (visual evoked responses) for up to 30 s after decapitation in chickens (laying hens) (Gregory and Wotton, 1986). Therefore, loss of consciousness may not be immediate. During this time, animals may feel pain due to afferent stimuli from the

trigeminal nerve (EFSA, 2004). No additional data are available in poultry to report whether decapitation leads immediate loss of consciousness (due, for example, to hypovolemia).

Considering these aspects, decapitation should not be used solely but it may be used as a killing method of unconscious birds.

Brain piercing following stunning

Specifically, a brain piercing device exists that does not induce concussion of the brain; it was originally designed and developed in the UK to kill pheasants and partridges that were wounded but not killed by lead pellets during the hunting season. According to Sparrey et al. (2014), it is a scissor-type device that has a cup that holds the bird's head and a spike that, when the tool is positioned correctly and the jaws closed, penetrates between the first vertebra and the base of the skull, killing the bird by damaging the brainstem as illustrated in Figure 14.

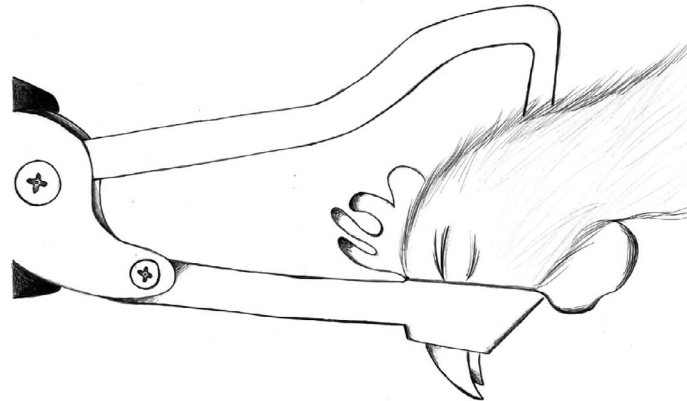


Figure 14: Illustration of a brain piercing device which operates like a pair of pliers, in which the bird's head is positioned in the cup-shaped jaw of the plier and the sharp end of the other jaw is pressed hard into the cranium through the occipital foramen (between the first vertebra and the base of the skull). Source: kindly provided by Meneghetti MM, based on a photo by J Hopkins, from Sparrey et al. (2014)

This device differs from the penetrating captive bolt in the sense that traumatic brain injury is produced without inducing brain concussion first and the speed of causing the brain injury depends upon the operators' skill.

Considering these aspects, brain piercing devices should not be used solely, but they may be used as a killing method by destroying the brain of unconscious birds.

3.4.5. Lethal injection

Process description

Killing of birds by lethal injection can only be carried out by authorised personnel. Birds should be injected with a lethal dose of anaesthetic drugs (AVMA, 2013). Whenever possible, intravenous injection of the drug is the preferred method. However, also intraperitoneal injection is also sometimes used (see Figure 15). The most commonly used drugs are barbiturates, or their derivatives administered alone or in combination with other euthanasia drugs. Other chemical agents such as T-61, a combination of embutramide, mebezonium iodide and tetracaine hydrochloride, can be used for the euthanasia of livestock. However, the humaneness of this has been questioned. Concerns with T-61 include the potential for pain and irritation during rapid injection, and paralysis that can result in the suppression of respiration before the onset on unconsciousness (EFSA, 2004). Because of these concerns, T-61 is no longer manufactured in the United States (AVMA, 2013). For these reasons, it is not recommended to be used for conscious animals.

Lethal injection can be used mainly for individual killing as birds have to be treated individually (see Table 2). Large-scale killing using lethal injection can occur in complement to other methods if there are extensive outbreaks of infectious diseases, when all electric or gassing devices are already in use. But this method is usually preferred for individual and small-scale killing due to the time and skills needed to perform it.

It is a stunning and killing method for poultry (see Table 3) because, when applied correctly, birds are rendered unconscious before death.



Figure 15: Administration of intra-peritoneal lethal injection of an anaesthetic drug. Source: kindly provided by Berg C

Doses, rates and routes of administration that cause rapid loss of consciousness followed by death should be used, according to manufacturers' instructions. Birds should be monitored to ensure the drugs have been effectively administered, and death must be confirmed before carcass disposal (Berg, 2012). There may be restrictions on how the carcasses can be disposed of based on health and safety or environmental concerns.

Death can be confirmed from the complete absence of breathing, heartbeats and movements. Barbiturates do suppress breathing heavily and the breathing interval can also be quite long in birds that are still alive.

Administration of chemicals without proven anaesthetic properties (e.g. potassium chloride) may be used to kill birds that have been rendered unconscious by other methods or anaesthetised with drugs (AVMA, 2013).

Related hazards and welfare consequences

The hazards identified during this process are: 'Manual restraint', 'Inappropriate route of administration' and 'Sublethal dose', which can cause the following welfare consequences to the birds: 'Not dead', 'Consciousness', 'Distress', 'Pain' and 'Fear'.

The hazards identified at 'Lethal injection', relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 20.

3.5. Unacceptable methods, procedures or practices on welfare grounds

The Panel agrees with the principle used to define the examples of methods, procedures or practices that cannot be considered acceptable reported in Chapter 7.5.10 of the OIE Terrestrial code (World Organisation for Animal Health, 2018), e.g. 'restraining methods ... that cause severe pain and stress in animals'.

In addition to this, in Chapter 7.6, the Code refers to the principle that 'when animals are killed for disease control purposes, methods used should result in immediate death or immediate loss of consciousness lasting until death; when loss of consciousness is not immediate, induction of unconsciousness should be non-aversive and should not cause anxiety, pain, distress or suffering in animals'.

The Panel agrees with this principle and considers it a basis for acceptability. On this basis, the following are examples of methods that should not be used on welfare grounds: killing poultry by burying, burning, drowning; or the addition of poisons, pesticides or any other toxic substances to feed or water for killing.

3.6. Response to ToR1: hazard identification, origin and specific preventive and corrective measures

According to EFSA AHAW Panel (2012a), a hazard is any aspect of the environment of the animal in relation to housing and management, animal genetic selection, transport and slaughter, which may have the potential to cause poor welfare.

In this Opinion, hazards have been identified through the activities described in Section 2.2 and analysed for each phase and process under consideration. The hazards listed in the following sections are related to conscious animals.

According to the mandate, the possible origin of the hazards, in terms of equipment or staff, should also be identified. When discussing these categories, it was agreed that the 'origin' can be explained further by detailing what actions from the staff or features from equipment and facilities can cause the hazard.

Therefore, for each 'origin category' (equipment and staff) relevant explanations (so-called origin specifications) have been specified.

The mandate also requests to identify the preventive and correctives measures related to the identified hazards. Quite often, hazard corrective measures do not exist. In this case, measures to mitigate the welfare consequences can apply. However, most of the times the main mitigation measure is to kill the animal as soon as possible (see also Section 3.7.1). In the case that the killing method fails, a back-up method should be applied to mitigate severe welfare consequences such as pain, fear and distress. When preventive and corrective measures can be identified, if they are specific for a particular hazard, they will be described in this section together with the relevant hazard. If the preventive and corrective measures available can apply to several hazards (general measures), they will be described under Section 3.8 (response to ToR3). When no further explanation is needed, reference to the outcome tables will be made.

The full list of the 29 hazards identified (see Table 5), with their definitions, indication of which process they apply to and relevant preventive and corrective measures, are reported in the following sections. In particular, hazards specific to the category of day-old chicks are reported in Section 3.9.

The identified hazards with relevant origin categories and origin specifications, are listed in the outcome tables (Tables 8–20; Section 3.10: first column – hazards, third column – origin category, fourth column – origin specification). In addition, considering that each hazard may lead to one or more negative consequences on the welfare of the birds, the outcome tables also report the welfare consequences with which each hazard is associated (second column of the outcome tables mentioned above).

3.6.1. List of hazards

3.6.1.1. People entering the house

Definition: People related to the operation entering the house in a way that cause fear to the animals.

The reasons for entering the house can be, for example: sealing, preparation of the house for gassing, etc.

Process to which this hazard applies: Handling.

Hazard's preventive and corrective measures: None (see Table 8).

3.6.1.2. Rough handling of the birds

Definition: handling of the animals inappropriately in a way that cause pain and fear and distress, e.g. by one leg or wing or by the neck.

Rough handling applies to different actions such as: catching, carrying birds, putting birds in containers, removing birds from containers, moving these from a point to another by handling these.

Process to which this hazard applies: Handling.

Hazard's preventive and corrective measures: One way to prevent rough handling is to minimise operator fatigue by placing the containers (crates) used for movement of birds as close as possible to the birds and decreasing the distance for which live birds are manually carried.

The traditional chicken crate measures have narrow opening at the top through which birds are put in or taken out; sometimes more than one bird at a time (Tinker et al., 2004). In contrast, modular

transport systems have large opening for loading and removing birds and are therefore better for bird welfare because rough handling might be prevented.

Operators could use their legs as breast support to calm the birds after inversion and minimise wing flapping (Figure 16) and carry the birds up to the containers and load these gently, ensuring wings, legs or heads of birds do not hit sharp edges and they are not caught in the lids (Figure 16). As best practice, operators should introduce birds into the containers heads first, such that the birds rest on their breast before releasing these. Any swinging or rotational movement should be avoided during loading into containers, as such movements may lead to dislocated hip joints (European Commission, 2018a).

Conveyor systems have been developed and used for moving 'end-of-lay hens' kept in cages to outside the houses for killing. Such a system could also be used to convey birds into a chamber containing gas mixtures.

Catching and movement of birds need to be planned and executed well to minimise chances of poor welfare outcomes. Dimming of lights or catching during dark hours of the day could help to minimise flightless and associated welfare risks.

AVMA (2013) guidelines suggest that drugs may be used to sedate very reactive animals such as game birds before killing these using an appropriate method. For example, pheasants, partridges, guinea fowl, and quail or other species of domestic poultry reared in free-range systems could be sedated by feeding these with alpha-chloralose in feed or water and then handled for killing. Catching these during dark hours with appropriate lighting would also be helpful.



Figure 16: Operator carrying multiple birds in each hand and using his thighs as breast support to minimise wing flapping. Source: kindly provided by Raj ABM

3.6.1.3. Unexpected loud noise

Definition: A noise that by its level suddenly induces fear to birds. Birds can be submitted to noise induced by equipment (e.g. by gas injection for whole house gassing) or people that enter the house without precaution (e.g. shouting while catching the birds).

Processes to which it applies: handling (the hazard will persist while applying the stunning/killing method until the animal is unconscious/dead), whole house gassing, whole house gassing with gas-filled foam.

Hazard's preventive and corrective measures: It is important to limit the unexpected loud noises, because they lead to fear and decrease coping capacities of birds. The preventive measure will consist in staff education and training: (i) to make these aware that the noise at birds' level should be avoided; and (ii) to make these avoid shouting and making noise with the equipment and identify and eliminate the sources of noise. In addition, the machine should be setup correctly to avoid excessive noise.

3.6.1.4. Inversion

Definition: holding birds in an upside-down position.

This situation can happen: (1) in the process of handling when birds are carried by operators; and (2) during the process of restraint in a cone (for application of head-only and head-to-body electrical methods), in a shackle (before applying waterbath and head-to-body electrical methods – this form of restraint causes additional welfare consequences due to shackling), or manually (e.g. for the mechanical methods).

As birds do not have diaphragms, inversion can provoke compression of the heart and lungs by the viscera and might compromise breathing and cardiac activity. This might cause pain and fear in conscious birds.

Processes to which this hazard applies: handling, restraint for electrical methods and for captive bolt, percussive blow and cervical dislocation.

Hazard's preventive and corrective measures: No preventive measures exist, except avoid inversion of conscious birds. To undertake that, it is preferable to place the birds in containers immediately after catching and carry these to the point of killing. No measures correcting the hazard exist.

3.6.1.5. Manual restraint

Definition: Catching and immobilisation of the bird with the hands of an operator. Key point in the manual restraint is identifying an optimal pressure: as best practice, birds should be manually restrained firmly enough to facilitate stunning/killing, but without excessive pressure that would cause pain and fear. Poor manual restraint can lead to misapplication of the stunning method.

Process to which it applies: Handling. Restraint for: head-only electrical stunning, captive bolt, percussive blow and cervical dislocation and lethal injection.

Hazard's preventive and corrective measures: No prevention/correction is possible for this hazard because it is part of the process/method. However, to minimise pain and fear, the restraint should be carried out with one hand covering both wings and the other holding both legs and supporting the breast (see Figure 17).

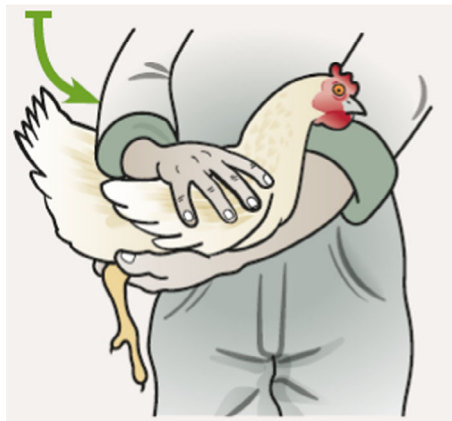


Figure 17: Manual restraint performed with two hands in a careful and gentle manner. Source: European Commission (2018a)

Alternatively, the operator can place both hands over the bird's wings and once the bird is under control, slide one hand under its body, grasping its legs between the fingers, and support its breast on the palm. The bird's wings can be controlled with the other hand, or by holding it under the arm. The bird's head is then accessible for stunning/killing. Smaller birds can be restrained by lifting these and holding by both legs.

3.6.1.6. Shackling

Definition: It is a restraining method that involves hanging birds up-side-down by inserting both legs into metal shackles. During shackling, the birds are also subjected to compression of their legs and wing flapping by the neighbour(s), if any.

Hanging upside down is a physiologically abnormal posture for chickens, and rough handling, inversion and shackling are practices that cause negative welfare consequences, such as, pain and

fear, in birds. For these reasons, approximately 90% of birds flap their wings immediately after shackling, and 66% flap their wings during any unevenness they experience in the line (Kannan et al., 1997). It is likely that such wing flapping could lead to dislocated joints and/or broken bones, which has not been quantified; when birds exhibit wing flapping while shackled, these vigorous movements can lead to haemorrhages of the wing tip (Shields and Raj, 2010).

Compression of the legs: Sparrey (1994) calculated that the resultant force on each leg of the bird could be 180 N applied over an area of 1 cm². The slot size of the shackle is particularly important because broilers show variable leg sizes, with males having consistently larger legs than females. The pressures required to compress broiler legs into shackles increases exponentially with deformation and it requires four times as much pressure to compress a 14.5 mm leg by 20% to fit into an 11.5-mm shackle, as it does to compress the same leg by 10% to fit into a 13-mm shackle (Sparrey, 1994). It is possible that these forces acting over relatively small areas of the leg would cause pain and distress to the birds and the welfare concerns of shackling have been reviewed by Sparrey (1994) and Gentle and Tilston (2000).

Wing flapping by adjacent bird(s): if a flapping bird hits the adjacent bird(s) with its wings, the neighbour(s) may also be disturbed, and they begin flapping. Fast line speeds may cause birds to notice inclines, to swing round any corners (if corners exist in the shackle line) and to lose contact with the breast contact strip, initiating wing flapping.

Processes to which this hazard applies: electrical waterbath stunning/killing and head-to-body electrical stunning/killing.

Hazard's preventive and corrective measures: No prevention/correction is possible for this hazard because it is part of the method. The measures proposed here are just best practices to decrease to the minimum the negative welfare consequences that shackling can cause in birds.

Shackle lines must be constructed and maintained so they do not jolt birds, because this is likely to stimulate flapping. Shackle line speeds must be optimum such that it does not cause the birds to struggle. Empty shackles may be wetted, just before shackling birds, to improve electrical conductivity and provide measures such as breast support help to minimise wing flapping.

Birds with large shanks tend to struggle more violently than do those with smaller shanks. Satterlee et al. (2000) show that male birds are heavier and have thicker shanks than females; they also struggle sooner after shackling and for longer duration. Male and female data combined, circumference of the shank was negatively correlated with latency to struggle and positively associated with number of struggling bouts and total time spent struggling. However, there were no detectable correlations within sex. Body weight was not significantly correlated with any of the struggling behavioural measures. Satterlee et al. (2000) concluded that use of shackles of fixed size may contribute to increased struggling behaviour in male broilers.

To minimise wing flapping, breast support can be provided to the birds; this support should be extended from the shackling to the stunning/killing point. An example is the use of a conveyor running underneath the shackle line allows the birds to rest on their breasts, supported on a horizontal conveyor with their legs extended behind them and engaged in shackles. The birds are transported in this way from the point at which they are shackled to the point at which they are stunned. For waterbath stunning, at the waterbath entrance the conveyor ends, the birds swing off the end of the conveyor and their heads fall directly and rapidly into the electrical waterbath (Lines et al., 2012). The breast-support conveyor appears to be a practical concept, which benefits the welfare of broilers on a shackle line both reducing struggling and promoting a cleaner entry into the proper stunning/killing process (e.g. the waterbath). The conveyor could also provide a further welfare benefit by allowing the time from hang-on to stunning to be reduced since the birds do not require time to settle. Processing lines that run in a straight line from hang-on to the stunning/killing process could introduce this equipment with relatively few other changes; however, it does not seem to be suitable for lines with corners. The most important additional changes, which may be needed to enable the breast-support conveyor to be used safely, is leg guards or other measures to prevent the birds from disengaging their legs from the shackle (Lines et al., 2012).

3.6.1.7. Inappropriate shackling

Definition: Within the shackling procedure, inappropriate shackling can also occur in several situations, such as when the shackles are too narrow or too wide, when the birds are hung by one leg, or when one bird is shackled on two different adjacent shackles. This last condition cannot occur in head-to-body method but only in waterbath.

Processes to which this hazard applies: electrical waterbath stunning/killing and head-to-body electrical stunning/killing.

Hazard's preventive and corrective measures: Contrary to the slaughter context (see EFSA AHAW Panel, 2019), in which each person can shackle up to 1,000 birds per hour, for on-farm killing it is difficult to give figures as it depends on the number of operators and the farm features (e.g. design of house). However, it is estimated that lower resources for shackling are needed on-farm. The portable waterbath system developed for on-farm killing is not conducive for achieving fast kill rate: the shackle line is short and the whole setup is expected to operate outdoor in bright lighting conditions without bird calming measures. People shackling live birds are not either systematically trained or skilled.

Conflicting bird welfare concerns involve using tight-fitting shackles. Although they may provide good electrical contact between the legs and metal shackles, they are likely to increase the severity of the pain associated with shackling (Sparrey, 1994) and especially the occurrence of bruising of the surface of leg and thigh muscles. To fix this, Lines et al. (2012) tested compliant shackles that are a simple concept aimed at avoiding the compression of the birds' legs while still maintaining good electrical contact. Compliant shackles developed for testing are based on the shackles already in use but had only a single pair of slots, the inner rails of which were free to move in response to the leg width. To ensure the shackle remained robust, the maximum slot width was limited, and the moving rails were held captive on the bottom rail (Figure 18).

Additionally, for waterbaths, it may happen that conscious birds are shackled after suffering injuries (e.g. with diseases or abnormalities of (leg/wing) to joints or bones or with (leg/wing) dislocated joints or bone fractures). Shackling has been reported to be painful (Gentle, 1992; Gentle and Tilston, 2000) and the pain associated with it is likely to be worse in birds with severe leg abnormalities or joint illness. Therefore, as best practice, birds that are visibly injured, those with severe leg abnormalities and runts that are likely to miss the waterbath should not be shackled. Instead they should be killed immediately using an appropriate method.

However, inappropriate shackling can be prevented by training staff to handle birds with care and compassion, shackle birds gently by both legs, kill injured birds before shackling, by rotating staff at regular intervals to avoid boredom and fatigue, and by using shackles that are appropriate to the species and size of the birds.



Figure 18: Compliant shackle (left) and standard plant shackle (right) installed in a processing plant. Reprinted by permission from: Universities Federation for Animal Welfare (UFAW), Lines et al., 2012

3.6.1.8. Pre-stun shocks

Definition: The bird experiences electric shocks before the onset of unconsciousness.

Pre-stun shocks usually occur when the leading wing or any part of the bird other than the head touches the electrical waterbath before the bird is effectively stunned/killed (DEFRA, 2007; Shields and Raj, 2010; Rao et al., 2013). Wing flapping at the entrance to the waterbath predisposes the occurrence of pre-stun electrical shocks (EFSA, 2004). Pre-stun shocks can also occur when electrically live water overflows out of the waterbath stunners and on to the entry ramp (HSA, 2006). Pre-stun

shocks lead to wing flapping and may cause the bird to lift its head and miss the waterbath stunner completely (also referred to in the literature as 'flying the stunner'). In this situation, conscious birds will reach the end of the process without being killed. This is a problem because in the absence of welfare monitoring at key stages during on-farm killing of poultry (EFSA AHAW Panel, 2013) and proper implementation of a back-up stunning/killing procedure, conscious birds may be disposed of when still alive and conscious.

Process to which this hazard applies: Electrical waterbath stunning/killing.

Hazard's preventive and corrective measures: Considering that wing flapping at the entrance to the waterbath would lead to pre-stun shocks, to prevent this hazard measures to calm the birds or to reduce the frequency of wing flapping can be put in place such as: breast rubs, low lighting, smooth transition into the waterbath and gentle shackling such that this does not trigger wing flapping.

Proper waterbath design, including a non-conductive entrance, will also help eliminate pre-stun shocks (AVMA, 2016). However, such measures are easier to put in place in slaughterhouses than in the on-farm context. The preventive measures are linked to the level of the water in the waterbath: in the optimal setting birds are immersed up to the base of their wings. The presence of an electrically insulated/isolated entry ramp at the entrance to the bath can minimise overflow of the water at the entrance of the waterbath (HSA, 2015; European Commission, 2017).

No corrective measure exists after the shocks have occurred.

3.6.1.9. Poor electrical contact

Definition: The electric contact is not sufficient to facilitate flow of current to immediately stun/kill the birds. It may occur:

- for electrical waterbath stunning/killing: between legs and shackle, between shackles and the earthing bar;
- for head-only electrical stunning: between the electrodes and head. This can result from: (i) an incorrect placement of the electrodes that do not span the brain; (ii) an intermittent contact; or (iii) the use of dirty/worn electrode(s).

For intermittent contact, repeated use, poor maintenance and lack of replacement of metal shackles can lead to corrosion and so increased resistance of the current flow and localised heat generation. In waterbath stunning/killing, unclear shackles electrical contact is interrupted, and hence, the desired flow of current through the brain is not achieved.

Dirt (e.g. originating from the birds' plumage or carbonised debris) may accumulate on the electrodes leading to increased resistance to the current flow. In waterbath stunning/killing, the electrodes will lead to increased electrical resistance due to accumulation of fat.

Processes to which it applies: electrical waterbath and head-to-body stunning/killing and head-only electrical stunning.

Hazard's preventive and corrective measures: For head-only electrical stunning, ensure correct presentation of the birds and ensure equipment includes electrodes for different sized animal in order that the current will flow easily through the brain. Electrodes must be properly constructed to ensure contact with skin through the bird's feathering. Placing water on the head of the bird reduces resistance. Four options are available for correct electrode placement for the head-only method, including on both sides of the head between the eye and ear, the base of the ear on both sides of the head, and diagonally below one ear and above the eye on the opposite side of the head (AVMA, 2016).

For waterbath stunning/killing, cleaning and disinfection of the equipment might prevent poor electrical contact: i.e. shackles should be routinely cleaned using appropriate detergent, empty shackles should be wetted before reaching live bird in the shackling area and the earth bars should be routinely cleaned (see also Section 3.6.1.6 Shackling).

3.6.1.10. Too short exposure time

Definition: The duration of exposure to the electrical current is too short to result in epileptiform activity in the brain and cardiac arrest, or, for modified atmosphere methods, the time of exposure is too low to kill all birds in the applied atmosphere.

Specifically, for whole house gassing with gas-filled foam, birds start wing flapping due to convulsions; these movements of the birds destroy the foam. If the production of foam cannot keep up with the rate of foam destruction by the birds, the animals will be exposed to the foam for a period of time too short to be killed.

Processes to which it applies: electrical waterbath and head-to-body stunning/killing and head-only electrical stunning, modified atmosphere methods.

Hazard's preventive and corrective measures: Measures aimed at maintaining adequate exposure time, or at increasing it will prevent or correct this hazard (see Tables 9–15).

For whole house gassing: Ensure that all birds are exposed to lethal concentration of the gas by monitoring and maintaining gas and for sufficient duration to cause death by timing the operation. To correct it, the process should continue until all birds are dead; sealing can also be improved. For gas mixtures in containers, it is important to have appropriate monitoring of the exposure time.

In LAPS, the specifications for the couple time/target pressure should be complied with to avoid this hazard.

For whole house gassing with gas-filled foam, it is important to ensure that the production of foam is enough and that it continues until birds are dead.

For electrical methods: the exposure time for each animal for 4 s at 50 Hz with 400 mA, will ensure death. Staff training and optimising kill/throughput rate can be suitable preventive measures to ensure a sufficient exposure of the birds.

3.6.1.11. Inappropriate electrical parameters

Definition: The electrical parameters (i.e. voltage, current, frequency, waveforms) fail to achieve epileptiform activity in the brain and cardiac arrest.

It is caused for example by: voltage being too low to generate sufficient current to achieve an effective stun; frequency being too high to cause immediate unconsciousness; or high electrical resistance of the bird in the system that prevents the current flow through the brain of the bird to cause immediate unconsciousness and death.

Processes to which it applies: electrical stunning and killing methods.

Hazard's preventive and corrective measures: No measures have been identified to correct this hazard.

To prevent this hazard, it is needed that parameters are appropriate to the frequency and waveforms of current.

For head-only electrical stunning, the parameters should be appropriate to the frequency and waveforms of the current. The main parameter that needs to be considered is the minimum current delivered to the birds, which would depend upon the output voltage from the equipment (Raj and O'Callaghan, 2004). The minimum current required to achieve effective stunning of chickens and turkeys is reported in Section 3.4.4.2. However, to ensure the voltage is sufficient to deliver minimum current, the responsible person of the on-farm killing as a best practice, should evaluate the incidence of failure of the stunning/killing equipment, using a small per cent of the population of birds. In this evaluation process, the factors that could contribute to high electrical resistance in the pathway (e.g. density of feathers and of bones, the design and construction of the electrodes) should be identified and ways of minimising or eliminating these should be explored (e.g. wetting of the heads with a wet sponge, selecting materials and design that reduce electrical resistance) (HSA, 2013). Another way of overcoming the problem of high resistance is using a constant current stunner. For example, equipment capable of delivering a pre-set constant current using variable voltages required to overcoming resistance in the pathway has been developed (Sparrey et al., 1993) and tested (Raj and O'Callaghan, 2004; Lambooi et al., 2010). Implementation of such equipment would greatly benefit poultry welfare during on-farm killing. It is worth mentioning that the effectiveness of the head-only electrical stunning has been shown to be dependent on the frequency of the current used (Raj and O'Callaghan, 2004).

For waterbath stunning/killing, the parameters we recommend are more than 400 mA and 50 Hz to ensure effective induction of cardiac arrest at stunning (HSA, 2017a). To ensure the voltage is sufficient to deliver minimum current to each bird in the waterbath, the operator needs to calculate the total amount of current (mA) based on the capacity of the waterbath stunner. Afterwards, the voltage can be adjusted accordingly. For example, if 400 mA per bird is required and 10 chickens are in the waterbath at any one time, the total current necessary can be calculated by multiplying $400 \text{ mA} \times 10 = 4 \text{ A}$. In addition, the operator should take into consideration the usual electrical resistance of the species of poultry to be stunned. Different values of electrical resistance are reported in the Guidance produce by the HSA (2015). There are also commercially available electronic stun monitors that could be used to set up the electrical parameters and verify whether the equipment is functioning properly (HSA, 2015). The personnel should ensure regular calibration and maintenance of the equipment to reach in any case the minimum current requested.

3.6.1.12. Prolonged stun-to-kill interval

Definition: the interval between end of stunning and the application of a killing method is too long to sustain unconsciousness until death occurs due to application of killing.

This is a hazard leading to recovery of consciousness.

Process to which it applies: Head-only electrical stunning and associated killing method.

Hazard's preventive and corrective measures: To prevent it, it is important to reduce the interval between stunning and killing of the birds. Head-only electrical stunning induces momentary loss of consciousness and therefore killing method should be applied immediately following stunning, as a best practice, this should occur no later than 10 s.

3.6.1.13. Too high temperature

Definition: The effective temperature perceived by an animal is the combination of the temperature, the humidity and the ventilation or speed of wind. In hot and humid environmental conditions, poor ventilation will exacerbate the perceived temperature. When the effective temperature is too high the thermoregulatory capacities of the birds for homoeothermy are exceeded, the mortality risk for the load increases and the percentage of birds that die due to thermal stress might increase also.

Process to which it applies: Whole house gassing.

Hazard's preventive and corrective measures: Preventive measures mainly refer to the application of the method: by qualified operators and following proper procedures. No corrective measures exist (see Table 12).

3.6.1.14. Too low temperature

Definition: The effective temperature perceived by an animal is the combination of the temperature, the humidity and the ventilation or speed of wind. In cold and humid environmental conditions with high wind speed the perceived temperature will decrease rapidly. When the effective temperature is too low the thermoregulatory capacities of the birds for homoeothermy are exceeded, the mortality risk for the load increases and the percentage of birds that die due to thermal stress might increase also. Birds can die from hypothermia if the conditions are too cold or the birds are wet and cold (Caffrey et al., 2017).

Processes to which it applies: whole house gassing, gas mixtures in containers.

Hazard's preventive and corrective measures: Compressed gases must be vaporised or heated before administration into the chamber and temperature has to be monitored. Under no circumstances, should solid (dry ice) or liquid CO₂ with freezing temperatures enter the chamber. Inhalation of dry gases will cause irritation to the tissues and therefore gas mixtures should be humidified at or before injection into the gas system. The injection points of the gas should be located to maximise utilising hot air inside the barn.

3.6.1.15. Too low gas concentration

Definition: The gas concentration is too low to kill all birds in the applied time of exposure.

Low gas concentrations will elevate the period of consciousness leading to prolonged respiratory distress that can be observed due to prolonged periods of gasping. Furthermore, low CO₂ or high residual O₂ concentrations will extend the duration of induction to unconsciousness, which can be observed by prolonged time to onset signs of consciousness, like muscle tone, righting reflexes, regaining posture, spontaneous eye blinking of unconsciousness.

Processes to which it applies: Whole house gassing, gas mixtures in containers.

Hazards' preventive and corrective measures: For gas stunning, it is important to have an adequate gas monitoring and to maintain the required gas concentration at the level at which birds' breath and keep injecting gas until the required levels are reached. Multiple injection points and pre-heating sufficient gas can help to create required gas concentrations faster. It is also important to protect the container from inclement weather (rain, wind, etc.) by covering the containers with wind shields.

3.6.1.16. Jet stream of gas at bird level

Definition: Injecting gas directly onto the birds.

Process to which it applies: Whole house gassing.

Hazard's preventive and corrective measures: Direct jet stream should be kept away from the birds. It should be also avoided that birds go into the jet stream source equipment, e.g. by preparing an

exclusion zone can be useful to avoid the bird to be into the jet stream. Injecting gas away from the birds by correcting the placement of the gas injectors.

3.6.1.17. Too small bubble size

Definition: Bubble size is too small, which will result in blocking the airways causing death by suffocation.

Process to which it applies: Whole house gassing with gas-filled foam.

Hazard's preventive and corrective measures: Increase the gas pressure and applying the right size and type of foam generator to increase bubble size. Increase the foam expansion ratio to at least 250:1. It is important to check and, if required adjust, the concentration of foam detergent in the water.

3.6.1.18. Low foam production rate

Definition: Foam production rate is too low to keep birds covered with foam until there are dead.

Process to which it applies: Whole house gassing with gas-filled foam.

Hazard's preventive and corrective measures: Maintain a good water quality verifying the hardness and the pH (physical/chemical quality) of the water to prepare the foam. Maintain the required foam concentration and gas pressure to create and maintain a sufficient volume of foam to completely cover the birds. Foam production capacity should be larger than the breakdown speed of the foam by the birds.

3.6.1.19. Inhalation of high CO₂ concentration

Definition: Birds are exposed to CO₂ concentrations higher than 40%.

Process to which it applies: Gas mixtures in containers.

Hazard's preventive and corrective measures: None, as it is a part of the method (see Table 14).

3.6.1.20. Overloading

Definition: adding more than one layer of birds at one time or quick succession.

Processes to which it applies: Gas mixtures in containers, maceration (see also Section 3.9.2).

Hazard's preventive and corrective measures: Operator should stop directing batch of birds into the container before previous layer of birds are dead (see Tables 14).

3.6.1.21. Too fast decompression

Definition: The decompression rate should not be greater than or equivalent to a reduction in pressure from standard sea level atmospheric pressure 760 to 250 Torr for at least 50 s. Reaching the same pressure in less than 50 s or a lower pressure within 50 s is considered too fast decompression. During a second phase, a minimum standard sea level atmospheric pressure of 160 Torr should be reached within the following 210 s.

A too fast decompression rate is associated with induction of pain and respiratory distress.

Process of slaughtering to which it applies: LAPS.

Hazard's preventive and corrective measures: As a prevention, no faster decompression than the one described above and in the LAPS process (Section 3.4.3.4) should be applied.

3.6.1.22. Expansion of gases in the body cavity

Definition: The decompression applied in the birds inside the chamber might lead to expansion of gases in body cavity such as in the gut, although no evidence of such process was found in the experiments performed on the LAPS. The welfare consequences of gas expansion have not been elucidated during the assessment of the LAPS system carried by EFSA AHAW Panel (2017). It is known that rupture of intestine due to the gas expansion is not occurring during LAPS (EFSA AHAW Panel, 2017), but no data are available to rule out the possibility of colic-like pain occurring in conscious poultry during the first phase of LAPS. The absence of proof for it in the literature should not be considered for now as a proof of absence of this specific hazard.

Since LAPS is not currently in place, this hazard could be only presumed to occur. But there is a certain level of uncertainty that cannot be ignored and needs to be highlighted mainly if, in the future, LAPS becomes a common practice.

Process of slaughtering to which it applies: LAPS.

Hazard's preventive and corrective measures: None (see Table 15).

3.6.1.23. Incorrect shooting position

Definition: When the captive bolt is positioned wrongly, unconsciousness of the birds might be not achieved. The captive bolt should be pointing perpendicularly on the parietal bones of birds.

In a study by Raj and O'Callaghan (2001), 19 broilers aged 6–7 weeks (kg live weight, mean \pm standard deviation (SD) = 2.9 ± 0.20) were used to evaluate the effect of captive bolt shooting at 90° (perpendicular to the skull, $n = 10$), 110° ($n = 3$), 120° ($n = 3$) or 130° ($n = 3$) angles. The diameter of the bolt, air line pressure and penetration depth were 6 mm, 827 kPa and 10 mm, respectively. The results showed that, compared to perpendicular shooting, non-perpendicular shooting failed to stun a significant proportion of the broilers tested and did not cause immediate death in any of these. Shooting broilers with a 6 mm diameter bolt at 90° with an air line pressure of 827 kPa resulted in immediate cessation of breathing and loss of neck muscle tension and eye reflexes. All the birds showed severe convulsions (wing flapping and leg kicking) immediately after shooting. None of the broilers survived after this treatment. When the captive bolt was shot at 110°, 120° or 130°, most birds (five out of nine) survived, continued breathing and showed no convulsions.

Process to which it applies: Captive bolt stunning/killing.

Hazard's preventive and corrective measures: Captive bolt should be pointed perpendicularly on the parietal bones of birds. This require training of staff and appropriate restraint.

3.6.1.24. Incorrect captive bolt parameters

Definition: The bolt parameters fail to provoke an effective stun and to render birds unconscious. It is caused for example by low air line pressure, low cartridge power, low bolt velocity, shallow penetration, and faulty equipment (too narrow bolt diameter).

Raj and O'Callaghan (2001) suggested that the appropriate variables for captive bolt stunning of broilers are a minimum of 6 mm bolt diameter driven at an air line pressure of 827 kPa and a penetration depth of 10 mm. In this study, shooting broilers with a 3 mm bolt at air line pressures of 620 kPa ($n = 2$) or 827 kPa ($n = 2$) failed to stun as indicated by the unaltered physical reflexes, electroencephalogram (EEG) and visual evoked potentials (VEPs). Shooting of two broilers with a 6 mm bolt at 620 kPa resulted in effective stunning and a very rapid recovery of consciousness in one bird and death in the other.

Processes to which it applies: captive bolt stunning/killing.

Hazard's preventive and corrective measures: Use equipment fit for the purpose.

3.6.1.25. Incorrect application of blow to the head and cervical dislocation

Definition: When the birds are hit either in the wrong place or with a force not sufficient to cause brain concussion.

For cervical dislocation, it may happen due to:

- A too slow stretching or twisting of the neck, in fact the manual or mechanical separation of the spine from the head should be carried out quickly and firmly, in one continuous motion (European Commission, 2017; pp. 156–157).
- The lack of separation of the brain and spinal cord that can occur for intact brain and spine or of incomplete separation or crushing of the spine.
- The incomplete severance of the carotid arteries leading to death as the failure to completely sever both carotid arteries leading to sustained oxygenated blood supply to the brain.

Although direct scientific evidence is lacking, expert opinion expressed in a previous EFSA Opinion (EFSA, 2006) states that death is not instantaneous for cervical dislocation, and the inflicted tissue damage may be perceived as painful. Therefore, cervical dislocation should only be used for killing stunned birds.

Processes to which it applies: percussive blow and cervical dislocation.

Hazard's preventive and corrective measures: Staff training on the correct use of cervical dislocation: use both stretching and twisting so that spinal cord is separated from the brain and brain is not supplied by oxygen (severance of carotids).

For percussive blow, it is important to place the head of the bird on a hard surface before delivering the blow.

3.6.1.26. Inappropriate route of administration

Definition: Any route of administration different from the ones recommended by the manufacturer.

It could include wrong route of administration, failure to use intended route and accidental spillage of irritating drug from intended route of administration.

Process to which it applies: Lethal injection.

Hazard's preventive and corrective measures: Use appropriate restraint to avoid animal moving. It is important to hold the animal firmly and gently to avoid any sudden movement on its part that could lead to injecting the product in the wrong place. A route of administration that has not been recommended in that species should not be used.

3.6.1.27. Sublethal dose

Definition: Use of a dose inferior than the one recommended by the manufacturer to kill a bird.

Process to which it applies: Lethal injection.

Hazard's preventive and corrective measures: Use the correct dose according to bird weight and species as described in the drug technical specifications.

3.6.2. Overview of the hazards in the different processes

An overview of the hazards described above in the different processes is visualised in Table 5.

Combination of hazards may exacerbate some animal welfare consequences. A combination exists when several factors are contributing to the same welfare consequence. For example, it is well described that 'rough handling' increases the risk of leg and wing fractures and haematomas of legs and wings. Conversely, during 'shackling', birds are subjected to compression of their legs and the wing flapping by the neighbour. Injured animals during 'rough handling' will experience more pain during 'shackling', 'inversion' or other forms of restraint. In this case the consequence of exposure to the two hazards will be greater than the sum of the consequences of the two hazards present separately (EFSA AHAW Panel, 2012a).

Table 5: Overview of hazards during the diverse processes of on-farm killing of poultry (for hazard’s description see Sections 3.6.1.1–3.6.1.27 and Sections 3.9.1–3.9.3)

	Hazard	Processes												
		Handling	Waterbath	Head only	Head to body	Whole house gassing	Whole house gassing with gas-filled foam	Gas mixtures containers	LAPS	Captive bolt	Percussive blow	Cervical dislocation	Maceration	Lethal injection
1	People entering the house	x												
2	Rough handling of the birds	x												
3	Unexpected loud noise	x				x	x							
4	Inversion	x	x	x	x					x	x	x		
5	Manual restraint	x		x						x	x	x		x
6	Shackling		x		x									
7	Inappropriate shackling		x		x									
8	Pre-stun shocks		x											
9	Poor electrical contact		x	x	x									
10	Too short exposure time		x	x	x	x	x	x	x					
11	Inappropriate electrical parameters		x	x	x									
12	Prolonged stun to stick interval			x										
13	Too high temperature					x								
14	Too low temperature					x		x						

	Hazard	Processes												
		Handling	Waterbath	Head only	Head to body	Whole house gassing	Whole house gassing with gas-filled foam	Gas mixtures containers	LAPS	Captive bolt	Percussive blow	Cervical dislocation	Maceration	Lethal injection
15	Too low gas concentration					X		X						
16	Jet stream of gas at bird level					X								
17	Too small bubble size						X							
18	Low foam production rate						X							
19	Inhalation of high CO ₂ concentration							X						
20	Overloading							X					X	
21	Too fast decompression								X					
22	Expansion of gases in the body cavity								X					
23	Incorrect shooting position									X				
24	Incorrect bolt parameters									X				
25	Incorrect application of blow to the head and cervical dislocation										X	X		

	Hazard	Processes												
		Handling	Waterbath	Head only	Head to body	Whole house gassing	Whole house gassing with gas-filled foam	Gas mixtures containers	LAPS	Captive bolt	Percussive blow	Cervical dislocation	Maceration	Lethal injection
26	Slow rotation of blades or rollers												X	
27	Rollers set too wide												X	
28	Inappropriate route of administration													X
29	Sublethal dose													X
	Total no. of hazards	5	7	6	6	6	4	5	3	4	3	3	3	3

LAPS: low atmospheric pressure stunning.

3.6.3. Assessment of uncertainty

Uncertainty related to the occurrence of false-negative and false-positive hazards was assessed (see methodology described in Section 2.2.3).

On the possible occurrence of false-negative hazards, the experts were 90–95% certain that they identified the main and most common welfare hazards considered in this assessment according to the three criteria described in the Interpretation of ToRs. However, when considering a global perspective, the experts were 95–99% certain that at least one welfare hazard was missing. This is due to the lack of documented evidence on all possible variations in the processes and methods being practised on a world-wide scale (see Interpretation of ToRs on the criteria for selection of stunning/killing methods to be included).

On the possible inclusion of false-positive hazards, the experts were 95–99% certain that all listed hazards exist during on-farm killing of poultry. This certainty applies to all processes described in this Opinion except the hazard ‘expansion of gases in the body cavity’ during stunning/killing with LAPS, in which the lack of field experience and scientific data reduces the level of certainty to 33–66% (see Section 3.6.1.22).

3.6.4. Origin categories and specifications

On the basis of experts’ knowledge, the origins of the hazards have been identified and categorised in terms of equipment or staff, as required by the mandate.

The category of ‘staff’ includes all the personnel involved in unloading, movement, restraint, stunning and killing of birds, including special personnel hire if there is large-scale depopulation.

‘Equipment’ includes machinery or tools used on live birds for handling, moving, restraining, stunning and killing. For example, containers used for transporting birds, forklift used for unloading, shelter system to protect birds, stunning devices and associated calibrating and monitoring systems, knives or mechanical cervical dislocation devices subsequently used for killing birds.

‘Staff’ origin contributes to most of the hazards. Almost all of the hazards originating from staff could be attributed to lack of the appropriate skill sets needed to perform tasks or to fatigue and therefore have preventive measures, which includes recruitment of people with right attitude and aptitude, staff training and staff rotation. This applies with special emphasis when specific staff are needed (e.g. for large-scale killing). In the cases of individual killing, the ‘staff’ is the farmer or his employees.

‘Equipment’ is an important category contributing to the second highest number of hazards in all the phases, especially during stunning.

Inevitably, preventive or corrective measures appropriate for a hazard would vary according to the origin category. The proportion of birds subjected to hazards could also vary according to the origin category.

An overview of the origin category(ies) pertaining to each of the hazards identified in the sections above is reported in Table 6.

Relevant origin specifications have been reported in the outcome tables developed by processes of the on-farm killing (see Section 3.10).

Table 6: Overview of the origin categories relevant to the hazards identified for the assessed processes

Hazards	Staff	Equipment
People entering the house	X	
Rough handling of the birds	X	X
Unexpected loud noise	X	X
Inversion	X	X
Manual restraint	X	
Shackling		X
Inappropriate shackling	X	X
Pre-stun shocks	X	X
Poor electrical contact	X	X
Too short exposure time	X	

Hazards	Staff	Equipment
Inappropriate electrical parameters	X	X
Prolonged stun to stick interval	X	
Too high temperature	X	
Too low temperature	X	X
Too low gas concentration	X	X
Jet stream of gas at bird level	X	
Too small bubble size	X	X
Low foam production rate	X	X
Inhalation of high CO ₂ concentration		X
Overloading	X	
Too fast decompression	X	X
Expansion of gases in the body cavity		X
Incorrect shooting position	X	
Incorrect bolt parameters	X	X
Incorrect application of blow to the head and cervical dislocation	X	X
Slow rotation of blades or rollers	X	X
Rollers set too wide	X	X
Inappropriate route of administration	X	
Sublethal dose	X	

3.7. Response to ToR2: Criteria to assess performance on animal welfare (including ABMs)

The mandate requests to define ABMs that can be used to assess welfare performance. In this Opinion, welfare performance is addressed by analysing the potential negative welfare consequences occurring to the birds due to the identified hazards. A 'welfare consequence' has been defined as the change in welfare that results from the effect of one or more factors (EFSA AHAW Panel, 2012a). Furthermore, ABMs that can be used to assess qualitatively or quantitatively the welfare consequences were evaluated and a set of ABMs was selected to be included in the outcome tables (Table 7 and Section 3.10).

3.7.1. Welfare consequences

There are several potential (negative) welfare consequences that an animal (bird) can experience when killed on-farm due to hazard(s) occurring. However, due to the complexity of the circumstances during killing procedures (e.g. disease control) and the limited accessibility to animals in some situations (e.g. whole house gassing or in the gas-filled containers, etc.) not all the welfare consequences can be assessed.

Eight welfare consequences occurring to birds during the processes of on-farm killing have been identified: not dead, consciousness, heat stress, cold stress, pain, fear, distress and respiratory distress. Some of the welfare consequences are specific to the handling of the animals or to people entering the facilities, others are specific to the killing procedure (consciousness, not dead).

To assess the welfare consequences several ABMs have been reported that can be applied for on-farm killing situations (Welfare Quality[®], 2009; EFSA AHAW Panel 2012b); for the assessment of the efficacy of the killing processes, qualitative and measurable criteria can be used. EFSA developed a Scientific Opinion on 'the monitoring procedures at slaughter for poultry' (EFSA AHAW Panel, 2013) in which ABMs for consciousness and signs of life have been selected based on their specificity and sensitivity. The 'toolboxes' developed for the different stunning/killing methods can be useful also for the on-farm killing assessment.

3.7.1.1. Description of the welfare consequences, associated ABMs and mitigation measures

The welfare consequences that have been identified as the ones that birds can experience when killed on-farm are described below in this section. The relevant ABMs that are feasible to assess in the

context of on-farm killing are also listed, and they will be described in detail in the following Section (3.7.2). The measures that can be used to mitigate the welfare consequences are also here reported.

Thermal stress (heat or cold stress)

Description: This is the inability to maintain a constant body temperature by behavioural and physiological adaptation alone. This can result in heat stress (Lara and Rostagno, 2013) or cold stress (Hunter et al., 2010; EFSA AHAW Panel, 2014).

Both welfare consequences related to thermal stress (heat stress and cold stress) in extreme cases (acute thermal discomfort) can lead to multiorgan failure and death. When the temperature is outside the upper level of this thermoneutral zone, birds are 'heat stressed' as they show difficulty achieving a balance between body heat production and body heat loss (DEFRA, 2007). This can occur at all ages and in all types of poultry systems and can be related to the killing method. Petracchi et al. (2006) considered that with an environmental temperature and humidity higher than 25°C and 70%, respectively, birds can experience heat stress.

During whole house gassing the injection of carbon dioxide in liquid form can decrease the environmental temperature around the birds below freezing (e.g. -50°C) and remain at that level for several minutes. Therefore, conscious birds can suffer from extreme cold stress that may result in freezing (Gerritzen et al., 2006). In extreme situations, such as direct contact with cold or liquid gases, birds can experience welfare consequence of acute hypothermia, as reported in humans (Hirvonen, 1976).

ABMs: The ABMs for **heat stress** are panting associated with a high respiration rate (Grilli et al., 2015) and, in extreme conditions, death. The potential ABMs for **cold stress** are shivering, huddling, pilo-erection, frozen animals and, in extreme conditions, death.

Mitigation measures: Measures to mitigate thermal stress are based on the corrections of the hazards 'too high' or 'too low' temperature (see Tables 12 and 14). Exposure to low temperatures can be mitigated by preventing birds being in the jet stream of cold gas, by using multi-injection points and direct mixing of gas with ambient air, or by pre-heating the gas to room temperature before injection into the building or container. Exposure to too high a temperature can be mitigated by providing ventilation or nebulisation to birds.

Fear

Description: When the bird experiences fear due to, for example, people entering the building or poor handling, it shows exaggerated signs of anxiety such as escape attempts or immobility.

ABMs: That can be used to assess fear as 'flight or startling behaviour' and 'vocalisations'. Fear can be assessed also by 'wing flapping' and 'escape attempts'.

Mitigation measures: Can be: entering the bird house and approaching the birds calmly with a minimum of noise to minimise disturbance; using separation gates or fencing to limit number of birds approached at the same time; using a minimum of light when approaching animals, enough to work properly; handling animals with care; supporting their bodies during carrying; and limiting sudden and extreme noise of equipment as much as possible. Careful selection of people with appropriate skills and the right attitude or training to acquire skills appropriate to the tasks and species of birds, would help to minimise fear when handling animals.

Pain

Description: It is an unpleasant sensory and emotional experience associated with real or potential tissue damage. Most processes related to on-farm killing are painful for conscious animals. The bird is in pain from an injury related to management procedures such as catching and handling. For electrical killing, if birds are shackled while conscious, pain can be expected from shackling to the point of killing (Jones and Satterlee, 1997; Gentle and Tilston, 2000). Pain due to shackling is likely to be worse due to a cumulative effect in birds that are already suffering from being injured. If waterbath design or electrical settings are suboptimal, this may cause pre-stun shocks or incomplete stunning and killing, which is painful to the birds. A similar situation may occur if birds are exposed to high concentrations of an irritating gas.

Inversion and shackling have been known to trigger stress (physiological and behavioural) responses in poultry (Bedanova et al., 2007). The legs of chickens are compressed during shackling and the degree of compression can be as high as 20% (Sparrey, 1994). Based on the presence of nociceptors in the skin covering the legs of poultry and the close similarities between birds and

mammals in nociception and pain, it has been concluded that shackling is a painful procedure (Gentle, 1992; Gentle and Tilston, 2000). The pain associated with forceful shackling would trigger wing flapping leading to further hazards during electrocution (e.g. pre-stun shocks or birds missing the bath).

ABMs: Assessing pain in poultry, based on behavioural measures, is not recommended because it is extremely difficult, and the behavioural expressions are not specific. However, pain can be indirectly assessed with 'injuries' and can be measured by e.g. number of fractures, dislocations, bruises and open wounds. During handling, shackling or exposure to pre-stun shocks and irritating gas mixtures ABMs include vigorous wing flapping, escape attempts, withdrawal reactions of wings or head and vocalisation.

Mitigation measures: Animals should be handled with care (see European Commission factsheet on animal transport²⁶); Always support birds under the breast/abdominal region; do not catch/carry birds by the neck or wings; make sure birds do not hit against objects, like the water system or perches; make sure broilers do not sway or swing while carrying. To reduce pain, injured birds should be processed as soon as possible. In addition, they should not be shackled when conscious and should be killed using a method that does not require shackling, to avoid additional pain.

Distress

Description: This is the state of an animal that has been unable to adapt to stressors, and that manifests as abnormal physiological or behavioural responses (OIE, 2019 – Chapter 7.8.1²⁷). However, distress is a welfare status difficult to describe, assess and quantify accurately. Distress implies an external and usually temporary cause of great physical or mental strain and stress, such as extreme anxiety or fear, impossibility to cope with environmental conditions, sadness or pain, or the state of being in danger or urgent need.

For on-farm killing, birds are exposed to a number of distressing situations over a short period of time. People entering the building can induce anxiety and fear, followed by catching and handling the animals causing fear, and when not handled with care this can cause injuries and can be painful. Different hazards will lead to a combination of welfare concerns including distress.

ABMs: No specific ABMs have been identified to assess distress. However, depending on the origin of the physical or mental distress, ABMs for other welfare consequences, e.g. pain or fear or thermal stress, can be applied.

Mitigation measures: End the process as soon as possible to reduce the time birds experience this welfare consequence.

Respiratory distress

Description: Mental or physiological suffering due to increased CO₂ levels or to lack of O₂ resulting in forced breathing, breathlessness or air hunger.

ABMs: In hypercapnic situations (induced by high CO₂): intense breathing (or gasping) is shown by all animals and it is characterised by breathing with an open beak (Gerritzen et al., 2006). Gasping is a form of very deep breathing accompanied with a wide open beak, stretching movements of the neck or bending the neck to backwards (Gerritzen et al., 2006).

In anoxic situations (e.g. lack of oxygen due to LAPS or exposure to inert gases), hyperventilation indicating air hunger can be seen.

Mitigation measures: Exposure to hypercapnic or anoxic situations is inherent to the killing methods that include exposure to gas. Therefore, there are no mitigating measure available for respiratory distress.

Consciousness

Description: This is the ability of an animal to feel emotions and being sensitive to external stimuli.

Despite some exceptions, such as electro-immobilisation or other provoked paralysis, an animal can be presumed to be unconscious when it loses its natural standing position, is not awake and does not show signs of positive or negative emotions such as fear or excitement. Sensitivity of an animal is essentially its ability to feel pain. In general, an animal can be presumed to be insensitive when it does not show any reflexes or reactions to stimulus such as sound, odour, light or physical contact [Council Regulation (EC) No. 1099/2009].

²⁶ <http://animaltransportguides.eu/wp-content/uploads/2016/05/Poultry-BroilersFINAL2.pdf>

²⁷ 2019 © OIE – Terrestrial Animal Health Code – 28/6/2019.

ABMs: Maintenance of sitting or standing position, eye reflexes, rhythmic breathing, response to pain stimuli, flight or escape response (EFSA AHAW Panel, 2013).

Mitigation measures: Controlling (measuring) and applying correct settings of equipment such as electrical current or gas concentrations to ensure that animals are rendered unconscious by the stunning/killing method. When it takes more time than expected to induce unconsciousness the electrical currents or gas concentrations should be increased. Exposure times should be long enough for the method to ensure that animals will not recover consciousness before death.

Not dead

Description: Animals that are not killed by the method and show signs of life.

According to Council Regulation (EC) No. 1099/2009, 'killing' means any intentionally induced process that causes the death of an animal. The purpose of killing methods is to induce death in all animals without requiring additional procedures. Death should be ensured before animal carcasses are disposed or transported to a rendering place.

ABMs: Death can be recognised by the permanent cessation of breathing, permanent cessation of heart activity, dilated pupils, relaxed body (EFSA AHAW Panel, 2013) and total absence of brain activity.

Mitigation measures: If animals are not killed, settings (e.g. currents, voltage, gas concentrations) should be increased to or above the minimum required settings. Exposure times should be increased to ensure that all animals are killed. If there are survivors, back-up methods should be available in close proximity to the place of killing, so that any delay in activity is minimised.

3.7.2. ABMs and their definitions

As mentioned previously, ABMs are used to assess the welfare consequences; indeed ABMs are the responses of an animal to a specific input and can be taken directly from the animal or indirectly by using implemented settings (e.g. gas concentrations, temperature, electrical currents) (EFSA AHAW Panel, 2012c). Some ABMs may not be feasible under certain circumstances, for example birds will not be visible during whole house gassing making it impossible to detect some ABMs. Under this situation if existence of the hazard is implemented, it should also be assumed that the related welfare consequences exist.

Table 7: List of ABMs with relevant definitions and welfare consequence(s) to which they are related. References for ABM definitions are given in parentheses; when references are not available the definition is based on expert opinion

ABMs	Definition with References	Relevant welfare consequences
Bunching	Clustering together on one part of the available floor space (see 'huddling')	Fear
Deep breathing	Deep breathing often with an open beak, can be accompanied by stretching the neck (gasping) (Gerritzen et al., 2006)	Respiratory distress
Escape attempts	Attempts to move, run or fly away from the situation (Graml et al., 2007).	Fear, pain
Flight	Moving, running or flying away or attempts to do so, often accompanied by vocalisations (see 'escape attempts')	Fear
Head shaking^(a)	Rapid shaking of the head, most times accompanied by stretching and or withdrawal movements of the head (Gerritzen et al., 2006)	Pain, fear and/or respiratory distress
Huddling	Sitting close together, crowding together in tight groups or clumps often with open space in between (Welfare Quality [®] , 2009)	Cold stress
Hyperventilation	Excessive rate and depth of breathing (https://edis.ifas.ufl.edu/vm019 , Butcher and Miles, 2018)	Respiratory distress
Injuries	Tissue damage (bruises, scratches, broken bones, dislocations) (EFSA AHAW Panel, 2012b)	Pain

ABMs	Definition with References	Relevant welfare consequences
Maintenance of posture	Birds in sitting or standing position capable of keeping their heads lifted and birds regaining posture after loss of balance (Gerritzen et al., 2004; Benson et al., 2012)	Consciousness
Muscle jerks	Muscle contractions similar to spasms, tremors and pedalling movements of the legs ²⁸	Pain
Overcrowding	When the space allowance is insufficient for birds to sit all at the same time without overlapping. It is measurable by counting the birds per m ²	Restriction of movement, heat stress
Panting	Breathing with short, quick breaths with an open beak (Welfare Quality [®] , 2009)	Heat stress
Piling up	Birds crowding against and on top of each other	Restriction of movement
Piloerection	Erection or ruffling or bristling of feathers (Strawford et al., 2011)	Cold stress
Signs of consciousness	Animals are conscious (EFSA AHAW Panel, 2013)	Consciousness
Signs of life	Animals are alive (EFSA AHAW Panel, 2013)	Not dead
Shivering	Shaking slightly and uncontrollably (Strawford et al., 2011)	Cold stress
Vocalisation	Single or repeated, short and loud shrieking (screaming) at high frequencies (Manteuffel et al., 2004)	Fear, pain
Wing flapping	A prolonged bout of continuous, rapid wing flapping (McKeegan et al., 2007)	Fear
Withdrawal reaction	Fast avoiding movement of the stimulated part of the body (i.e. neck, head, wing, or leg; Erasmus et al., 2009)	Pain

(a): Due to exposure to gas mixture.

3.8. Response to ToR3: Identification of preventive and corrective measures

The hazards that potentially appear during on-farm killing can be prevented or corrected by putting in place structural or managerial actions. Preventive and corrective measures refer to the actions that can be implemented to avoid or stop the hazard. If there is no possible correction for certain hazards, then measures to mitigate welfare consequences linked with the hazards have been described in the text of the Opinion (see Section 3.7.1).

In general, according to the mandate, preventive and corrective measures can be grouped into two broad categories:

- 'Structural' measures mean infrastructure or equipment required to minimise or eliminate occurrence of hazards or minimise welfare consequences in birds.
- 'Management' measures mean decisions to be made or resources to be put in place by personnel/farmer with responsibility or legal obligation for animal welfare.

On the basis of expert knowledge and, when available, considering the literature, for each of the hazards identified, relevant preventive and corrective measures have been listed in the outcome tables, developed by the process of on-farm killing (for details, see Section 3.10, Tables 8–20).

In addition, specific preventive and corrective measures have been developed in association with the relevant hazard description in Section 3.6.

Preventive measures that apply to more than one hazard (e.g. staff training) are described below in Section 3.8.1, whereas corrective measures, when available, are specific for each hazard (and then described in Section 3.6).

For corrective measures, only those that are considered feasible to implement during on-farm killing have been reported.

²⁸ <https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Fact-Sheets/Myoclonus-Fact-Sheet>

3.8.1. Preventive measures that apply to multiple hazards²⁹

3.8.1.1. Staff training

Description: training of staff to acquire knowledge and skills required to perform their allocated task efficiently and to let these know that animals are sentient beings that can suffer from pain, fear and distress and, therefore, should be treated with care to avoid negative welfare consequences. Staff training, including farmers and farm employees has been identified as a preventive measure for hazards in all the process assessed (see Tables 8–20). This shows that even in a well planned and managed operation, training of staff is a key point to ensure the protection of animals (HSA, 2017a).

For example, all staff involved in the catching and handling of poultry must be trained as it is the only identified way to raise awareness of the importance of humane handling. Grandin (1994) showed that the most important aspect that influences how animals are treated is management attitude. Furthermore, the employees' skill levels and their proper supervision largely determines how many birds are injured (Kettlewell and Turner, 1985) and if catchers are careful, conscientious and properly supervised then manual catching can result in low levels of injuries (Ekstrand, 1998).

3.8.1.2. Staff rotation

Description: Staff rotation is a management policy in which employees are moved between two or more tasks to avoid boredom and fatigue, impairing judgement and concentration, lowering motivation, slowing reaction time, and increasing risk-taking behaviour (Guide for Managing The Risk Of Fatigue At Work, Safe Work Australia, November 2013³⁰). Lack of staff rotation is one of the most important factors that can lead to hazards during killing of poultry on-farm during large-scale killing for disease control purposes (HSA, 2017a).

Staff rotation has been identified as an important preventive measure also during electrical and mechanical stunning/killing methods due to associated bird handling and restraining involved.

3.8.1.3. Slow down the process

Description: Rushing to complete the task of catching and removal of birds from barns or cages for killing can lead to poor welfare consequences that can be prevented by slowing down the process (e.g. decrease the number of processed birds per hour).

3.8.1.4. Slow down line speed

Description: When using an electrical waterbath for killing birds, a faster line speed (throughput rates) is not always conducive to maintaining good welfare, especially during shackling. In the current industrial situation, such a physically demanding task would lead to poor welfare consequences for birds (due for example to rough handling or inappropriate shackling) and staff, if the staff are inexperienced or fatigue sets in. In this situation, one way of preventing the hazard is to slow down line speed.

3.8.1.5. Proper machine construction

Description: Machines used for movement of containers should be constructed and well maintained to avoid poor welfare due to loud noise or emissions (HSA, 2015; European Commission, 2017).

3.8.1.6. Ensure correct maintenance of the equipment

Description: Design, construction and routine maintenance of equipment is important to ensure good welfare. This would apply to all the equipment used for killing birds. Birds in containers should be handled with care during movement on-farm. Uneven floors and faulty or poorly maintained equipment, such as forklifts, used in the movement of containers would be prone to tipping or tilting of containers, which would have serious welfare consequences.

3.8.1.7. Regular calibration and maintenance of the equipment (electrical stunners)

Description: electrical stunners, especially waterbath systems, should display the output voltage and, ideally, the total amount of current under load. For these displays to be accurate, the stunners should be regularly calibrated and maintained according to the manufacturer's instruction (AVMA, 2016). Failing to perform so will have severe welfare consequences due to the use of inappropriate

²⁹ See Tables 8–20.

³⁰ <https://www.safeworkaustralia.gov.au/system/files/documents/1702/managing-the-risk-of-fatigue.pdf>

parameters leading to ineffective stunning/killing and relying on bleeding to cause death, which is not preferable on good biosecurity grounds.

3.8.1.8. Adjust equipment accordingly to what is required

Description: Electrical parameters used for head-only, head-to-body or waterbath stunning/killing should lead to effective stunning or killing, and the outcome should be routinely monitored, and equipment adjusted if necessary (HSA, 2017a).

Failing to achieve effective head-only stunning followed swiftly by a killing method or killing via the induction of cardiac arrest after head-to-body or waterbath application would have serious welfare consequences or add biosecurity risks.

3.8.1.9. Proper monitoring of gas equipment

Description: Proper monitoring and maintenance of gas concentration is vital to ensuring good animal protection during killing on-farm. Gas concentration(s) in the poultry house or killing equipment should be continuously monitored and such devices (oxygen or carbon dioxide monitors) should be routinely calibrated to ensure they read and display accurately (HSA, 2017a).

3.8.1.10. Use of equipment fit for the purpose

Description: Choice of adapted stunning equipment, e.g. for captive bolt gun and associated bolt parameters (diameter, penetration depth, velocity) must be adapted to the species and size of birds to render these immediately unconscious leading to death (HSA, 2017a). This is valid for all the methods that require the use of an equipment.

For example, the power of cartridge, compressed air line pressure or spring should be appropriate for the species and size of birds. Cartridges must be stored in a dry place according to the manufacturer's instruction. Operator fatigue and overheating of the gun due to repeated firing in quick succession would lead to poor welfare consequences. There should be sufficient guns such that they can cool between operations, and they should be cleaned and maintained according to manufacturer's instruction. Similarly, lack of complete severance of brain and spinal cord and/or blood vessels in the neck following mechanical cervical dislocation would lead to poor welfare consequences.

3.8.1.11. Written SOP in place

Description: For whole house gassing to be efficient, businesses should have written SOPs for each premise/building as the size of poultry houses and their amicability to seal and other factors such as structural stability may vary. There should also be contingency plans to mitigate adverse outcomes (Raj et al., 2006). Gassing in containers also requires SOPs to ensure bird welfare is not compromised (Raj et al., 2008a).

In addition, injection of gas under pressure into houses requires specially trained and qualified operators to ensure effective administration of the gas and also maintain health and safety of personnel in the vicinity.

However, any process used for killing animals on-farm should be described in a written procedure.

3.8.1.12. Proper planning and execution

Description: Proper planning and execution of whole house gassing is critical to avoid thermal stress in birds. Forced ventilation should be maintained during sealing of the house and until start of the administration of gas. Any delay between ventilation shut down and gas administration could lead to severe thermal stress in birds (HSA, 2017a).

3.8.1.13. No preventive measures

Description: This means that the only option to prevent the hazard is to change the method or to try to reduce the consequences of the hazard on the welfare of the birds (see mitigation measures to the welfare consequences, Section 3.7.1).

3.9. Response to ToR4: specific hazards for animal categories

The European Commission mandate requests to point out specific hazards related to species or types of animals; when maceration is used to kill day-old chicks on-farm (see Section 3.4.4.3 for the process description), some specificities have been pointed out.

The hazards identified for maceration, with relevant welfare consequences and related ABMs, hazard's origins, preventive and corrective measures are reported in Table 19.

3.9.1. Slow rotation of blades or rollers

Definition: Speed not high enough to ensure immediate death of animals.

Process to which it applies: Maceration of day-old chicks.

Hazard's preventive and corrective measures: The rotation should be fast enough to result an immediate death in chicks. Slower rotations or overloading will result in accumulation of chicks over the blades leading to poor welfare outcomes.

3.9.2. Overloading

Definition: Adding more than one layer of chicks at one time or quick succession, introduction of a batch into macerator before previous chicks are dead.

Process to which it applies: Maceration of day-old chicks (see also Section 3.6.1.20).

Hazard's preventive and corrective measures: Batch size should be appropriate for the capacity of the equipment and it is also necessary to avoid adding chicks before the previous ones went through the rollers and died. It is important to ensure that the flow of birds into the equipment is slow enough to avoid jamming, birds rebounding from the blades or birds suffocating before maceration (HSA, 2017b).

3.9.3. Rollers set too wide

Definition: The gap between the rollers failing to crush the head of chicks inducing immediate death.

Process to which it applies: Maceration of day-old chicks.

Hazard's preventive and corrective measures: The gap between rollers must ensure chicks' heads are crushed instantaneously leading to death (HSA, 2005). This can be achieved by setting space less than 10 mm between rollers. In other situations, there is a risk that the chick's abdomen will be crushed without causing any damage to the brain, leading to serious welfare consequences such as pain, distress and fear.

3.10. Content of outcome tables linking the aspects requested by the ToRs

Outcome tables were developed to include summarised information linking all the aspects analysed to respond to the ToRs of this Opinion – i.e. hazards, welfare consequences, relevant ABMs, origin of hazards, preventive and corrective actions. The outcome tables are intended as the main result of this Scientific Opinion with a concise presentation of all retrieved information. Detailed and supporting background information are included in the previous sections of the Assessment.

Table 8: Outcome table on 'handling (catching and moving) of birds': hazards (with the No. of the section in which hazard's full description is provided), with relevant welfare consequences, ABMs, origin of hazards and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
People entering the house (3.6.1.1)	Fear	Staff	Some methods require catching and removal of birds and some other methods require preparation of the house	None (unavoidable as part of the method)	None
Rough handling of the birds (3.6.1.2)	Pain, fear, distress	Staff, equipment	Unskilled personnel, operator fatigue, high throughput rate, poorly designed containers (with small openings)	<ul style="list-style-type: none"> • Staff training; • Staff rotation; • Change container system; • Slow down the process 	None
Unexpected loud noise (3.6.1.3)	Fear	Staff, equipment	Staff shouting, machine noise, killing method	<ul style="list-style-type: none"> • Identify and eliminate the source of noise; • Staff training; • Avoid personnel shouting 	None
Inversion (3.6.1.4)	Pain, fear	Staff	Carrying of birds by their legs	<ul style="list-style-type: none"> • Staff training; • Carrying of birds without inverting these or use containers to move birds to the point of killing 	None
Manual restraint (3.6.1.5)	Pain, fear	Staff	The process of handling implies to manually restrain the birds	None (unavoidable as part of the process)	None

ABMs: vocalisations, flight, injuries, wing flapping, attempt to regain posture

ABM: animal-based measure; SOP: standard operating procedure.

Table 9: Outcome table on 'electrical waterbath stunning and killing': hazards (with the No. of the section in which hazard's full description is provided), welfare consequences and relevant ABMs; hazard's origin and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Inversion (3.6.1.4)	Pain, fear	Equipment	Shackling	None	None
Shackling (3.6.1.6)	Pain, fear	Equipment	Shackling is part of the method	None	None

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Inappropriate shackling (3.6.1.7)	Pain, fear	Staff, equipment	Lack of skilled operators, operator fatigue, rough handling during catching, crating and uncrating, fast line speed, size and design of the shackle inappropriate to the bird size, force applied during shackling	<ul style="list-style-type: none"> • Staff training, • Staff rotation, • Appropriate number of people shackling to match the line speed, shackle carefully, • Size and design of shackle appropriate to bird sizes, • Stun the birds before shackling, • Kill injured birds before shackling 	Shackle correctly
Pre-stun shocks (3.6.1.8)	Pain, fear	Staff, equipment	Rough handling of birds during shackling, shackling of birds with broken or dislocated wings, poor setting up of equipment, absence of breast comfort plates, inappropriate shackle size, inappropriate positioning of the waterbath in relation to the shackle line and/or bird size, wing flapping at the entrance to the waterbath, overflow of electrified water at the entrance to the waterbath, lack of an electrically isolated entry ramp	<ul style="list-style-type: none"> • Staff training, • Gentle shackling of birds, • Do not shackle birds with broken or dislocated wings; • Proper setting up of equipment, • Providing measures to prevent shocks at the entrance to waterbath, • Use breast comfort plates and other measures to minimise wing flapping, • Use appropriate shackle size, • Position the waterbath according to the size and species, • Avoid overflow of the water at the entrance, implement measures, such as electrically isolated entry ramp, to prevent wings making contacts with water before immersion of the head. 	None
Poor electrical contact (3.6.1.9)	Not dead, consciousness, pain, fear	Staff, equipment	Lack of skilled operators, inappropriate shackling practices (e.g. shackling of small/underweight birds, shackling by one leg), poor maintenance of equipment, poor or intermittent contact between shackles and earth bar, due to incorrect positioning and dirtiness, shackles inappropriate to the size of the birds, dirty and dry shackles	<ul style="list-style-type: none"> • Staff training, Position the earth bar correctly and clean it regularly to maintain good electrical contact with the shackle; • Use shackles appropriate to the size of birds; • Clean the shackles using proper detergents; • Wet shackles before hanging birds. 	None

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Too short exposure time (3.6.1.10)	Not dead, consciousness, pain, fear	Staff	Lack of skilled operators, high throughput rate in a multiple birds waterbath stunning, poor setting up of the waterbath	<ul style="list-style-type: none"> • Staff training, • Reduce throughput rate appropriately to the electrical stunning/killing parameters 	None
Inappropriate electrical parameters (3.6.1.11)	Not dead, consciousness, pain, fear	Staff, equipment	Wrong choice of electrical parameters or equipment, poor or lack of calibration, voltage/current applied is too low, frequency applied is too high for the amount of current delivered, lack of skilled operators, lack of monitoring of stun quality, lack of adjustments the settings to meet the requirements	<ul style="list-style-type: none"> • Use parameters appropriate to the frequency and waveforms of current; • Ensure the voltage is sufficient to deliver minimum current to each bird in the waterbath; • Regular calibration and maintenance of the equipment; • Staff training; • Consider the factors contributing to high electrical resistance and minimise–eliminate the source of high resistance; • Monitor stun/kill quality routinely and adjust the equipment accordingly 	None

ABMs: signs of life, signs of consciousness, injuries, attempt to regain posture; wing flapping, vocalisations, withdrawal reaction, muscle jerks, escape attempts

ABM: animal-based measure; SOP: standard operating procedure.

Table 10: Outcome table on 'head-only electrical stunning': hazards (with the No. of the section in which hazard's full description is provided), welfare consequences and relevant ABMs; hazard's origin and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Manual restraint (3.6.1.5)	Pain, fear	Staff	Presentation of birds to the method is required	None	None
Inversion (3.6.1.4)	Fear	Equipment	Restraint in a cone	Avoid the inversion of conscious animals	None

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Poor electrical contact (3.6.1.9)	Consciousness, pain, fear	Staff, equipment	Lack of skilled operators, staff fatigue, incorrect placement of the electrodes, poorly designed and maintained equipment, intermittent contact	<ul style="list-style-type: none"> • Staff training; • Staff rotation; • Ensure correct presentation of the birds, • Ensure correct maintenance of the equipment; • Ensure the equipment includes electrodes for different sized animals; • Ensure continuous contact between the electrodes and the birds; • Ensure regular calibration of the equipment 	None
Too short exposure time (3.6.1.10)	Consciousness, pain, fear	Staff	Lack of skilled operators, high throughput rate	<ul style="list-style-type: none"> • Staff training; • Reduce throughput rate; • Ensure a timer is built in the equipment to monitor the time of exposure or use of a visual or auditory warning system to alert the operator 	None
Inappropriate electrical parameters (3.6.1.11)	Consciousness, pain, fear	Staff, equipment	Wrong choice of electrical parameters or equipment, poor or lack of calibration, voltage/current applied is too low, frequency applied is too high for the amount of current delivered, lack of skilled operators, lack of monitoring of stun quality, lack of adjustments to the settings to meet the requirements	<ul style="list-style-type: none"> • Use parameters appropriate to the frequency and waveforms of current; • Ensure the voltage is sufficient to deliver minimum current; • Regular calibration and maintenance of the equipment; • Staff training; • Consider the factors contributing to high electrical resistance and minimise–eliminate the source of high resistance; • Monitor stun quality routinely and adjust the equipment accordingly; • Use constant current source equipment; • Wetting the head of the bird with a damp sponge 	None
Prolonged stun-to-kill interval (3.6.1.12)	Consciousness, pain, fear	Staff	Lack of skilled operators, too long time between stunning and the application of the killing method	<ul style="list-style-type: none"> • Staff training; • Accurate killing; • Kill immediately after stunning 	None

ABMs: signs of life, signs of consciousness, injuries, wing flapping, vocalisations, attempt to regain posture, escape attempts

ABM: animal-based measure; SOP: standard operating procedure.

Table 11: Outcome table on 'head-to-body electrical stunning and killing': hazards (with the No. of the section in which hazard's full description is provided), welfare consequences and relevant ABMs; hazard's origin and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Inversion (3.6.1.4)	Pain, fear	Staff, equipment	Shackling or restraint in a cone	Avoid the inversion of conscious animals	None
Shackling (3.6.1.6)	Pain, fear	Equipment	Shackling is part of the method	Restraint in a cone	None
Inappropriate shackling (3.6.1.7)	Pain, fear	Staff, equipment	Lack of skilled operators, operator fatigue, size and design of the shackle inappropriate to the bird size, force applied during shackling	<ul style="list-style-type: none"> • Staff training, • Staff rotation, • Shackle carefully, • Size and design of shackle appropriate to bird sizes 	Shackle correctly
Poor electrical contact (3.6.1.9)	Not dead, consciousness, pain, fear	Staff, equipment	Lack of skilled operators, staff fatigue, incorrect placement of the electrodes, poorly designed and maintained equipment, intermittent contact	<ul style="list-style-type: none"> • Staff training; • Staff rotation; • Ensure correct presentation of the birds, • Ensure correct maintenance of the equipment; • Ensure the equipment includes electrodes for different sized animals; • Ensure continuous contact between the electrodes and the birds 	None
Too short exposure time (3.6.1.10)	Not dead, consciousness, pain, fear	Staff	Lack of skilled operators, high throughput rate	<ul style="list-style-type: none"> • Staff training; • Reduce throughput rate; • Ensure a timer is built in the equipment to monitor the time of exposure or use of a visual or auditory warning system to alert the operator 	None

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Inappropriate electrical parameters (3.6.1.11)	Not dead, consciousness, pain, fear	Staff, equipment	Wrong choice of electrical parameters or equipment, poor or lack of calibration, voltage/current applied is too low, frequency applied is too high for the amount of current delivered, lack of skilled operators, lack of monitoring of stun quality, lack of adjustments to the settings to meet the requirements	<ul style="list-style-type: none"> • Use parameters appropriate to the frequency and waveforms of current; • Ensure the voltage is sufficient to deliver minimum current; • Regular calibration and maintenance of the equipment; • Staff training; • Consider the factors contributing to high electrical resistance and minimise– eliminate the source of high resistance; • Monitor stun quality routinely and adjust the equipment accordingly; • Use constant current source equipment; • Wetting the head of the bird with a damp sponge 	Use appropriate electrical parameters

ABMs: signs of life, signs of consciousness, injuries, wing flapping, vocalisations, attempt to regain posture, escape attempts

ABM: animal-based measure; SOP: standard operating procedure.

Table 12: Outcome table on ‘whole house gassing stunning and killing’: hazards (with the No. of the section in which hazard’s full description is provided), welfare consequences and relevant ABMs; hazard’s origin and preventive and corrective measures

Hazard	Welfare consequence (s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure (s) of the hazards
Unexpected loud noise (3.6.1.3)	Fear	Staff, equipment	Staff shouting, machine noise, killing methods	<ul style="list-style-type: none"> • Identify and eliminate the source of noise; • Staff training; • Avoid personnel shouting 	None
Too high temperature (3.6.1.13)	Heat stress	Staff	Lack of skilled operators, too early ventilation shutdown, long delay between sealing house and gas injection	<ul style="list-style-type: none"> • Ensure a qualified operator/company; • Use of proper procedure (written SOP in place, proper planning and execution) 	Increase ventilation

Hazard	Welfare consequence (s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure (s) of the hazards
Too low temperature (3.6.1.14)	Cold stress	Staff, equipment	Lack of skilled operators, CO ₂ injection without proper heating, injection on the birds, physical property of gas, too fast injection rate	<ul style="list-style-type: none"> • Ensure a qualified operator/company; • Use of proper procedure (written SOP in place, proper planning and execution); • Multiple injection points; • Heating the gas; • Prevent birds to being in the gas flow; • Monitor the temperature inside the barn; • Locate injection points to maximise utilising hot air inside the barn 	Optimise gas injection/ flow rate
Too short exposure time (3.6.1.10)	Not dead, consciousness, pain, fear, respiratory distress	Staff	Premature evacuation of the gas, gas escaping the premise (inadequate sealing)	<ul style="list-style-type: none"> • Staff training; • Ensure that all birds are dead before evacuating the gas 	Continue the process until all birds are dead, improve sealing
Too low gas concentration (3.6.1.15)	Not dead, consciousness, pain, fear, respiratory distress	Staff, equipment	Lack of skilled operators, property of the gas, concentration of the gas, uneven distribution of the gas, method of injection, frozen equipment	<ul style="list-style-type: none"> • Ensure a qualified operator/company; • Use of proper procedure (written SOP in place, proper planning and execution); • Monitor and achieve required gas concentration; • Vaporise the gas before injection; • Monitor temperature 	Add more gas or increase the exposure time to kill all birds
Jet stream of gas at bird level (3.6.1.16)	Pain, fear	Staff	Lack of skilled operator, injection pipes located at bird level, lack of protection of the birds in front of injection pipes	<ul style="list-style-type: none"> • Ensure a qualified operator/company; • Use of proper procedure (written SOP in place, proper planning and execution); • Direct jet stream away from birds; • Avoid birds coming into the jet stream 	None

ABMs: signs of life, signs of consciousness, panting, shivering and (if prolonged) frozen animals, head shacking, escape attempt, wing flapping, injuries, bunching

ABM: animal-based measure; SOP: standard operating procedure.

Table 13: Outcome table on ‘whole house gassing with gas-filled foam stunning and killing’: hazards (with the No. of the section in which hazard’s full description is provided), welfare consequences and relevant ABMs; hazard’s origin and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Unexpected loud noise (3.6.1.3)	Fear	Staff, equipment	Staff shouting, machine noise, killing methods	<ul style="list-style-type: none"> Identify and eliminate the source of noise; Staff training; Avoid personnel shouting 	None
Too short exposure time (3.6.1.10)	Not dead, consciousness, fear, respiratory distress	Staff	Lack of skilled operators; too low foam capacity or foam production	<ul style="list-style-type: none"> Staff training; Ensure enough production of foam 	Continue foam production until all birds are dead
Too small bubble size (3.6.1.17)	Respiratory distress (suffocation), pain, fear	Staff, equipment	Inappropriate surfactant concentration, inappropriate gas supply	<ul style="list-style-type: none"> Ensure a qualified operator/company; Adequate equipment and foam monitoring; Adequate gas supply 	Adjust the method to the correct settings (e.g. foam detergent concentration)
Low foam production rate (3.6.1.18)	Not dead, consciousness, fear	Staff, equipment	Too low capacity of equipment	<ul style="list-style-type: none"> Ensure a qualified operator/company; Use equipment with sufficient capacity; Maintenance of good water quality; Maintenance of required foam level 	Increase foam production

ABMs: signs of life, signs of consciousness, wing flapping, escape attempts, vocalisations

ABM: animal-based measure; SOP: standard operating procedure.

Table 14: Outcome table on ‘gas mixtures in containers stunning and killing’: hazards (with the No. of the section in which hazard’s full description is provided), welfare consequences and relevant ABMs; hazard’s origin and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure (s) of the hazards
Too low temperature (3.6.1.14)	Cold stress	Staff, equipment	Lack of skilled operators, liquid delivery of gas, physical property of gas, too fast gas injection rate	<ul style="list-style-type: none"> Staff training; Heating the gas/vaporising gas before administration 	Optimise gas injection
Inhalation of high CO₂ concentration (3.6.1.19)	Pain, fear, respiratory distress	Equipment	Due to the method, property of the gas	None	None

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure (s) of the hazards
Overloading (3.6.1.20)	Pain, fear, respiratory distress	Staff	Lack of skilled operators, adding more than one layer of birds at one time or quick succession, introduction of a batch into container before previous batch of birds are dead	<ul style="list-style-type: none"> • Staff training; • Ensure birds are not showing any sign of life before adding the subsequent batch of birds 	Stop adding birds before the previous ones are dead
Too short exposure time (3.6.1.10)	Not dead, consciousness, respiratory distress	Staff	Lack of skilled operators, lack of monitoring of the exposure time	<ul style="list-style-type: none"> • Staff training; • Appropriate exposure time monitoring 	Adjust exposure time
Too low gas concentration (3.6.1.15)	Not dead, consciousness, respiratory distress	Staff, equipment	Lack of skilled operators, lack of monitoring of the concentration, inadequate property of the gas, uneven distribution of the gas, incorrect method of injection, frozen equipment, weather (windy and temperature), inappropriate containers	<ul style="list-style-type: none"> • Staff training; • Appropriate gas monitoring and maintenance of required concentration; • Containers being fit for purpose; • Vaporise the gas before injection; • Monitor temperature 	Add more gas or increase the exposure time to kill all birds

ABMs: signs of life, signs of consciousness, shivering, escape attempt, wing flapping, head shaking and injuries

ABM: animal-based measure; SOP: standard operating procedure.

Table 15: Outcome table on 'low atmospheric pressure stunning/killing (LAPS)': hazards (with the No. of the section in which hazard's full description is provided), welfare consequences and relevant ABMs; hazard's origin and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure (s) of the hazards
Too fast decompression (3.6.1.21)	Pain, (respiratory) distress	Staff, equipment	Lack of skilled operators, wrong rate of decompression	<ul style="list-style-type: none"> • Staff training; • Use correct rate of decompression 	None
Expansion of gases in the body cavity (3.6.1.22)	Pain	Equipment	Part of the method	None	None

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Too short exposure time (3.6.1.10)	Not dead, consciousness, (respiratory) distress	Staff, equipment	Lack of skilled operators, too short duration of exposure considering the rate of decompression	<ul style="list-style-type: none"> • Staff training; • Maintain sufficient duration and decompression rate 	Adjust exposure time

ABMs: signs of life, signs of consciousness, escape attempts, wing flapping, hyperventilation

ABM: animal-based measure; SOP: standard operating procedure.

Table 16: Outcome table on 'captive bolt stunning and killing': hazards (with the No. of the section in which hazard's full description is provided), welfare consequences and relevant ABMs; hazard's origin and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Manual restraint (3.6.1.5)	Pain, fear	Staff	Presentation of birds to the method is required	None	None
Inversion (3.6.1.4)	Fear	Staff, equipment	Manual restraint with inversion or in a cone	Avoid the inversion of conscious animals	None
Incorrect shooting position (3.6.1.23)	Not dead, consciousness, pain, fear	Staff	Lack of skilled operators, operator fatigue, poor presentation of birds	<ul style="list-style-type: none"> • Staff training and rotation; • Appropriate restraint. 	Kill in the correct position
Incorrect captive bolt parameters (3.6.1.24)	Not dead, consciousness, pain, fear	Staff, equipment	Lack of skilled operator, wrong choice of equipment, poor maintenance of the equipment, too narrow bolt diameter, shallow penetration, low bolt velocity	<ul style="list-style-type: none"> • Staff training; • Ensuring equipment is fit for the purpose 	None

ABMs: signs of life, signs of consciousness, injuries, wing flapping, vocalisations, attempt to regain posture

ABM: animal-based measure; SOP: standard operating procedure.

Table 17: Outcome table on 'percussive blow': hazards (with the No. of the section in which hazard's full description is provided), welfare consequences and relevant ABMs; hazard's origin and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Manual restraint (3.6.1.5)	Pain, fear	Staff	Presentation of birds to the method is required	None	None
Inversion (3.6.1.4)	Pain, fear	Staff	Manually inverting the birds for the application of the blow	Avoid the inversion of conscious animals	None
Incorrect application (3.6.1.25)	Not dead, consciousness, pain, fear	Staff	Lack of skilled operator, operator fatigue, poor restraint, hitting in wrong place, not sufficient force delivered to the head	<ul style="list-style-type: none"> • Staff training and rotation; • Place the head of the bird on a hard surface while delivering the blow 	Correct application of the method

ABMs: signs of life, signs of consciousness, injuries, vocalisations, wing flapping

ABM: animal-based measure; SOP: standard operating procedure.

Table 18: Outcome table on 'cervical dislocation'^(a): hazards (with the No. of the section in which hazard's full description is provided), welfare consequences and relevant ABMs; hazard's origin and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure (s) of the hazards
Manual restraint (3.6.1.5)	Pain, fear	Staff	Presentation of birds to the method is required	None	None
Inversion (3.6.1.4)	Pain, fear	Staff, equipment	Manually inverting the birds for the application of the method or restraint in a cone	Avoid the inversion of conscious animals	None
Incorrect application (3.6.1.25)	Not dead, consciousness, pain, fear	Staff, equipment	Lack of skilled operators, operator fatigue, equipment not suitable for size/species of birds, attempt to induce cervical dislocation by crushing of the neck rather than by stretching and twisting	<ul style="list-style-type: none"> • Staff training and rotation; • Use of equipment fit for purpose 	Use cervical dislocation by stretching and twisting

ABMs: signs of life, signs of consciousness, injuries, vocalisations, wing flapping

ABM: animal-based measure; SOP: standard operating procedure.

(a): Manual in birds up to 3 kg and mechanical in birds weighing from 3 to 5 kg.

Table 19: Outcome table on killing with 'maceration'^(a): hazards (with the No. of the section in which hazard's full description is provided), welfare consequences and relevant ABMs; hazard's origin and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Slow rotation of blades or rollers (3.9.1)	Not dead, consciousness, pain	Staff, equipment	Lack of training, inappropriate setting	<ul style="list-style-type: none"> • Staff training; • Use equipment fit for the purpose; • Use correct rotation per minute 	None
Overloading (3.9.2)	Pain, distress, fear	Staff	Lack of training	<ul style="list-style-type: none"> • Staff training; • Batch size should be appropriate for the capacity of the equipment 	Stop loading chicks before the previous ones are dead, reduce the flow of chicks at the entrance to the machine
Rollers set too wide (3.9.3)	Not dead, consciousness, pain	Staff, equipment	Lack of training, inappropriate setting	<ul style="list-style-type: none"> • Staff training; • Purpose-built equipment; • Proper setting of the rollers 	None

ABMs: signs of life, signs of consciousness, injuries, vocalisations

ABM: animal-based measure; SOP: standard operating procedure.

(a): Applicable to day-old chicks.

Table 20: Outcome table on killing with 'lethal injection': hazards (with the No. of the section in which hazard's full description is provided), with relevant welfare consequences, ABMs, hazard's origin and preventive and corrective measures

Hazard	Welfare consequence(s) occurring to the birds due to the hazard	Hazard origin(s)	Hazard origin specification	Preventive measure(s) of hazards (implementation of SOP)	Corrective measure(s) of the hazards
Manual restraint (3.6.1.5)	Pain, fear	Staff	Presentation of birds to the method is required	None	None
Inappropriate route of administration (3.6.1.26)	Not dead, consciousness, pain, distress	Staff	Lack of skilled operators, inappropriate restraint, selection of wrong route of administration	<ul style="list-style-type: none"> • Staff training; • Follow the manufacturer's instructions; • Use appropriate restraint 	Adjust injecting with right amount of drug using appropriate route
Sublethal dose (3.6.1.27)	Not dead, consciousness, fear, distress	Staff	Administration of wrong dose of drug	<ul style="list-style-type: none"> • Staff training; • Follow the manufacturer's instructions to calculate dose appropriate to species/bird live weight 	Inject with right amount of drug

ABMs: Signs of life, signs of consciousness, vocalisations, wing flapping, attempt to regain posture

ABM: animal-based measure; SOP: standard operating procedure.

4. Conclusions

4.1. General conclusions

This Scientific Opinion focuses on the identification of hazards leading to negative animal welfare consequences during the killing of poultry for other purposes than slaughter (so-called on-farm killing). The hazards, their origins, preventive and corrective measures, welfare consequences and related ABMs have been identified based on a literature search and expert opinion and considering the common on-farm killing practices. All these aspects have been reported in the outcome tables.

The outcome tables summarise the main results of this Opinion with a concise presentation of all retrieved information.

Uncertainty in this Opinion mainly relates to the possibility of: (i) incomplete listing of hazards, namely some welfare-related hazards may be missing in the identification process as considered not existing or not relevant (false negative); and (ii) hazard not relevant for the welfare of poultry at slaughter being included in the outcome tables (false positive).

The uncertainty analysis on the set of hazards for each process provided in this Opinion revealed that the experts were 90–95% certain that they identified the main and most common welfare hazards considered in this assessment according to the three criteria described in the Interpretation of ToRs. However, when considering the situation world-wide, there is a 95–99% certainty that at least one welfare hazard is missing. At the same time, the experts were 95–99% certain that all listed hazards exist during on-farm killing of poultry, except for LAPS (see Conclusion No. 4 of Section 4.2.3).

Similarly, uncertainty exists related to the possibility of incomplete or misclassified listing of hazard origins, preventive, corrective measures, welfare consequences and ABMs, but owing to the limited time available to develop this Scientific Opinion, there is not an uncertainty analysis of this.

- 1) In total, 29 welfare-related hazards have been identified during on-farm killing. Some of these hazards are common to different processes (e.g. inversion) or stunning/killing methods (e.g. manual restraint). Hazards linked to failure in provoking death are the most represented.
- 2) Animal welfare consequences can be the result of single or several hazards. The combination of hazards would lead to a cumulative effect on the welfare consequences (e.g. pain due to injury caused by rough handling during catching will lead to more severe pain during shackling).
- 3) In total, eight welfare consequences that can be experienced by poultry during slaughter have been identified; they are: not dead (after application of killing method), consciousness (after application of killing method), heat stress, cold stress, pain, fear, distress and respiratory distress.
- 4) The birds will experience the negative welfare consequences only when they are conscious. 'Animals not dead' is considered a welfare consequence after failure of stunning/killing process since animals are subjected to the risk of being disposed (e.g. buried, sent to rendering plant) alive.
- 5) All the processes described in this Opinion have hazards. On the stunning/killing methods, some methods present hazards related to the restraint of birds (i.e. electrical and mechanical methods, lethal injection) other methods to the induction phase to unconsciousness (modified atmosphere methods).
- 6) Some hazards are inherent to the stunning/killing method and cannot be avoided, (e.g. shackling in waterbath), other hazards originate from suboptimal application of the method, mainly due to unskilled staff (e.g. rough handling, use of wrong parameters for electrical methods).
- 7) A smooth management during stunning and killing procedure aiming at avoiding pain, fear and distress, especially during large-scale killing, is considered a pre-requisite to safeguard the welfare of the animals.
- 8) Lack of staff training is a major contributor to many of the hazards (24 out of 29).
- 9) Even if welfare consequences cannot be assessed during on-farm killing, it does not imply they do not exist.
- 10) Under certain circumstances, not all the ABMs can be used to assess the welfare consequences because of low feasibility.

- 11) For most of the hazards, preventive measures can be put in place, whereas relevant corrective measures are not always available.
- 12) If not followed by appropriate measures correcting the hazard, a welfare consequence will persist, until the animal is unconscious or dead.
- 13) The Panel agrees with the principles given in Chapters 7.5.10 and 7.6 of the OIE Terrestrial code (World Organisation for Animal Health, 2018) to define methods, procedures or practices that cannot be considered acceptable on welfare grounds. On this basis, examples of methods that should not be used: killing poultry by burying, burning, drowning; the addition of poisons, pesticides or any other toxic substances to feed or water for killing.

4.2. Conclusions specific for the processes

4.2.1. Handling

(The specific information can be retrieved in Table 8.)

- 1) Five hazards have been identified in this process. All of these have staff as origin (ToR1).
- 2) Fear is considered the most frequent welfare consequence occurring to birds in this process (ToR2).
- 3) Preventive measures are mainly staff training aiming at appropriate handling of the birds; no corrective actions have been identified (ToR3).

4.2.2. Electrical methods

They include: waterbath stunning/killing, head-only stunning, and head-to-body stunning/killing methods (information can be retrieved in Tables 9–11).

- 1) Nine hazards have been identified for these processes. Six of these are common to the three methods. Four hazards have staff and equipment as origin, three only staff and two only equipment (ToR1).
- 2) Head-only electrical stunning does not lead to death; therefore, it needs to be followed by a killing method. (ToR2).
- 3) Hanging upside down is a physiologically abnormal posture for poultry; inversion, and shackling are practices that cause unavoidable pain and fear in conscious birds (ToR2).
- 4) In electrical waterbath stunning, not all birds processed at the same time are receiving the same current. Therefore, some birds do not receive sufficient current to be unconscious due to the electrical current usually used (ToR2).
- 5) Preventive measures are mainly linked to correct setting of the parameters and of the equipment to reach onset of death for all birds, whereas corrective actions exist for two out of the nine hazards as the hazards are linked to the method (ToR3).

4.2.3. Modified atmosphere methods

These methods include: whole house gassing stunning/killing, whole house gassing with foam stunning/killing, gas mixtures in containers (gassing in containers, containerised gassing systems, exposure of birds in containers to high expansion foam created using gas mixtures) and low atmospheric pressure stunning/killing (LAPS) (information can be retrieved in Tables 12–15).

- 1) Twelve hazards have been identified for modified atmosphere methods. Ten of these have staff as origin (ToR1).
- 2) Since modified atmosphere methods do not induce immediate loss of consciousness, the welfare consequences (e.g. pain and fear) can be experienced by the birds during the induction phase (ToR2).
- 3) Preventive measures can be put in place for 10 of the hazards identified in these processes; but there are no corrective actions for five out of the 12 hazards, as the hazards are linked to the method (ToR3).
- 4) For the hazard 'expansion of gases in the body cavity' related to LAPS, the lack of field experience and of scientific data has reduced the global certainty level of this hazard being a false positive to 33–66%.

4.2.4. Mechanical methods

They include captive bolt, percussive blow, cervical dislocation, decapitation, piercing devices and maceration (information can be retrieved in Tables 16–19).

- 1) Eight hazards have been identified for mechanical methods. All of these have staff as origin (ToR1).
- 2) Captive bolt, percussive blow and maceration are considered stunning/killing methods.
- 3) Cervical dislocation, decapitation and piercing devices are considered killing methods only and therefore they should only be applied on unconscious animals.
- 4) When captive bolt is properly applied in poultry the process is already enough to kill the animal. Nevertheless, death should be confirmed after shooting.
- 5) Preventive measures (mainly staff training) can be put in place for seven of the eight hazards identified in these processes, while no measures have been identified for 'manual restraint' (ToR3).
- 6) Corrective measures have been identified only for three of the eight hazards, and they are mainly related to the correct application of the method (ToR3).
- 7) Three hazards have been identified for the specific category of day-old chicks killed by maceration: 'slow rotation of blades or rollers', 'rollers set too wide' and 'overloading'; all of these have staff as origin. Prevention mainly consist of staff training and proper setting of the equipment, whereas corrective actions have been identified only for overloading (ToR4).

4.2.5. Lethal injection

The specific information can be retrieved in Table 20:

- 1) Three hazards have been identified for lethal injection. All of these have staff as origin (ToR1).
- 2) If not performed correctly, lethal injection can be very painful and birds remain conscious/alive experiencing severe welfare consequences, such as pain, fear and distress (ToR2).
- 3) Preventive measures mainly refer to training of the staff and correct application of the method (ToR3).

5. Recommendations

- 1) The welfare status of birds should be assessed and monitored at each process of the on-farm killing (both in large-scale and individual killing) by assessing the ABMs provided in this Opinion and identifying the existing hazards. When use of ABMs is not feasible and if the hazard is present, it should be assumed that also the related welfare consequences are experienced by the birds.
- 2) Priority should be given to the implementation of preventive measures. When the bird is already exposed to an identified hazard, appropriate corrective measures should be applied (see outcome tables).
- 3) When no measures to correct the hazard exist, measures to mitigate the welfare consequences should be put in place.
- 4) All processes of the on-farm killing should be carried out by trained and skilled personnel and also involve proper maintenance and use of stunning/killing equipment.
- 5) Training of farm staff to acquire skills necessary to perform on-farm killing of birds should be implemented.
- 6) Roles and responsibilities of staff involved in large-scale killing on-farm should be clearly identified. The responsible person of the animals' on-farm killing should put in place appropriate actions to prevent the occurrence of hazards and guarantee that birds do not suffer welfare consequences. Such measures should include: (i) have in place proper procedure (e.g. written SOP, contingency plans); (ii) training and rotation of the staff; and (iii) appropriate setting and use of the equipment (see outcome tables).
- 7) A back-up killing method should be ready at any time to reduce the welfare consequences experienced by the animal and to lead the animal to death as soon as possible.
- 8) Death should always be confirmed at the end of the killing process, before disposing of carcasses.

- 9) If on-farm killing is performed by using a simple (reversible) stunning method (e.g. head-only electrical stunning), a killing procedure should follow (e.g. cervical dislocation).
- 10) For on-farm killing of poultry using a waterbath a minimum current of 400 mA and frequency of maximum 50 Hz should be used.
- 11) Considering that whole house gassing does not require handling of birds, it should be the preferred method, when feasible to seal the barn, to be used for stunning and killing a whole barnful of birds.
- 12) In whole house gassing, direct injection of liquid gas in the barn should not be used.
- 13) Repeated use of a captive bolt gun and in quick succession will lead to overheating of the barrel and failure of the gun. A sufficient number of guns should be made available such that each one can be rested to cool off.
- 14) Cervical dislocation by crushing should not be used.
- 15) Cervical dislocation by stretching and twisting of the neck should only be applied to kill unconscious birds.
- 16) Decapitation and brain piercing should not be used for killing conscious birds.
- 17) Lethal injection of anaesthetic drug should be administered strictly following the manufacturer's instructions on dose, route and rate of administration.
- 18) Poisons/toxins should not be used for on-farm killing.
- 19) Technology to prevent the necessity of killing surplus/unproductive animals (e.g. male day-old chicks from layers' genotypes) should be encouraged. This is recommended in single-farm-scale killing as well as in bigger scale (e.g. maceration in big hatcheries).
- 20) Ranking of the hazards in terms of severity, magnitude and frequency of the welfare consequences of the birds during on-farm killing should be carried out to be able to prioritise actions and improve the procedure of the on-farm killing accordingly.

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Glossary

Animal-based measure	a response of an animal or an effect on an animal. It can be taken directly from the animal or indirectly and includes the use of animal records (EFSA AHAW Panel, 2012a).
Corrective measure	measure that can put in place to correct an existing hazard.
Depopulation	the process of killing animals for public health, animal health, animal welfare or environmental reasons under the supervision of the competent authority (Council Regulation (EC) No. 1099/2009).
Emergency killing	the killing of animals that are injured or have a disease associated with severe pain or suffering and when there is no other practical possibility to alleviate this pain or suffering.
Hazard	any aspect of the environment of the animal in relation to housing and management, animal genetic selection, transport and slaughter, which may have the potential to cause poor welfare (EFSA AHAW Panel, 2012a).
Inversion	holding birds in an upside-down position.
Killing	any intentionally induced process that causes the death of an animal (Council Regulation (EC) No. 1099/2009).
Lairaging	keeping animals in stalls, pens, covered areas or fields associated with or part of slaughterhouse operations (Council Regulation (EC) No. 1099/2009).
Mitigation measure	measure that can put in place to reduce the welfare consequences(s).
Pithing	the laceration of the central nervous tissue and spinal cord by means of an elongated rod-shaped instrument put into the cranial cavity (Council Regulation (EC) No. 1099/2009).
Poultry	all domesticated birds, including backyard poultry, used for the production of meat or eggs for consumption, for the production of other commercial products, for restocking supplies of game, or for breeding these categories of birds, as well as fighting cocks used for any purpose. Birds that are kept in captivity for any reason other than those reasons referred to in the preceding paragraph, including those that are kept for shows, races, exhibitions, competitions or for breeding or selling these categories of birds as well as pet birds, are not considered to be poultry (Glossary of the 2018 © OIE – Terrestrial Animal Health Code – 10 August 2018).
Preventive measure	measure that can put in place to prevent the occurrence of a hazard.
Related operations	operations such as handling, lairaging, restraining, stunning and bleeding of animals taking place in the context and at the location where they are to be killed (Council Regulation (EC) No. 1099/2009).
Restraint	the application to an animal of any procedure designed to restrict its movements sparing any avoidable pain, fear or agitation to facilitate effective stunning and killing [Council Regulation (EC) No. 1099/2009].
Shackling	hanging birds up-side-down by inserting both legs into metal shackles.
Slaughtering	the killing of animals intended for human consumption (Council Regulation (EC) No. 1099/2009).
Standard Operating Procedures	a set of written instructions aimed at achieving uniformity of the performance of a specific function or standard [Council Regulation (EC) No. 1099/2009].
Stunning	any intentionally induced process that causes loss of consciousness and sensibility without pain, including any process resulting in instantaneous death [Council Regulation (EC) No. 1099/2009].
Welfare consequence	the change in welfare that results from the effect of one or more factors (EFSA AHAW Panel, 2012a).

Abbreviations

ABM	animal-based measure
AC	alternating current
AEP	auditory evoked potential
AHAW	EFSA Panel on Animal Health and Welfare

APHIS	Animal and Plant Health Inspection Service
AVMA	American Veterinary Medical Association
CAS	controlled atmosphere stunning
CBS	captive bolt stunning (penetrating or non-penetrating)
CD	cervical dislocation
DEFRA	Department for Environment, Food and Rural Affairs (UK)
EEG	electroencephalogram
GAS	gas atmosphere stunning
GC	gassing in containers
HO	head-only electrical stunning
HPAI	highly pathogenic avian influenza
HSA	Human Slaughter Association
LAPS	low atmospheric pressure stunning
LS	literature search
MCD	manual cervical dislocation
NMCD	novel mechanical cervical dislocation
OIE	World Organisation for Animal Health
RH	relative humidity
RPM	rotation per minute
SOP	standard operating procedure
ToR	Term of Reference
VEP	visual evoked potential
WB	waterbath electrical stunning
WG	Working Group

Appendix A – Literature searches

As described in Section 2.2.1, two LSs were carried out to identify peer-reviewed scientific evidence on the topic of 'killing of poultry for purposes other than slaughter' ('on-farm killing of poultry') that could provide information on the aspects requested by the ToRs (i.e. description of the processes, identification of hazards, origins, preventive and corrective measures, welfare consequences and ABMs):

- 1) The first search (Search 1) was a broad literature search under the framework of 'welfare of poultry at slaughter and killing' (for details, see EFSA AHAW Panel, 2019).

For the current assessment, the publications obtained from this first search were screened for their relevance to the on-farm killing context: 21 papers resulted as relevant.

- 2) The second literature search (Search 2) aimed specifically at retrieving additional publications relevant to on-farm killing of poultry.

Full details of protocol, strategies and results of Search 2 are provided below.

A.1. Sources of information included in Search 2

Bibliographic database: Web of Science.

Search string used in the bibliographic database:

The search string was designed to retrieve papers relevant to 'animal welfare' during 'killing for purposes other than slaughter (on-farm killing)' for 'poultry'. Restrictions on the different species of poultry were applied by including the genus name of different species of birds that are used for human consumption to obtain studies on domesticated birds used for meat production. Restrictions applied in the search strings were related to the date of publication as it was applied to Search 1. No language or document type restrictions were applied in the search strings.

Web of science (all databases):

Date of the search: 20 December 2018

Set	Query	Results
#1	Ts = Welfare OR 'animal welfare' AND kill* OR stun* AND bird* OR poultr* OR chicken* OR gallus OR turkey* OR meleagris OR quail* OR callipepla OR duck* OR anas OR geese OR goose OR anserini OR pheasant* OR phasianus OR partridge* OR perdix OR pigeon* OR columbidae OR pullet* OR fowl* OR galloanserae OR guinea fowl OR numididae OR hen* AND on-farmTimespan = 2004–2018Search language = Auto	34

A.2. Refinement of literature search results

In total, 34 records resulted from Search 2. Duplicates among the results pertaining to 'on-farm killing' of Search 1 (for details, EFSA AHAW Panel, 2019) were first removed; titles and abstract of the 17 resulting records were screened for their relevance to poultry on-farm killing. Full text publications were screened if title and abstract did not allow assessing the relevance of a paper. The screening was performed by one reviewer, with support by a second reviewer if there are doubts. From Search 2, five records resulted as pertaining to poultry on-farm killing.

An overview of the numbers of the records that resulted from the two LSs is reported in Table A.1, and Table A.2 shows the resulting list of relevant publications.

Table A.1: Overview of the numbers of results of the LSs (Search 1 and Search 2)

	Initial count	After deduplication among Searches 1 and 2	Screening, limited to English publications, to identify relevant literature to poultry on-farm killing
Search 1	412		21
Search 2	34	17	5
Total no. of relevant publications			26

Table A.2: List of publications relevant to on-farm killing resulting from the LSs

ID	Reference
1	Berg et al. (2014)
2	Cors et al. (2015)
3	EFSA (2008)
4	Erasmus et al. (2010c)
5	Gavinelli et al. (2014)
6	Gerritzen et al. (2007)
7	Gerritzen and Sparrey (2008)
8	Gerritzen and Raj (2009)
9	Gibson et al. (2018)
10	Gurung et al. (2018a)
11	Martin et al. (2016d, 2018a)
12	Martin et al. (2017)
13	Martin et al. (2018a)
14	Martin et al. (2018b)
15	McKeegan et al. (2011)
16	McKeegan et al. (2013)
17	Raj (2004)
18	Raj (2008)
19	Raj et al. (2006)
20	Raj et al. (2008a)
21	Sparrey et al. (2014)
22	Thornber et al. (2014)
23	Turner et al. (2012)
24	Webster and Collett (2012)
25	Woolcott et al. (2018a)
26	Woolcott et al. (2018b)