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To the Minister of Agriculture, Nature and Food Quality

To the Inspector-General of the Netherlands Food and Consumer Product Safety Authority

From the Director of the Office for Risk Assessment & Research

Advice on the transport of finisher pigs and broilers during (extremely) high temperatures

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Our reference
TRCVWA/2020/4161

Date
5 augustus 2020

Background

The summers of 2018 and 2019 both experienced heat waves confirmed by the Royal Netherlands Meteorological Institute (KNMI) (minimum of 5 days ≥ 25ºC and a minimum of 3 days ≥ 30ºC). Under these types of weather conditions, animal transport takes place with a potential risk to animal welfare.

The European legislation on the transport of animals is outlined in the Animal Transport Regulation (Council Regulation (EC) No. 1/2005)[1] and applies to all vertebrates. Cooperation between the sectors has led to a National Plan for livestock transport at extreme temperatures, which comes into force when temperatures of ≥ 27ºC are expected according to weather forecasting by the KNMI at De Bilt. The National Plan does not have a legal basis. The current Animal Transport Regulation has open standards, which complicates oversight, also in conjunction with the absence of scientific underpinning of the National Plan. Oversight depends on veterinarians to determine the adverse effects of animal transport on the animal during weather conditions with high temperatures. Substantiation of the animal welfare risk is required alongside guidelines for more concrete implementation of the supervision of animal transports under the conditions outlined.

The Enforcement directorate of the Netherlands Food and Consumer Product Safety Authority (NVWA) has submitted the following question to the Office for Risk Assessment & Research (BuRO): *What are the animal welfare risks to finisher pigs and broilers during transport at (extremely) high ambient temperatures? Please take into account the animal indicators in order to determine welfare levels.*

Approach

This advice will focus on the transport of finishing pigs and broilers to the slaughterhouse by road during (extremely) high ambient temperatures. The transport of live animals in the Netherlands is made up largely of pigs and poultry.[2] In addition, these animals are more sensitive to high temperatures than

[1] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32005R0001:NL:HTML
[2] https://ec.europa.eu/food/sites/food/files/animals/docs/traces_report_annual_2017_eu_nld_eng.pdf

some other production animals, due to their species-specific physiology (Fisher et al., 2009; Renaudeau et al., 2012), i.e. their inability to perspire. Furthermore, genetic selection programmes aimed specifically at production traits have increased sensitivity to high ambient temperatures due to the strong correlation between production levels and heat production (Sandercock et al., 2006; Renaudeau et al., 2012; Ross et al., 2015; Rioja-Lang et al., 2019). In consultation with the Enforcement and Inspection directorates, it was therefore decided that this advice should focus on the transport of these two animal species.

This advice will be limited to determining the impact of (extremely) high temperatures on animal welfare, with the effects of the cold not forming part of this advice. This advice principally focusses on conditions in the truck or trailer and the loading process and conditions at the slaughterhouse (stationary period, lairage) are taken into account to a limited extent.

The risk assessment was carried out on the basis of the EFSA methodology(EFSA, 2009;2012b;2012a), which consists of a hazard identification, a hazard characterisation, an exposure assessment and a risk characterisation (see Annex A).

The risk assessment was conducted based on (recent) scientific literature and relevant data from the NVWA, KNMI and Weerplaza. The literature review carried out by BuRO involved searches on Google, Google Scholar, PubMed and Scopus for – combinations of – the English and Dutch keywords: varken, kip, pluimvee, pig(s), grower/growing pig, finisher/finishing pig, swine, poultry, broiler, animal, transport, transportation, temperatuur, temperature, heat, stress, heat stress, hittestress, thermoregulation, thermoregulatie, thermoneutral zone, upper critical temperature, welfare, behaviour, behavior, thermal stress, heat load, heat index, high ambient temperature, extreme temperature(s), microclimate. The snowball method (search through identified sources) was used in this regard.

In addition, BuRO made use of data on broilers from Pladmin (2017, 2018, 2019) available within the NVWA as well as of data from the KNMI and Weerplaza to assess the impact (effects on animal welfare) of transport on broiler chickens during high ambient temperatures. The weather data relates to ambient temperature and humidity for the months of May to September. The analysis only includes days with temperatures over 20ºC. The formula underpinning the Livestock Weather Safety Index was used to calculate the THI (Temperature Humidity Index). The SAS Enterprise Guide was used for the analyses. The piecewise regression was carried out according to the approach set out by Ryan et al. (Ryan et al., 2007).

BuRO held four expert consultations in April 2020 aimed at evaluating the draft risk assessment. The experts that were invited and who participated were selected based on their animal welfare expertise with a focus on transport. Their remarks were subsequently used by BuRO to further improve the risk assessment. Annex E to this advice contains a summary of the expert consultations.

Finally, BuRO conducted a survey within the EFSA Animal Health and Welfare Network for any data available from European Member States to substantiate the risk assessment – this did not result in any usable data. The same question was put out through the European Reference Centre for Animal Welfare (EURCAW) for pigs, however, did not receive any responses.

BuRO took note of the report entitled *Op de bres tegen hittestress*, drafted by De Dierenbescherming in collaboration with Eyes on Animals (2019).

The literature review, the data analysis and the risk assessment were carried out independently by BuRO.

Findings

Animals, laws and regulations

- Finisher pigs and broilers are relatively sensitive to heat stress due to their inability to perspire. In addition, their heat tolerance has decreased due to selection for production traits. This may vary per genotype. Other animal-based characteristics, such as body weight and health status, also play a key role.
- The thermoneutral zone is the zone in which animals have no need to increase heat loss or to reduce heat production. For finisher pigs, the thermoneutral zone is between 16ºC–22.9ºC, with an upper limit of 23ºC–25.5ºC. For broilers, that thermoneutral zone is between 8ºC and 18ºC.
- Unlike as is the case for pigs, the European Animal Transport Regulation[3] on long journeys relating to poultry, does not set out requirements in relation to the obligation to have mechanical ventilation in place, nor have any standards for minimum or maximum temperatures been laid down. Even for short journeys, there are no requirements or standards regarding the foregoing parameters either for finisher pigs or broilers.
- Under Regulation (EC) No 561/2006[4] drivers are required to have a rest period of 45 minutes after a driving period of 4.5 hours.
- A 2017 survey[5] conducted among various EU Member States showed a diversity of national recommendations or additional requirements relating to periods with high ambient temperatures (both in terms of time restrictions and regarding various degrees of changes to the loading density). It also showed that there is a widely felt need for cross-EU criteria, such as specification of the maximum permitted ambient temperature, adjustments of the loading density.
- Within the NVWA, a so-called signal threshold (0.5%) and intervention threshold (1%) was used during the drafting of this risk assessment for the Death-On-Arrival (DOA%) rate at herd/flock level. Exceeding these thresholds could be constitute grounds for a warning and/or fine.

Hazard identification

- During transport at high ambient temperatures, a combination of hazards determines the impact on animal welfare (multifactorial cause). The combination of high ambient temperatures, a high level of humidity, which are

[3]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. Please see: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32005R0001:NL:HTML
[4]Regulation (EC) No 561/2006 of the European Parliament and of the Council of 15 March 2006 on the harmonisation of certain social legislation relating to road transport. Please see: https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=celex%3A32006R0561
[5] Internal information NVWA Inspection directorate

combined in the heat index (THI), with absent/inefficient ventilation, is the most significant hazard.

- In addition, an (overly) high loading density, a long journey duration and stationary time of the vehicle may contribute to amplifying heat stress effects on the animals, due to lack of ventilation and an associated increase in humidity and reduction of heat loss.
- In addition to the hazards identified, other factors such as body weight, nutritional levels and health status also affect the way an animal interacts with its environment. Stress preceding (such as due to the capture and loading of the animals) and during transport may also affect animals' tolerance to heat. The conditions (such as climate control) at the slaughterhouse also play a key role in this regard.

Hazard characterisation (heat stress)

- The impact on animal welfare of transport during high ambient temperatures in conjunction with other factors is heat stress. Heat stress can range from being limited and short-term, where physiological and behavioural changes such as panting are sufficient to maintain body temperature, to being severe, resulting in death.
- The principal animal indicator used to determine heat stress in finisher pigs and broilers during transport is panting. There is limited data in the literature on the prevalence of this indicator in relation to high ambient temperatures. The Welfare Quality protocol for pigs uses a criterion of either less than or more than 20% panting. In poultry, 1-6% of panting broilers during transport is cited as an indication of heat stress. The body temperature of individual animals would ideally act as an indicator of heat stress, however, it is not used in practice for a number of reasons, including due to limited applicability in large numbers of animals.
- The scientific literature consulted contained hardly any data (such as on animal numbers, indicators) on the occurrence of heat stress in practice.
- Heat stress in finisher pigs and broilers seems to occur at temperatures between 25ºC and 30ºC and the adverse effects of exposure to high ambient temperatures increase with increasing temperatures and longer distances, particularly if other conditions during transport are not optimal. Based on the literature that was found, it is not possible to determine at what outdoor temperatures (whether or not in combination with humidity) the effects on animal welfare in the form of heat stress start and progress over time for finisher pigs and broilers during transport.
- Data analysis of internal NVWA slaughter data for broilers from the years 2017, 2018 and 2019 shows that a slightly increased Death-On-Arrival rate (DOA%) can be seen between temperatures from 25ºC to 30ºC and a significantly increased DOA% on days with temperatures ≥30ºC. In addition, in 2017 and 2018, the DOA% per flock at these high temperatures is more often above the signal threshold or intervention threshold, primarily at slaughterhouses that continue working after 4.00 p.m.

Exposure

- At present, animal indicators, other than the DOA% in poultry, such as the percentage of panting animals or quality defects of the meat, which may reveal effects on the animals as a result of transport during high ambient temperatures during the ante mortem (AM) or post mortem (PM) inspections, are not systematically recorded or stored.

- Both at the AM inspection and the PM inspection at the slaughterhouse, attention is paid to the possible occurrence of heat stress and any abnormalities are recorded that strongly correlate to heat stress, such as DOA%. Data on DOA% in pigs in the Netherlands is not systematically accessible at the NVWA, however, it is known that this is approximately 0.01% - 0.02% on an annual basis. The DOA% in broilers on average fluctuates around 0.14% year-on-year[6].
- Examples of resource-based indicators are the temperature in the truck, the humidity and the carbon dioxide levels, of which the temperature is the most useful, applicable and robust indicator during transport. The temperature varies depending on the location in the truck.
- Based on KNMI data from 2017 to 2019, it appears that on days with a maximum temperature of ≥27ºC and on days with a maximum temperature of ≥30ºC, there are on average only slight differences in temperature and humidity levels within the Netherlands. This means that under these conditions, the temperature data in De Bilt apply to the Netherlands as a whole.
- Between 2000 and 2019, there were an average of 12 days per year with temperatures ≥27ºC, of which 8 days with temperatures ≥30ºC.

Risk characterisation

- Although ideally the heat index (temperature combined with humidity) is the best indicator for determining animal welfare during transport, there are no freely accessible weather forecasts available in the Netherlands that provide such data. In the absence of an unambiguous multi-day heat index forecast for animals, the forecast maximum ambient temperature is the best resource-based indicator for heat stress.
- On days with temperatures of ≥27ºC, there is a real risk to both finisher pigs and broilers to develop heat stress with death during transport being the ultimate effect. The risk to animal welfare of transport on days with (extremely) high ambient temperatures for finisher pigs is estimated to be moderate. The risk to animal welfare of transport on days with (extremely) high ambient temperatures for broilers is estimated to be moderate to high.
- On days with temperatures of ≥27ºC, the critical period is between approximately 12 p.m. to 8 p.m. based on the sharp increase in ambient temperature in the afternoon and temperature drop in the evening respectively.
- During this critical period, 27,000 finisher pigs and 1,008,000 broilers are transported daily that may experience heat stress.
- The DOA% for broilers starts to increase within the temperature range from Tmax >27ºC. NVWA data from 2017 and 2018 shows that on days with temperatures of ≥30ºC the average DOA% at four large poultry slaughterhouses (with over 20% of Dutch slaughter capacity) was over three times higher than the average of four large poultry slaughterhouses (similarly with approximately 20% of Dutch slaughter capacity) that did not carry out slaughter activities in the afternoon and in the evening or early nighttime.
- Furthermore, the NVWA data on the daily working hours of the slaughterhouses and the average daily slaughter capacity was used to calculate that without adjustments to the working hours, over 40% of the

[6] https://english.nvwa.nl/about-us/documents/consumers/food/safety/documents/advice-on-the-risks-in-the-poultry-meat-supply-chain

broilers and finisher pigs supplied experience a moderate to significantly elevated risk of (severe) heat stress on days with temperatures of ≥27ºC.

- As a result of EU Regulation (EC) No 561/2006[7], certain pig transports, i.e. those without mechanical ventilation, with a duration of 4 – 8 hours and all poultry transports longer than 4 hours, have a higher risk of heat stress at ambient temperatures above the thermoneutral zone. This risk is increased due to unplanned stationary periods or the compulsory resting periods of the driver (in the event of a truck manned by a single driver), due to the fact that when a vehicle is stationary this will lead to an increase in temperature and humidity.

Risk mitigation measures

- There are various options to reduce the level of risk to animal welfare during transport at high ambient temperatures, including reducing the loading density, catching, loading and transporting animals during cooler spells, efficient scheduling of transports. These options are all familiar and available to stakeholders and are included in the Animal Transport Regulation, the National Plan and the sectoral protocols. However, they are not very concrete and those included in the National Plan and sectoral protocols are non-binding in nature.
- In Canada, there is a loading density calculator (transport stocking density calculator[8]) that calculates adjustments of the loading density, taking into account the expected travel distance and the expected temperatures en route.
- The poultry sector in particular has failed to express commitment to the National Plan, however does have its own set of precautions. The latter appear to be insufficient to prevent heat stress during periods of (extremely) hot weather based on this risk assessment for broilers.
- Essential components for the successful reduction of the effects of heat stress during transport under extremely hot weather conditions are the avoidance of stress prior to transport, effective ventilation within the transport compartments, in conjunction with appropriate reduction of the loading density of the vehicles, the avoidance of stationary periods of the vehicles if no mechanical ventilation is present and restriction of the transport hours for part of days on which the ambient temperature exceeds a critical limit.
- It is crucial that the responsibilities to animal welfare in the pathway from farm up to and including slaughter should rest with multiple actors. The farmer is responsible for the pre-transport phase (health status of animals, catching and loading the animals), the transporter is responsible during transport and the slaughterhouse is responsible for the phase during which the animals are at the slaughterhouse. Within the period of arrival at the slaughterhouse up to and including the unloading process, in formal terms the unloading process is part of the transport time, whereas the transporter has little influence over the period of time between arrival at the slaughterhouse site and the actual unloading of the animals.

[7] Regulation (EC) No 561/2006 of the European Parliament and of the Council of 15 March 2006 on the harmonisation of certain social legislation relating to road transport. Please see: https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=celex%3A32006R0561

[8] https://www.manitobapork.com/animal-care/transportation/transport-stocking-density-calculator

Response to research question

What are the animal welfare risks to finisher pigs and broilers during transport at (extremely) high ambient temperatures? Please take into account the animal indicators in order to determine welfare levels.

The risk to animal welfare during transport at (extremely) high ambient temperatures relates to heat stress experienced by the animals. This may be mild to severe heat stress for some of the animals, unevenly distributed across the various transport compartments, as well as very severe heat stress followed by death (Death-On-Arrival = DOA) for a smaller group of animals. The milder to severe heat stress is principally characterised by accelerated breathing of the animals (panting) as well as abnormal body posture of pigs.

No data was found in the literature regarding robust indicators for heat stress, such as the percentage of panting animals. Neither did this knowledge appear to be available among scientists during follow up, let alone that there are threshold values. The percentage death-on-arrival is a robust, reliable indicator, which, although it cannot be translated into heat stress one-on-one, does strongly correlate with severe heat stress, particularly if this mortality increases during transport at high temperatures.

Advice BuRO

To the Minister of Agriculture, Nature and Food Quality

- Mechanical ventilation should be made a mandatory requirement for all transports of finishing pigs and broilers over 27ºC.
- Initiative should be taken, preferably at the European level, to establish mandatory rules on (long) journeys to ensure that stakeholders in the finishing pig and broiler sectors and in the transport sector for live animals take adequate risk mitigation measures against heat stress at temperatures ≥30ºC [9].

To the Inspector-General of the NVWA

- The risk mitigation measures of the National Plan should be developed further in order to better safeguard animal welfare (specifically that of finishing pigs and broilers) during transport to slaughter during periods with high ambient temperatures. The development of the National Plan should therefore be continued, with the number of participants increased, particularly with parties from the poultry sector. In addition, there should be ongoing commitment to involving all relevant parties in the live animal transport sector.
- Physical inspection on hot days when the National Plan is being implemented should be limited in order to prevent halting of transport and thus increased heat stress. In this regard, it should be examined which other means of monitoring and supervision would be more appropriate without increasing animal welfare risks.
- A more comprehensive and more integrated use of (animal) indicators should be pursued to determine the welfare of animals (especially pigs and broilers) during transport, with any observed data being recorded from temperatures >25ºC.
- The recording and accessibility of data regarding animal welfare, such as that of DOA% and any abnormalities observed at the slaughterhouse, loading density, temperature logs and details of transporter and slaughterhouse, should be intensified to enable better insight into and benchmarking of transporters and slaughterhouses.

Yours sincerely,

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

[9] https://www.rijksoverheid.nl/documenten/kamerstukken/2019/09/04/kamerbrief-over-het-dierenwelzijn-tijdens-de-hitteperiode

Substantiation

Transport of animals in the Netherlands

Farm animals are transported for a variety of purposes, in order to be sold, for pasture management or to be transported to the slaughterhouse (Appleby, 2008). The lives of production animals can be divided into the following phases. Everything starts at the primary phase: at the farm where these animals are born and where they grow up until they are fit for slaughter. During this phase, some production animals are transported from establishment to establishment for further fattening or rearing. Then the second phase begins: the phase of transport to the slaughterhouse, slaughter and the cutting plant.

Most of the animals supplied for slaughter in the Netherlands are slaughtered in the Netherlands (Hoste et al., 2013; Directorate-General for Health and Food Safety (European Commission) et al., 2017), however some are transported to slaughterhouses in other countries for slaughter there (Directorate-General for Health and Food Safety (European Commission) et al., 2017). Within the EU, the free movement of animals from one Member State to another (e.g. due to a surplus of animals in one region and demand for animals in another region) and more uniformity between production animals and production systems has led to more long journeys from farm to farm or from farm to slaughterhouse (Lambooij, 2014).

Road transport of production animals includes the assembly and loading of the animals at the place of origin into the vehicle, the journey to the destination and the unloading of the animals at the destination (Schwartzkopf-Genswein et al., 2012). Under the Animal Transport Regulation, the waiting period in the lairage of the slaughterhouse is not included within the definition of transport. The internal climate and temperature in livestock transport vehicles is determined by external weather and climate conditions, the ventilation regime, the internal air flow patterns and the overall heat and moisture production of the animals (EFSA, 2004; Mitchell & Kettlewell, 2009; Ellis et al., 2010; Fiore et al., 2012).

Temperatures in a vehicle may vary according to the location inside the vehicle (top, bottom, back, front) as well as during transport (EFSA, 2011; Fiore et al., 2012; Gerritzen et al., 2012; Cockram & Dulal, 2018; Bracke et al., 2020) and will often be higher inside the vehicle than outside (Bracke et al., 2020). Humidity is more evenly distributed across the vehicle (Fiore et al., 2012), however there may be differences according to the location inside the vehicle if (mechanical) ventilation does not meet requirements (Cockram & Dulal, 2018). There may be natural or mechanical ventilation during transport (SCAHAW, 1999; Consortium of the Animal Transport Guides Project, 2017b). Natural ventilations occurs due to the pressure difference on both sides of the opening, with ventilation increasing due to the movement of the vehicle as it drives. In the case of mechanical ventilation, the air flow is actively generated by fans (SCAHAW, 1999). During long journeys (>8 hours) of Equidae, cattle, sheep, goats and pigs that are kept as farm animals, vehicles must have mechanical ventilation in place. In general, temperatures in the compartments of a stationary vehicle (loading/unloading/waiting period) will increase and will decrease when the vehicle is in motion. Relative humidity follows a similar patterns. These changes in temperature and humidity levels in the compartments reflect the changes in air speed (ventilation) within the vehicle. Ventilation is low when the vehicle is stationary and increases when the vehicle is in motion (Mitchell & Kettlewell, 2009; Sutherland et al., 2009; Ellis et al., 2010), provided that the vents are open, there is no tarpaulin covering the trailer and in the event of the absence of mechanical ventilation. Concentrations of carbon dioxide that are measured in a compartment of the vehicle are an indirect indicator of the degree of ventilation in that compartment. The higher the concentration of carbon dioxide, the less efficient ventilation will be (SCAHAW, 1999; Ellis et al., 2010). During transport, when the vehicle is in motion, outside air enters the rear of the vehicle, with air flow moving forward and leaving the vehicle there (Mitchell & Kettlewell, 2009; Ellis et al., 2010).

The transport of live animals in the Netherlands is made up largely of pigs and poultry.[10] Road transport is the most preferred method of transport for pigs, with the pigs generally being transported in large trucks or trailers with a capacity of up to 200 animals (Lambooij, 2014). These livestock trailers are divided into compartments and have two or three tiers that are 90 centimetres high (EFSA, 2011; Lambooij, 2014). In Denmark, the Netherlands and Belgium, pigs are mostly transported in 3-tiered trucks or trailers (Brandt & Aaslyng, 2015). The pigs can be loaded directly into the vehicle from the housing unit on the farm or can be kept in a separate area for a given time before they are loaded (Dalla Villa et al., 2009). The most common method of ventilating the compartments and containers is through the ventilation openings that have been placed at the top on either side of the vehicle (Lambooij, 2014). During short journeys (< 8 hours), there will often be natural ventilation and mechanical ventilation during long journeys (> 8 hours) (Dalmau et al., 2009; Consortium of the Animal Transport Guides Project, 2017b). Upon arrival at the slaughterhouse, pigs can be unloaded directly, however, the time until the unloading process for the trailer may vary and can range from several minutes to 4 hours (Faucitano & Goumon, 2018). Often pigs are placed in a lairage after having been unloaded until they can be slaughtered (Velarde & Dalmau, 2018).

All poultry species in intensive production systems are transported at least twice during their lifetime, as chicks and eventually to the slaughterhouse (Mitchell, 2006; Mitchell & Kettlewell, 2009). Road transport is the most common method of transport. Broilers are caught, placed in containers, which are subsequently loaded into a trailer to be transported to the slaughterhouse (Dalla Villa et al., 2009; Mitchell & Kettlewell, 2009). A container will on average contain 281±59 broilers. The broilers will be divided across 8 or 10 trays depending on the container system of the respective slaughterhouse (Gerritzen et al., 2019). The transport vehicles will often be equipped with adjustable tarp covers that can be open and closed (Fisher et al., 2009). Mechanical ventilation is not very common when transporting broilers (Dalla Villa et al., 2009). Upon arrival at the slaughterhouse, the containers in which the broilers are transported are unloaded an placed in lairage. The time the animals spend there may vary, but can be up to several hours (Welfare, 2019).

Laws and regulations

The transport and slaughter of animals must comply with European and national legislation, which prohibits animals to be transported by principal or third parties in such a way as to likely cause injury or unnecessary suffering.

[10] https://ec.europa.eu/food/sites/food/files/animals/docs/traces_report_annual_2017_eu_nld_eng.pdf

Europe
The European legislation on the transport of animals is outlined in the Animal Transport Regulation (Council Regulation (EC) No. 1/2005)[11] and applies to all vertebrates. In this regulation, transport is defined as: 'the movement of animals effected by one or more means of transport and the related operations, including loading, unloading, transfer and rest, until the unloading of the animals at the place of destination is completed.' This regulation lays down certain requirements for the transport of animals. The requirements relating to weather (climatic) conditions state that the vehicle must protect the animals from inclement weather, extreme temperatures and adverse changes in climatic conditions. A distinction is made between short (< 8 hours) and long (>8 hours) journeys. The following standards, linked to weather conditions, have been laid down in the European legislation for long journeys for pigs (not for poultry):

- 'Ventilation systems on means of transport by road shall be designed, constructed and maintained in such way that, at any time during the journey, whether the means of transport is stationary or moving, they are capable of maintaining a range of temperatures from 5 ºC to 30 ºC within the means of transport, for all animals, with a +/- 5 ºC tolerance, depending on the outside temperature.' In other words: the temperature in the means of transport by road may be between 0°C and 35°C.
- 'The ventilation system must be capable of ensuring even distribution throughout with a minimum airflow of nominal capacity of 60 m3/h/KN of payload. It must be capable of operating for at least 4 hours, independently of the vehicle engine.'
- 'Means of transport by road must be fitted with a temperature monitoring system as well as with a means of recording such data. Sensors must be located in the parts of the lorry which, depending on its design characteristics, are most likely to experience the worst climatic conditions.'
- 'Means of transport by road must be fitted with a warning system in order to alert the driver when the temperature in the compartments where animals are located reaches the maximum or the minimum limit.'

The Animal Transport Regulation states that the loading density may be reduced due to weather conditions in long journeys (> 8 hours) of pigs by increasing the minimum surface area per pig by up to 20%. In the case of poultry, the Animal Transport Regulation states that the minimum surface area may be adjusted in view of meteorological conditions and journey time, without providing any concrete percentages.

Finally, the Animal Transport Regulation states that in order to obtain authorisation for long journeys (> 8 hours), transporters must have a contingency plan in place. The contingency plan should include what action must be taken by the transporter in the event of an emergency during extreme temperature conditions. In the Netherlands, permits for long journeys can be applied for from the NVWA[12]. The vehicle will be inspected by the Netherlands Vehicle Authority (Dienst Wegverkeer, RDW). The NVWA also issues permits to transporters for short journeys, for which vehicles need not undergo inspection.[13]

[11] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32005R0001:NL:HTML
[12] https://www.nvwa.nl/onderwerpen/vervoer-levende-dieren/langer-dan-8-uren
[13] https://www.nvwa.nl/onderwerpen/vervoer-levende-dieren/korter-dan-8-uren

In 2018, the European Commission stated that the 5-degree tolerance should no longer be maintained when scheduling longer journeys and that transports should not take place in such cases (Bracke et al., 2020).

National legislation
The Dutch Animals Act[14] recognises the intrinsic value of animals, in any case ensuring that violations of the integrity or welfare of animals is prevented, beyond what is reasonably necessary. To this end, five freedoms (FAWC, 1993) are included in the law, whereby animals must be protected inter alia from physical and physiological distress and restrictions on their natural behaviour. This Act sets out general animal welfare rules, but does not include standards for the transport of live animals.

The Regulations on Animal Husbandry[15] complements the Animal Transport Regulation through a number of points regarding the transport of animals, however, does not cite specific standards relating to animal welfare during transport.

In 2019, the Ministry of Agriculture, Nature and Food Quality in a Letter to Parliament[16] pledged that a ban on the transport of animals at temperatures >35ºC on Dutch territory would be enshrined in law. In addition, this Letter states that the Ministry welcomed the European Commission's call for long journeys to be suspended if predicted temperatures should exceed >30ºC on the road.

National Plan
In 2015, the sector, working alongside the NVWA, began drawing up a National Plan for livestock transport under extreme ambient temperature conditions, in order to give more substance to the legal requirements[17]. The National Plan came into force on 1 July 2016 and is made up of various sectoral protocols and NVWA regulations. The plan comes into effect if temperatures of ≥27ºC are expected on four consecutive days according to the weather forecast of the KNMI in De Bilt. The threshold of 27 degrees Celsius was chosen to align with the National Heat Plan[18], which is aimed at helping people. Actual cases of extreme heat or cold during transport are determined based on actual temperatures that are detected at the site of the (forthcoming) transport using the app with data from the KNMI: 'Het Weer in Nederland' (The Weather in the Netherlands). The National Plan outlines the temperatures at which additional measures will be taken as well as the responsibilities of the various parties. Where the Animal Transport Regulation only prescribes additional measures, the National Plan stipulates that no animal transports should take place at temperatures >35ºC. In addition, the NVWA offers a hot weather schedule for certification to take place either earlier or later in the day to avoid the heat during the middle of the day. In addition, following the first two reviews of the National Plan, it was decided that export certification would be suspended in places where the KNMI had issued a 'Code Red' hot weather warning

[14] https://wetten.overheid.nl/BWBR0030250/2020-01-01
[15] https://wetten.overheid.nl/BWBR0035248/2018-11-01
[16] https://www.rijksoverheid.nl/documenten/kamerstukken/2019/09/04/kamerbrief-over-het-dierenwelzijn-tijdens-de-hitteperiode
[17] https://www.nvwa.nl/documenten/dier/dierenwelzijn/welzijn/publicaties/nationaal-plan-voor-veetransport-bij-extreme-temperaturen-2018
[18] https://www.rivm.nl/bibliotheek/rapporten/2014-0051.pdf

(>35ºC). At present, only the poultry sector has not committed itself to the National Plan.

NVWA monitoring
Monitoring of animal welfare in relation to animal transport is based on the Animal Transport Regulation and the Animals Act[8]. The NVWA monitors animal welfare during transport, at the inspection at the housing unit prior to export or at the start of export. Road transports are checked at the farm, along the road, at assembly centres or at the slaughterhouse. Aspects that are monitored include the condition of the animals, the soundness of the means of transport in the context of safety and the welfare of the animals, such as resting time, loading density, water supply, surface area and the standing height[19,20]. The NVWA carries out additional controls on transports (both short and long) during hot weather conditions, specifically focusing on temperature, contingency plan, water supply and ventilation. Additional monitoring measures by the NVWA for livestock transport already take effect on the first hot day (predicted temperature ≥27ºC)[21]. During the unloading of the animals at assembly centres or slaughterhouses, the inspectors must assess welfare in accordance with operational instructions, such as the way in which animals are treated, prevention of overheating and the number of animals that were dead on arrival[22,23]. Export certification of live animals is not carried on days with temperatures of >35ºC at the time of departure, at the place of departure.

Responsibilities
During the transport of animals, all relevant parties have a joint responsibility for the welfare of the animals[24]. Before the start of transport, it is the responsibility of the owner of the animals to ensure that only those animals that are fit for transport are loaded into the vehicle. During transport, the transporter is responsible for the welfare of the animals. During the unloading process (and possible reloading in the case of a stopover), this responsibility lies with the managers of the relevant facility (e.g. the slaughterhouse) and with the carrier. The NVWA monitors the welfare of the animal throughout the entire supply chain (please see NVWA Monitoring).

EU Member States
In 2015, the European Commission launched an Animal Transport Guidelines Project with the aim of improving animal welfare during transport by developing and issuing guidelines for 'good practices' (procedures and processes aimed at complying with current laws and regulations) and 'better practices' (providing a direction as to where and how processes and implementation thereof could be improved beyond the definitions of the laws and regulations). This resulted in the 'Animal Transport Guides'[25] for the transport of cattle, pigs, sheep, poultry and

[19] L&N03 VV 12 Operational instructions transport control of animals and animal products
[20] K-LV-WLZVL-01 Welfare procedure during transport of vertebrates
[21] K-LV-WLZVL-02, Certification under extreme ambient temperature conditions
[22] WLVZVL-017 - Monitoring of welfare of ungulates and farmed game at slaughterhouses
[23] K-PL-WLZ-WV-01, Monitoring procedure for welfare of poultry and rabbits at the slaughterhouse
[24] oie.int/index.php?id=169&L=0&htmfile=chapitre_aw_land_transpt.htm
[25] http://animaltransportguides.eu/materials/

horses. In January 2018, the first sub-group on the theme of 'animal transport' was established within the European animal welfare platform. In addition to other issues within the domain of transport of live animals, this sub-group focuses on transport at extreme temperatures (cold and heat), building on the work done by the Animal Transport Guidelines Project.

In 2017, the Inspection directorate of the NVWA conducted a survey among European Member States on animal transport at extreme ambient temperatures with the aim of surveying ongoing activities and available information. The survey inter alia enquired about the existence of national regulations or guidelines in supplement to the European Animal Transport Regulation. Various Member States have drafted national guidelines for transport at extreme temperatures, which provide recommendations on how to safeguard animal welfare. In Sweden, for example, mechanical ventilation is recommended for long journeys during exterior temperatures of 20ºC or above and in some German federal states certification takes place between 5ºC and 30ºC, retaining the +/-5ºC from the Animal Transport Regulation for any temperature changes. In addition, there are national guidelines, manuals and recommendations, most of which make general recommendations to improve animal welfare during transport. These are often similar and consist inter alia of rescheduling transport to cooler periods, discouraging long journeys, the use of mechanical ventilation and reduction of the loading density (from 10% reduction at temperatures above 25ºC in a German federal state to 30% reduction at an unspecified temperature level in the Czech Republic and Austria). Not all countries have established national guidelines: in Belgium, for example, there are no such guidelines. Many countries indicate that uniformity is needed within Europe or that standards should be concretised.

Thermoregulation

Birds and mammals, including poultry and pigs, are warm-blooded or homeothermic animals with a constant body temperature, independent of exterior temperatures (SCAHAW, 2000; Pereira & Naas, 2008; Renaudeau et al., 2012). The balance between heat production and heat loss mechanisms, driven by the thermoregulation process (Klaver, 2006), ensures that homeothermic animals are able to maintain a constant body temperature within their comfort zone, despite relatively significant changes in ambient temperature (Terrien et al., 2011). In the literature (Schrama et al., 1996; Huynh et al., 2005a; Aarnink et al., 2016), Mount's model (1979) or a similar model (Yousef 1985, cited in (EFSA, 2004)) is used to demonstrate the effects of ambient temperature on the thermoregulation of homeothermic animals. These models are based on a thermoneutral zone, in which body temperature is kept constant (Terrien et al., 2011) and at which metabolic heat production and energy consumption are minimal and the animal is comfortable (EFSA, 2004).

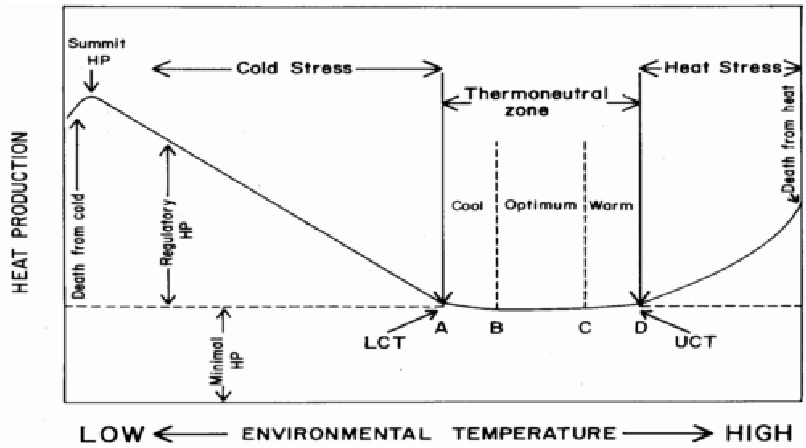


Figure 1 Schematic representation of ambient temperature and heat production (thermoregulation) in an animal (Yousef 1985, cited in (EFSA, 2004))

The thermoneutral zone is bounded at the top by the upper critical temperature (Figure 1 - UCT), above which physiological mechanisms (such as the dilation of blood vessels) attempt to prevent the rise in body temperature (EFSA, 2004; Renaudeau et al., 2012). In order to achieve this, the heat production of the animal can be reduced and the animal will absorb less energy (feed) and reduce activity. Increasing heat loss is the other side of the coin (Terrien et al., 2011). An animal can lose heat through evaporation, conduction, convection and radiation. Heat loss through convection and radiation depends mainly on the temperature gradient between the animal and the air. Heat loss through conduction is determined by the thermal temperature gradient between the animal and objects in the vicinity (Renaudeau et al., 2012; Spiers, 2012). The main driving force key to evaporation is the humidity in the surrounding air (Renaudeau et al., 2012), given that heat loss occurs when the water evaporates (passes into a gaseous state). If humidity levels are high, evaporation will occur less and there will essentially be less to no heat dissipation (Spiers, 2012). In the case of higher temperatures, adjustments to physiological mechanisms and behaviour will initially increase heat loss through conduction, convection and radiation (DeShazer et al., 2009). As soon as the ambient temperature approaches the skin temperature of the animal, heat loss via these pathways will decrease, allowing for overheating to take place (Spiers, 2012). Evaporation through the skin and through the respiratory system then becomes a key heat loss pathway (Renaudeau et al., 2012).

Thermoregulation in finisher pigs
Because pigs cannot perspire, heat loss for pigs through the surface of the skin (evaporation) can only take place if the skin is (made) wet. Pigs that are kept outside wet their own skin by covering themselves with mud (wallowing) in order to stimulate heat loss (Bracke, 2011). Inside the housing units, at high temperatures, pigs will prefer to lie on the slatted floor instead of on a solid floor. This is the first behavioural change that becomes visible at high ambient temperatures (Huynh et al., 2005b).

By nature, pigs will adapt their recumbent behaviour at high temperatures. More pigs will lie on their sides as opposed to taking a sternal or seated posture and pigs will also prefer to lie further away from conspecifics. This is likely to increase heat loss through conduction and to prevent heat absorption through radiation

(Huynh et al., 2005b). Even during transport at increasing temperatures, there will be a decrease in the number of pigs standing up (EFSA, 2011).

The first measurable physiological indicator of pigs in response to high ambient temperatures is an increase in their breathing rate (from 22.4ºC). The loss of heat via evaporation through respiration, by panting, is key in the heat balance in pigs, due to their inability to perspire (Huynh et al., 2005a). Panting starts through the nose and continues as rapid breathing with an open mouth with short breaths and a lot of salivation (Velarde & Dalmau, 2012). In the case of growing pigs with a weight of 60 kg, an elevation of the rectal temperature (at ambient temperatures over 26.1ºC) is an indicator of the ambient temperature exceeding the thermoneutral zone (Figure 1) (Huynh et al., 2005a). In the literature, various thermoneutral temperature zones are cited for (finisher) pigs. The zone is situated within a lower bound of 16ºC-22.9ºC and an upper bound of 23ºC-25.5ºC ((SVC, 1997; Myer & Bucklin, 2001; Quiniou et al., 2001; Huynh et al., 2005a; Brown-Brandl et al., 2013).

Thermoregulation in broilers
The optimum comfort temperature for older broilers (>4 weeks) inside a housing unit is situated between 21°C and 24°C, with the upper critical temperature (UCT) lying between 29°C and 32°C (Pereira & Naas, 2008). Chickens become inactive at high temperatures, keeping their wings away from their bodies, breathing with their beaks open, taking dust baths to cool off (Kettlewell & Turner, 1985; RDA, 2006) and distancing themselves from conspecifics (Daghir, 2008).

Other signs of stress caused by high ambient temperatures include rapid breathing (panting) (Kettlewell & Turner, 1985; Warriss et al., 2005) and an elevated body temperature (Warriss et al., 2005). Chickens do not have sweat glands (Renaudeau et al., 2012; Spiers, 2012) and to a large extent are dependent on heat loss through the airways (Renaudeau et al., 2012) by way of panting.

The ambient temperature that an animal experiences depends on interactions within and between their environment and also depends on animal-specific parameters (EFSA, 2004), such as the age, physiological status, acclimatisation status, dietary and nutritional intake of the animals. The genotype, slow versus fast-growing broilers, likewise plays a key role (Sandercock et al., 2006). These parameters will be important to take into account when determining the desired thermoneutral conditions (Mitchell, 2006). As stated previously, the climate inside the vehicle may vary (please see Transport of animals in the Netherlands). Tables 1 and 2 show that the dependence on a variety of factors that determine the climate inside a vehicle lead to dispersion of recommended temperatures during transport of finishing pigs and broilers.

The Table below shows several recommendations from the literature regarding maximum or optimal temperatures during transport of finishing pigs.

Table 1 Recommended maximum or optimal temperatures during transport of finishing pigs

Recommendation	Remarks	Source
<30°C	Maximum	(Dalla Villa et al., 2009)
10°C - 25°C (optimal 18°C - 20°C)	External temperature, no signs of heat stress	(EFSA, 2004)
25°C - (30°C *)	Inside the vehicle, * with mechanical ventilation and misting facilities	(EFSA, 2004)
29°C (>95% humidity) / 32°C (<95% humidity)	Maximum temperatures inside the vehicle.	(SCAHAW, 1999)
10°C - 28°C	Recommended temperature in the vehicle	(Anon., 2019)

Table 2 shows various recommendations from the literature for optimal or maximum temperatures during transport of broilers.

Table 2 Recommended maximum or optimal temperatures during transport of broilers

Recommendation	Remarks	Source
24°C - 25ºC (with a relative humidity of ≥70%)	Upper limit inside a container.	(EFSA, 2011)
<23°C - 24ºC, 20°C - 21ºC	Maximum or optimal temperature respectively inside containers/crates	(Mitchell & Kettlewell, 2009)
23°C - 27ºC	Maximum limit and range for safe transport of broilers	(Warriss et al., 2005)
10ºC - 15ºC	Air temperature around well-feathered broilers.	(Weeks et al., 1997)
8ºC - 18ºC	Thermoneutral zone for well-feathered broilers inside a container or crate in a moving vehicle.	(Webster et al., 1993)

Risk assessment
The risk assessment was carried out on the basis of the EFSA methodology (EFSA, 2009;2012b;2012a), which consists of a hazard identification, a hazard characterisation, an exposure assessment and a risk characterisation (see Annex A).

Hazard Identification
The hazards during transport are the factors that affect the animal's ability to lose heat (DeShazer et al., 2009), where a combination of factors (hazards), i.e. temperature, humidity, ventilation, loading density and journey duration, is

responsible for the effect on animal welfare (Mitchell & Kettlewell, 2008; Marahrens et al., 2011; Schwartzkopf-Genswein et al., 2012).

Temperature

The temperature in a vehicle is determined by the external meteorological conditions and the heat that is produced by the animals inside the vehicle (EFSA, 2004; Fiore et al., 2012). Heat loss from the vehicle depends on the gradient between the temperature inside or of the vehicle and the outdoor temperature (Schrama et al., 1996; Hahn et al., 2009). As a result, when the external temperature rises, the temperature inside the vehicle will increase (EFSA, 2004), unless this is regulated otherwise (e.g. by mechanical ventilation).

Humidity

The humidity inside a vehicle is determined by the external humidity, on the one hand, and by the animals present producing moisture, on the other (Dewey et al., 2009; Samal et al., 2017; Cockram & Dulal, 2018). Heat loss by the animal through respiration is determined by the difference in humidity of the exhaled air and the inhaled air (DeShazer et al., 2009). At higher levels of humidity, less water is able to evaporate per cubic meter of inhaled air (Aarnink et al., 2016). Higher levels of humidity therefore can significantly reduce heat loss through evaporation (Huynh et al., 2005a; Warriss et al., 2005; Spiers, 2012).

Ventilation

Ventilation is crucial to the removal of moisture and heat produced by the animals (Schrama et al., 1996; Consortium of the Animal Transport Guides Project, 2017b). Ventilation reduces the humidity inside the vehicle and increases the gradient with the external temperature. In addition, moving air results in more heat loss of the animal into the air (through conduction) and, in this way, the circulation of air can lead to improved heat tolerance (Schrama et al., 1996; DeShazer et al., 2009). When the vehicle is not moving, there is no external force that drives ventilation and the draining of heat and moisture will depend on any airflow present (Mitchell & Kettlewell, 2009). In addition, for efficient ventilation, it is vital there should be sufficient space above the animals (EFSA, 2004;2011). For both finishing pigs and broilers, inadequate ventilation combined with heat is a hazard during transport (EFSA, 2011).

Loading density

An increase in the loading density leads to an increase in moisture production by the animals and subsequently to an increase in humidity, which hampers heat loss by evaporation through respiration (SCAHAW, 2000; Nijdam et al., 2004; Abudabos et al., 2013). In addition, more heat per unit of volume is produced by more animals on the same surface area. The thermoregulatory behaviour of broiler chickens transported in containers is restricted (Mitchell & Kettlewell, 1998), thereby increasing heat radiation from broiler to broiler (SCAHAW, 2000).

The situation is virtually identical when transporting finishing pigs. In order to increase heat loss at high ambient temperatures, pigs will attempt to increase their distance from other pigs (Huynh et al., 2005b; Dalla Villa et al., 2009; Aarnink et al., 2016). Due to the limited surface area per pig during transport, this is made more difficult and therefore the physical surface area for each pig should increase at increasing temperatures (Huynh et al., 2005b; Bracke et al., 2020).

Due to the sensitivity of pigs and poultry to high ambient temperatures, Broom (Grandin, 2014) recommends that the loading density should be reduced at temperatures of 20ºC or above in order to avoid the risk of reduced animal welfare.

Journey duration

In the Animal Transport Regulation, transports are classified into short (< 8 hours) and long (> 8 hours) journeys. The effects of sub-optimal climate conditions during transport show a positive correlation with the duration of the journey (EFSA, 2011) and may increase the severity of the impact on animal welfare. For pigs and poultry, this means that the duration of the journey is a hazard to animal welfare if other factors, such as weather conditions or ventilation during transport, are not taken into account (van Reenen et al., 2008; EFSA, 2011; Nielsen et al., 2011; Brandt & Aaslyng, 2015).

Drivers of lorries or trucks are subject to a maximum uninterrupted driving period[26], which may not exceed 4.5 hours. After 4.5 hours of driving, the driver must take a break of at least 45 minutes. In the absence of mechanical ventilation, this 45-minute break may lead to elevated temperatures and humidity in the vehicle and in this way constitutes an additional risk factor to the animals being transported during longer journeys, as a break will be required. In the case of multi-manned vehicle with two drivers, no 45-minute break is required if the drivers switch after 4.5 hours.

Multifactorial impact of the hazards during transport

When the vehicle is not moving, critical situations may arise due to the absence of natural ventilation (in the absence of mechanical ventilation) and the increase of the temperature and humidity (EFSA, 2004; Mitchell & Kettlewell, 2009; Ellis et al., 2010; Gerritzen et al., 2019). Given that there is no external ventilation during stationary periods, heat and moisture reduction will depend on any wind present (Mitchell & Kettlewell, 2009).

As such, as long as the vehicle is moving and there is adequate ventilation, temperature and humidity will pose less of a threat to the welfare of the animals than when the vehicle is stationary and there is no mechanical ventilation (Faucitano, 2018; Jacqueline Berghout, 2018). This plays a key role in situations such as during the catching, loading and unloading processes of the animals. In order to prevent a rise in temperature and humidity, it is recommended that the animals should be unloaded as soon as possible, for which effective coordination of the supply of animals at the slaughterhouse is a key prerequisite (Consortium of the Animal Transport Guides Project, 2017a; Faucitano, 2018).

The loading density is a reinforcing factor in relation to the foregoing factors and will contribute to the severity of these factors and the same applies to the duration of the journey. In addition, transport causes stress from the moment the animals are loaded into the vehicle, resulting in an increase in body temperature, which can increase the impact of high external temperatures (Gerritzen et al., 2012).

[26] https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=celex%3A32006R0561

Other factors

Stress in general causes a change in the heat production of animals (Schrama et al., 1996). During transport, including during loading and unloading, animals are exposed to a broad variety of unfamiliar factors (EFSA, 2004), which may cause stress (Mitchell & Kettlewell, 2008; Consortium of the Animal Transport Guides Project, 2017a). This can make it more difficult for animals to cope with their surroundings, such as with high ambient temperatures (EFSA, 2004; Broom, 2014). If animals are producing more heat during transport as a result of stress, this will lead to a reduction of heat tolerance (Schrama et al., 1996). Animal-specific factors, such as age, body weight, genotype, thermal insulation (such as feather condition), the surface covering inside the vehicle, nutritional levels, level of production and health status can similarly all have an effect on the animal's ability to cope with its ambient temperature (EFSA, 2004; Broom, 2014; Cockram & Dulal, 2018). Finally, the climate conditions in the lairage area at the slaughterhouse play a key role (Vitali et al., 2014) alongside the duration of the stay in the lairage area (Nijdam et al., 2004).

Hazard characterisation

First and foremost, what the impact of the (combination of) hazards on the welfare of finishing pigs and broilers may be during transport will be outlined. Subsequently, how the various hazards in combination with one another impact animal welfare will be demonstrated based on existing models. Finally, an estimate will be provided of the welfare impact (severity x duration of the welfare problem).

Animal welfare and the (combination of) hazards during transport

Animal welfare is a broad concept and various definitions of it have been formulated. BuRO approaches animal welfare as described by EFSA (2012), which in turn uses the definition given by Broom (1986), which is an internationally accepted and widely-used definition of animal welfare:

'The welfare of an individual is its state as regards its attempts to cope with its environment' (Broom 1986).

Various systems operate within the body of animals that strive to achieve a constant internal environment or to minimise changes due to the external environment (Spiers, 2012). Stress is the biological response that is triggered when an animal identifies a threat (stressor) to its homeostasis (constant internal environment). When the stress response threatens the animal's well-being, the animal will experience 'distress' (negative stress) (Moberg & Mench, 2000). In this case, the animal (either voluntarily or involuntarily) will respond by deploying various coping mechanisms to survive (DeShazer et al., 2009).

The hazards (or stressors) cited under the hazard identification, certainly in combination with one another, constitute a threat to the homeostasis of finishing pigs and broilers. This threat, or the effect on animal welfare, is heat stress. Heat stress can range from being limited and short-term, where physiological and behavioural changes such as panting are sufficient to maintain body temperature, to being severe, resulting in death (Lara & Rostagno, 2013). These effects may be visible post mortem as the reduced quality of the meat.

During transport, the animals are hindered in the performance of thermoregulatory behaviour (Warriss et al., 2005; Aradom et al., 2012; Rioja-Lang et al., 2019) and are thus less able to cope with the impact of their environment. Heat stress can be characterised by the increase in exertion required for the thermoregulation (physiological and behavioural adjustments) and the success of that exertion (Mitchell & Kettlewell, 2008).

Additional effects of heat stress include dehydration (EFSA, 2011; Renaudeau et al., 2012; Kumar et al., 2017) and a disturbance of the acid-base balance (respiratory alkalosis) in broilers (Duncan, 2010; Song & King, 2015) caused by panting due to accelerated exhalation of CO_2. This disturbance can lead to the broiler's death (Kumar et al., 2017).

Heat stress can lead to the death of finishing pigs and broilers (EFSA, 2011; Schwartzkopf-Genswein et al., 2012; Correa et al., 2013; Lara & Rostagno, 2013; Jacobs et al., 2017). Death during transport is usually preceded by a period of reduced welfare (Broom, 2014). The number of animals that are dead on arrival at the place of destination (DOA) is then a key indicator of welfare (Butterworth et al., 2009; Dalla Villa et al., 2009; Dalmau et al., 2009) during transport. In addition, it is likely that the welfare of the surviving animals will also have been affected if the overall mortality rate during transport is high (Warriss, 1998; Dewey et al., 2009; Cockram & Dulal, 2018). In broilers, external temperatures can cause a rapid increase in the DOA rate (DOA%) from temperatures over 18ºC (Cockram & Dulal, 2018). In finishing pigs, increased mortality has been reported over 20ºC (Faucitano, 2018; Rioja-Lang et al., 2019) and the risk of death is 1.4 times higher at temperatures between 29ºC and 33ºC than between 12ºC and 26ºC (Peterson et al., 2017).

Heat stress can lead to a decrease in the quality of the meat both in pigs and poultry (Gregory, 2010; Schwartzkopf-Genswein et al., 2012; Lambooij, 2014; Petracci et al., 2015). Factors prior to slaughter, such as increased activity and a high ambient temperature in the summer, can increase the body temperature of animals. Higher post mortem muscle temperatures combined with an increase in lactate formation may lead to a higher incidence of PSE meat (Lambooij, 2014; Spurio et al., 2016). PSE (pale soft exudative) meat describes meat that is paler and softer and has an increased 'drip loss' and is worth less money due to colour differences and moisture loss (Petracci et al., 2015).

Welfare impact

Welfare impact is expressed as a function of severity and duration (EFSA, 2012a; Visser et al., 2015). The impact on the animal welfare of finishing pigs and broilers during transport at (extremely) high ambient temperatures in conjunction with the other hazards identified is heat stress, possibly resulting in death. The duration of the welfare effects in this risk assessment is considered equal to the duration of the transport at (extremely) high ambient temperatures.

Finishing pigs

No impact assessment for heat stress during transport was found in relation to finishing pigs. A report (van Reenen et al., 2008) focusing on the transport of finishing pigs identified and characterised various hazards during the transport of pigs. The hazard characterisation in this report is defined as: the impact of a certain environmental factor on the welfare of the animal (van Reenen et al., 2008), where the duration of the welfare impact is not cited. Although the risk assessment methodology used by Reenen (EFSA, 2006) has been refined (EFSA, 2012a), it does provide tools for the severity of the 'heat stress' welfare impact during transport to be assessed for pigs for the purposes of this risk assessment. Relevant aspects of the report (van Reenen et al., 2008) include the hazards of poor ventilation, high ambient temperatures during delays, a high loading density and a long journey duration, which are all characterised as severe (score of 4) to very severe (score of 5) (van Reenen et al., 2008). Death as a result of heat stress due to the presence of (a combination of) hazards outlined under the hazard identification increases in finishing pigs during transport and this welfare impact is classified as very severe (EFSA, 2009). The foregoing information results in an estimated score of the severity of the welfare impact of 4-5 (Severe – Very Severe, Table 3).

Transport of finishing pigs within the Netherlands often falls into the category of short journeys (<8 hours) (van Dixhoorn et al., 2010) and a European survey has shown that in most European countries, pig transports to the slaughterhouse take less than 2 hours (Dalla Villa et al., 2009). The annex[27] to a Letter to Parliament on animal welfare shows that most pigs are transported for <4 hours for export purposes. A project in which guidelines for risk assessment during transport, including for pigs, were developed scored the duration of a welfare impact during transport at 1 for a duration of up to 3 hours, with a score of 2 for a duration of between 3-8 hours (Dalla Villa et al., 2009). Based on this information, the duration of the welfare impact of heat stress in pigs is estimated to be a score of 1-2.

The Visser report (Visser et al., 2014) determined the impact of heat stress of finishing pigs from unloading at the slaughterhouse to slaughter to be score of 6. In the report, this score is defined as: extreme changes in respect of normal conditions that indicate pain, malaise, anxiety, fear or disease, resulting in death.

Based on the foregoing information, the impact for finishing pigs is estimated at a score of 4-6 (please see Table 3).

Table 3 Effect of welfare impact (based on severity and duration) on finishing pigs

Finishing pigs				
Welfare impact	**Severity score**	**Duration score**	**Impact score**	**Prevalence**
Hyperthermia leading to stress, dehydration, death	4 to 5	1 to 2	4 to 6	?*

* Prevalence of the welfare impact during transport is unknown (please see explanatory note below).

[27] https://www.rijksoverheid.nl/documenten/publicaties/2018/10/04/omvang-en-duur-export-slachtdieren

Broilers

In the risk assessment of animal welfare in the white meat chain (Visser et al., 2015), the welfare impact of hyperthermia leading to stress in broilers during transport was determined as being severe (score of 4). During transport, the severity of the welfare impact can increase to very severe (score of 5), possibly resulting in extreme changes in respect of normal conditions, which may be life threatening (death: increase in DOA). For that reason, the severity of the welfare impact of heat stress is scored between 4-5 (Severe – Very severe, Table 1).

As shown in the Animal Welfare Checkpoints (Visser et al., 2013), the period from the start of the catching process to arrival of the vehicle at the slaughterhouse may take an average of 2 hours and 46 minutes. The duration of the welfare impact in the risk assessment of animal welfare in the white meat chain (Visser et al., 2015) was determined and scored as 'short' (< 5 minutes, score of 1). Based on the foregoing duration of the journey cited in the Animal Welfare Checkpoints, the duration of the stress, caused by hyperthermia, experienced by broilers may last longer than 5 minutes. According to Visser et al., 2015 the duration is then classified as 'long' (score of 3). In summary, duration has therefore been scored as 1-3 (please see Table 4).

Based on the foregoing information, the impact for broilers is estimated at a score of 4-7.

Table 4 Effect of welfare impact (based on severity and duration) on broilers

Broilers				
Welfare impact	**Severity score**	**Duration score**	**Impact score**	**Prevalence**
Hyperthermia leading to stress, dehydration, alkalosis, death	4 to 5	1 to 3	4 to 7	?*

* Prevalence of the welfare impact during transport is unknown (please see explanatory note below).

Explanatory note

In order to determine the impact, it has been assumed that the animal welfare impact, i.e. heat stress, is present for the full duration of the journey and that all animals (100%) would experience this welfare effect during transport at high temperatures, where the intensity may vary per animal.

No data is available or was found in the literature regarding the prevalence of the animal welfare effect, i.e. the occurrence of non-fatal heat stress (visible by way of signs such as panting in finishing pigs and broilers during transport). Severe heat stress leading to death during transport may be made visible by an increase in the DOA% during transport on days with high temperatures. In order to reflect the impact of heat stress, this risk assessment therefore has focused on the (iceberg) mortality indicator (DOA%).

Although mortality cannot always be linked to heat stress directly, the analysis of the internal NVWA data[28], combined with open data from the KNMI, has shown that in 2017, 2018 and 2019 a significantly[29] higher mortality rate for broilers occurs during transport and that this increase is most salient at temperatures >30ºC (please see Figure 2 and Annex B). This increase is least significant in the year 2017.

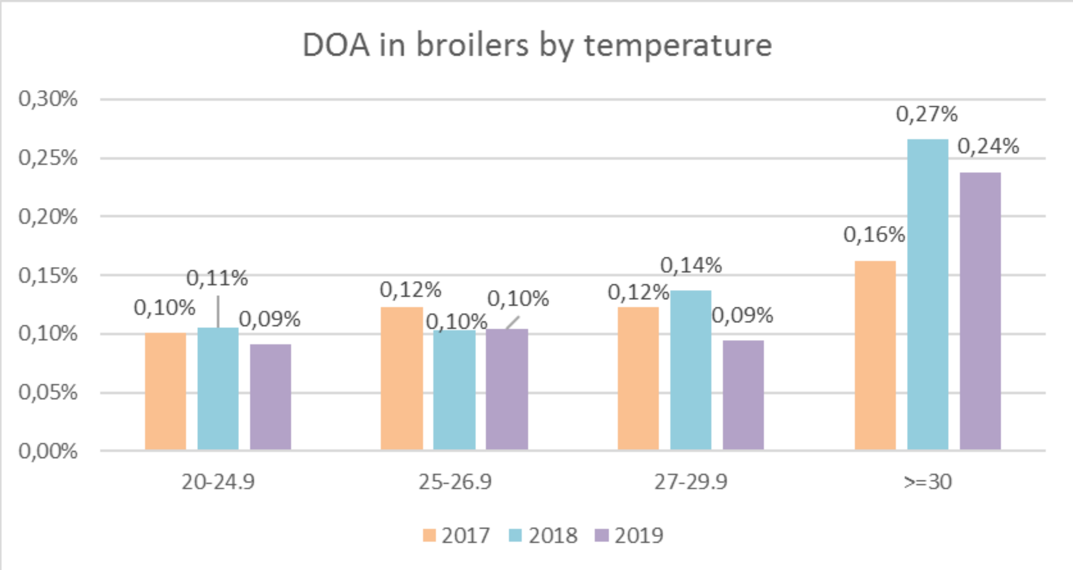


Figure 2 Weighted average DOA per temperature range between May and September in 2017, 2018 and 2019. NVWA data for broilers (Pladmin). (Annex B, Table B1)

Internal NVWA data on deaths of finishing pigs during transport is not yet systematically recorded in a single digital system and, as such, is not suitable for data analysis. The DOA% has been reported in the literature and is situated between 0.01% (Gade et al., 2007) and 0.50% (Warriss, 1998) with an average of 0.17% (±0.14 s.d., n=53 studies). The average DOA% in EU countries is approximately 0.13% (n=26). The values for the DOA% found in the literature between 0.3% and 0.5% often relate to reports of exceptional circumstances, such as to a stress-prone pig breed (0.5%, (Warriss, 1998)) or to extreme heat (0.46%, (Haley et al., 2010)).

Recent information on the situation in the Netherlands was found in public data from VION, one of the largest slaughterhouses in the Netherlands. In 2017, 99.98% of all transported animals for slaughter arrived at VION slaughterhouses alive[30]. Based on VION's public data[31] specifically on pigs, it can be inferred that between 2014 and 2016 the average DOA% per year likewise amounted to 0.02%. In the last two quarters of 2017 and 2018, this percentage increased to an average of 0.03%. The quarter with the highest DOA% (Q3-2018) coincides

[28] Pladmin 2017/2018/2019; Dead on arrival at the slaughterhouse
[29] This increase is not significant in the year 2017 for the temperature range >25ºC to 25-27ºC. As significant, P<0.002. Please see Annex B, Table B3.
[30] https://www.vionfoodgroup.com/app/uploads/2019/04/Vion-MVO-rapport-2017.pdf
[31] https://www.vion-transparantie.nl/keuringsresultaten/keuringsresultaten-archief/

with the heat wave in that year and it seems likely that there is a correlation (please see Annex D).

Dose response

The relationship between air temperature and humidity is crucial from the point of view of animal welfare during the transport of animals (Miranda-de la Lama et al., 2014). These hazards combined have the most effect on the potential for heat loss (Hahn et al., 2009). The temperature humidity index (THI) is a value that is calculated based on the combined effects of the external air temperature and humidity. THI formulae have been developed for various animal species based on physiological parameters, such as respiratory frequency and body temperature, heat production by the animals and production levels (including increase in body weight) (X. Tao & H. Xin, 2003; Samal et al., 2017).

	Relative humidity %														
Temp ºC	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
23	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73
24	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75
26	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76
27	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78
28	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80
29	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82
30	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84
31	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86
32	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87
33	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89
34	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
36	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93
37	79	90	82	83	84	85	86	87	88	89	90	91	93	94	95
38	80	82	83	84	85	86	87	88	90	91	92	93	94	95	97
39	81	83	84	85	86	87	89	90	91	92	94	95	96	97	98
40	82	84	85	86	88	89	90	91	93	94	95	96	98	99	100

Categories of Livestock Weather Safety Index associated with THI values

Normal: ≤ 74 Alert: 75 - 78 Danger: 79 - 83 Emergency : ≥ 84

Figure 3 Temperature humidity index (THI) adapted to (Hahn et al., 2009). This heat index was developed as a tool to predict heat stress in dairy cattle.

The THI-index shown in Figure 3 is based on the Discomfort Index for humans, which forms the basis for the Livestock Weather Safety Index (LWSI). In the LWSI, the heat stress risk categories associated with the external temperature and humidity are shown for the animal (Hahn et al., 2009; Aradom et al., 2012; Gaughan et al., 2012). It can be used both for animals in intensive livestock farming and for animals during transport (Hahn et al., 2009). The LWSI was developed to predict heat stress in dairy cattle, but is used as a standard tool for a wide variety of animal species (Gaughan et al., 2012) and can be used for pigs during transport to assess the threat to animal welfare during hot and humid weather conditions (Xiong et al., 2015). However, because pigs do not have sweat glands it is likely that the threshold values relevant to determining the welfare impact on these animals will be lower than for cattle (Fiore et al., 2009; Samal et al., 2017). This is also highly likely for broilers, as they are similarly unable to perspire (Hahn et al., 2009) and are more susceptible to heat stress than cattle (Fisher et al., 2009).

Studies have been conducted with regard to broilers on the combined effect of temperature and humidity during transport and the subsequent physiological stress caused in the animals as a result of this combination (please see Figure 4). Within the 'Safe' zone, the stress caused by heat during transport will be minimal. If temperature and humidity enter the 'Alert' zone, there will be some stress due to heat (hyperthermia and acid-base balance disturbance). Within the 'Danger' zone, animals will experience severe physiological heat stress and mortality will increase (Mitchell, 2006).

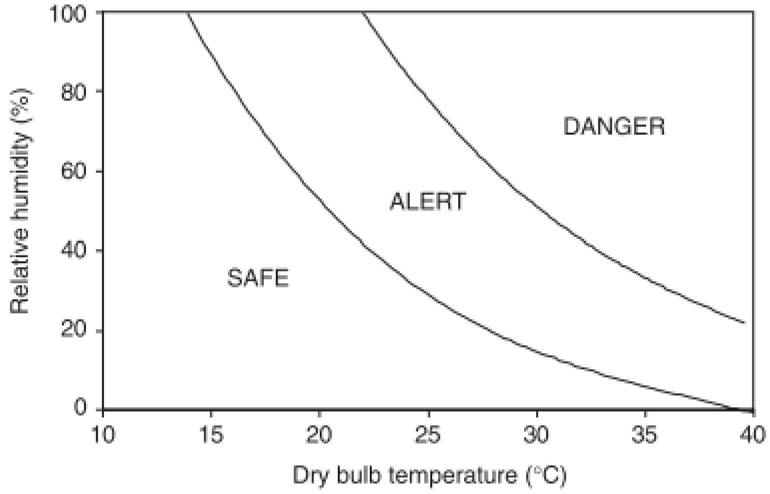


Figure 4 Combined effect of relative humidity and dry-bulb temperature (Mitchell, 2006) and the associated physiological stress shown in 3 gradations. Dry-bulb temperature is the temperature of the air, which does not take into account humidity.

Figure 5 shows the DOA% for broilers (Pladmin data) shown per THI category. The temperature humidity index (THI) is calculated using the LWSI[32] formula as a reference and meteorological data from the KNMI. Figure 5 shows that the DOA% increases with a higher THI[33].

[32] THI = (1.8 * T + 32) - (0.55 - (0.55 * H)) * abs((1.8 * T + 32) - 58) with T (°C) = temperature in De Bilt and H = humidity in De Bilt.
[33] Significant, P<0.002, please also see Annex B, Table B4

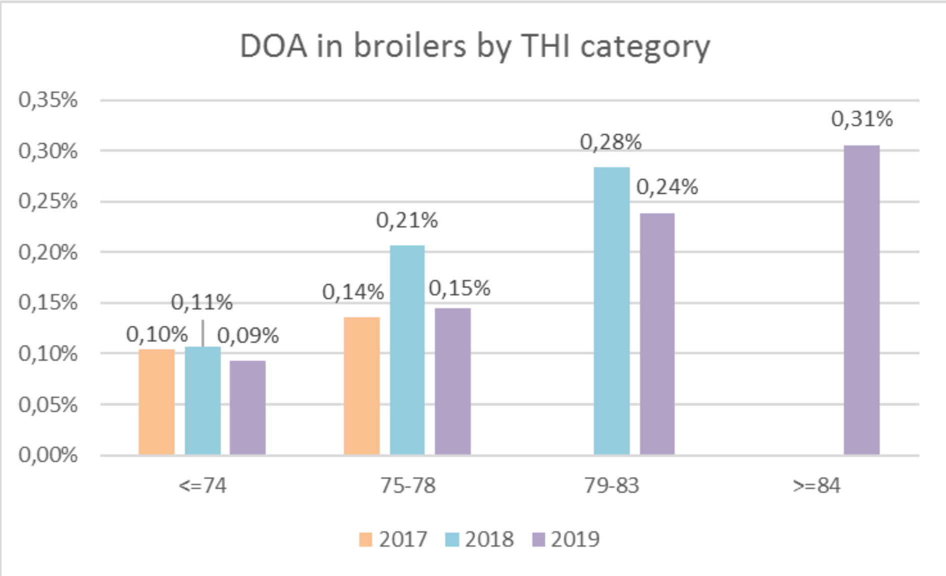


Figure 5 The Death-On-Arrival rate (DOA%) of broiler chickens recorded prior to slaughter, per year and per THI category based on the LWSI (≤74 = Normal, 75-78 = Alert, 79-83 = Danger, ≥84 = Emergency). (data from 2017, 2018, 2019, Annex B, Table B1).

The meteorological data used for previous analysis and further analyses in this risk assessment comes from public data from the KNMI[34] and data obtained from Weerplaza, which is also based on the KNMI. KNMI temperature (T) and relative humidity (H) data. Please see Annex C for the Weerplaza data used.

In Figures 6 and 7, a segmented regression analysis (also referred to as a piecewise regression) was carried out based on the internally available data from Pladmin (DOA%) and the temperature (T) and THI (index value of a combination of temperature and humidity) respectively. The breaking point is the point at which an increase in temperature or THI has a greater effect on the DOA%. In Figure 6, the breaking point is situated at T=27.3ºC. Above this temperature, there will be a greater effect on the DOA% for every 1ºC increase in temperature than at an 1ºC rise below this temperature.

[34] https://projects.knmi.nl/klimatologie/uurgegevens/selectie.cgi

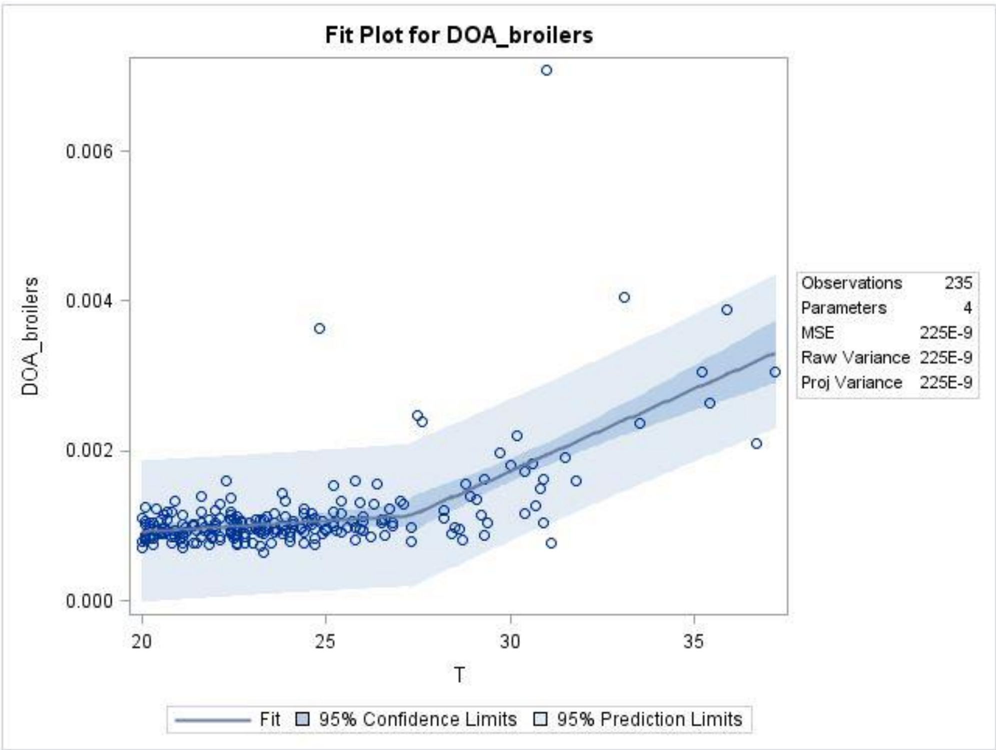


Figure 6 Piecewise regression analysis of the Death-on-Arrival rate (DOA%) of broilers established prior to slaughter relative to ambient temperature (data from 2017, 2018, 2019, Annex B, Table B1).

A similar segmented regression analysis (piecewise regression) was carried out for the calculated THI (please see Figure 7). Figure 7 shows the breaking point at THI = 75.5. Above THI = 75.5, an increase of one THI point therefore will have a greater effect than an increase of one THI point below 75.5.

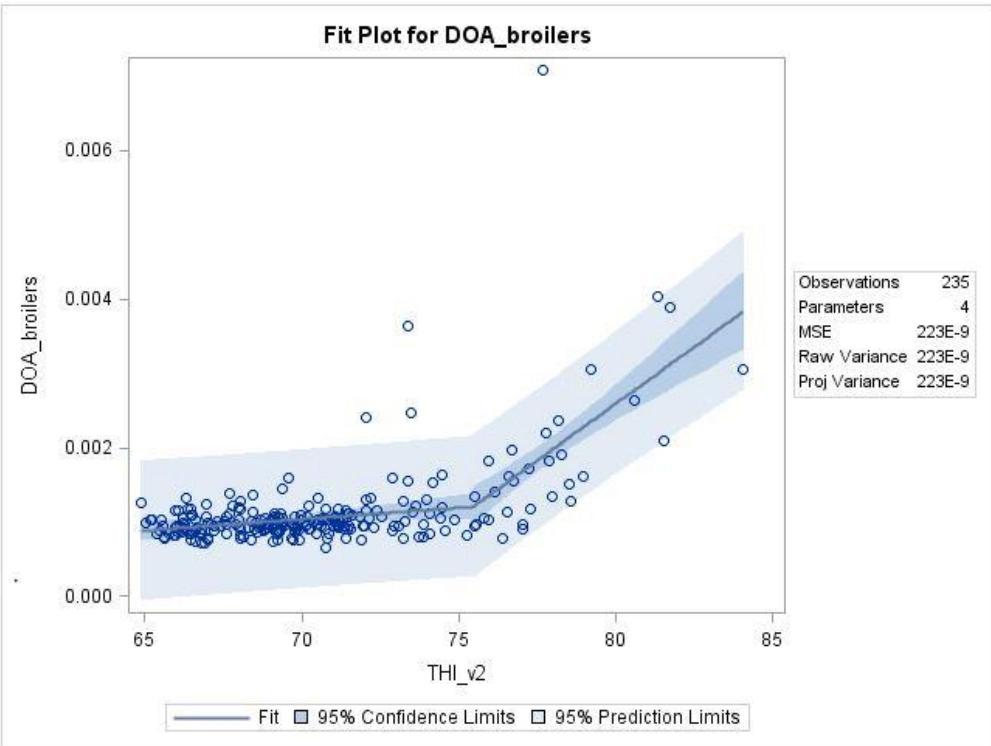


Figure 7 Piecewise regression analysis of the Death-on-Arrival rate (DOA%) of broilers established prior to slaughter relative to the temperature humidity index (data from 2017, 2018, 2019, Annex B, Table B1).

According to the LWSI, a THI of 75.5 falls within the Alert phase. This means that there may already be an impact on the DOA% and an adverse impact on animal welfare at this stage.

The THI Index, however, has a number of limitations, for example, it does not take into account the duration of exposure to a high THI or the effect of airflow and ventilation (Gaughan et al., 2012; Samal et al., 2017). The longer an animal is exposed to a THI outside the safe zone, the more stress the animal will experience (Villarroel et al., 2011; Gaughan et al., 2012), as may be the case during long journeys (Nielsen et al., 2011).

Ventilation plays a key role in the dissipation of heat and humidity as produced by animals during transport (Schrama et al., 1996; Consortium of the Animal Transport Guides Project, 2017b). In a controlled study in broiler chickens at slaughter weight, air speed (V) was integrated into the THI (X. Tao & H. Xin, 2003). In this study, the broilers were exposed to temperatures between 35°C and 41°C at various levels of humidity and different air speeds. In addition, the effect on the broilers (in this study, the increase in body temperature Δ x°C) of the duration of exposure to a certain temperature is visible (please see Figure 8). A higher level of humidity in the air will worsen the effect of high temperatures. A higher air speed (in practice: ventilation) will reduce this effect in turn.

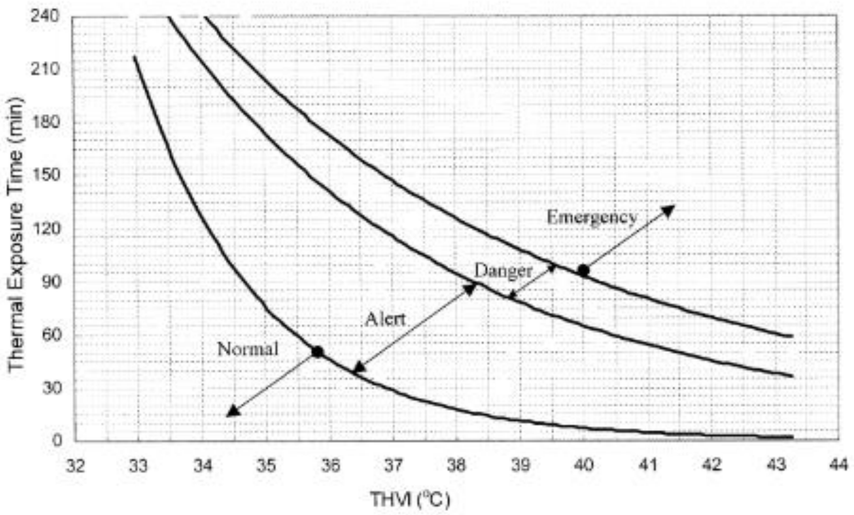


Figure 8 The difference (Δ) in body temperature for the normal, alert and danger state and an emergency state is Δ 1.0°C, Δ 2.5°C, Δ 4.0°C en Δ >4.0°C(X. Tao & H. Xin, 2003) respectively.

The figures above show that the combination of high humidity levels and high ambient temperatures pose the most significant threat to animal welfare. Ventilation plays a key role in reducing the impact of the combination of these hazards.

Exposure to hazards
The National Plan for livestock transport comes into force when extreme temperatures of ≥27ºC are expected according to weather forecasting by the KNMI at De Bilt. Table 5 inter alia shows the number of days on which temperatures exceeded ≥27ºC between 2000 and 2019, following analysis of open data from the KNMI.

Table 5 KNMI weather data 2000-2019 De Bilt (rounded up)

KNMI data 2000 - 2019 (averages/year)	
Number of days ≥27ºC	12
Number of days ≥30ºC	8
Number of days ≥35ºC	1
Period of 4 days or longer of ≥27ºC	2

In the Netherlands, the local climate, and the number of (extremely) hot days, is variable, with more hot weather days in the south-east of the Netherlands than in the coastal areas. For that reason, weather data both from De Bilt and data from Arcen in the south was analysed (please see Annex C). Following analysis, these sites appear to be comparable and this exposure assessment is therefore based on the data from De Bilt (please see Annex C). The months with the most risk are July and August in particular, however, the months of May to September equally contain the possibility of adverse effects due to heat stress on hot, sunny days (Timmerman et al., 2018). This exposure assessment (as well as the data analysis of the slaughterhouse data for broilers) therefore is based on data for the months of May to September.

The exposure assessment encompasses both the duration and the prevalence of the hazards during transport. In addition to high external temperatures, there are other hazards that play a key role in causing adverse welfare impacts in finishing pigs and broilers during transport, such as high humidity levels, although these are lowest in the Netherlands during the summer months (Timmerman et al., 2018). During these high-risk months, wind speeds are at their lowest (Timmerman et al., 2018), which can lead to reduced natural ventilation during transport. There is no data on the prevalence of the individual hazards referred to in relation to hazard identification during transport (e.g. temperature records of the temperature in the vehicle during transport of finishing pigs or broilers in the Netherlands) and there is little data on the duration of exposure to the hazards during transport. Due to the absence of this data, the exposure is based on an estimate. The hazard 'high external temperature' is used as the starting point in relation to which an attempt has been made to take into account the combination of 'external temperature' and 'humidity'. Any potential variation in temperature and humidity at various locations within the vehicle has not been taken into account.

The National Plan comes into force for weather forecasts of four consecutive days of temperatures ≥27ºC, however, additional monitoring measures on the part of the NVWA are put in place on the first day with temperatures ≥27ºC. This exposure assessment is based on a day on which temperatures of ≥27ºC are expected. It is assumed that on these days (critical days, ≥27ºC), there will be effects on the welfare of finishing pigs and broilers (heat stress, ranging from panting to death) during transport to the slaughterhouse in the Netherlands. This is based on the recommended temperatures during transport in the literature (please see Table 1 and 2), the elevated DOA% in broilers and evidence from the literature and external data of a similar effect on the DOA% in finishing pigs (internal NVWA data; please see welfare impact).

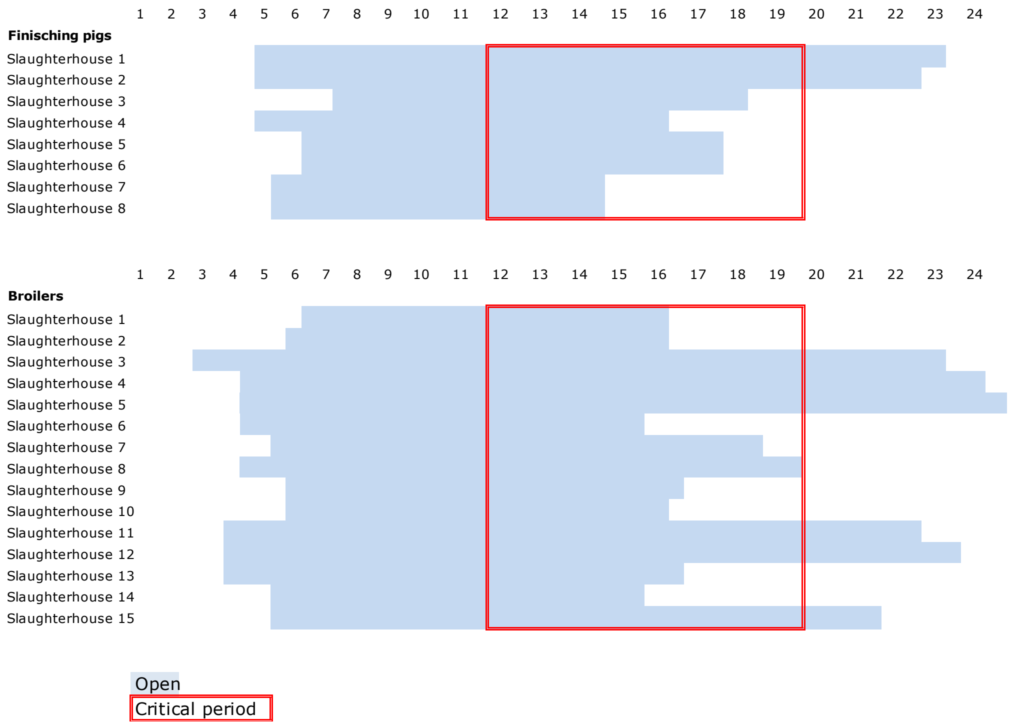
<u>Critical period</u>

During any given day, external temperature will generally present a type of progression, where temperatures decrease during the night, increase in the morning, with the hottest period being reached after noon. As the evening approaches, temperatures once again decrease. In 2018 (May to September), on days with temperatures of ≥27ºC or above, the highest average temperatures were reached at 5 p.m., with the lowest average temperatures recorded at 6 a.m. in the morning.

Humidity levels practically display an inverse pattern, with humidity levels increasing at night, decreasing in the morning and afternoon and rising again in the evening ahead of nighttime (please see Annex C). In 2018 (May to September), on days with temperatures of ≥27ºC or above, the highest average humidity levels were reached at 6 a.m. (89%), with the lowest average humidity levels being recorded at 4 p.m. in the afternoon.

In this exposure assessment, days on which external temperatures of ≥27ºC or above are expected are referred to 'critical days'. The hottest period during a day, which is reached in the afternoon, is referred to as the 'critical period' (12-8 p.m., please see Annex C). This critical period was established following analysis of the Weerplaza data (based on KNMI data), which shows that on days with temperatures ≥27ºC on average these temperatures are reached at 12 p.m. in the afternoon and then drop below that point after 8 p.m. In addition, the number of times temperatures reach ≥27ºC at a given hour increases at 12 p.m. in the afternoon and decreases again at 8 p.m. in the evening. This does not mean that temperatures of ≥27ºC are entirely excluded outside the critical period. The analysis of the meteorological data showed that on days where temperatures of ≥27ºC or above were measured, these temperatures were not reached before 8 a.m. in the morning. In 2018, temperatures of ≥27ºC were reached at 8 a.m. as a one-off measurement. The critical period from 12 p.m. to 8 p.m. can be supported judging by the measuring points for the whole of 2018 in the months of May to September.

Transport to the slaughterhouse will mainly take place during, and depending on the duration of the journey, prior to the working hours[35] of the slaughterhouses, depending on aspects such as the capacity of the supply hall of a slaughterhouse (animals may be supplied earlier). In the Netherlands, slaughterhouses have variable working hours (please see Figure 9). Certain slaughterhouses only operate in the early morning and during the day, whereas others are open in the evening. Figure 9 shows the critical period (hottest period in a day) indicated in red. At slaughterhouses that slaughter finishing pigs, 45% of the hours that the slaughterhouses are open fall within the critical period; for slaughterhouses that slaughter broilers, this is 42%. This exposure assessment does not take into account potential changes in the working hours of the slaughterhouses in response to hot weather.



[35] Working hours are defined as the hours the slaughterhouse is open for business and when animals are actually slaughtered. This information is based on internal NVWA scheduling.

Figure 9 Working hours of slaughterhouses in the Netherlands (2017 internal NVWA). The hottest temperatures on a critical day (≥27ºC) together constitute the critical period (12-8 p.m.).

At-risk population

The at-risk population is made up of the finishing pigs and broilers that are transported to the slaughterhouse in the Netherlands on a critical day. Transport of finishing pigs and broilers to the slaughterhouses in the Netherlands in general takes no longer than 4 hours (please also see welfare impact). As such, the duration of exposure is assumed to be equal to the transport time of 4 hours.

The finishing pigs and broilers that are slaughtered on any given critical day are transported to the slaughterhouse, where the following scenarios are possible:

1. Transport takes place entirely outside the critical period. This means that transport will have taken place during the cooler period of the day.
2. Transport has taken place partly within the critical period. This means that transport may have partly taken place during the cooler period and partly during the critical period.
3. Transport takes place entirely within the critical period.

In scenario 1, the finishing pigs and broilers that arrive at the slaughterhouse are very likely to experience little to no reduction in animal welfare in the form of heat stress during transport. This is due to the absence or low exposure to the hazard, i.e. high external temperatures.

The finishing pigs and broilers arriving at the slaughterhouse in scenario 2 are exposed to the hazard of high external temperatures to a greater or lesser extent, depending on the start time of transport. This cannot be quantified further due to a lack of data. Transports that depart before 8 a.m. in the morning and with a maximum journey time of 4 hours will likely cause little to no reduction in animal welfare in the form of heat stress during transport, as is the case for the animals in scenario 1. This is due to the absence or low exposure to the hazard, i.e. high external temperatures. Transports that depart later, assuming a journey time of 4 hours, will arrive within the critical period where the animals are exposed to the hazard, during which they may experience reduced animal welfare in the form of heat stress with varying durations.

The finishing pigs and broilers that arrive at the slaughterhouse under scenario 3 will be exposed to the hazard of high external temperatures, most likely resulting in the welfare effect of heat stress, varying in terms of its impact.

The fact that exposure corresponds to the time at which the transport takes place is supported by an analysis of internal NVWA data. In Figure 10, the percentage of flocks with a (significantly) increased DOA% per temperature range above 25ºC is compared with the temperature range <25ºC and expressed as relative increase. A threshold of 0.5% (signal threshold) is used for the increased DOA%. In addition to the signal threshold, the DOA% in Figure 13 and Annex B is also compared to a 1% threshold (intervention threshold)[36].

[36]The terms signal threshold ('signaalgrens') and intervention threshold ('interventiegrens') were used internally within the NVWA until 2019.

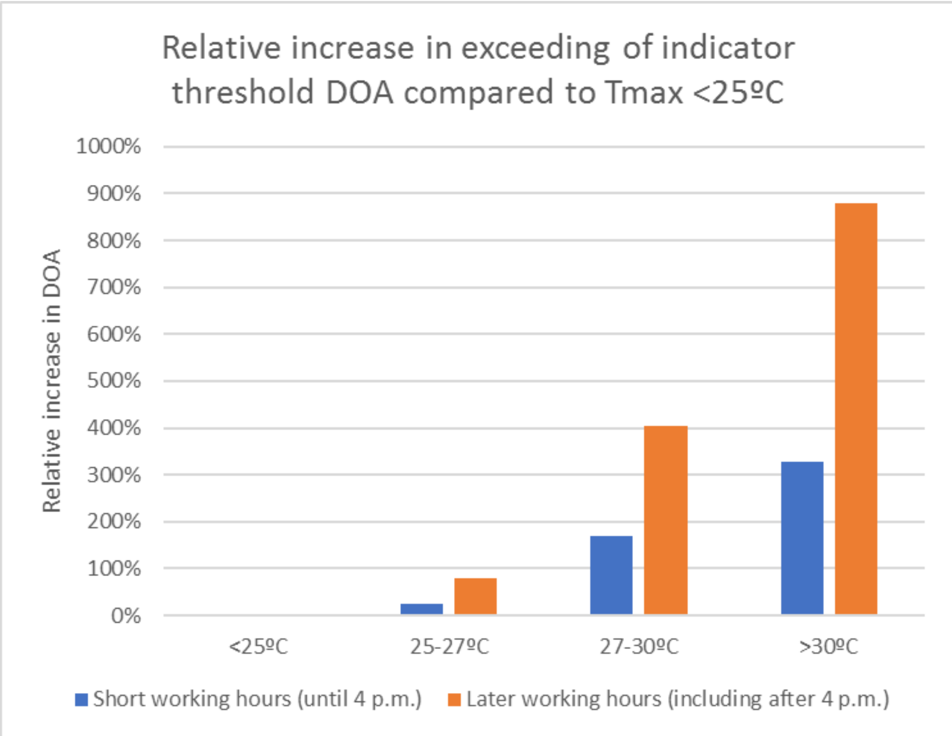


Figure 10 NVWA data on broilers for May-September 2018 period. Relative increase in exceeding DOA% (signal) threshold of broilers and comparison of this increase at slaughterhouses with early or late working hours. (please see Annex B, Table B6)

Figure 10 shows that an increase of the % of flocks with an elevated DOA% (DOA% > 0.5%) takes place for all slaughterhouses at rising temperatures. The higher the temperature, the clearer this difference becomes. In the case of slaughterhouses with short working hours, the % of flocks with an increased DOA > 0.5% is three times higher at temperatures of >30ºC compared to temperatures of <25ºC. Working hours later on in the day means that transport took place more frequently according to scenario 3, meaning that it took place during the critical period in its entirety (12-8 p.m., hottest period of the day). At slaughterhouses that also slaughter animals later in the day, the increase in the % of flocks with an increased DOA > 0.5% is almost nine times higher. Due to the absence of data on this aspect, the possible presence of climate control in the slaughterhouses and the differences in this regard between slaughterhouses has not been taken into account. As such, other factors may be in play beyond supply later in the day.

Scenario 3 is used for both finishing pigs and broiler chickens. This is the worst case scenario and means that these animals are exposed to the hazard of high external temperatures for the entire duration of transport (100% exposure). It is estimated that in this scenario, more animals will experience the highest impact of heat stress. This is supported by the increase in the DOA% of broilers at higher temperatures (please see Figure 2).

Finishing pigs

In 2017, an average of 60,000 finishing pigs were slaughtered per day. Based on the working hours of the slaughterhouses, 45% of these pigs will have been transported to the slaughterhouse during the critical period. This means that 27,000 finishing pigs would have been exposed to high temperatures, potentially causing heat stress, during transport on a critical day. The pigs that are transported under scenario 2 will be partially exposed (depending on the departure time of the transport). This means that according to a realistic worst case scenario, exposure will be higher than 45%.

Broilers

In 2017, an average of 2.4 million broiler chickens were slaughtered per day. Based on the working hours of the slaughterhouses, 42% of these broilers would have been transported to the slaughterhouse during the critical period. This means that 1,008,000 broilers would have been exposed to high temperatures, potentially causing heat stress, during transport on a critical day. The broilers that are transported under scenario 2 will be partially exposed (depending on the departure time of the transport). This means that according to a realistic worst case scenario, exposure will be higher than 42%.

The following assumptions in this exposure assessment were made due to an absence of data:

- The number of pigs or broilers slaughtered/per hour is constant every hour.
- The hazard of 'temperature' plays a key role to the same extent throughout transport. Potential mitigation measures during transport, such as ventilation, have not been taken into account.
- The highest temperatures are reached during the critical period on each critical day.
- The working hours of the slaughterhouses are the same on all critical days.
- Transport journeys of finishing pigs and broilers to the slaughterhouse in the Netherlands take up to 4 hours. This is the duration of exposure.

This exposure assessment does not explicitly take into account the time required to load and unload the animals and the waiting periods at the slaughterhouses. As such, the duration of exposure may be underestimated. This is highly likely the case for animals transported under scenario 2. These animals often arrive at the slaughterhouse at the start of the critical period. Depending on the waiting period (the longer, the greater the impact) and mitigation measures of the slaughterhouses, they may be exposed to high temperatures during these waiting periods. In addition, the practices of the slaughterhouses vary and the climate control facilities may vary from slaughterhouse to slaughterhouse. Both of these factors can affect the duration of exposure as well as the impact of heat stress and the DOA%. In addition, in broilers, the DOA% is established at the slaughter line and therefore no distinction can be made in terms of when death occurred (during transport or in lairage).

Risk characterisation

The risk characterisation below is based on the exposure that occurs during transport during the critical period. The risk is therefore characterised on the basis of the worst case scenario outlined in the previous section. Heat stress, the adverse welfare effect of transport during extreme temperatures, varies in terms of severity. Heat stress can be expressed in the form of panting, but can also result in death. No data is available that allows the further quantification of this variation. For that reason, the distribution of the welfare impact is taken into account when assessing the risk.

In order to assess the risk to the animal welfare of finishing pigs and broilers transported in the Netherlands on days with high temperatures, the welfare impact of the welfare effects identified (heat stress) has been plotted against the probability of transport to slaughter during a critical period and on a critical day (temperature >27ºC).

Finishing pigs

The impact assessment of heat stress for finishing pigs that are transported to the slaughterhouse during high temperatures in the Netherlands is a score of 4-6. How often and to what extent heat stress occurs is unknown. In the worst case scenario, 45% of transports take place during the critical period. It follows that the estimated risk to animal welfare for transports during high temperatures is moderate (please see Figure 11). The vertical arrow shows the distribution of the impact of the animal welfare effect of heat stress (impact score of 4-6).

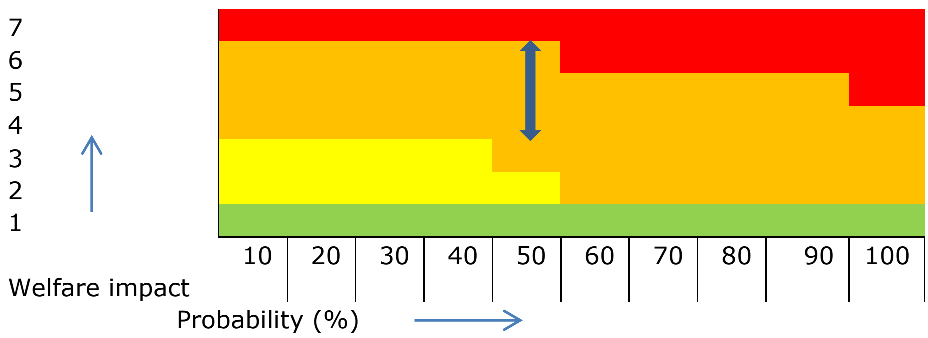


Figure 11 Risk assessment of transport of finishing pigs at high temperatures (blue arrow, welfare impact 4-6 and 45% probability) Green: no risk; yellow: low risk; orange: moderate risk; red: high risk.

Broilers

The impact assessment of heat stress for broilers that are transported to the slaughterhouse during high temperatures in the Netherlands yields a score of 4-7. How often and to what extent heat stress occurs is unknown. In the worst case scenario, 42% of transports take place during the critical period. It follows that the estimated risk to animal welfare for broilers in transports during high temperatures is moderate to high (please see Figure 12). The vertical arrow shows the distribution of the impact of the animal welfare effect of heat stress (impact score of 4-7).

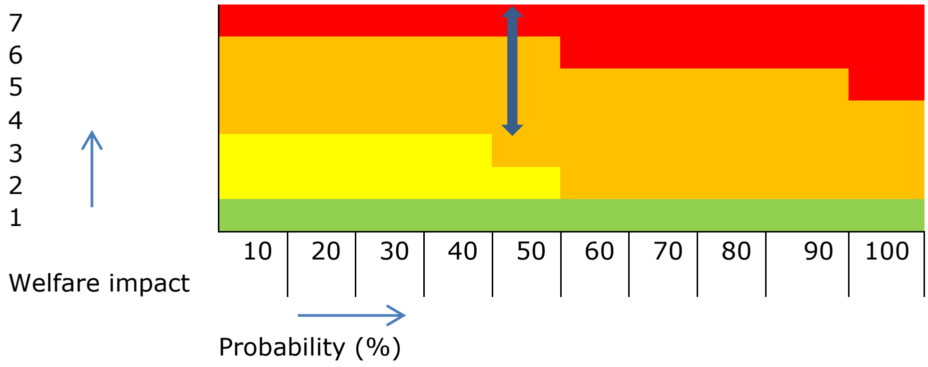


Figure 12 Risk assessment of transport of finishing pigs at high temperatures (blue arrow, welfare impact 4-7 and 42% probability) Green: no risk; yellow: low risk; orange: moderate risk; red: high risk.

<u>Explanatory note</u>

The risk assessment of animal welfare is based on transport during the critical period. This means maximum exposure to the hazard and variable impact on animal welfare. In the scenarios (please see step 3, exposure) in which transport takes place outside or partly within the critical period, exposure to (a combination of) hazards may equally occur. This may affect animal welfare in the form of heat stress. As demonstrated by the dose-response relationship, there is a correlation between the temperature (and humidity) levels and the severity of the welfare impact. There may therefore be a (slightly) elevated risk of reduced animal welfare. The exact number of animals that will be exposed in these scenarios cannot be estimated, however, for both finisher pigs and broilers the risk (blue zone) in Figure 11 and 12 will shift to the right due to an increase in the number of animals exposed. This shift, which depends on the increase in exposure, leads to an increase of the risk to animal welfare and then reflects the realistic worst case scenario. In addition, it can be argued that based on the dose-response relationship, the distribution of the impact of the welfare impact of heat stress will not be linear. The higher the temperature, the more animals are likely to experience a higher negative impact on their welfare.

Both graphs show a vertical distribution of the risk. This is caused by a distribution of the welfare impact due to the variation in the estimated severity of heat stress (which may also vary for each individual animal) and the lack of factual knowledge/data on the duration of the welfare effect of heat stress during transport.

The definitions of critical day and critical period as stated in relation to exposure may result in an underestimation of the number of animals exposed. A critical day is currently defined as a day on which external temperatures of ≥27ºC have been predicted without taking into account the impact of the other hazards. The literature has shown that a combination of hazards, particularly the combination of temperature and humidity, appear to have the greatest impact on the onset of heat stress in finishing pigs and broilers. This is certainly the case in relation to absent/malfunctioning (mechanical) ventilation. In the absence of data, the risks cannot be refined any further based on a combination of hazards. The combination of hazards, however, can lead to a potential accumulation of effects and lead to a higher risk to animal welfare. Finally, the defined critical period does not take into account the possibility that temperatures may have been reached outside of this period, possibly in conjunction with other hazards, with welfare impacts on finishing pigs and broilers.

This risk assessment takes little or no account of the duration of the loading process and waiting periods at the slaughterhouses. These periods fall within the definition of transport under the European Animal Transport Regulation. As a result, the duration of exposure may be underestimated, which, in turn, applies to the risk on animal welfare.

Conclusions
On days with external temperatures of ≥27ºC, there is a risk to animal welfare for both finishing pigs and broilers in the form of heat stress during transport. The severity of heat stress can range from mild discomfort in the form of panting to the death of the animal. Exposure, and therefore the risk, is greatest during the critical period (12-8 p.m.). For finishing pigs, this risk is moderate and for broilers this risk is moderate to high.

Analysis of internal NVWA data (2017, 2018 and 2019, please see Figure 2) has shown that the DOA% in broilers increases at rising temperatures. This DOA% increases more strongly at temperatures above 30ºC compared to temperatures above 27ºC. The intervention threshold used by the NVWA also seems to be exceeded more often at these high temperatures. Taken together, this indicates that the risk to animal welfare increases above 30ºC. In addition, Figure 1 already shows a relative increase in the DOA% in broilers from 25ºC, meaning that therefore based on this data it is very likely that the risk will increase from as low as 25ºC and that measures should be taken from the level of that temperature to reduce or prevent the risk to animal welfare.

The exposure assessment provides an overview of the working hours of the slaughterhouses (please see Figure 9). The internal NVWA data relating to DOA% was combined with the working hours of the slaughterhouses shown in the table below. Based on the NVWA DOA data from 2018, the differences in the DOA% between poultry slaughterhouses that primarily were open at night until the afternoon (until 4 p.m.) versus the slaughterhouses that continued slaughter activities through late afternoon and into the evening (until after 9 p.m.) were reviewed. In 4 large poultry slaughterhouses (with over 20% of NL slaughter capacity), the average DOA% was over 3 times higher on days with ≥30ºC than the average of 4 large poultry slaughterhouses that did not slaughter animals in late afternoon and evening (similarly approximately 20% of NL capacity) and an increased number of incidents can be seen from the exceeding of the signal and intervention threshold (please see Figure 13). This substantiates the defined critical period and demonstrates that the risk increases in late afternoon due to increasing temperatures.

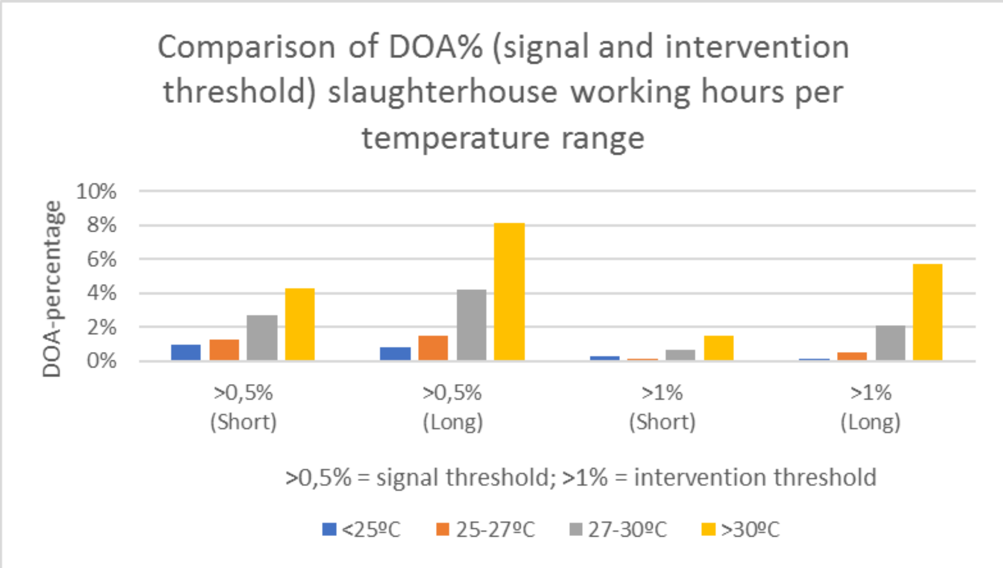


Figure 13 Comparison of the DOA% of slaughterhouses with short working hours (until 4 p.m.) and slaughterhouses with later working hours (after 9 p.m.) between May and September 2018 based on NVWA data on broilers (please see Annex B, Table B6).

Internal NVWA data on finishing pig mortality during transport is not systematically recorded in a single digital system and, as such, is not available. A similar effect can be expected in these animals, based on the identified literature, VION data and risk assessment.

Potential risk mitigation

In order to reduce the level of risk to animal welfare during transport, it is vital to examine the two key areas where this can be achieved:

Reducing exposure

Reducing exposure during transport leads to fewer animals ending up in a situation where they are exposed to (a combination of) hazards, possibly resulting in heat stress. Previous chapters indicate that exposure to high ambient temperatures primarily occurs roughly between noon and 8 p.m. in the evening. This means that the risks to animal welfare can be prevented by ensuring that transport takes place outside of this period of time on days with external temperatures of ≥27ºC or by discouraging or even prohibiting such transports altogether. Considering the recommended temperatures during transport (please see Tables 1 and 2) and the risk characterisation, the risks to animal welfare are most significant in transports with temperatures of ≥30ºC. This also applies to journeys during which temperatures ≥30ºC are expected.

In addition, if transport takes place between noon and 8 p.m., the length of the journey will determine the duration of exposure to the hazard. Longer journeys mean a higher likelihood of adverse consequences for animal welfare in the form of heat stress. Furthermore, longer breaks are taken in view of the mandatory resting periods for drivers in animal transports of 4 hours or longer (if manned by a single driver). This leads to an increase of the temperature and humidity inside the vehicle and a greater risk to animal welfare. Discouraging or prohibiting journeys longer than 4 hours may then be a potential method of risk mitigation.

Reducing the welfare impact
Reducing the welfare impact means reducing the impact on the animal (welfare impact = severity x duration). Welfare impact reduction is achieved by reducing the severity or duration of the welfare impact, i.e. heat stress. Heat stress arises as the animal is no longer able to maintain its body temperature by means of physiological or behavioural changes. It can be prevented through measures aimed at supporting the animal in its options to achieve heat loss. There are several measures that can reduce the effect of (extreme) ambient heat on the animal, which are included inter alia in the EU Animal Transport guide, good and best practices (Consortium of the Animal Transport Guides Project, 2017a;2017b): reducing the loading density, increasing ventilation, use of climate-controlled vehicles, use of misting spray systems and rescheduling of transports to cooler periods. Many of these measures, in fact, have already been included in the sectoral protocols[37], due to the responsibility to animal welfare that lies with the various contracting parties during transport.

Reducing loading density during high temperatures improves heat loss and reduces the production of heat by the animals. In the sources of information consulted, various suggestions are made for the necessary reduction in loading density at high temperatures and percentages ranging between 10-30% are cited. Ideally, concrete recommendations should be issued at a European level, given the large number of international transports and given the needs of (the representatives of) Member States. Mechanical ventilation is mandatory during long journeys (> 8 hours) for pigs. The risk assessment has clearly highlighted the importance of ventilation in reducing the risk of heat stress. On critical days with temperatures ≥27ºC, mechanical ventilation on all journeys (including < 8 hours) may also be a possible solution to stimulating dissipation of heat and moisture.

Scheduling inspections
Inspections conducted during a vehicle's journey require the vehicle to be brought to a standstill. This leads to an increase in temperature and humidity in the vehicle, resulting in an increased risk to animal welfare. Routine inspection (on a random basis) during animal transports on days with high external temperatures would lead to an increased risk to animal welfare. More targeted inspections, on the basis of existing data or data still to be collected (temperature logs for long journeys, DOA%, rejection at the slaughterhouse, welfare controls upon arrival at the slaughterhouse, etc.) remain a key option for monitoring animal welfare risks during transport (Bracke et al., 2020). Combining this data with the meteorological data may be valuable in demonstrating the impact of transport during high ambient temperatures on animal welfare in practice. This method also allows for the possibility of information to be collected on specific parties (farmers, transporters and slaughterhouses) in the supply chain and the possibility for that information to be compared (benchmarking).

Various measures have been set out that are aimed at reducing the impact of high ambient temperatures on animal welfare outlined in the Animal Transport

[37] https://assets.cov.nl/p/4227073/COV%20protocol%20-%20extreme%20temperaturen-%20mei%202020.docx en http://www.avined.nl/sites/www.avined.nl/files/2016-000-n0042g.pdf

Regulation, the National Plan and the sectoral protocols, however, they have not been implemented either fully or at all. Preparation is crucial to managing a high-risk situation (Nienaber & Hahn, 2007), where the relevant parties are informed in a timely manner, a plan is in place and appropriate action is taken at the right time. The National Plan for livestock transport at extreme temperatures partly and/or broadly sets out the steps mentioned above. Further specification and implementation of the agreements in the National Plan (with the sector) and in relation to the monitoring of the NVWA may lead to mitigation of the animal welfare risks. This would include making agreements on reducing loading density, the use of mechanical ventilation on all transports at high temperatures, establishing a maximum journey duration by mutual consultation and/or drafting minimum requirements for slaughterhouses to comply with in order to carry out slaughter activities at (extremely) high temperatures. Furthermore, the drafting of a roadmap may be considered, in the same manner as was drawn up for animal disease control[38]. Coordination of agreements with Dutch export partners is crucial in this regard, in order to be able to safeguard animal welfare on international transports.

Guidelines on monitoring animal welfare during transport

Welfare indicators
The factors that affect the welfare of animals include the resources available to an animal, such as feed, water, a place to rest and management by the keeper, such as the use of mechanical ventilation during transport (environmental indicators/input indicators). An animal responds to these factors or the factors have an impact on an animal, which are affected by aspects such as species, age, etc. Animal indicators measure the response of the impact of factors (/hazards) on animals (output-based welfare indicators) (EFSA, 2012c;2012d).

The welfare impact of heat stress on finishing pigs and broilers can be measured using animal indicators. Physiological response, behavioural responses, injury or mortality during transport are often used for that purpose (Broom, 2005).
In 2011, EFSA (EFSA, 2011) described the welfare of animals during transport in a scientific opinion. Providing useful animal indicators during transport to assess the welfare of animals was part of this opinion. EFSA argues that the animal indicators in Table 6 and 7 for evaluating the presence of heat stress are the most important indicators (EFSA, 2011). The Tables are supplemented with animal indicators found in the literature.

Table 6 Animal indicators during transport of finishing pigs

Finishing pigs	
Animal indicator	**Sources**
Thermal panting	(Bracke, 2011; EFSA, 2011;2012c; Rioja-Lang et al., 2019; Bracke et al., 2020)
Salivating	(EFSA, 2011; Velarde & Dalmau, 2012)
Exhaustion, collapse	(EFSA, 2011; Bracke et al., 2020)
Breathing with open mouth	(EFSA, 2011; Rioja-Lang et al., 2019)
Heavy abdominal breathing	(Bracke et al., 2020)

[38] https://www.nvwa.nl/documenten/dier/dierziekten/vogelgriep/protocollen/nvwa-draaiboek-uitvoering-ai-kvp--avp-en-mkz

Death	(Haley et al., 2008; EFSA, 2011; Correa et al., 2013; Rioja-Lang et al., 2019; Bracke et al., 2020)
Dog-sitting position	(Bracke et al., 2020)
Recumbent position, Separate recumbent position, Recumbent location	(Bracke, 2011; EFSA, 2011;2012c; Rioja-Lang et al., 2019)
Skin discolouration (red/blue/rash)	(EFSA, 2011)
Clinical indicator	
Increased respiratory rate (>20%), normal 32–58/min[39]	(EFSA, 2011)
Body temperature 38.7–39.8ºC[40]	(EFSA, 2011)

The Welfare Quality® protocol for pigs (Dalmau et al., 2009) provides animal indicators for measurement at the slaughterhouse, which can be used for the impact of transport on the welfare of finishing pigs. This protocol focuses on the number of finishing pigs that is panting upon arrival at the slaughterhouse and in lairage to measure thermal comfort, classified into: score of 0 (0% panting), score of 1 (< 20% panting), score of 2 (> 20% panting). These scores correspond to good welfare, compromised welfare and poor and unacceptable welfare respectively. This method can be useful to determine the degree to which there is a reduction in welfare due to heat stress in finishing pigs during transport.

Table 7 Animal indicators during transport of broilers

Broilers	
Animal indicator	**Sources**
Thermal panting	(Warriss et al., 2005; EFSA, 2011;2012d; Kumar et al., 2017; Welfare, 2019)
Salivating	(EFSA, 2011)
Exhaustion, collapse	(EFSA, 2011; Kumar et al., 2017)
Breathing with open beak	(Kettlewell & Turner, 1985; RDA, 2006; EFSA, 2011)
Gular fluttering (rapid oscillations of beak-throat-bottom with open mouth)	(EFSA, 2011)
Death	(Nijdam et al., 2004; Ritz et al., 2005; Warriss et al., 2005; EFSA, 2011; Schwartzkopf-Genswein et al., 2012; Lara & Rostagno, 2013; Grandin, 2014; Song & King, 2015; Spurio et al., 2016; Jacobs et al., 2017; Cockram & Dulal, 2018; Welfare, 2019)
Restless behaviour in the crate/scrambling	(EFSA, 2011)
Glazed look/dull eyes	(EFSA, 2011; Kumar et al., 2017)
Bloody discharge from the beak	(EFSA, 2011)
Excessive defaecation	(EFSA, 2011)

[39] https://www.merckvetmanual.com/special-subjects/reference-guides/resting-respiratory-rates
[40] https://www.merckvetmanual.com/special-subjects/reference-guides/normal-rectal-temperature-ranges

(damp/wet)	
PSE meat	(EFSA, 2011; Spurio et al., 2016)
Clinical indicator	
Increased respiratory rate (>20%)	(EFSA, 2011; Kumar et al., 2017)
Body temperature[41] 40.6–43.0ºC	(EFSA, 2011)

The Welfare Quality® protocol for poultry (Butterworth et al., 2009) provides animal indicators for measurement at the slaughterhouse, which can be used for the impact of transport on the welfare of broilers. Similar to finishing pigs, thermal comfort can be measured by the percentage of broilers that is panting. Panting has a high presence predictive value for the presence of heat stress in broilers (EFSA, 2012d). It is recommended that 20 crates containing broilers should be observed at various locations in the vehicle (front, middle, rear) or in lairage. The number of broilers that pant can be quantified according to the following formula: % of broilers panting = (number of broilers panting) / (number of broilers per container x number of containers monitored)) x 100% (Butterworth et al., 2009). Heat stress may occur with a percentage of panting broilers between 1% and 6% (Berghout et al., 2018).

Other key animal indicators for both finishing pigs and broilers, which can demonstrate the impact of transport at high ambient temperatures, include the DOA% and abnormalities of the meat. These animal indicators can be determined at the slaughterhouse after transport and at the post mortem inspection respectively.

Animal welfare during transport is also dependent on the quality of the environment (EFSA, 2011). Environmental indicators may occasionally be easier and faster to measure, as in the case of transport (EFSA, 2011;2012c;2012d). Environmental factors, which may be of value in determining the risk to animal welfare in addition to the animal indicators, include temperature (external and inside the vehicle), humidity, carbon dioxide levels, loading density and cooling options present ((EFSA, 2011;2012c;2012d; Brandt & Aaslyng, 2015; Bracke et al., 2020).

Thermal imaging is a fairly new method that can be used to measure the body temperature of the animal using cameras (EFSA, 2011). This method seems promising for the detection of heat stress (Brown-Brandl et al., 2013; Koltes et al., 2018). Due to the significant variation between individual animals, measurement at animal level seems the most useful (Koltes et al., 2018), e.g. during unloading at the slaughterhouse (EFSA, 2011), or to substantiate the adverse effects of heat stress during inspection of a large group of animals (EFSA, 2011).

Measuring both animal indicators and environmental indicators can be difficult during transport due to the way in which the animals are transported (e.g. broilers in containers or crates) (Consortium of the Animal Transport Guides Project, 2017a) or because the materials that are required to measure these indicators are

[41] https://www.merckvetmanual.com/special-subjects/reference-guides/normal-rectal-temperature-ranges

less suitable during transport (inaccurate/non-robust humidity meters) (EFSA, 2011). Using a set of indicators during inspection (animal indicators and environmental indicators) may provide a great deal of information about the level of the impact of the hazards on animal welfare during inspection.

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Annex A Risk assessment methodology

This risk assessment was carried out on the basis of the EFSA risk assessment methodology (EFSA, 2009;2012a;2012b) and as such is in line with the Codex Alimentarius (Joint, 1995). Part of the methodology was specified in greater detail by Wageningen Livestock Research (Visser et al., 2015).

1. Hazard identification: The factors that had the potential to cause inadequate animal welfare during transport of finishing pigs and broiler chickens at high ambient temperatures were identified. These factors were determined on the basis of a literature review. The literature review carried out by BuRO involved searches on Google, Google Scholar, PubMed and Scopus for – combinations of – the English and Dutch keywords: varken, kip, pluimvee, pig(s), grower/growing pig, finisher/finishing pig, swine, poultry, broiler, animal, transport, transportation, temperatuur, temperature, heat, stress, heat stress, hittestress, thermoregulation, thermoregulatie, thermoneutral zone, upper critical temperature, welfare, behaviour, behavior, thermal stress, heat load, heat index, high ambient temperature, extreme temperature(s), microclimate.
2. Hazard characterisation: Animal welfare impact is the negative change in animal welfare, which is the result of the impact of a factor or a combination of factors. The severity is the intensity of the animal welfare impact caused by exposure to a hazard, meaning the extent to which it causes an animal distress (please see Table A2) The duration of the welfare impact caused by exposure to a hazard or a combination of hazard is classified as short, medium or long. Hazard characterisation involves a semi-quantitative impact of an animal welfare effect being determined based on the severity and duration (please see Table A1). The welfare impact is a function of the duration and severity and is attributed a score from 1-7.
3. Exposure assessment: Estimation of the duration of the exposure to the hazard/hazards identified in step 1 of the finishing pigs and broilers during transport.
4. Risk characterisation: This final step shows a function of the probability of the adverse effects on welfare and the scope of those effects in a given population, following exposure to a certain factor or exposure to a scenario.

Table A1: The welfare impact is determined on the basis of the classification of the severity and duration of the welfare impact (Visser et al., 2015).

Duration x Severity	None	Low	Moderate	Severe	Very severe
Short	1	2	3	4	5
Medium	1	3	4	5	6
Long	1	4	5	6	7

Table A2: Explanatory note on the various categories of severity of a type of welfare impact (EFSA, 2009; Visser et al., 2015)**.**

Score	Severity	Definition
1	None	No pain, malaise, frustration or fear, as demonstrated by a number of behavioural, physiological and clinical studies.
2	Low	Minimal changes compared to normal that are indicative of pain, malaise or fear.
3	Moderate	Moderate changes compared to normal that are indicative of pain, malaise or fear. Marked change in adrenal (hormone) or behavioural responses, such as motor responses and vocalisations.
4	Severe	Substantial changes compared to normal that are indicative of pain, malaise or fear. Significant change in adrenal (hormone) or behavioural responses, such as motor responses and vocalisations (reversible).
5	Very severe	Extreme changes compared to normal – usually in terms of various parameters – that are indicative of pain, malaise or fear that can be life threatening if they persist (irreversible).

Annex B Basic data NVWA Pladmin

The tables in this Annex provide an overview of the data from Pladmin that was used and provide a number of additional insights by way of analyses set out in the figures.

Table B1: Overview of broiler data NVWA Pladmin for 2017, 2018, 2019 (May-Sept) per temperature range corresponding to Figure 2.

Year	Temperature(ºC)	No. Of days	No. Of transports	DOA per transport (not weighted)	Total no. supplied	No. supplied dead	DOA per broiler (weighted)
2017	20-24.9	61	8,461	0.10%	124,743,171	125,909	0.10%
2017	25-26.9	8	1,298	0.12%	18,923,982	23,155	0.12%
2017	27-29.9	6	933,000	0.11%	14,285,064	17,542	0.12%
2017	>=30	3	410,000	0.13%	5,855,992	9,519	0.16%
2018	20-24.9	56	7,566	0.10%	108,611,772	11,477	0.11%
2018	25-26.9	17	2,641	0.10%	37,526,841	38,551	0.10%
2018	27-29.9	10	1,206	0.13%	17,280,400	23,649	0.14%
2018	>=30	8	1,288	0.23%	17,709,184	47,062	0.27%
2019	20-24.9	46	6,294	0.09%	89,356,730	813,360	0.09%
2019	25-26.9	7	1,091	0.09%	15,075,778	15,709	0.10%
2019	27-29.9	4	208,000	0.13%	2,989,504	2,823	0.09%
2019	>=30	9	1,358	0.19%	18,489,099	43,986	0.24%

Table B2: Overview of DOA% in broilers calculated based on NVWA Pladmin data 2017, 2018, 2019.

Temperature (ºC)	2017	2018	2019
20-24.9	0.10%	0.11%	0.09%
25-26.9	0.12%	0.10%	0.10%
27-29.9	0.12%	0.14%	0.09%
>=30	0.16%	0.27%	0.24%

Table B3: Significance test DOA weighted average per temperature range in May and September period in 2017, 2018 and 2019 (please see Figure 2).

Year	Category	Total no. Supplied	No. supplied dead	DOA%	pu	qu	sigma	z	Signif
2017	20-24.9	124.743.171	125.909	0,10%	0,001037565	0,998962435	7,9423E-06	-26,9738	**
2017	25-26.9	18.923.982	23.155	0,12%	0,001225479	0,998774521	1,22622E-05	-0,36015	Not signif
2017	27-29.9	14.285.064	17.542	0,12%	0,001343574	0,998656426	1,79737E-05	-22,1166	**
2017	>=30	5.855.992	9.519	0,16%					
2018	20-24.9	108.611.772	114.769	0,11%	0,001049141	0,998950859	6,13002E-06	4,795884	**
2018	25-26.9	37.526.841	38.551	0,10%	0,001134887	0,998865113	9,78815E-06	-34,8639	**
2018	27-29.9	17.280.400	23.649	0,14%	0,002020916	0,997979084	1,51855E-05	-84,8803	**
2018	>=30	17.709.184	47.062	0,27%					
2019	20-24.9	89.356.730	81.336	0,09%	0,00092926	0,99907074	8,48362E-06	-15,5315	**
2019	25-26.9	15.075.778	15.709	0,10%	0,001025835	0,998974165	2,02674E-05	4,820481	**
2019	27-29.9	2.989.504	2.823	0,09%	0,002179332	0,997820668	2,90692E-05	-49,3553	**
2019	>=30	18.489.099	43.986	0,24%					

Significance on rule 1 -> comparison between rule 1 and 2

Table B4: Significance test Death-On-Arrival rate (DOA%) of broiler chickens recorded prior to slaughter, per year and per THI category (please see Figure 5).

Year	Category	Total no. Supplied	No. supplied dead	DOA%	pu	qu	sigma	z	signif
2017	<=74	146.051.053	151.919	0,10%	0,00107519	0,99892481	8,23641E-06	-39,2151	**
2017	75-78	17.757.156	24.206	0,14%					
2018	<=74	153.488.881	163.569	0,11%	0,001199162	0,998800838	7,6688E-06	-131,187	**
2018	75-78	23.481.441	48.647	0,21%	0,002187536	0,997812464	2,48581E-05	-30,9708	**
2018	79-83	4.157.875	11.815	0,28%					
2019	<=74	104.771.851	97.192	0,09%	0,000953952	0,999046048	1,34694E-05	-38,941	**
2019	75-78	5.530.358	8.031	0,15%	0,002117486	0,997882514	2,31846E-05	-40,3722	**
2019	79-83	13.592.787	32.462	0,24%	0,002474934	0,997525066	3,74989E-05	-17,9117	**
2019	>=84	2.016.115	6.169	0,31%					

Significance on rule 1 -> comparison between rule 1 and 2

Figures B1 and B2 (with corresponding Tables B5 and B6) show that there is a significant increase (related to ambient temperature) in the exceeding of the DOA indicator and intervention threshold.

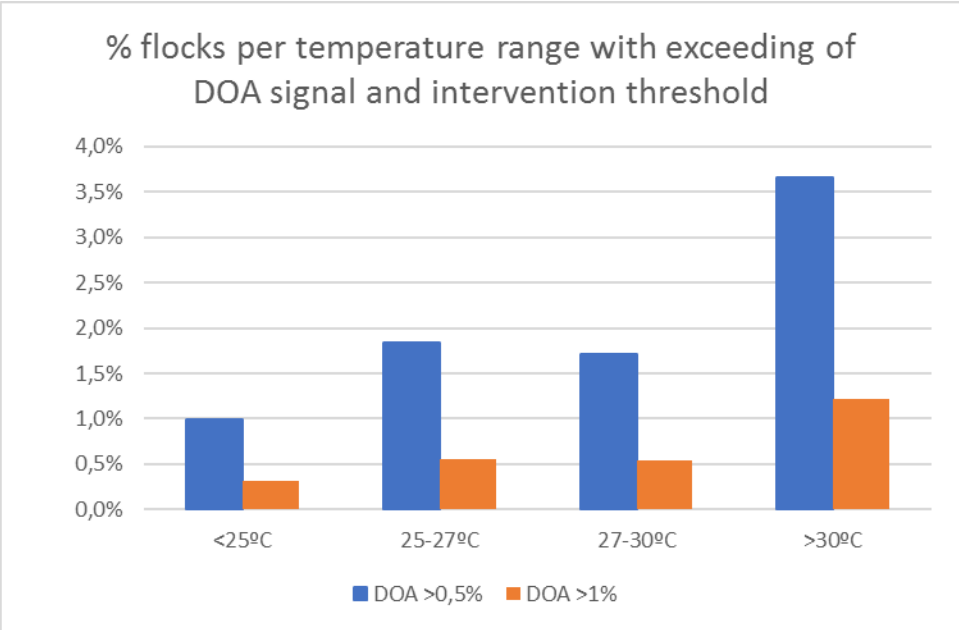

Figure B1: Percentage of flocks per temperature range of broilers in the year 2017 (May-Sept). DOA > 0.5% = NVWA indicator threshold, DOA > 1% = NVWA intervention threshold.

Table B5: Pladmin data May-Sept 2017 corresponding to Figure B1.

Temp. range (ºC)	Number of animals	Number of records (flocks, N)	Number of N with DOA of 0.5-1	Number of N with DOA > 1	DOA >0.5 %	DOA 0.5 1%	DOA >1%
<25	220,444,405	14,994	101	48	0.99%	0.67%	0.32%
25-27	24,008,503	1,630	21	9	1.84%	1.29%	0.55%
27-30	14,285,064	933	11	5	1.71%	1.18%	0.54%
>30	5,855,992	410	10	5	3.66%	2.44%	1.22%

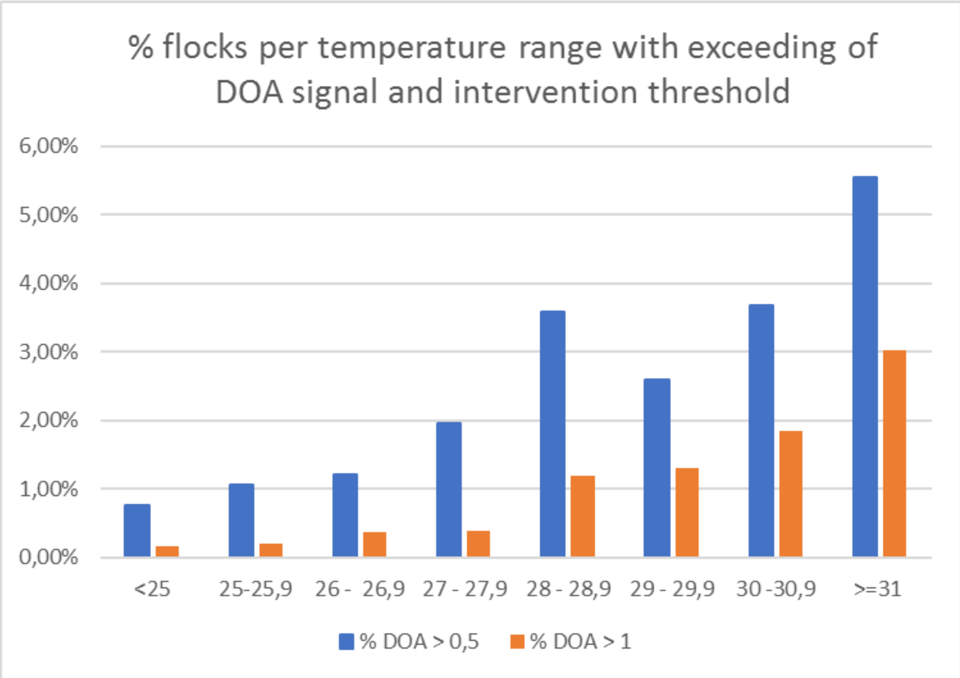

Figure B2: Percentage of flocks per temperature range of broilers in the year 2018 (May-Sept). DOA > 0.5% = NVWA indicator threshold, DOA > 1% = NVWA intervention threshold.

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Date
5 augustus 2020

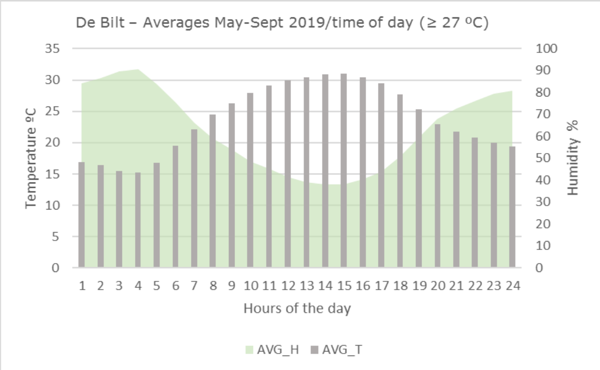
Our reference
TRCVWA/2020/4161

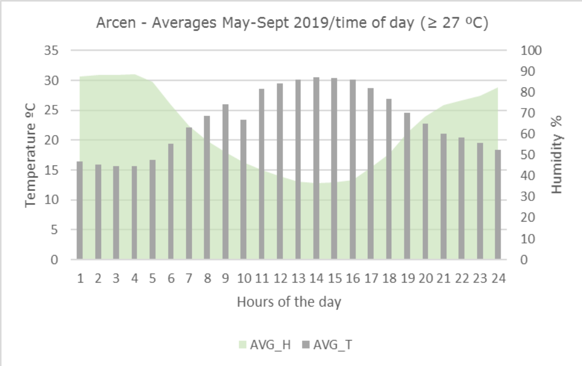
Table B6: Pladmin data May-Sept 2018 corresponding to Figure B2.

Temp. range (ºC)	Number of records (flocks, N)	Number of N DOA 0.5-1.0	Number of N DOA >=1.0	DOA >0.5%	DOA 0.5-1%	DOA >1%
<25	11,473	69	18	0.76%	0.60%	0.16%
25-25.9	2,074	18	4	1.06%	0.87%	0.19%
26-26.9	1,327	11	5	1.21%	0.83%	0.38%
27-27.9	513	8	2	1.95%	1.56%	0.39%
28-28.9	167	4	2	3.59%	2.40%	1.20%
29- 29.9	695	9	9	2.59%	1.29%	1.29%
30-30.9	652	12	12	3.68%	1.84%	1.84%
>=31	793	20	24	5.55%	2.52%	3.03%

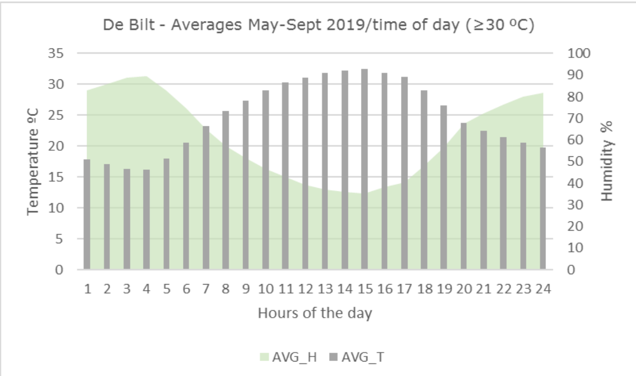
Annex C Meteorological data

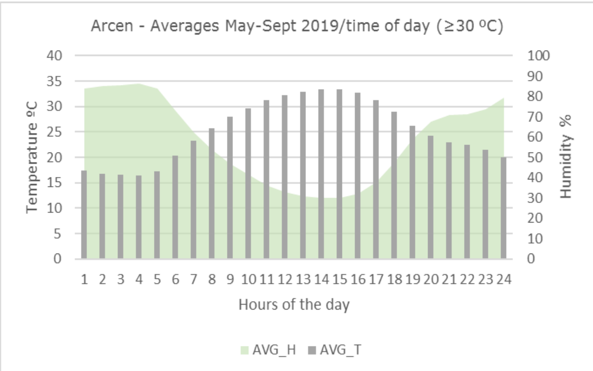
The figures below (C1 to C4) show the progression of temperature (T) and humidity (H) levels in De Bilt and Arcen. Specifically, the data relates to progression/hour/day on all days (8 days) in May to September 2018 and 2019 on which temperatures were ≥27ºC or ≥30ºC. Two sites were selected, given that there may be a difference between the temperatures at De Bilt (central Netherlands) and Arcen (southern Netherlands). The progression of the temperature and humidity levels at both sites is comparable, with temperatures increasing throughout the day and decreasing during the (late) evening and night time. Humidity levels increase in the evening and at night and decrease during the day. Tables C5, C6 and C7 (2018) provide an overview of the various averages in both De Bilt and Arcen.



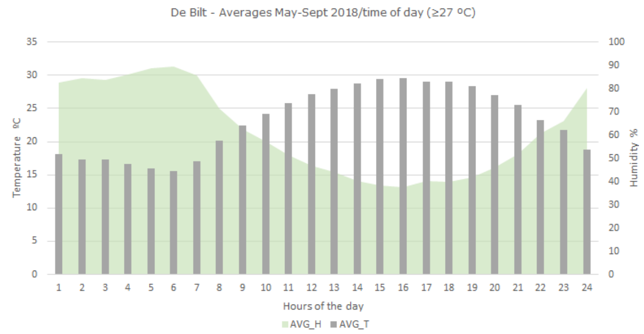


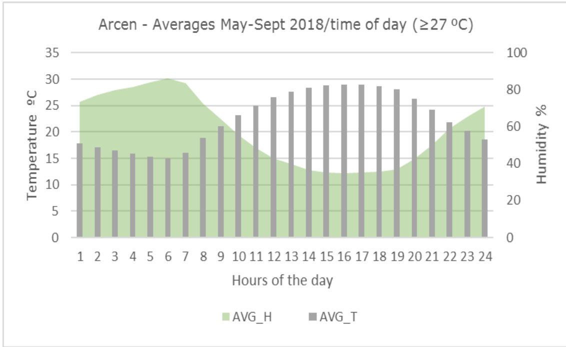
Figures C1: Progression of temperature (T) and humidity (H) in De Bilt and Arcen per hour of the day on days with temperatures ≥27°C in 2019.





Figures C2: Progression of temperature (T) and humidity (H) in De Bilt and Arcen per hour of the day on days with temperatures ≥30°C in 2019.





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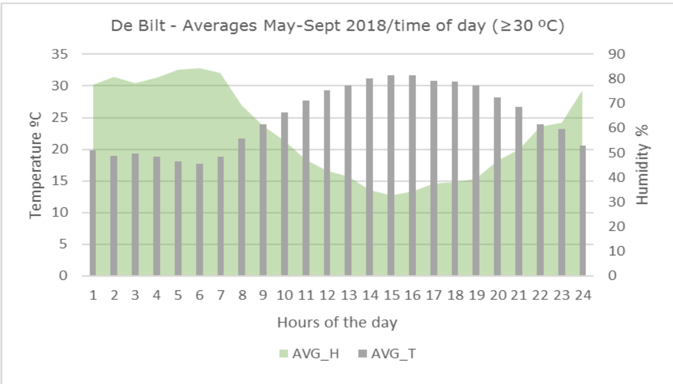
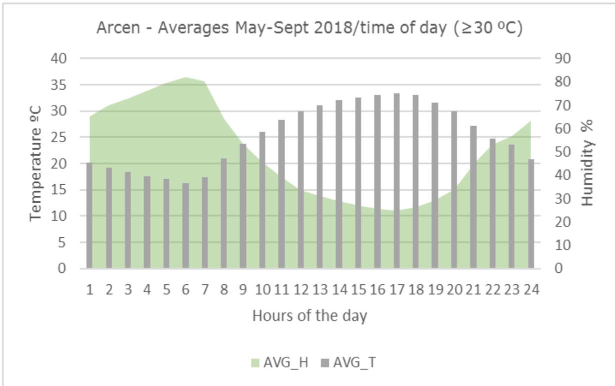
Figures C3: Progression of temperature (T) and humidity (H) in De Bilt and Arcen per hour of the day on days with temperatures ≥27°C in 2018.





Figures C4: Progression of temperature (T) and humidity (H) in De Bilt and Arcen per hour of the day on days with temperatures ≥27°C in 2018.

Table C5: De Bilt and Arcen discrepancies on hot days >=30°C May-Sept period

Temperature >=30°C					
Year	**# days max T ≥30˚C**	**Avg T max ºC**	**Avg T ºC 12-20 p.m.**	**Avg THI 12-20 p.m.**	**Avg H 12-20 p.m.**
2017					
De Bilt	3	30.6	25.9	72.3	52
Arcen	8	31.5	27.8	74.8	50.2
2018					
De Bilt	8	32.1	29.2	75.5	42.6
Arcen	13	33.7	30.7	76.2	33.2
2019					
De Bilt	11	32.7	29.9	77	44.9
Arcen	14	33.9	30.4	76.7	41.9

Table C6: De Bilt and Arcen discrepancies on hot days >=27°C May-Sept period

Temperature >=27˚C					
Year	**# days max T ≥27˚C**	**Avg T max ºC**	**Avg T ºC 12-20 p.m.**	**Avg THI 12-20 p.m.**	**Avg H 12-20 p.m.**
2017					
De Bilt	10	28.9	25.9	73.1	54.9
Arcen	20	29.4	26.4	73.4	52.2
2018					
De Bilt	19	30	27.7	74.1	44.4
Arcen	51	29.8	27	72.8	41.1
2019					
De Bilt	16	31.3	28.5	75.5	47.2
Arcen	27	31.2	28	74.5	46.6

Table C7: De Bilt and Arcen discrepancies on hot days >=25°C May-Sept period

Temperature >=25˚C					
Year	**# days max T >25˚C**	**Avg T max ºC**	**Avg T ºC 12-20 p.m.**	**Avg THI 12-20 p.m.**	**Avg H 12-20 p.m.**
2017					
De Bilt	20	27.5	24.6	71.5	55.4
Arcen	34	27.9	25.1	72	54.5
2018					
De Bilt	42	27.7	25.4	71.6	47.5
Arcen	73	28.7	26	71.9	44.5
2019					
De Bilt	24	29.5	26.8	73.7	51.3
Arcen	44	29.2	26.2	72.6	49

The graphs below (C8 and C9) show the evolution of the heat index (temperature and humidity, HI according to Weerplaza), the average temperature (T), the maximum heat index (MAX HI) and the minimum heat index (MIN HI) on the days that temperatures reached ≥27ºC in De Bilt (6 days) and Arcen (13 days) in May-September 2018. These graphs were compiled based on the data obtained from Weerplaza.

The graphs show temperatures increasing at both locations from 12 p.m. as well as the absolute number of times the heat index (HI) increases ≥27ºC at a certain time (red numbers). Based on the graphs below, the critical period on a critical day (≥27ºC) is proposed to be fixed at 12-8 p.m. (please see exposure to hazards).

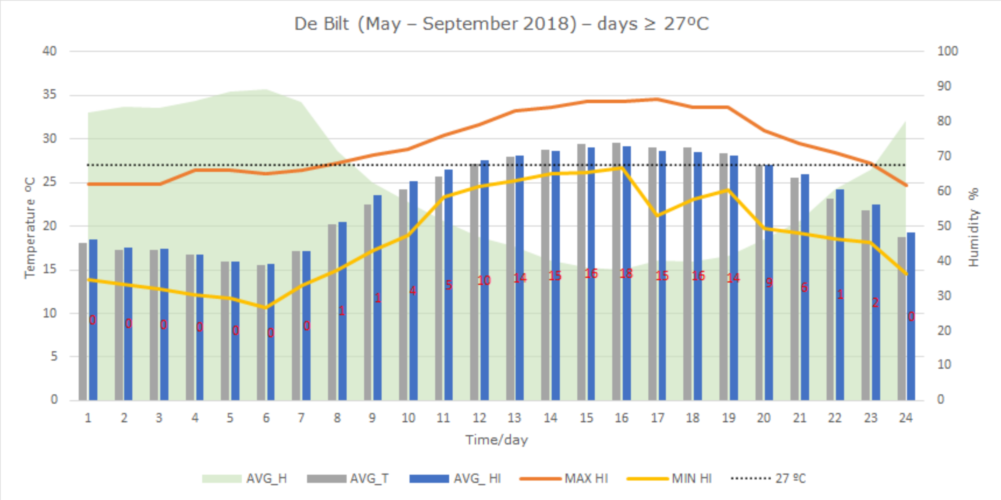


Figure C8: Evolution of the hourly averages in temperature (T), humidity (H), heat index (HI), maximum heat index (MAX HI), minimum heat index (MIN HI) at De Bilt on days with temperatures over 27ºC. The red numbers indicate the absolute number of times that the heat index (HI) was ≥27ºC at that time of day.

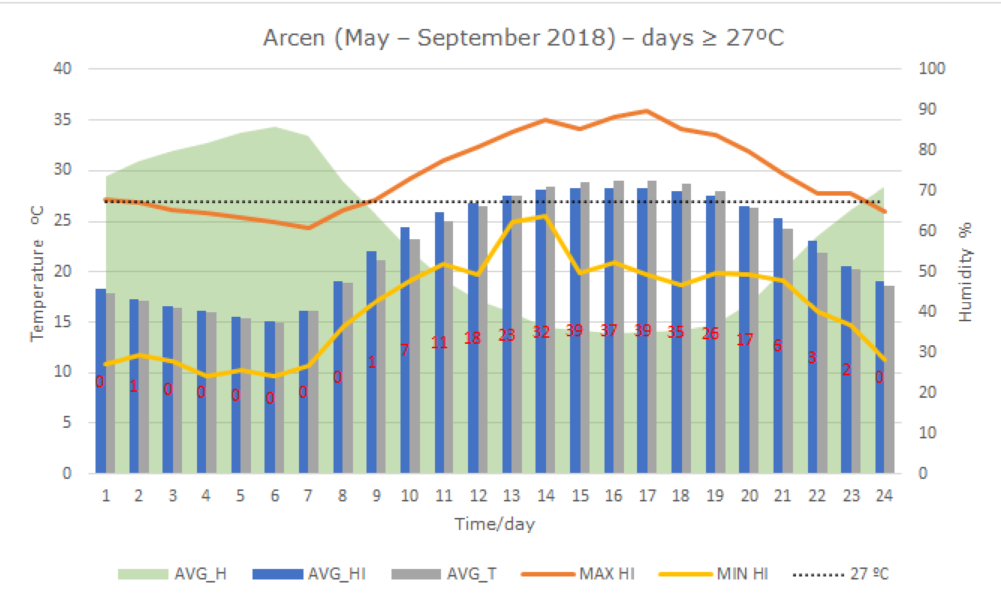


Figure C9: Evolution of the hourly averages in temperature (T), humidity (H), heat index (HI), maximum heat index (MAX HI), minimum heat index (MIN HI) at Arcen on days with temperatures over 27ºC. The red numbers indicate the absolute number of times that the heat index (HI) was ≥27ºC at that time of day.

Figure C10 and C11 show the same, but for days temperatures were ≥30ºC.

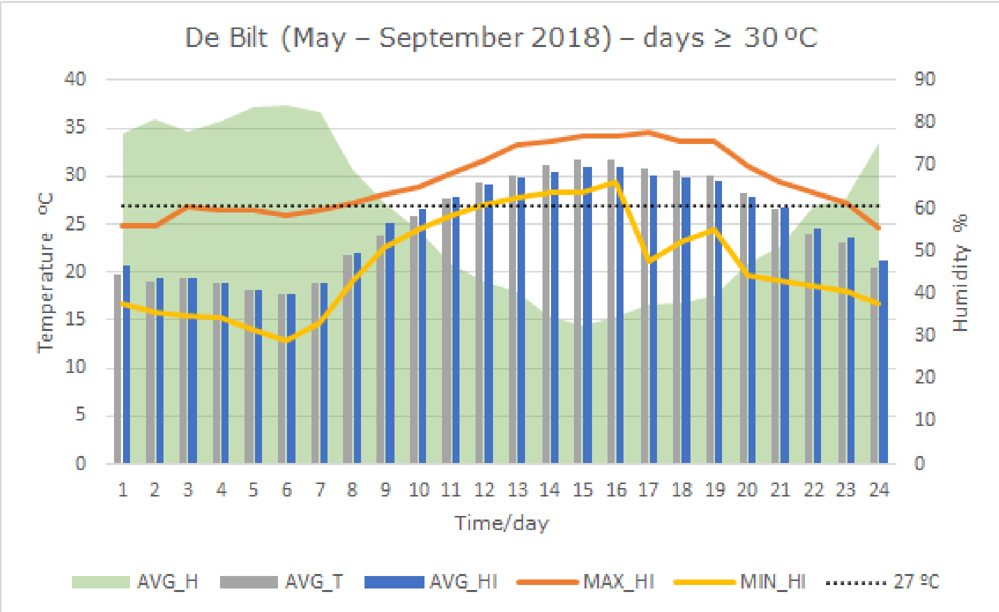


Figure C10: Evolution of the hourly averages in temperature (T), humidity (H), heat index (HI), maximum heat index (MAX HI), minimum heat index (MIN HI) at De Bilt on days with temperatures over 30ºC.

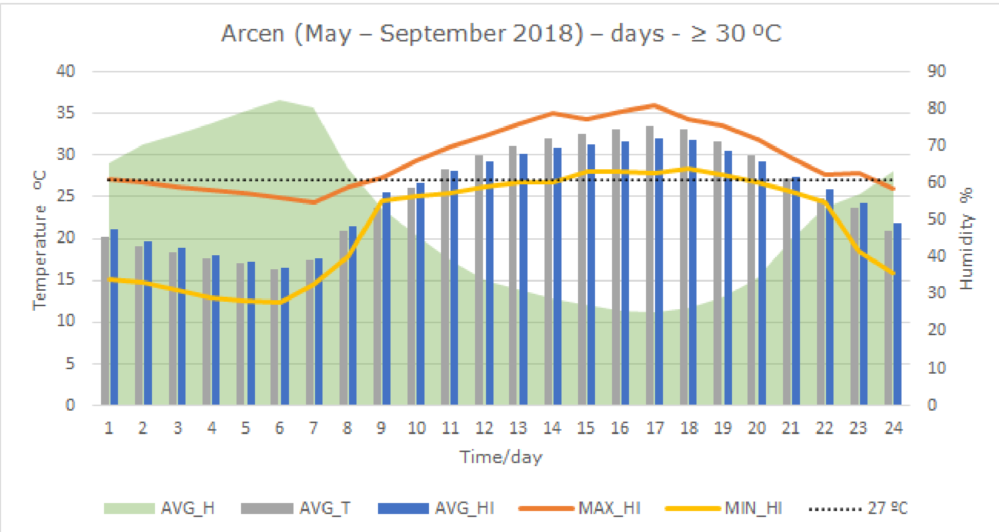


Figure C11: Evolution of the hourly averages in temperature (T), humidity (H), heat index (HI), maximum heat index (MAX HI), minimum heat index (MIN HI) at Arcen on days with temperatures over 30ºC.

Annex D VION DOA for pigs

The Figure below shows that the DOA in the years 2014 to 2016 was 0.02%. This data is based on information from the VION archives[42] and relates to pigs without a distinction being made in their stage of life. The increase to 0.04% in Q3 appears to coincide with the heatwaves in July/August of 2018.

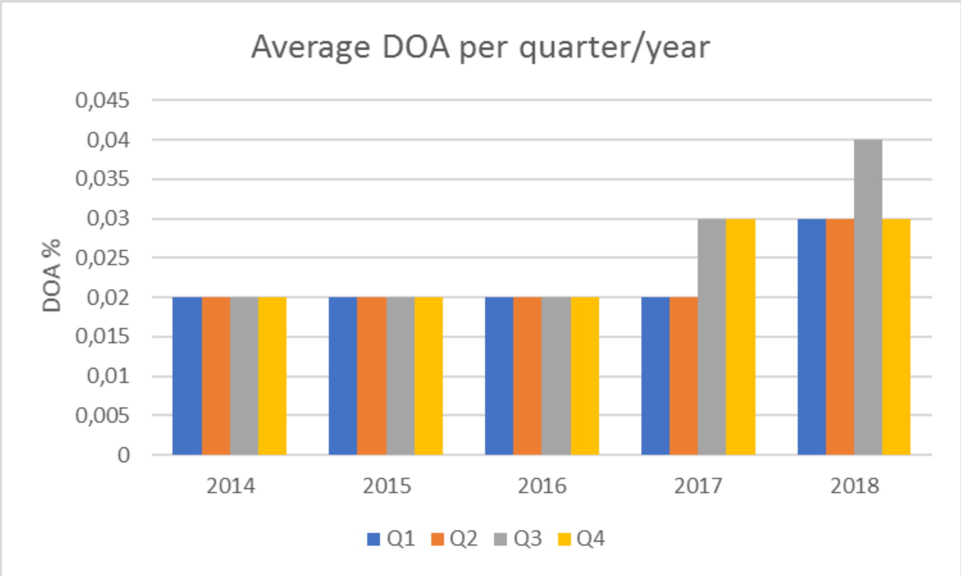


Figure D1: Average DOA (%) of pigs on arrival at VION slaughterhouse. The percentages indicate the number of pigs that were classified as 'Dead on arrival' during the live inspection upon arrival at the slaughterhouse.

Not all data for 2019 is available on the VION site (consulted on 25/05/20) and as such has not been included in this overview.

[42] https://www.vion-transparantie.nl/keuringsresultaten/keuringsresultaten-archief/

Annex E Expert consultation – summary

In April 2020 four expert meetings took place. Experts were invited by the Office of Risk Assessment & Research (BuRO) for their expertise on animal welfare research. Due to COVID-19-related meeting restrictions, the expert meetings were held as four separate virtual meetings using Skype.

All three meetings were hosted by Johan Bongers and Lodi Laméris, employees at BuRO. The first meeting took place on April 22, 2020 and was attended by: dr. Hans Spoolder (Wageningen Livestock Research, WUR) and dr. Ingrid de Jong (Wageningen Livestock Research, WUR). The second meeting took place on April 23, 2020 and was attended by dr. Antoni Dalmau (IRTA Institute of Agrifood Research and Technology), dr. Antonio Velarde (IRTA Institute of Agrifood Research and Technology), dr. Mette Herskin (Aarhus University) and dr. Virginie Michel (French Agency for Food, Environmental and Occupational Health & Safety, ANSES). The third meeting took place on April 24, 2020 and was attended by dr. Anneleen Watteyn (Flanders Research Institute for Agriculture, Fisheries and Food, ILVO) and dr. Marien Gerritzen (Wageningen Livestock Research, WUR). The fourth meeting took place on April 29, 2020 and was attended by dr. Michael Marahrens (Friedrich-Loeffler-Institut, FLI).

Prior to the meeting, the experts were sent an informative PowerPoint (in PDF form) of the draft risk assessment 'transport of finishing pigs and broilers at high temperatures' by e-mail. The experts were invited to comment on this draft. In addition of the draft risk assessment, the PowerPoint contained questions which were to be discussed during the session.

The meetings started with a short summary of the previously sent presentation, followed by a discussion on the draft risk assessment, using the list of questions as a guide.

The BuRO employees integrated the reports of the individual expert meetings into the following summary, categorised in the following headings. The experts were given a single opportunity to comment on this summary. After that, the summary was completed. Comments were then used by BuRO to further improve the final risk assessment.

<u>General comments</u>

Experts recognised the draft risk assessment as a sound and solid risk assessment, taking into account the limitations in data availability. They recommended to make the underlying assumptions and uncertainties more explicit, given the limited availability of data. None of the experts could point out further data to substantiate the risk assessment.

<u>Comments on the risk assessment</u>

Experts recognised that the welfare impact experienced by the animals during transport (including pre-transport hazards as rough loading and catching) is multifactorial in origin (hazards). The effects of these individual hazards cannot be identified in isolation from each other and cumulation of effects is likely.

Experts recognised that the impact scores as selected by BuRO are expert estimates, and thus arbitrary choices, but appear acceptable. Better estimates are not likely to be found until further research is done. Also the choice for the critical day, i.e. at temperatures > 27°C, in combination with the critical period, i.e. between 12:00 and 20:00, is recognised as an arbitrary choice which will serve the purpose for which it is meant. As the risk characterisation concerns animals that are transported on a critical day during the critical period, some experts questioned whether the particular risk could be extrapolated to the whole day. This is particularly relevant as the percentage of Death-On-Arrival (%DOA) was examined within the critical periods. To extrapolate to whole days, a comparison should be made with the %DOA on non-critical days. Other experts indicated that extrapolation to whole days is possible, with the caveat that animal species / age-dependent susceptibility to heat stress will remain. Experts stressed that the %DOA alone is not the best indicator for poor animal welfare due to heat stress as there might be other causes. But if significantly more animals die during transport with high temperatures, this means that there is also poor welfare due to heat stress for the animals that do not die and %DOA thus underestimates animal welfare risks. Risk mitigation should not be focused on reduction of %DOA only, but should start at lower temperatures than established on increase in rate of the %DOA only.

Some experts pointed out that the risk assessment did not take into account the temperature within the truck, which is often higher than the external temperature with significant differences within the truck. The location of the animals in the vehicle is also important. Furthermore, the temperature is often higher at the front of the truck, near the cabin. When poultry is transported, it can be assumed that poultry in the containers placed in the middle of the truck experience higher temperatures than those in the containers on the outside of the vehicle. In addition, the temperature within in the truck will differ depending on whether the truck is moving or stationary.

A further comment is that the risk assessment does not take into account waiting times at the slaughterhouse. This may affect the broiler %DOA, as no distinction can be made between death on arrival and death in the waiting area. In addition, the risk assessment likewise did not take into account the variable conditions at slaughterhouses, for example when climate control is concerned, which can also affect the %DOA.

Comments on animal indicators

Experts recognised that the most significant animal indicator for determining heat stress in both finishing pigs and broilers is panting. However, if panting is observed, there are no scientifically substantiated threshold values for panting related to heat stress and when only panting is taking into account it is not scientifically substantiated that this is always solely caused by heat stress. In the case of finishing pigs, the sitting or lying posture (dog sitting, lying laterally) and skin discolouration are important animal indicators in addition to panting.

Comments on risk mitigation options

Experts suggested that proper conditions at the slaughterhouse, such as sufficient shade for waiting trucks, climate control in the waiting areas, possible options for spraying the animals (provided there is sufficient ventilation), etc. could be suitable risk mitigation options. Also tight planning at the slaughterhouses should be implemented to keep waiting time to a minimum and unload the animals as soon as they arrive to the slaughterhouse. In addition, slaughterhouses could prioritise the trucks for unloading based on measured animal indicators. During the summer, transportation should preferably take place during cooler periods of the day.

Ventilation during transport and on arrival at the slaughterhouse is important to facilitate heat loss of the animals and to reduce humidity. In addition, stagnation of transport must be avoided. For poultry, there are no legal guidelines for ventilation. Leaving containers / drawers empty can improve ventilation. Also, the loading density should be lowered to give animals more space for thermoregulation. Improved ventilation and reduction of stocking density should be applied starting at outside temperatures in the range of 22-25°C. Discouraging long journeys only would make sense if loading time and waiting time are included in overall transporting time, although long journeys during high temperatures will likely impair welfare.

For finishing pigs, there should be sufficient water supply during long journeys with the condition that the drinking facilities are sufficient for all animals. Wetting animals preferably in combination with ventilation is an option, provided that air humidity is taken into account. Finishing pigs are best showered instead of sprayed / misted.

Comments on collecting data
Experts recognised the need for the collection of more and better data on: unloading time of the broilers from the crates, animal indicators such as panting in addition to resource-based indicators, %DOA data from finishing pigs, time of fasting in advance of transportation, characteristics of poultry flocks (breed, weight, type of farm, etc.), and feather condition of broilers.