Opinion on alternatives to culling newly hatched chicks in the egg and poultry industries

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Animal Welfare Committee
Nobel House
17 Smith Square
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The Animal Welfare Committee is an expert committee of the Department for Environment, Food and Rural Affairs, the Scottish Government and the Welsh Government. Information about the Committee may be found at: https://www.gov.uk/government/groups/animal-welfare-committee-awc

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Introduction and scope

1. The Farm Animal Welfare Committee (FAWC) traditionally provided detailed expert advice to Ministers in Defra and the Scottish and Welsh Governments on the welfare of farmed animals on farm, at market, during transport and at slaughter. In October 2019, FAWC was renamed the Animal Welfare Committee (AWC) and its remit was expanded to include companion animals and wild animals kept by people, as well as farmed animals. This enables it to provide authoritative advice, which is based on scientific research, stakeholder consultation and experience, on a wider range of animal welfare issues.

2. This Opinion principally addresses chicken (*Gallus gallus domesticus*) chicks and embryos from breeds selected for commercial egg production. It also covers the chicks and embryos of this species that become broiler breeder birds, as well as newly hatched turkey poults (*Meleagris gallopavo domesticus*) and newly hatched ducklings (*Anas platyrhynchos domesticus*).

3. AWC has been asked to consider whether there are promising technologies that could help end the culling of newly hatched male chicks in the laying hen industry by identifying and/or determining the sex of chick embryos before hatching. These technologies are at different stages of technical development and some are already used at scale in large hatcheries in some other countries. Issues include whether sentience is likely to be less developed at the ninth day of pre-hatch embryonic development than at one day following hatching, and the implications of error rates for whether alternatives to current post-hatch sexing should be pursued.

4. AWC has also been asked to identify any animal welfare risks that might result from newly hatched male chicks no longer being culled. Such chicks are used in large numbers to feed (captive and other) raptors, as well as animal and bird species kept in zoos and as pets.

5. AWC has also been invited to offer any other ideas or views on this topic. It has identified the processing of all newly hatched chicks, the use of dual-purpose chicken breeds and implications for the sexing of broiler breeder chicks and turkey poults as additional areas requiring consideration.

Climate change

6. In hatcheries for laying hens and broiler breeders, approximately 40–45million male chicks / year that are not required for natural mating are currently being incubated to hatching then killed when newly hatched (see 28). Energy is being used to incubate male eggs and unviable eggs even though these will not provide food for human consumption.

7. In some European egg production systems newly hatched male chicks are not culled but reared. Male chicks from layer lines that are reared for meat make a much greater environmental impact than conventional broilers.[1]

8. The use of currently available in-ovo sexing technologies, in preference to post-hatching sexing methods, would be likely to require a greater number of eggs (c.10%), and therefore additional parental stock, and associated feed, energy and accommodation. This is because of lower sexing accuracy (see 109) and the negative impacts on hatchability resulting from at least some in-ovo sexing methods.

9. With dual-purpose breeds, males are reared for meat and females may be used for both egg and meat production. These breeds are likely to be better suited to diets containing ingredients that are of low value to humans such as by-products, recycling these 'waste' streams in a circular economy and reducing the environmental burden resulting from the growing of new feed crops (which includes the use of fertilizers, pesticides and natural habitats). Dual-purpose breeds have lower amino acid demands[2], are less affected by low protein and low soya diets than broiler and layer lines[3] and show good productivity on diets containing low-quality ingredients that humans cannot eat.[4] However, dual-purpose breeds currently exhibit a lower feed conversion efficiency than commercial broilers.

10. Dual-purpose breeds could further reduce waste and the associated carbon footprint by offering lower mortality then many fast-growth broiler breeds[5] and fewer carcass rejections at slaughter due to skin lesions, joint disorders and other conditions that are prevalent in fast-growing broiler strains. The hens that have reached the end of their productive laying life could be slaughtered for sale to retail customers as whole birds rather than used for wholesale or in composite products.

Definitions

11. In this Opinion, key terms are used as follows:

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[1] Based on carcass yield per kilogram, male chicks from layer lines that are raised for meat have been shown to produce over three times more CO_2 (9.7 kg vs. 3.0 kg) and use over three times as much land for feed production (17.1 m² vs. 4.8 m²) and twice as much water (196 l vs 92 l) than broiler strains. They also potentially make almost four times as much impact on acidification (88.6 kg vs. 22.7 kg sulphur dioxide) and contribute three times as much to eutrophication (23.6 kg vs. 7.6 kg phosphate) than broiler birds. W Bessei. Comparison of the environmental impact of growing males of a brown layer line and a fast growing broiler line – greenhouse gases, acidification, eutrophication, land and water use. *European Poultry Science* 86 (2022), 357.

[2] L Baldinger and R Bussemas. Dual-purpose production of eggs and meat — Part 1: cockerels of crosses between layer and meat breeds achieve moderate growth rates while showing unimpaired animal welfare. *Organic Agriculture* 11 (2021), 489–98.

[3] M Kreuzer, S Müller, L Mazzolini, RE Messikommer and IDM Gangnat. Are dual-purpose and male layer chickens more resilient against a low-protein-low-soybean diet than slow-growing broilers? *British Poultry Science* 61 (2020), 33–42.

[4] I Röhe, J Urban, A Dijkslag, J te Paske and J Zentek. Impact of an energy- and nutrient-reduced diet containing 10% lignocellulose on animal performance, body composition and egg quality of dual purpose laying hens. *Archives of Animal Nutrition* 73 (2019), 1–17.

[5] LM Dixon. Slow and steady wins the race: the behaviour and welfare of commercial faster growing broiler breeds compared to a commercial slower growing breed. *PLoS One* 15 (2020), e0231006.

- allantoic fluid: the fluid in the sac within an egg that aids the exchange of embryonic gas and liquid waste
- chick: a newly hatched bird of the species *Gallus gallus domesticus*
- culling: the killing of chicks or turkey poults
- genetic modification: changing a genome by human intervention in a way that could not be the result of a traditional breeding process
- hen: a female of the species *Gallus gallus domesticus*
- in-ovo: inside an unhatched egg
- sexing: identifying whether an embryo, chick or turkey poult is male or female
- table egg: an egg that is sold for domestic consumption

Legal context

12. Under the Animal Welfare Act 2006, section 4 in England and Wales, and the Animal Health and Welfare (Scotland) Act 2006, section 19, it is an offence for a person to cause unnecessary suffering to any protected animal. Under the same Acts, sections 9 and 24 respectively, a person commits an offence if they do not take reasonable steps given the circumstances to ensure that an animal's needs for a suitable diet and protection from pain[6], suffering, injury and disease are met. Under the same Acts, sections 1 and 16 respectively, nothing in them applies to an animal while it is in its foetal or embryonic form. The destruction of an animal in an appropriate and humane manner is not an offence under this legislation.

13. The Animals (Scientific Procedures) Act 1986 Amendment Regulations 2012, which apply to animals used in scientific research, define as a protected animal any mammal, bird or reptile for which two-thirds of the gestation or incubation period for the relevant species has elapsed.

14. Part 1, section 1, paragraph 2, of the Genetic Technology (Precision Breeding) Act 2023, which applies to England only, defines an organism as 'precision bred' if every feature of its genome that results from the application of modern biotechnology could have resulted from traditional processes, whether or not in conjunction with selection techniques alone and if its genome does not contain any feature that results from the application of any artificial modification technique other than modern biotechnology as defined in specified paragraphs of the Genetically Modified Organisms (Deliberate Release) Regulations 2002. In relation to animals, traditional processes are listed as sexual fertilisation, spontaneous mutation, artificial insemination, in vitro fertilisation, embryo transfer, polyploidy induction and the recovery and transfer of primordial germ cells.

15. The retained Council Regulation (EC) 1099/2009 on the protection of animals at the time of killing, Annex I, chapter I, tables 1 and 3, permit the killing of poultry using inert gases (e.g., argon or nitrogen), with or without CO_2, as well as using CO_2

[6] Pain is absent from the Scottish legislation.

alone. The maceration of egg embryos and of chicks aged up to 72 hours is also permitted, as is cervical dislocation.

16. The same Regulation, Annex I, chapter II, division 3, states that no person may perform manual cervical dislocation on more than 70 animals per day.

17. The retained Council Regulation (EC) 1069/2009 laying down health rules as regards animal by-products and derived products not intended for human consumption, article 10 (k) and (l), places hatchery by-products, eggs and egg by-products, including egg shells, and day-old chicks killed for commercial reasons, in Category 3. Article 9 (f) places animals killed for disease control purposes, foetuses and dead-in-shell poultry in Category 2. Article 14 (d) and (e) permits Category 3 items to be used for the manufacture of feed for farmed animals and pets and for the production of raw petfood. Article 18, paragraph 1, permits the competent authority, by way of derogation from that article, to authorize, under conditions which ensure the control of risks to public and animal health, the collection and use of Category 3 material for feeding to zoo animals, circus animals and reptiles and birds of prey other than zoo or circus animals. It makes similar provisions for Category 2 material, provided that this comes from animals that did not die as the result of the presence or suspected presence of a disease communicable to humans or animals.

18. The Welfare of Animals at the Time of Killing (England) Regulations 2015, Schedule 2, paragraph 44, permit the killing of surplus chicks less than 72 hours old in hatchery waste by maceration, exposure to a permitted gas mix, or, where there is no other available method, by cervical dislocation. Chicks must remain in the gas mixture until dead and must be killed as rapidly as possible. These provisions are also in the equivalent Welsh Regulations (Welfare of Animals at the Time of Killing (Wales) Regulations, 2014). Similar provisions are in place in Scotland through Schedule 11 of the Welfare of Animals (Slaughter or Killing) Regulations (1995).

19. For Scotland, the Welfare of Animals (Slaughter or Killing) Regulations (1995), Schedule 11, paragraph 5, state that no person shall kill, or cause or permit to be killed, any embryo in hatchery waste, except by use of a mechanical apparatus producing immediate death. Paragraph 6 states that this apparatus must contain rapidly rotating mechanically operated killing blades or projections and that the capacity of the apparatus must be sufficient to ensure that every embryo is killed immediately. The Welfare of Animals (Slaughter or Killing) Regulations (1995) and subsequent amendments were revoked in England and Wales by The Welfare of Animals at the Time of Killing (England) Regulations 2015 and the Welfare of Animals at the Time of Killing (Wales) Regulations, 2014. Neither of those regulations cover the killing of embryos in hatchery waste, which is permitted instead by Annex 1 of the retained European Council Regulation 1099/2009 on the protection of animals at the time of killing (PATOK), which lists maceration as a permitted method for killing egg embryos. PATOK is implemented and enforced by WATOK in England and Wales.

20. The Code of Practice for the Welfare of Laying Hens and Pullets (2018) for England closely corresponds with a similar Code for Wales (2019) and Guidance for Scotland (2020). Paragraph 111 states that surplus chicks and in-shell embryos, including in hatchery waste, must be culled humanely by a trained and competent

person and in accordance with the specific welfare at the time of killing legislation (see 18).

21. The Codes of Recommendations for the Welfare of Livestock: Turkeys (1987), which apply to England, Wales and Scotland, contains detailed provisions relating to the disposal of unwanted poults and hatchery waste. Paragraph 54 states that unwanted poults awaiting slaughter should be treated as humanely as those intended for retention or sale. Paragraph 56 states: ‘Methods of killing which involve suffocation by tightly packing the unwanted poults in a confined space, or by drowning, or in which irritant liquids such as carbon tetrachloride are allowed to come into direct contact with the poults, are inhumane and should not be used.’ Paragraph 57 states that all hatchery waste should be treated (e.g., by rapid maceration) so as to kill instantaneously any living embryos.

22. In the same Code, paragraph 55 states: ‘Poults should always be killed humanely by a skilled operator. The method which should be used is to place them in an atmosphere with the highest obtainable concentration of CO_2 and a source of 100% CO_2 should therefore be used as the disposing agent. This is the most humane method and detailed advice on its use is given in ADAS advisory publication P568. However, where very small numbers of poults are involved, they may be killed humanely by dislocation of the neck or by decapitation. Whatever method is used the poults should be thoroughly inspected afterwards to ensure that all are dead.’ But see 15.

23. The Codes of Recommendations for the Welfare of Livestock: Ducks (1987), which apply to England, Wales and Scotland, contains detailed provisions relating to the disposal of unwanted ducklings and hatchery waste. Paragraph 49 states that unwanted ducklings awaiting slaughter should be treated as humanely as those intended for retention or sale. Paragraph 51 states: ‘Methods of killing which involve suffocation by tightly packing the unwanted ducklings in a confined space, or by drowning, or in which irritant liquids such as carbon tetrachloride are allowed to come into direct contact with the ducklings, are inhumane and should not be used.’ Paragraph 52 states that all hatchery waste should be treated (e.g., by rapid maceration) so as to kill instantaneously any living embryos. Paragraph 53 states that day-old ducklings should be picked up bodily in the palm of the hand.

24. In the same Code, paragraph 50 states: ‘Ducklings should always be killed humanely by a skilled operator. The method which should be used is to place them in an atmosphere with the highest obtainable concentration of CO_2 and a source of 100% CO_2 should therefore be used as the disposing agent. This is the most humane method and detailed advice on its use is given in ADAS advisory publication P568. However, where very small numbers of ducklings are involved, they may be killed humanely by dislocation of the neck or by decapitation. Whatever method is used the ducklings should be thoroughly inspected afterwards to ensure that all are dead.’ But see 15.

Background

Laying hen production

25. British Egg Industry Council figures for 2022 indicate that total UK table egg production was 10.4 billion eggs, of which 338 million were exported. 1.5 billion eggs were imported.

26. Eggs produced at commercial scale for human consumption are laid by hens bred for this purpose. The hatcheries survey conducted by Defra, RESAS and DAERA shows that, in 2022, 96m layer hatching eggs were set. This represents a fall from a high of 112.4m set layer hatching eggs in 2017.

27. Approximately 10% of all incubated eggs are infertile or contain undeveloped embryos and for these reasons never hatch. Other eggs may contain a viable embryo but do not hatch within the specified period. In UK hatcheries, approximately 2.2 hatching eggs are currently incubated per female chick sold.

28. Because laying breeds typically have slow growth rates and produce limited thigh and breast muscle, they are considered uneconomic to rear for meat. The females are reared to maturity and subsequently lay eggs, but the newly hatched male chicks are killed. Assuming a 90% hatch rate, the hatcheries survey data suggests that, in GB, approximately 40–45 million male chicks hatched into layer lines are killed each year, depending on total annual production.

29. Since the early 1990s, there has been great consolidation in GB of the hatching of laying hens. The layer market is now principally supplied by two hatcheries that operate at full commercial scale and also supply the whole of the Republic of Ireland. One of these is the largest layer hatchery in Europe. A third hatchery provides specialist breeds at a smaller scale. Each hatchery supplies a different range of breeds and all three are located in England. Statutory oversight of hatcheries rests with local authorities.

Broiler breeder production

30. In GB, approximately 1.1bn meat chickens are produced each year. The hatcheries survey indicates that, in 2022, 67.9m broiler breeder eggs were set in GB. This represents a fall from 79.5m eggs set in 2016, which was a 53-week year.

31. The females hatched in breeder lines are used to produce chicks that will be reared for slaughter as meat chickens. Industry has reported to AWC that it also aims to sell all surplus male ‘parent' chicks hatched into commercial chicken meat production and that these birds are economically viable. Higher generation progeny going into commercial production still have the inherent genetics to perform well, although slightly higher levels of 7-day mortality are observed. These are linked to reduced vigour due to being of a higher generation, and to handling during sexing.

32. In some cases, male and female chicks from slower growing broiler breeds are not sold into commercial production if the hatch produces more birds than are needed to meet immediate broiler stocking requirements. These chicks are culled. Also, female broiler breeder chicks from slower growing breeds may be culled if they are not required by a farm as parent stock, because these breeds are less commercially viable if moved into a standard rearing system. Broiler chicks are

therefore not routinely culled as a byproduct and, since the majority retain some production value, are unlikely to be killed in the same volumes as male layer chicks.

33. In both laying hen and broiler breeder production, eggs that are infertile or unhatched at the end of the specified hatching period are destroyed. This is because an egg could be unhatched due to disease or bacterial contamination and is therefore categorized as Category 2 waste (see 17) and not legally permitted to be fed to animals in any form.

Hatching and post-hatch sexing

34. Eggs may be stored prior to the start of incubation, which is initiated by a rise in the setter chamber temperature to an appropriate level. Throughout incubation and at hatching, eggs need to be maintained at a specified temperature and humidity.

35. In order to prevent the embryo sticking to the egg shell, eggs need to be rotated at least three times per day. In practice, whole setter trays are mechanically turned by angling through 40–45 degrees at hourly intervals or more frequently. This maintains the embryo in a resting position on top of the yolk, which tends to float upwards to a position on top of the albumen. Eggs are traditionally rotated until day 18 of incubation, but turning may be stopped earlier. The larger end of the egg is left facing upwards. At 18 days after incubation, eggs are transferred into the hatcher. Most eggs hatch within 24–48 hours of being placed in the hatcher, after which the trays, and their contents, are removed.

36. In hatcheries in GB, newly hatched chicks and turkey poults are individually handled and examined. Commercial brown layers (brown-feathered birds that lay brown-shelled table eggs for human consumption) currently represent 85% of the British chicken egg laying flock. The sex of these birds is indicated by feather colour: females have brown feathers and males have yellow/white feathers. The automated sexing of hatched chicks by feather colour has been reported to be possible.[7]

37. Other sexing methods are also in use for different chicken breeds and other poultry species. These do not depend on feather colour. Several commercial white layer breeds can be sexed using their wing feathers; the female chicks are fast feathering (i.e., the primary wing feathers are thicker and longer than the covert feathers) and the male chicks are slow feathering (i.e., the primary and the covert feathers are similar in length and thickness). Cloacal (or vent) sexing is frequently used for turkey poults that are bred for meat as males and females may be separated for rearing due to differing growth rates. This sexing method is also routinely used for broiler chickens, if they are sexed. In cloacal sexing, faeces are squeezed out, opening the cloaca (anal vent) so that the presence or absence of a protruding genital organ may be identified. An experienced sexer is able to sex 1,000 birds per hour at a 98% accuracy rate.[8] In some breeds, sex has classically been

[7] PT Jones, SA Shearer and RS Gates. Edge extraction algorithm for feather sexing poultry chicks. *Transactions of the ASAE* 34 (1991), 635–40.

[8] I Biederman and MM Shiffrar. Sexing day-old chicks: A case study and expert systems analysis of a difficult perceptual-learning task. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 13 (1987), 640–5.

identified by observing a variety of external characteristics such as down colour, down striping or markings, beak colour and shank colour.[9] It has been suggested that, in white laying hens, egg shape index, length, width and volume display slightly different profiles depending on sex.[10]

Culling

38. Despite being referred to as 'day old', most chicks and turkey poults identified as male are likely to be 12–36 hours old (measured from the time that an individual hatches) when killed. At arrival on farm, female chicks, which are also commonly referred to as 'day-old', may be two or more days old (see 58). AWC has therefore chosen to use the term 'newly hatched' and to refer to actual durations, and to avoid the use of the term 'day old'.

39. In the laying hen industry in GB, all newly hatched chicks identified as male are killed using argon gas in a depleted oxygen chamber. This is in accordance with the Lion Code of Practice. (EU hatcheries use CO_2 for this purpose, which is more aversive to the chick.) In GB layer hatcheries, CO_2 is not used, and live, healthy chicks are not macerated.

40. In some EU countries, legislation has been passed, or is in progress, banning routine chick culling and/or specifying the latest point of embryonic development at which the killing of chick embryos is permitted. This is providing impetus for research into new sexing technologies and their development and commercialization.

41. In EU countries in which newly hatched chicks are no longer legally permitted to be killed, unless under derogation, all male chicks must be reared to a normal broiler slaughter age. Rearing may occur within the country of hatching or in other EU or third countries, including Africa and Russia. The welfare and biosecurity of birds reared outside the EU may be lower than in GB. It is reported that the export of live chicks from some EU countries to third countries, and the sale of the meat of reared birds, has had significant negative impacts on poultry businesses in those third countries.

Turkeys

42. Turkey poults are known to be particularly vulnerable to mortality during the first week of life, with mortality rates reported of up to 6%.[11] This is due to a range of factors that are not fully understood. After hatching, poults require significant periods of darkness and rest, which sexing processes or other handling may disrupt.

43. In at least one large turkey breeder hatchery, some newly hatched male poults are culled rather than reared for meat. In this instance the majority (70%) of all disposed of poults are male, with 70% of these being surplus to breeding

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[9] JP Quinn and CW Knox. Sex identification of Barred Plymouth Rock baby chicks by down, shank, and beak characteristics. *Poultry Science* 18 (1939), 259–64.

[10] B Yilmaz-Dikmen and S Dikmen. A morphometric method of sexing white layer eggs. *Brazilian Journal of Poultry Science* 15 (2013), 203–10.

[11] C Roehrig and S Torrey. Mortality and early feeding behavior of female turkey poults during the first week of life. *Frontiers in Veterinary Science* 6 (2019), 3389.

requirements and 30% being a product of over-production. In this example, a very small number of female breeder poults were also disposed of, again due to over-production. It has been suggested to AWC that, in some turkey hatcheries, poults have, in the past, been stunned and killed by means of a gas mixture so that they may be used, like chicks, as whole feed for raptors and some exotic species. However, hatcheries have reported to AWC that the usual killing method for male poults, and for downgraded poults, is maceration, as the relatively small numbers of newly hatched poults are uneconomic to store and/or distribute as whole food in ways that maintain biosecurity.

44. When turkeys are sexed, cloacal (vent) sexing is typically used (see 37).

45. In meat turkey hatcheries, newly hatched poults are sometimes culled due to overproduction. This typically happens in hatcheries that serve the seasonal Christmas retail market rather than in continuously run hatcheries. Because female poults are less economic to rear for meat than male poults, due to their poorer and leaner muscle gain, producers may opt to cull females and rear males. However, both sexes are increasingly reared in different sheds and/or farms to meet differing market weight requirements.

Ducks

46. As far as AWC has been able to establish, ducklings are not routinely culled in GB. Following rearing and a period of egg production, female ducks are slaughtered for human consumption. Males from breeder and layer lines are reared for meat. It is possible that some sexing is undertaken on a small scale for breeding purposes.

Sentience

47. Sentience may be defined as the capacity of an organism to have subjective perceptual experiences. These may consist of positive, neutral or negative mental states (e.g., pleasure, awareness or pain). For suffering to be possible, there must be both a nervous system able to transmit sensory signals and a brain that is sufficiently developed to be able to interpret these signals. The ability to sense pain is often taken as a marker of sentience, because pain is, by definition, a conscious experience.

48. After laying, eggs may be stored for several days prior to incubation, which is initiated by the exposure of the egg to an appropriate constant ambient temperature. In a chick embryo, the development of the central nervous system begins on day 2 of incubation. The embryo’s neurological sensory mechanisms develop over stages, including tactile (day 6), proprioceptive-vestibular (day 8–10), taste (day 12), auditory (day 12–14), visual (day 18) and olfactory (day 20), prior to hatch on day 21.[12]

[12] DC Deeming. Incubation and chick rearing. In *The Welfare of Farmed Ratites*, 65–89. Springer, Berlin, 2011; DJ Mellor and TJ Diesch. Onset of sentience: the potential for suffering in fetal and newborn farm animals. *Applied Animal Behaviour Science* 100 (2006), 48–57.

49. Poultry embryos possess the capacity to experience in-ovo nociception.[13] In a chick embryo, the first sensory afferent nerves develop on day 4 of incubation, but a synaptic connection to the spinal cord is not present until day 7, making nociception, and therefore pain perception, very unlikely during the first third (before day 7) of incubation due to the immaturity of the neural apparatus[14,15].

50. In a chick embryo, neurons begin working on day 7 of incubation and neural tubes develop into a functional brain at approximately 10.5 days.[16] Brain waves in the embryo, measured via electroencephalograph (EEG) waves, are initiated as early as, but not before, day 13, then go through a progressive developmental series.[17] Erratic spikes appear by day 15 and, by day 18, EEG waves similar to slow/fast sleep waves appear. By days 19–20 the EEG waves become similar to the waves detected in the hatchling during sleep.

51. This suggests that a chick embryo is not capable of consciously feeling pain until day 13 of incubation. Beyond this point, it is possible that the onset of sentience may be precipitated by an invasive event.[18]

52. In a chick embryo, skeletal muscular activity appears to commence around day 6, although early movement may be an automatic reflex rather than a conscious reaction to stimuli. The embryo is 3 cm long at day 9 and can measure up to 15 cm long (claw to beak tip) at day 15 .

53. The physical and neurological development of turkey poults and ducklings is similar to that of chicks but takes approximately one third longer. Both poults and ducklings typically hatch 28 days following the start of incubation.

54. Because poultry embryos develop outside of the mother, they are particularly influenced by external environmental conditions. Several days before hatching, there is coordinated behaviour between the embryos in adjacent eggs and responsiveness to tactile, auditory and visual stimuli. During the later phase of incubation, embryos are able to vocalize and initiate the hatching process. This includes the use of sound

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[13] S Bjørnstad, LPE Austdal, B Roald, JC Glover and RE Paulsen. Cracking the egg: potential of the developing chicken as a model system for nonclinical safety studies of pharmaceuticals. *Journal of Pharmacology and Experimental Therapeutics* 355 (2015), 386–96.

[14] AL Eide and JC Glover. Developmental dynamics of functionally specific primary sensory afferent projections in the chicken embryo. *Anatomy and Embryology* 195 (1997), 237–50; AL Eide and JC Glover. Development of the longitudinal projection patterns of lumbar primary sensory afferents in the chicken embryo. *Journal of Comparative Neurology* 353 (1995), 247–59.

[15] M-E Krautwald-Junghanns, K Cramer, B Fischer, A Förster, R Galli, F Kremer, EU Mapesa, S Meissner, R Preisinger, G Preusse, C Schnabel, G Steiner and T Bartels. Current approaches to avoid the culling of day-old male chicks in the layer industry, with special reference to spectroscopic methods. *Poultry Science* 97 (2018), 749–57; E Aleksandrowicz and I Herr. Ethical euthanasia and short-term anesthesia of the chick embryo. *ALTEX-Alternatives to Animal Experimentation* 32 (2015), 143–7.

[16] B Close, K Banister, V Baumans, EM Bernoth, N Bromage, J Bunyan . . . and C Warwick. Recommendations for euthanasia of experimental animals: Part 2. *Laboratory Animals* 31 (1997), 1–32.

[17] Sandra Kollmansperger, Malte Anders, Julia Werner, Anna M. Saller, Larissa Weiss, Stephanie C. Süß, Judith Reiser, Gerhard Schneider, Benjamin Schusser, Christine Baumgartner and Thomas Fenzl, 'Nociception in chicken embryos, part II: embryonal development of electroencephalic neuronal activity in ovo as a prerequisite for nociception', *bioRxiv* preprint awaiting peer review.

[18] DJ Mellor and TJ Diesch. Onset of sentience: the potential for suffering in fetal and newborn farm animals. *Applied Animal Behaviour Science* 100 (2006), 48–57.

synchronization to coordinate hatching via the production of a clicking sound by tapping the egg tooth against the egg shell.[19]

55. There is strong evidence that newly hatched chicks, turkey poults and ducklings are capable of experiencing negative states such as fear, as indicated by distress calling.[20] The intensity of this response correlates with established behavioural and physiological indices of stress and is susceptible to modulation by anxiolytic drugs. This suggests that whenever they are handled and/or culled, their welfare should be fully considered.

Chick hatchery handling and processing

56. Chicks are wheeled in hatcher basket modules from the hatcher, which is a warm, humid and dark environment, to the sexing area, which is bright and noisy. They are manually dropped onto conveyors moving at various velocities, and at points are automatically dropped from one belt onto a lower belt. This exposes any chicks with musculoskeletal weaknesses to limb injury risk. At feather sexing, chicks identified as male are handled (e.g., picked out of the basket, examined and dropped down a chute) in order to be separated from chicks identified as female.

57. Where a gas stunning and killing system is in use, male chicks are moved on a conveyor, and potentially again dropped, into trays, which minimizes handling. They are then moved into the stunning/killing apparatus (see 62), either by manual loading or an automated conveyor.

58. Females are handled as part of an initial examination (quality control) and pass through an accelerator to be counted, prior to transfer to another part of the hatchery for vaccination and (optional) beak tipping. Here they are manually placed onto a carousel and secured by means of head holders and additional sternal and leg support. The females are then released and fall down a chute into trays. Once full, each tray is inserted into a wheeled module, which is placed in a holding area to await collection or delivery, which might not occur until the next day. During this period, the females may not have any access to water for hydration or to feed for energy. Those that hatch first may be deprived of hydration for up to 72 hours before unloading and stocking at the rearing site.[21]

59. In chickens, feed access within 24 hours of hatching has been shown to support the utilization of residual yolk and, within the yolk sac, higher protein content and lower lipid concentration. Early feed access has also been associated with significantly heavier liver, pancreas and jejunum weights at 7 days of age than for chicks not fed until 32–48 hours, and with significantly higher weight at 5 weeks of

[19] Q Tong, CE Romanini, V Exadaktylos, C Bahr, D Berckmans, H Bergoug, N Eterradossi, N Roulston, R Verhelst, IM McGonnell and T Demmers. Embryonic development and the physiological factors that coordinate hatching in domestic chickens. *Poultry Science* 92 (2013), 620–8.
[20] KA Herborn, AG McElligott, MA Mitchell, V Sandilands, B Bradshaw and L Asher. Spectral entropy of early-life distress calls as an iceberg indicator of chicken welfare. *Journal of the Royal Society Interface* 17, 167 (2020), 20200086.
[21] M Boyner, E Ivarsson, M Andersson Franko, M Rezaei and H Wall. Effect of hatching time on time to first feed intake, organ development, enzymatic activity and growth in broiler chicks hatched on-farm. *Animal* 15 (2021), 100083.

age than for those not fed until 40–48 hours[22], as well as impacting disease immunity.[23] For females that are not fed and watered until very late (54 hours after hatch), behavioural responses to the surrounding environment may be reduced in later life.[24]

60. In some hatcheries, as well as on some farms on which broilers are hatched, a source of hydration and energy is made available immediately or soon-after hatching. Such provision has been associated with reduced weight loss following hatching and subsequent improved growth.[25]

Killing methods

61. There is a lack of formal peer-reviewed research on the welfare consequences of killing methods for chicks. Although the killing of poultry using gases is well studied, research has focused on commercial slaughter and on emergency killing. In the few studies that have examined chick culling, which are cited in this section, the reported welfare assessments are mostly limited to basic measures, such as time to loss of posture and time to motionless. Whether, and to what extent, welfare findings from older birds may be reliably applied to chicks is unclear.

62. In the UK, healthy male chicks from layer lines are normally killed by argon gas exposure. There are also other legal methods (see 15). The use of argon, and potentially of other inert gases, minimizes aversion, although the extent to which the inhalation of such gases induces a sensation of breathlessness in birds is currently unknown. When argon is applied, the level of residual oxygen (from air) is crucial and should be less than 2%, because even 5% residual oxygen will result in prolonged deaths and the survival of some chicks.[26] The gas should be maintained at an appropriate ambient temperature and chicks should remain exposed to it for a duration sufficient to guarantee death. The SOPs supplied to AWC by commercial hatcheries in the UK suggest that appropriate safeguards are in place relating to residual oxygen control, dwell time and confirmation of death by pinch testing random samples of chicks from each batch. Detailed independent advice on using gas to kill chicks is available.[27]

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[22] SK Bhanja, C Anjali Devi, AK Panda and G Shyam Sunder. Effect of post hatch feed deprivation on yolk-sac utilization and performance of young broiler chickens. *Asian-Australasian Journal of Animal Sciences* 22 (2009), 1174–9; OM El-Husseiny, A El-Wafa and HMA El-Komy. Influence of fasting or early feeding on broiler performance. *International Journal of Poultry Science* 7 (2008), 263–71.
[23] HR Juul-Madsen, G Su and P Sørenson. Influence of early or late start of first feeding on growth and immune phenotype of broilers. *British Poultry Science* 45 (2004), 210–22.
[24] MS Hollemans, S de Vries, A Lammers and C Clouard. Effects of early nutrition and transport of 1-day-old chickens on production performance and fear response. *Poultry Science* 97 (2018), 2534–42.
[25] T Incharoen, W Jomjanyouang and N Preecha. Effects of aqua agar as water replacement for posthatch chicks during transportation on residual yolk-sac and growth performance of young broiler chickens. *Animal Nutrition* 1 (2015), 310–12.
[26] AB Raj and PE Whittington. Euthanasia of day-old chicks with carbon dioxide and argon. *Veterinary Record* 136 (1995), 292–4.
[27] https://www.hsa.org.uk/downloads/technical-notes/tn14-gas-killing-of-chicks-in-hatcheries-jan-2023.pdf

63. The induction of unconsciousness and death is more rapid when CO_2 is used than when argon or other inert gases are used alone.[28] However, the available data suggest that, from a welfare viewpoint, argon exposure is preferable. Exposure to CO_2 as a method of stunning and killing is under increasing scrutiny because it presents two major potential welfare concerns: pain due to the activation of mucosal nociceptors (due to reacting with water to create carbonic acid, which has an irritant effect on these receptors), and unpleasant respiratory sensations (breathlessness). The association of the killing of chicks using CO_2 with welfare harms is supported by recent research, which reports behavioural signs of distress with both gradual exposure to CO_2 and immersion in it at an initially high concentration.[29]

64. The only chicks, turkey poults or ducklings likely to be macerated are those that appear abnormal, because of conditions such as developmental abnormalities, pasted vents (droppings stuck to the down in the vent area), abdominal distension (inflation) or red skin, or that are still damp and so unlikely to survive processing. However, in laying hen hatcheries, in which argon is used to stun and kill male chicks, chicks of either sex that appear abnormal may be stunned and killed either using this method or by cervical dislocation. Effective maceration is typically assumed to lead to immediate loss of consciousness and death and thus to cause minimal welfare harm. However, it destroys chicks, turkey poults or ducklings such that they may not be used as whole feed for other animals. AWC understands that a very small proportion of the chicks hatched into broiler breeder lines are culled (see 32) either by maceration or CO_2 exposure.

65. When cervical dislocation is performed on chicks the neck is typically crushed against a hard fixed object; however, the brain stem may not be reliably broken and the blood supply may not be immediately disrupted, meaning that the onset of brain death may take an extended period of time. Cervical dislocation is impractical for large numbers of chicks and requires training and skilful application. It is most likely to be used for injured chicks, which should be killed promptly.

Hatchery waste

66. Eggs that do not hatch within the specified time period (see 35), but which may still contain a viable chick, are usually macerated. The product resulting from this is disposed of by an approved method, which is usually rendering.

67. The machines used for egg maceration have typically been designed for macerating newly hatched chicks and may not be suited to macerating eggs containing chicks. There are two designs: a roller type, which causes crushing between two rotating rollers; and a knife type, which contains blades that perform a mincing action. The operators of macerators need to be well trained. Slow blade

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[28] S Gurung, D White, G Archer, D Zhao, Y Farnell, JA Byrd, ED Peebles and M Farnell. Evaluation of alternative euthanasia methods of neonatal chickens. *Animals* 8 (2018), 37.
[29] BI Baker, S Torrey, TM Widowski, PV Turner, TD Knezacek, J Nicholds, TG Crowe and K Schwean-Lardner. Evaluation of carbon dioxide induction methods for the euthanasia of day-old cull broiler chicks. *Poultry Science* 98 (2019), 2043–53.

rotation, or rollers set too wide, may result in fully grown unhatched chicks not being instantaneously killed.[30] Overloading may lead to jamming or reduced performance.

Sexing technologies

68. Egg candling is the traditional method used to verify embryo development and viability. On chick eggs it can be performed at day 18, but also following the first mortality peak at 7–10 days. Traditional candling cannot be used to detect embryo sex.

69. Globally, several new technological applications to identify or determine the sex of in-ovo chick embryos are under development or in commercial use.

70. In countries in which in-ovo sexing technologies for chicks are in use, a typical business model is that a technology owner places the sexing machinery in a hatchery and operates it on a contract basis. The hatchery pays the technology owner a fee for each egg analysed or for each female hatched. This results in an additional cost for each layer chick supplied, which is then passed on to the pullet farmer or rearer. The hatchery also potentially makes efficiency savings resulting from not having to fully incubate and hatch those eggs identified as male. A female chick that has been sexed in-ovo might cost a farmer £3 (2023 figure), which is four times the 75 pence price for a standard chick. Spread across approximately 350 table eggs, laid over a bird's lifespan, this equates to a little under a penny extra per table egg. This business model removes from the hatchery responsibility for the very high level of initial capital investment (e.g., £2m) required to acquire these technologies, and reduces the financial risk generated by market uncertainties.

71. In order to maintain a high level of biosecurity and disease prevention during the sexing process, an internal clean room or area is required for the sexing machinery to be placed within, or immediately adjacent to, the existing hatchery buildings. This is likely to need to be of a substantial size. When sexing technology is first introduced into a hatchery, production will probably be disrupted. Both of the main laying hen hatcheries in England have reported that their existing infrastructure would require extending in order to house such technology. For some technologies, a container laboratory may be brought onto site and located adjacent to existing buildings and some parts of the sexing process operated from there. Any sexing process requires appropriate staffing.

72. As with any egg handling procedure, temperature changes that result from a sexing process may have the potential to impact hatchability. Any physical damage to the remaining female eggs caused during the sexing process may also affect hatchability.

73. After sexing, eggs that are identified as female are returned to the incubator and eggs that are identified as male, or are unidentified, are destroyed if this is legally permitted. Methods currently used include maceration with or without prior

[30] EFSA Panel on Animal Health and Welfare (AHAW), SS Nielsen, J Alvarez, DJ Bicout, P Calistri, K Depner . . . and V Michel. Killing for purposes other than slaughter: poultry. *EFSA Journal* 17 (2019), e05850.

electrical stunning. The resulting product may be used to produce animal feed components.

74. Some of the methods presented have been developed in commercial settings rather than by the application of published scientific research.

Allantoic fluid analysis methods

75. By drilling a small hole through an egg shell, extracting a sample of the fluid contained in the sac within the egg and analysing this, the sex of the egg may be detected.

76. Some of these technologies require a significant volume of chemical reagents and a prolonged analysis process.

Analysis of allantoic fluid to measure the concentration of female growth hormone

77. From 9–10 days after chick incubation begins, when the allantoic sac is at its maximum size and easily locatable and a sufficient volume of hormone in waste products has accumulated, a small (0.3 mm) hole is drilled in the egg shell using a laser. It is possible to extract an adequate fluid sample from approximately 98% of eggs. Although the hole made in the egg is small enough for the inner membrane to reseal, the hole in the outer shell is closed with beeswax in order to improve hatching rates. The sample is subject to endocrinological analysis with a patented enzyme-linked immunosorbent assay (ELISA) to quantify the concentration of oestrone sulphate using a colour change reaction. Under experimental conditions, this has been found to have a short-term impact on weight during rearing, but the laying performance, adult body weight and egg weight of the sexed laying hens did not differ significantly from the control group.[31] This analysis takes at least 20 minutes, after which the eggs are robotically sorted. The handling process is fully automated and there is no physical human contact with the eggs at any point.

78. A fully automated system currently in use is able to test 3,600 eggs per hour at a reported 97–98% accuracy, and with low reported embryo losses and therefore high hatchability.

Polymerase chain reaction (PCR) test to detect the presence of female DNA

79. From 9 days after chick incubation begins, eggs in setter trays are manually placed onto the sexing machine. Robotic arms utilise suction to transfer the eggs out of the setter tray into a cup set in a carrousel. A laser cuts a small (0.3 mm) hole in each egg and 25 µl of allantoic fluid is extracted. The area around the hole in the outer shell is closed with beeswax and the eggs are individually returned to the setter trays by the robotic arms. The pipette tip containing the fluid is deposited into a box and manually removed to the laboratory for analysis. Samples are manually loaded, mixed with a reagent and run through a PCR testing machine to detect the presence

[31] A Weissmann, S Reitemeier, A Hahn, J Gottschalk and A Einspanier. Sexing domestic chicken before hatch: a new method for *in ovo* gender identification. *Theriogenology* 80 (2013), 199–205.

of female DNA using optical measurement and fluorescence dyes, and so the genetic sex of the embryo. Sampled eggs are left on a trolley for one hour until the test result is available. Eggs identified as female are marked with a symbol, transferred to a different tray and then returned to the incubator.

80. For this technology, the recommended age of parent hens is 28–65 weeks and the accuracy is 98–99%, although over 5% of samples are currently unusable due to an insufficient volume of fluid being extracted. One such system is able to sex 3,000 eggs per hour and 24-hour continuous operation is possible.

81. A developer of this technology has reported that this sexing method is potentially usable at day 6 of incubation, providing that allantoic fluid removal is possible at this stage.

Mass (Raman) and fluorescence spectroscopy to measure the presence of a biomarker in allantoic fluid

82. In this technology, which may be used from 4 days after chick incubation begins, a large (12 mm) hole is drilled in the egg shell and a laser is directed through it into the egg to analyse the spectral signature of germinal or blood cells in allantoic fluid, which is different depending on sex. This acts as a biomarker. The shell is then repatched. This process has been reported to be 93% accurate.[32] When the hole size is reduced so that the inner egg shell membrane is kept intact, in order that hatchability is less affected by the sexing process, the sexing accuracy falls to 90%.[33]

83. In another application of the same biomarker method, from 9 days after chick incubation begins, a small hole is made in each egg with a needle and an allantoic fluid sample is extracted. In order to increase accuracy, sampling typically occurs at 11 days. Eggs are simultaneously sampled, with each batch being drilled, sampled and patched with gel in less than one second. A robotic arm sorts eggs sexed by the biomarker into a tray. The sexing process is fully automated, although two machine operators are required. 3,600 eggs may be sexed each hour with a waiting period before the sample result is obtained.

Evaluation of fluid analysis methods

84. Allantoic fluid sampling is invasive because a hole has to be drilled into every egg sampled. This is likely to have some negative impact on the hatchability and survivability of the hatched (mostly female) chicks. Invasive methods also pose a microbiological contamination risk to the embryo, although this is unlikely to present a risk to consumer health. Nevertheless, drilling as part of a sexing process is likely

[32] R Galli, G Preusse, O Uckermann, T Bartels, M.-E. Krautwald-Junghanns, E Koch and G Steiner. In ovo sexing of chicken eggs by fluorescence spectroscopy. *Analytical and Bioanalytical Chemistry* 409 (2017), 1185–94; R Galli, G Preusse, O Uckermann, T Bartels, M-E Krautwald-Junghanns, E Koch and G Steiner. In ovo sexing of domestic chicken eggs by Raman spectroscopy. *Analytical Chemistry* 88 (2016), 8657–63.

[33] R Galli, G Preusse, C Schnabel, T Bartels, K Cramer, M.-E. Krautwald-Junghanns, E Koch and G Steiner. Sexing of chicken eggs by fluorescence and Raman spectroscopy through the shell membrane. *PLoS ONE* 13 (2018), e0192554.

to be less problematic than drilling for in-ovo vaccination, which is the type of drilling of which most GB hatcheries have had experience.

85. The disruption of foetal development may cause discomfort and have implications for future health and welfare.[34] There is potential for any invasive testing method to interrupt the sleep-like state of unconsciousness that poultry embryos experience during the latter part of incubation (see 50).[35] The fluid analysis methods presented here may, and should, be used prior to the start of this period.

86. Due to error rates and hatchability implications for some embryos, fluid analysis sexing methods typically require significantly more eggs to produce the same number of females as when post-hatch sexing is used (see 109). This means that, when these methods are used, more embryos will be destroyed than the number of newly hatched chicks that are currently killed, and that more breeder birds need to be reared, housed and managed. With continuing technological refinements this additional input is likely to lessen with time.

Imaging methods

Hyperspectral imaging to detect the colour of embryo feathers

87. This method is suitable for use on brown layer strains in which male chicks have yellow/white plumage and female chicks have brown plumage. These strains currently account for 85% of the market in GB (see 36). Brown feathering has been identified as a risk factor for injurious pecking due to behavioural differences between brown and white breeds.

88. At 13 days after chick incubation begins, when the embryo is more resilient to temperature change and downy plumage colour is identifiable, trays of eggs are temporarily removed from incubation and 'candled' by a light source being shone through them. Images of the light passing through the eggs are collected using a hyperspectral camera, which takes multiple photos at different wavelengths, and are analysed. Light spectra profiles indicate whether the embryo feathers are brown or yellow/white and so indicate the embryo sex. Infertile eggs, which are 'clear', are also identifiable. The heat generated by the light is dissipated by mechanical ventilation. Following analysis, eggs are printed with a marker showing whether they have been identified as female, male or unviable, and are manually sorted. Eggs identified as female are placed into setter trays and returned to incubation.

89. Sexing accuracy varies with incubation duration, rising in one research project from 86.5% on day 12 to 97.8% on day 13 and 99.5% on day 14.[36] By day 18, accuracy fell to 94.6% due to stronger light attenuation by the growing embryos. The use of 'day zero' spectra to correct for variability in eggshell properties (colour, shape

[34] M Campbell, D Mellor and P Sandøe. How should the welfare of fetal and neurologically immature postnatal animals be protected?' *Animal Welfare* 23 (2014), 369–79.
[35] DJ Mellor and TJ Diesch, 'Birth and hatching: key events in the onset of awareness in the lamb and chick. *New Zealand Veterinary Journal* 55 (2007), 51–60.
[36] M Corion, J Keresztes, B De Ketelaere and W Saeys. In ovo sexing of eggs from brown breeds with a gender-specific color using visible-near-infrared spectroscopy: effect of incubation day and measurement configuration. *Poultry Science* 101 (2022), 101782.

and structure) increased the day 13 sexing accuracy to 99%. A system currently in use is able to analyse 20,000 eggs per hour. This is quick compared with other methods and more closely matches the throughput of a large hatchery that does not currently sex eggs (i.e., 30–40,000 eggs per hour).

90. The breed and age of the parental flock can affect the sexing accuracy of this method.[37]

91. Eggs identified as male are electrically stunned by being punctured via two electrodes transmitting 110 volts over 2 seconds, at a 99% success rate. This is immediately followed by maceration, with the product used in animal feed manufacture.

Magnetic resonance imaging (MRI) of embryos combined with artificial intelligence

92. At 12–13 days, chick embryo anatomy is observable by MRI of the intact egg. Eggs are temporarily removed from incubation and the sex is identified based on embryo morphology. A de-stacker brings trays of eggs on a trolley to the machine. A conveyor system with suction cups is used to lift eggs out of the setter tray. These are run through the MRI scanner tube in series and the scanning duration is less than one second. Each scanned egg is automatically sorted into one of two groups, female and male/unviable. Any egg identified as female is placed in a hatcher tray that is collected and returned to the setter chamber for a further five days of incubation.

93. The current analysis rate is 3,000 eggs per hour, but multiple machines can work in parallel and the combination of MRI and Artificial Intelligence (AI) computer analysis of the MRI images is reported to have the potential to increase processing to 24,000 eggs per hour. Accuracy is reported to 96% but improvements in artificial intelligence could increase this. The technology could potentially be used at 11 days after incubation begins when combined with the use of a biomarker, but this technology is still under development.

Hyperspectral imaging before incubation

94. A large set of infrared images is taken within a specified wavelength range. Image features are analysed using artificial intelligence and machine learning in order to classify one or more indicators of fertility and then of sex. This method potentially has a high degree of accuracy and currently appears to be the most advanced egg sexing method that can be used before incubation begins. AWC is unaware of any published peer-reviewed research describing or evaluating this sexing method.

Hyperspectral imaging before incubation to detect the presence of genetically modified material

[37] Anke Förster, Laura Zumbrink and Jörg Hurlin. L’imagerie hyper-spectrale comme outil d’ovo-sexage pour les embryons des souches d’œufs bruns. *Quatorzièmes Journées de la Recherche Avicole et Palmipèdes à Foie Gras*, Tours, 9-10 March 2022.

95. The sex chromosome complement of birds is different from that of mammals. In birds, females are heterogametic (ZW) and males are homogametic (ZZ). Because sex is determined by the female gamete, sperm selection is not an applicable sexing method for birds. Embryo selection is the only remaining option for sex identification.

96. The Z-chromosome of breeding hens can be genetically modified to include a green fluorescence protein.[38] This protein could then be detected by hyperspectral imaging to a high level of accuracy.

Evaluation of imaging methods

97. For imaging technologies that are already used in commercial hatcheries outside of GB, accuracy rates are influenced by egg development age, and the imaging of embryos is not suitable for detecting sex until a relatively late point in the incubation of the embryo.[39] However, newer hyperspectral imaging methods that are currently under development are expected to allow sexing before, or close to the start of, incubation.

98. Light-based and MRI-based image sampling is non-invasive, which may result in a higher hatchability rate than if an invasive method were used.

99. AWC is not aware of any negative welfare effects on embryos resulting from the use of imaging sexing technologies. Compared with invasive methods, imaging methods are reported to be cost-effective and quick to operate.

Influencing the sex of the chick

100. Instead of detecting the sex of an egg once this has been genetically activated, the sex that is presented or activated may be influenced by human intervention.

Sound vibration methods

101. Within the incubator, different sound frequencies and amplitudes can be combined with adapted temperature conditions to create pulsed sound vibrations. Sensors monitor sound, setter chamber gas concentrations and air temperature. When correlated with sex outcomes for each egg batch, alteration of these variables algorithmically informs future machine settings. In genetically male embryos, exposure to the combination of sound, temperature and gas concentrations results in the degeneration of one testicle into an ovary. Some genetically male embryos become functional females as indicated by sexual organ development, feather patterns, and DNA and comb shape and development. These changes mirror sex reversal processes observable in nature.

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[38] TJ Doran, KR Morris, TG Wise, TE O'Neil, CA Cooper, KA Jenkins and MLV Tizard. Sex selection in layer chickens. *Animal Production Science* 58 (2017), 476–80.
[39] D Göhler, B Fischer and S Meissner. In-ovo sexing of 14-day-old chicken embryos by pattern analysis in hyperspectral images (VIS/NIR spectra): a non-destructive method for layer lines with gender-specific down feather color. *Poultry Science* 96 (2017), 1–4.

102. Sound vibration methods for altering chick sex are currently being developed. It has been stated that hatchability is unaffected and that the composition and nutritional value of eggs from reversed males matches that of eggs from females. However, other research has reported that genetically male (ZZ) birds which have been genetically modified so that an ovary develops in place of testes are virtually identical to other genetic males and do not display female characteristics[40]. Therefore, it is currently questionable whether these modified males can reliably produce eggs.

Genetic modification

103. In birds, cell fertilization and gene activation operate differently from in mammals, with multiple sperm required to fertilize a single egg cell. Genetic activation occurs in two waves, with the maternal genes activated in the zygote and the paternal genes activated later. This may prevent the genetic complications that would otherwise result from the presence of multiple sperm each with a different set of genes.

104. There has been some limited research discussion of using genetic modification to determine egg sex. For example, the CRISPR (Clustered Regularly Interspaced Short-Palindromic Repeats) and Cas9 (CRISPR-associated-protein 9) gene editing system could potentially be used to trigger lethality in male embryos[41], with the modified DNA being activated when eggs are exposed to blue light for several hours.

Evaluation of sex alteration methods

105. Sound vibration and genetic modification methods for altering chick embryo sex are not yet commercialized. Their success rates and ability to produce chickens able to lay eggs at commercial yield are currently unknown.

106. From a legal perspective, genetic modification methods for altering chick embryo sex are currently at an experimental research stage. Since the methodological detail of any techniques which may in due course be commercialised is not yet known, it is currently unclear whether they will fall under the Genetic Technology (Precision Breeding) Act 2023 and / or other legislation and regulation relevant to genetically modified organisms (see 'Legal Context' above).

107. There is a significant risk that any modification of the genomes of animal species may have unintended negative side effects on the welfare and/or performance of proximate or further removed progeny that would be difficult to reverse.

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[40] J Ioannidis, G Taylor, D Zhao, L Liu, A Idoko-Akoh, D Gong, R Lovell-Badge, S Guioli, MJ McGrew and M Clinton. Primary sex determination in birds depends on DMRT1 dosage, but gonadal sex does not determine adult secondary sex characteristics. *PNAS* 118 (2021), e2020909118.
[41] C Douglas, V Maciulyte, J Zohren, DM Snell, SK Mahadevaiah, OA Ojarikre, PJ Ellis and JM Turner. CRISPR-Cas9 effectors facilitate generation of single-sex litters and sex-specific phenotypes. *Nature Research* 12 (2021), 6926, 6–7.

108. If sex determination by a method that involves genetic modification becomes commercialized in other countries, it is possible that eggs for which the sex has been determined by genetic modification, or chicks hatched from such eggs, will be imported into GB from these countries, if such import is legal.

Significance of error rates

109. The accuracy rate for post-hatch feather sexing by an experienced person is potentially above 99%.[42] As already indicated, the accuracy rates for all in-ovo methods using sexing technologies are lower.

110. It is important to distinguish precision, which is the percentage of eggs able to be sampled or otherwise analysed, from accuracy, which is the percentage of eggs correctly sexed, or in which the sex is successfully determined. Due to the extremely large numbers of embryos and chicks involved (see 28), even a small error, or difference in error, may be ethically and commercially significant. If 100 million chick embryos were to be sexed each year in GB, a 0.1% difference in error rate would equate to 100,000 embryos and/or chicks. For management purposes, hatcheries need to know approximately how many females will hatch. Predictable hatching rates are therefore important. Excess chicks cannot be delivered to farm as this would be likely to infringe stocking density limits.

111. In countries where the routine killing of chicks is legal, effort is likely to be focused on minimizing sexing errors in which females are misidentified as males, because this leads to the unnecessary killing of females. It can also lead to males being accidentally placed on laying farms and then having to be killed by the farm producer (most likely by cervical dislocation) at a later stage.

112. In countries where the killing of chicks is illegal, effort is likely to be focused on minimizing sexing errors in which males are misidentified as females. This is because hatched males are required to be reared, yet at 70 days a layer line male typically produces only 250–300g of meat.

113. Laying hen breeders may now be kept for up to 100 weeks of age, although the GB norm has been 75 weeks and the hatchability of the eggs produced can begin to decline from 60 weeks. By 70 weeks they are producing eggs that are reported to be more difficult to sex accurately using some hyperspectral imaging methods (see 90) than eggs from younger breeder birds.

Dual-purpose breeds

[42] A Nakamura, K Nagao, T Tsunekawa, K Kino, K Noda and H Kondo. Accuracy of feather sexing in newly hatched Nagoya breed chicks. *Research Bulletin of the Aichi Agricultural Research Center* 42 (2010), 107–12.

114. A dual-purpose chicken breed is one that can be used to produce both eggs and meat. In GB, the use of dual-purpose breeds is currently extremely limited. They have a lower feed efficiency than conventional, fast-growth broiler breeds.[43] However, some dual-purpose breeds for which data exist (e.g., Lohmann Dual, Novogen Duals) show comparable or better feed efficiency than slower-growing broiler breeds.[44]

115. Some studies have suggested that, with similar feed intakes, dual-purpose breeds show comparable growth rates to slower-growth broiler breeds[45], reaching marketable slaughter weight of ≥ 2kg at 8–9 weeks of life[46], in line with slaughter age standards for higher welfare, slower growing breeds. The breast meat yields of dual-purpose breeds are lower than those of fast-growing broiler breeds but the leg meat yields of dual-purpose breeds are higher.[33] The taste of the meat of dual-purpose breeds is reportedly different from that of fast-growing breeds[47] but the physiochemical meat quality is comparable.[48]

116. Dual-purpose breeds display improved welfare outcome indicators and more normal behaviours compared to fast-growing broilers, such as fewer or no foot pad lesions and hock burns, improved feather cleanliness, better mobility and increased perching behaviour.[49] Dual-purpose breeds are more suited to free range systems than fast-growing breeds. The use of dual-purpose breeds could therefore improve welfare in meat chicken production.

117. Hens from dual-purpose lines produce more meat per bird at the end of the laying cycle than commercial layer lines[50]. They may consume lower-value and more sustainable foodstuffs. See also 9.

118. Hens from dual-purpose breeds lay significantly fewer eggs than conventional breeds within a given laying period. Studies have reported 10–27% fewer eggs

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[43] I Tiemann, S Hillemacher and M Wittmann. 'Are dual-purpose chickens twice as good? Measuring performance and animal welfare throughout the fattening period. *Animals* 10 (2020), 1980.
[44] S Mueller, S., M Kreuzer, M Siegrist, K Mannale, RE Messikommer and IDM Gangnat. Carcass and meat quality of dual-purpose chickens (Lohmann Dual, Belgian Malines, Schweizerhuhn) in comparison to broiler and layer chicken types. *Poultry Science* 97 (2018), 3325–36; S Mueller, L Taddei, D Albiker, M Kreuzer, M Siegrist, RE Messikommer and IDM Gangnat. Growth, carcass, and meat quality of 2 dual-purpose chickens and a layer hybrid grown for 67 or 84 D compared with slow-growing broilers. *Journal of Applied Poultry Research* 29 (2020), 185–96.
[45] Mueller et al. Carcass and meat quality.
[46] L Siekmann, S Janisch, R Wigger, J Urban, J Zentek and C Krischek. Lohmann Dual: a dual-purpose chicken as an alternative to commercial broiler chicken? Aspects of meat quality, lipid oxidation, shear force and muscle structure. *European Poultry Science* 82 (2018), 1399; Tiemann et al. Are dual-purpose chickens twice as good?; L Baldinger and R Bussemas. Dual-purpose production and meat — Part 1.
[47] L Siekmann, L Meier-Dinkel, S Janisch, B Altmann, C Kaltwasser, C Sürie and C Krischek. Carcass quality, meat quality and sensory properties of the dual-purpose chicken Lohmann Dual. *Foods* 7 (2018), 156.
[48] Mueller et al. Carcass and meat quality.
[49] J Malchow and L Schrader. Effects of an elevated platform on welfare aspects in male conventional broilers and dual-purpose chickens. *Frontiers in Veterinary Science* 8 (2021), 660602; Mueller et al. Growth, carcass, and meat quality.
[50] Tiemann, Are dual-purpose chickens twice as good?; Ibrahim, Dual-purpose production.

depending on breed.[51] However, egg quality (e.g., shell quality, albumen dry matter, yolk weight and yolk colour) has been found to be similar in dual-purpose and layer breeds.[52]

119. The use of dual-purpose breeds could improve animal welfare in egg production as reduced calcium demands, due to lower production rates, could avoid structural bone being utilized in egg shell production and consequent osteoporosis and bone fragility.[53] No difference in keel bone fracture rates between dual-purpose and layer lines (Lohmann Duals and Lohmann Traditions) has been observed.[54] There is evidence for improved immune system functioning in dual-purpose breeds, such as greater tolerance of parasitic infection, compared to conventional broilers and layers.[55,56]

120. Improved plumage condition has been observed in dual-purpose birds compared with layer line birds (Lohmann Dual versus Lohmann Tradition).[57] This may indicate a lower prevalence of feather pecking in dual-purpose lines, which is another major welfare concern in laying hens.

121. For eggs, the use of dual-purpose breeds has been estimated to result in a price increase roughly equal to that associated with the use of in-ovo sexing technology, e.g., c.2.2 eurocents per egg, although the increase is likely to vary by production system and region.[58] For meat, if they are proven to be sufficiently productive, dual-purpose breeds could be an economically viable alternative to chick culling, even though the profit margin may be significantly lower (e.g., 1.5 euros per bird less) than for conventional broiler breeds.[59]

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[51] L Baldinger and R Bussemas. Dual-purpose production of eggs and meat—part 2: hens of crosses between layer and meat breeds show moderate laying performance but choose feed with less protein than a layer hybrid, indicating the potential to reduce protein in diets', *Organic Agriculture* 11 (2021), 73–87; D Ibrahim, G Goshu, W Esatu and A Cahaner (2019). Dual-purpose production of genetically different chicken crossbreeds in Ethiopia. 2. Egg and meat production of the final-crossbreed females and males. *Poultry Science* 98 (2019), 3405–17.
[52] M Hammershøj, G Kristiansen and S Steenfeldt. Dual-purpose poultry in organic egg production and effects on egg quality parameters. *Foods* 10 (2021), 897.
[53] M Fernyhough, CJ Nicol, T van de Braak, MJ Toscano and M Tønnessen. The ethics of laying hen genetics. *Journal of Agricultural and Environmental Ethics* 33 (2020), 15–36.
[54] J Malchow, BK Eusemann, S Petow, ET Krause and L Schrader. Productive performance, perching behavior, keel bone and other health aspects in dual-purpose compared to conventional laying hens. *Poultry Science* 101 (2022), 102095.
[55] Stehr, M., Grashorn, M., Dannenberger, D., Tuchscherer, A., Gauly, M., Metges, C.C. and Daş, G., 2019. Resistance and tolerance to mixed nematode infections in relation to performance level in laying hens. Veterinary
[56] Stehr, M., Zentek, J., Vahjen, W., Zitnan, R., Tuchscherer, A., Gauly, M., Metges, C.C. and Daş, G., 2019. Resistance and tolerance to mixed nematode infections in chicken genotypes with extremely different growth
rates. International journal for parasitology, 49(7), pp.579-591.
[57] Malchow, Productive performance.
[58] J Diekmann, D Hermann, and O Musshoff. How high is the price of giving up killing chicks? Assessment of the dual-purpose chicken and brother rooster concept as an economic alternative to fattening and laying hybrids. *Berichte über Landwirtschaft* 95 (2017).
[59] L Baldinger and R Bussemas. Dual-purpose production and meat — Part 1.

Implications for feeding other bird and animal species

122. Most of the 40–45m newly hatched chicks that are killed in GB each year (see 28) are used to feed raptors and exotic animal species in a range of settings. In order to minimize infection risk, culled chicks must be quickly cooled, and frozen within 3–4 hours, either on site or on a transport vehicle. Newly hatched chicks are cheap and readily available and are also easy to store frozen and thaw for use. For hatcheries this is a very small (<1%) part of their business. It removes the need to pay for these chicks to be rendered and, taking into account the costs of argon and staff time, is likely to be roughly cost neutral.

123. Exotic pet food wholesalers have played a key role in developing the argon gas system that enables these chicks to be stunned and killed humanely while remaining whole (see 62). They may provide this system, and the associated equipment such as trays, chillers and sometimes freezers, to hatcheries.

124. Due to being whole food, including feathers, muscles, bones, organs, fluids and flesh, newly hatched chicks bring some nutritional advantages as a food source and promote normal behavioural repertoire at feeding. In raptors, and some other bird species, the consumption of whole chicks enables pellet formation, which is important for digestive health, and any alternative would need to provide sufficient roughage to permit this. However, the calcium–phosphorus ratio provided by chicks does not always meet the nutritional requirements of raptors and other species to which chicks may be fed, and dietary supplementation may be required.

125. Approximately 70% of the chicks killed in laying hen hatcheries in GB currently go to two large wholesalers that freeze and sell them for use as animal food. Of this supply, approximately 60% goes to feed raptors in a variety of settings, 30% to zoos that use them to feed a range of species, and 5% to reptiles kept as pets. The remaining 30% of newly hatched chicks are sold directly by hatcheries to regional customers (see 133–134).

126. Dead chicks are much cheaper than potential alternatives. The unit weight and cost of three different frozen food sources available from a major British supplier is: chicks, 40g, £2/kg; small rats, 80g, £36/kg; mice, 20g, £44/kg.

127. Neither broiler breeder chicks nor turkey poults are currently used commercially as whole food for other species in GB, although turkey poults may occasionally be obtained from hatcheries for this purpose on a sale and collection basis. This is due to the small and variable volume of potential supply relative to that from laying hen hatcheries and the consequent difficulty of establishing economic and biosecure supply systems from these broiler breeder or turkey hatcheries. The lack of regular supply in seasonal turkey production settings presents further practical obstacles.

128. Suppliers have stated that avian influenza and other factors have led them to diversify their whole food product range.

129. It is reported that, due to the level of demand for whole feed, approximately 30% of the newly hatched chicks used for this purpose in GB are imported. Significant numbers of dead chicks have been exported to Middle Eastern countries by companies based in European countries. However, AWC has been told that, across Europe, due to the culling bans that are coming into force in some countries, internal supply and demand are now approximately equal. Outside of Europe, the supply of dead, newly hatched chicks is plentiful.

130. There are currently no specific import or export codes to allow GB trade in dead chicks to be monitored. Defra's veterinary export health certificates (EHCs) are generated only when required by the importing authority, or, in rare instances, by UK legislation. The EHC that could potentially cover dead chicks for animal consumption would also include other raw animal by-products, such as frozen meat and offal not for human consumption. HMRC collects and publishes trade data relating to exports, but the tariff commodity code designated for this purpose covers a range of products, of which dead chicks intended for animal consumption are just one.

Raptors and other birds of prey in conservation and rehabilitation settings

131. Newly hatched chicks have been a valuable food source for birds of prey that have been reintroduced or conserved in the wild. These have included red kites, white-tailed sea eagles and hen harriers. In the future, similar programmes might include kestrels, falcons and white storks.

132. Newly hatched chicks are also fed to birds of prey in rehabilitation centres. They are easy to skin, which is often a requirement for sick birds.

Mammals, birds of prey and reptiles kept in zoos

133. Approximately 30% of the chicks killed in GB hatcheries are sold directly by hatcheries to zoos and wildlife centres, including animal rescue centres. Total annual consumption is estimated at approximately 3.5 million chicks, ranging widely between zoos from 50 to 300,000 chicks.

134. The large majority of British zoos (c.90% in 2021, according to a survey by the British and Irish Association of Zoos and Aquariums) use dead chicks as an inexpensive and easily available food source for a wide range of carnivorous and omnivorous animal and bird species. These include meerkats, raccoons, exotic cats, falcons, buzzards, owls, storks, large lizards and snakes. For species such as storks, chicks are likely to form a substantial part of their diet in zoos.

135. There has been a shift towards more varied diets and whole animal food sources, including several rodent species and quail, due the differing nutritional profiles they offer. Some British zoos breed their own rodents for use as whole food.

Raptors and reptiles kept in private settings

136. In GB, there is a long tradition of keeping birds of prey for hunting, sports and leisure purposes. Native species that are kept, including falcons, eagles, buzzards, harriers, goshawks, ospreys and merlins, normally have to be registered. However, common non-native species such as the Harris hawk do not have to be registered if they are just being kept and not allowed to hunt.

137. GB has a strong reputation for breeding raptors for the world market. Many of these birds are likely to be fed newly hatched chicks. AWC believes that once raptors have been transported to their export destination, their welfare is not always high, and any long distance transport of these birds is in itself a welfare issue.

138. Newly hatched chicks are also fed to reptile species kept as pets. However, they are unsuited to the dietary needs of the reptile species that are kept in GB in greatest numbers.

Evaluation

139. If the routine killing of newly hatched chicks and turkey poults in GB were to be banned, dead chicks could be imported from countries where the practice is legal, unless such importation was made illegal. However, if more countries move to prohibit or restrict chick killing, import availability is likely to decline.

140. Imported frozen feeder rodents pose risks to human health due to the potential presence of *Salmonella* or other infectious agents, and imports from one country have been banned on this basis. However, imported chicks might also be infected with *Salmonella*, and close monitoring of the supply chain is needed.

141. The replacement of dead chicks or turkey poults with other food sources is possible in almost all species and the provision of a variety of food sources is increasingly advocated to promote raptor health. These alternative sources include rats and mice (‘pinkies’), which are currently imported from outside of the EU as well as bred within GB in ‘backyard’ settings, pieces of larger animals, including chicken, or minced meats, and quail. For mammals, the alternatives include beef or chicken, including in minced form. The use of these replacements raises ethical issues (see 151).

142. The keeping of non-domesticated bird of prey and reptile species in private settings raises welfare and ethical issues. Reducing the numbers of these animals kept would reduce the demand for dead chicks and turkey poults used as feed.

Ethical analysis

143. If carried out correctly, using humane methods, the routine killing of chicks is principally an ethical issue rather than a welfare problem because it does not lead to direct welfare harms. The routine killing of male chicks and turkey poults forms part of a ‘legacy system’ that would not be considered ethically acceptable if it did not already exist.

144. The male chicks hatched in layer hatcheries cannot be said to have a life worth living. Although they typically have an appropriate ambient temperature and are protected from disease, they are often not provided with a source of hydration and opportunities to enjoy positive welfare are entirely absent. These chicks do not experience maternal care, they live in an entirely artificial environmental and they have no opportunities to exercise choice or to explore their surroundings. It would be ethically desirable to reduce the number of chicks experiencing this low quality of life to the minimum number possible given the current state of technology. The female chicks have similarly low welfare while within the hatchery and, moreover, are likely to be waiting in trays contained within wheeled modules for onward transportation for several hours or even overnight. However, for females, this poor welfare may potentially be offset by opportunities for positive welfare during their future lives.

145. In consumer research undertaken in European countries, many respondents have considered the killing of newly hatched chicks to be unpalatable. This feeling reflects valid ethical concerns, such as that there is a right to life and that life opportunities should be able to be realized. It has been reported to AWC that some hatchery staff dislike killing newly hatched chicks because it goes against the goal of producing healthy chicks.

146. The breeding of chicks that are destined to be killed when newly hatched, and probably sold as feed for other animals at a low price, signals a devaluation of the lives of all chickens that is detrimental to them and to humans. This devaluation is arguably also signalled by the low age at which commercially reared broilers are slaughtered and the low price at which they are sold to retail consumers.

147. From when they become sentient, it is in the interest of chick embryos to be protected from pain and noxious stimuli. However, if any harm caused to the embryo during a sexing process is always less than the harm that would be caused to the chick following hatching, it can be argued on utilitarian grounds that in-ovo sexing should happen regardless of the degree of embryo sentience that may be present at any given incubation stage.

148. A precautionary approach suggests that sexing should happen when the development of sentience is as little advanced as possible, However, for currently available technologies, the sexing accuracy rate is lower the less developed an embryo is and there is always the potential for embryonic development to be affected by an invasive method. In settings where the killing of incorrectly sexed newly hatched chicks is legal and is undertaken in preference to raising males for their meat, decreased accuracy rates are likely to lead to increased rates of killing.

149. A laying hen is likely to lay approximately 350 eggs across her lifespan. With average GB egg consumption at 200 eggs per adult per year, this means that, without sexing, one male and one female are currently killed approximately every 21 months to meet an average person’s egg needs. Because the number of eggs laid by hens over their lifespans is progressively increasing the number of male chicks and end-of-lay hens killed per person per year, to allow a given level of consumption, is gradually decreasing.

150. In Britain, consumers have, in the past, voiced a range of ethical concerns about the genetic modification of plant and animal species. These include that modified products are unnatural and that consuming them may pose a risk to human health.[60] However, genetic modification to halt the development of male embryos in layer lines is likely to function by activating a change only to these male embryos, rather than to the female embryos who will develop into hens and produce table eggs for human consumption.

151. Rearing young mammals (e.g., rats or mice) to be killed and fed to raptors and exotic animals, in place of newly hatched chicks, would be likely to have significant ethical implications for the species being reared. The supply of mammalian alternatives to chicks on a large scale would require forced weaning, the rapid removal of litters and unnatural remating rates. Moreover, because rodent birth weights are much lower than hatch weights for chicks (e.g., 1–2g for mice and 5–6g for rats versus 25g for chicks), a rearing period would be required to bring the rodent up to a similar body weight, which would be probably vary depending on the birth weight of the rodent species used. Unless closely regulated and inspected, the welfare of these animals would be likely to be low.

Conclusions

152. The lives of all chicks and turkey poults have intrinsic value, and the killing of chicks in extremely large numbers as a routine part of egg and poultry production is, from an ethical viewpoint, highly problematic.

153. In hatcheries, the welfare of chicks, turkey poults and ducklings should be safeguarded at hatching, sexing and processing. Whenever chicks or poults are killed, this should be done humanely.

154. At present, poultry embryos used in research have legal protection from two-thirds of the way through incubation, whereas those in hatcheries have no legal protection.

155. Current evidence based on neural networks and EEGs suggests that chick embryos have the capacity for sentience from day 13 of incubation. From this point onwards, subjecting them to noxious stimuli, avoidable pain or interventions likely to precipitate the onset of sentience should be avoided wherever possible. This suggests that in-ovo sexing technologies should preferably be used no later than day 12 of incubation. However, any negative welfare impact resulting from sexing is likely to be less severe that the negative welfare impacts associated with hatching and processing within current commercial systems (see 144). It would, therefore, be preferable to undertake sexing procedures on an embryo at any incubation stage rather than to allow male chicks to hatch and then be processed for killing.

156. The methods for sexing before hatching that are currently available have varying precisions and accuracies at different stages of incubation.

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[60] L Bredahl. Determinants of consumer attitudes and purchase intentions with regard to genetically modified food – results of a cross-national survey. *Journal of Consumer Policy* 24 (2001), 23–61.

157. The ability to sex eggs before, or close to the start of, incubation would improve the ethical justification and ethical sustainability of egg and poultry production in settings where newly hatched chicks and turkey poults are currently killed. It would also bring long-term economic benefits to hatcheries, because eggs containing male embryos would not be incubated at all, or not for as long as at present, and (with the exception of any error rate associated with the sexing procedure) male chicks and poults would not be hatched, processed, and killed.

158. AWC recognizes that dead newly hatched chicks have become widely used as a food source for raptors, and other birds and animals, in a variety of settings. If the routine culling of chicks and turkey poults were to be banned in GB, this would be likely to have the effect of increasing the import of dead newly hatched chicks from countries with lower welfare standards, unless such importation were prohibited. A ban could also have the effect of greatly increasing the unregulated breeding in GB of alternative whole food sources such as small rodents and quail. This would be likely to bring significant welfare and biosecurity risks. Further consideration of this issue is beyond the scope of this Opinion.

Recommendations

159. Government should make the routine culling of newly hatched chicks and turkey poults, due to their sex, illegal as soon as reliable, accurate methods for sexing eggs prior to hatch are available to be implemented in GB hatcheries.

160. When this happens, the import of eggs and of female chicks and poults from production systems in which there is routine culling should be made illegal.

161. For eggs, meat chickens and turkeys, any future Government welfare labelling scheme should, when defining its standards, take account of whether, in the production system used, chicks or poults are routinely culled due to their sex.

162. Until then, Governments should offer financial support for the introduction and use of egg sexing technologies, before or after the start of incubation, that have no significant negative welfare impacts. Technologies currently available for use are allantoic fluid analysis, hyperspectral imaging and magnetic resonance imaging. These techniques should preferably be used no later than day 12 of incubation.

163. The culling of hatched birds that have been wrongly sexed, and of those with evident abnormalities, should continue to be permitted.

164. Industry may wish to continue to develop ‘day zero’ methods for sexing eggs before the start of incubation. Currently these are not commercially available but may be economically preferable to methods that require egg incubation. If ‘day zero’ methods were to make use of genetic modification, this would need to be legal and the methods applied would need to meet all relevant legal requirements.

165. At any stage of incubation when a poultry embryo has legal protection, the level of this protection should be the same regardless of the setting in which the embryo is kept or used (e.g., farming or research).

166. In hatcheries, chicks, turkey poults and ducklings should be provided with a source of hydration.

167. Governments should support the development and use of dual-purpose breeds, such as via regenerative and agroecological farming programmes, especially in line with the Climate Change Commitee's recommendation on a reduction in meat consumption to achieve the government's net zero emissions target.

168. Retailers should label the eggs and meat from dual-purpose flocks, in order to enable consumer choice.

169. The only legally permitted gas method of stunning and killing newly hatched poultry in large numbers should be the use of inert gas (in accordance with the parameters of the retained Council Regulation (EC) 1099/2009, Annex 1), and the use of carbon dioxide should be prohibited.

170. Machinery suited to macerating unhatched incubated eggs, which may contain a developed embryo, should be available for use at scale and operators should be appropriately trained in its use.

171. So that import and export data for frozen newly hatched chicks are collected and may be analysed, the APHA should designate a specific code number to identify these.

172. For dead newly hatched chicks imported into GB, the killing method used should be at least as humane as the methods permitted in GB. The import of all other dead newly hatched chicks should be illegal.

173. When the routine killing of newly hatched chicks becomes illegal, there may be a consequent increase in the price of foodstuffs available for birds of prey and other animals. Governments should consider making financial support available for any rehabilitation and conservation projects that are affected by this and ensure that any mis-sexed chicks are allocated primarily to this purpose.

174. When the routine killing of newly hatched chicks becomes illegal, there is likely to be a consequent increase in demand for rodents as a source of food for birds of prey and other animals. Governments should take steps to closely regulate the breeding of rodents as alternative food sources in order to protect their welfare and biosecurity. A detailed consideration of the breeding of rodents as an alternative food source, including consideration of the lifetime welfare standards under which breeding females and their offspring are kept, biosecurity, and health status does not fall within the scope of this report and should be commissioned.

175. For dead rodents imported into GB, the killing method used should be at least as humane as the methods permitted in GB. The import of all other dead rodents should be illegal.

176. Research should be undertaken into the practical economic and environmental sustainability of dual-purpose chicken breeds and systems, including

with reference to the Climate Change Committee's and the Intergovernmental Panel on Climate Change's principles and recommendations on diet and agricultural practices. AWC realise that such a production system would likely target a niche 'premium' market within the UK.

177. Research should be undertaken into the development of whole food sources that could, in future, replace or complement newly hatched chicks as a food source for birds of prey and other animals, which provide appropriate nutrition, texture and consistency.

178. Governments should update the Codes of Recommendations for Livestock: Turkeys (1987) and Ducks (1987), making their provisions consistent with the retained Regulation 1099/2009 on the protection and animals at the time of killing and the Welfare of Animals at the Time of Killing Regulations (Scotland 2012, Wales, 2014, England 2015).

Glossary

albumen: an egg white

allantoic fluid: the fluid in the sac within an egg that aids embryonic gas and liquid waste exchange

auto-sexed: a breed in which sex is indicated by standardized physical features

broiler: a chicken raised primarily for meat production

candling: introducing a bright light source behind an egg so that the embryo may be viewed through the egg shell

chick: a recently hatched bird of the species *Gallus gallus domesticus*

clear: an egg that is non-fertile at 18 days from laying

cloaca: the anal vent of a chick

culling: the killing of chicks or turkey poults

duckling: a recently hatched duck

endocrine system: the network of glands and organs in which hormones are located

eutrophication: the gradual increase of mineral and nutrient levels in water

gamete: an unfertilized reproductive cell

genetic modification: changing a genome by human intervention in a way that could not be the result of a traditional breeding process

hen: a female bird of the species *Gallus gallus domesticus*

heterogametic: having two different types of sex chromosomes

homogametic: having a single type of sex chromosome

incubation: the process by which a warmed egg develops from fertilization to hatching

in-ovo: inside an egg

integrator: a poultry enterprise that is involved at all production stages including breeding, laying and killing

killing: any intentional process that causes death layer: a chicken bred primarily to produce eggs for human consumption

maceration: instantaneous mechanical destruction

nociception: the activation of a nervous system by noxious stimuli

pain: the subjective experience of nociception

phenotype: the set of observable characteristics or traits of an organism

poult: a recently hatched turkey

raptor: bird of prey

reagent: a substance or compound that can facilitate a chemical reaction

sexing: identifying whether an embryo or chick is male or female

zygote: a fertilized egg

Z-chromosome: a sex chromosome in birds and some reptiles

Appendix 1: AWC membership

Prof Madeleine Campbell—Chair
Dr Gareth Arnott
*^ Dr Andy Butterworth
Dr Emily Craven
Dr Jane Downes
* Dr Troy Gibson
Prof Simon Girling
*^ Dr David Grumett
*^ Richard Jennison
*^ Peter Jinman (Chair to December 2022)
*^ Richard Kempsey
Dr Julian Kupfer
* Stephen Lister
* Dr Dorothy McKeegan
Dr Romain Pizzi
Dr Pen Rashbass
Prof Sarah Wolfensohn
Dr Julia Wrathall
Dr James Yeates

* = member of the Working Group for this Opinion
^ = AWC member until December 2022 and co-opted to the Working Group for the remainder of the project

Co-opted Working Group members
Prof Siobhan Mullan, University College Dublin
Dr Elizabeth Rowe, University of Reading

AWC is grateful to the AWC Secretariat and APHA and Defra staff who gave assistance.

Note: One member of AWC did not feel able to support all of the Recommendations in this Opinion

Appendix 2: Those who gave evidence and assistance

Agri Advanced Technologies GmbH

Avara Foods Ltd.

Aviagen®

British and Irish Association of Zoos and Aquariums

British Egg Industry Council

British Poultry Council

Cherry Valley Farms (UK) Limited

Compassion in World Farming

Crowshall Vet Services

Hendrix Genetics

Het Anker B.V.

Honeybrook Animal Foods

Hy-Line UK

In-Ovo B.V.

Kiezebrink UK Ltd

Orbem GmbH

PD Hook (Grp) Ltd

PLANTegg GmbH

SELEGGT GmbH

SOOS Technology Ltd