ALTERNATIVES TO MALE CHICK CULLING
Summary

THE PROBLEM

Globally, an estimated **6.5 billion newly hatched male chicks are culled each year** by maceration or asphyxiation (gassing), and possibly even less humane methods where no regulation exists, as they are considered surplus to the egg industry since they cannot lay eggs. This is a major ethical issue for the egg industry and reflects wider concerns over the highly specialised selection of poultry for high meat or egg production and the welfare issues associated with this. Increasing consumer concern has led to existing and upcoming legislative bans on chick culling in Germany, France, and Italy, with an EU wide ban possibly on the table. Alternatives to this practice are needed urgently.

RECOMMENDATIONS

Compassion is committed to ending the practice of culling day-old male chicks and is asking for:

- **Best practice**: use of **dual-purpose breeds** with good welfare outcomes where the male chicks can be reared for meat.
- Where using dual-purpose breeds is not practicable, **in-ovo sexing** and the destruction of eggs containing male embryos before they become sentient is an acceptable alternative.
  - ✓ ***Sexing must be performed before the embryo is capable of feeling pain*** according to the latest available science. Currently, research indicates that pain perception is not physically possible before embryonic day (ED) 7. We therefore advise those seeking to make the switch to adopt methods performed **before ED7** when they become commercially available. Until then, the earliest available methods should be used (currently available at ED9).*
  - ✓ The least invasive methods are preferred, and it is important that the sexing procedure does not cause damage to embryos which survive beyond the point of sentiency, and in particular does not cause death or welfare problems to chicks that go on to hatch.
  - ✓ The sexing method used should be highly accurate (at least equal to the 98.5% accuracy rate of post-hatch sexing methods).
  - ✓ Any males hatched as a result of sexing errors should be reared in higher welfare systems (i.e. at least to the European Chicken Commitment requirements).
  - ✓ The sexing method should be scalable and capable of being adopted by the industry.
- **Rearing the male layer chicks ("brother hens") for meat** in higher welfare systems that provide enough space and enrichment is also a possible solution, but a better understanding of the welfare implications of rearing those birds is needed before this is considered an acceptable alternative to the culling of male chicks.

** We continue to support those early pioneers who have already adopted in-ovo sexing methods up to ED14.*

ALTERNATIVES TO MALE CHICK CULLING
Scientific Review

THE PROBLEM

Due to the differentiation of selection for egg and chicken meat production over the last 100 years, raising male chicks from the laying hen industry for meat is not considered economically viable. The males from layer breeds cannot produce eggs and cannot compete in terms of growth with broiler strains and are thus considered surplus to the industry. As a result, globally, **an estimated 6.5 billion[1] (330 million in the EU alone[2]; 38.2 million in the UK[3]) newly hatched male chicks are culled in hatcheries each year**. Maceration or asphyxiation (gassing) are the culling methods permitted within the EU, while less humane methods may be practiced elsewhere where there is no regulation.

The mass killing of day-old male chicks is a major ethical issue in the egg industry[4]. The killing method also raises welfare concerns for those animals. EFSA in their 2019 report on killing of poultry[5] list a series of potential welfare consequences associated with the different killing methods of male chicks, from cold stress, pain, fear, respiratory distress, and ineffective stunning. For maceration, staff error and/or incorrect equipment settings can lead to severe negative welfare consequences. In the case of gassing with high concentrations of CO_2, the method is aversive in itself[5].

Furthermore, the selection for highly specialised egg or meat production in the poultry industry, which has resulted in the male layer chicks seen as surplus, is one of the leading causes of welfare issues within the industry (both for the laying hens and for the broiler chickens). Selection for fast growth and increased breast meat yield in broiler chickens has led to a high incidence of severe welfare problems. Fast growing broilers show high incidences of leg disorders, cardiovascular diseases, as well as high mortality, while also showing few indicators of positive welfare relative to slower growing breeds[6,7]. In laying hens, the selection for high egg production is associated with poor bone health and a high incidence of keel bone fractures[8,9], which is painful for the birds[10] and results in reduced mobility and negative emotional states[11]. Bone lesions, specifically keel bone fractures, have been identified as a highly relevant welfare consequence for laying hens by the European Food and Safety Authority (EFSA)[12].

When consumers are aware of the practice of male chick culling, it is met with widespread disapproval[13–16]. Importantly, studies from Switzerland and the Netherlands have shown that consumers are willing to pay more for poultry products that avoid culling of male chicks[14,15].

Increasing consumer concern has led to some recent changes in legislation in Europe and increased research efforts into viable alternatives. Within the EU, the practice of culling male chicks has already been banned by both Germany and France since January 2022, while Italy has committed to drafting legislation to end the practice by 2026 (see Table 1 for details). A wider EU ban may also be on the table. Recently, 11 member states supported a call for an EU-wide ban on the practice of male chick culling. The Commissioner for Food Safety, Stella Kyriakides responded positively to the call and has agreed to perform an impact assessment before making a legislative proposal (which may even be included in the upcoming revision of the animal welfare legislation at the end of 2023)[2].

A number of alternatives to the culling of day-old male chicks exist, including breeding dual-purpose breeds where the males can be reared for meat and females for egg production, or rearing the male layer chicks (the "brothers" of the laying hens) themselves for meat production; in-ovo sex determination so that male eggs can be identified and destroyed before hatching; and skewing the sex ratio in favour of females [4,17]. The merits of each alternative are discussed below.

Table 1. Legislation on male chick culling in various EU countries

Germany	
Male chick culling banned since 1st January 2022 · From 1st January 2024: in-ovo sexing must be performed before day 13* · Male chicks hatched due to sexing errors must be reared for at least 10-14 weeks · Applies to chicks of laying hen breeds only. https://www.bundesrat.de/SharedDocs/drucksachen/2023/0201-0300/273-23.html	Derogations: None
France	
Male chick culling banned since 1st January 2023 · In-ovo sexing must be performed before day 16. · Applies to chicks of laying hen breeds only. https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000045124750 https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000046704513	Derogations: · Chicks destined for breeding. · Chicks used for research. · Chicks used for animal feed. · Chicks from white feathered breeds. · Male chicks hatched due to sexing errors
Italy	
Proposal for ban on male chick culling by the 31st of December 2026 expected in August 2023. https://www.camera.it/leg18/410?idSeduta=0736&tipo=documenti_seduta - Art. 18	Derogations: No details available
Austria	
The "senseless" killing of male chicks is banned from 1st January 2022. https://ktn.lko.at/m%C3%A4nnliche-legek%C3%BCken-sinnvoll-verwenden+2400+3554268	Derogations: · Chicks used for animal feed.

THE SOLUTIONS

REARING THE MALE CHICKS FOR MEAT

The culling of day-old male chicks can be entirely avoided by rearing them for meat. There are two different strategies to rear the male chicks for meat production: one alternative is to use dual-purpose breeds where males can be reared for meat and females for egg production, while the second consists of simply keeping the "brothers" of the laying hens without changing the genetics used.

DUAL-PURPOSE BREEDS

In a dual-purpose breed, the females are kept for egg production while the males are reared for meat. Due to the more balanced breeding, those strains have more moderate levels of production of both eggs and meat, which can address many of the welfare issues associated with chicken meat and egg production. Dual-purpose breeds can come from native breeds - breeds that haven't been selected for either high egg or meat production – or breeds that have been developed from crossing commercially selected layer and broiler lines, such as the Lohmann Dual[18].

There is not an extensive body of scientific literature looking at the welfare outcomes or economics of dual-purpose breeds. What little research there is, has mostly focussed on the Lohmann Dual, with only a few studies looking at other commercial or native breeds. This makes it difficult to make generalisations about the suitability of these other breeds for commercial production.

In terms of welfare, evidence from laying hens indicates that selection for high egg production results in a higher risk of keel bone fractures[19,20]. Hens of dual-purpose breeds have reportedly low incidences of keel bone deformations (~10%) when kept in mobile housing[18]. For some native breeds, the prevalence of keel bone fractures in hens is reportedly very low, and did not occur in males, at least in caged systems[21]. Injurious feather pecking is a major welfare issue in laying hens which results in wounds and pain for the affected animals and has been identified as a hazard for group stress in laying hens[12]. Lohmann Dual hens show far less injurious pecking behaviour compared to conventional layers[22,23], and less fear of novelty and humans, indicating they may be less stressed by management procedures[24].

The cockerels of selected dual-purpose lines have been shown to have better walking ability, foot pad health, and plumage condition than fast growing broiler strains[25] and comparable welfare outcomes to slower growing broilers[26]. While Lohmann Dual males were found to have higher fear responses than conventional male layers in the pre-lay period[27], the opposite was found at older ages[24].

A benefit of dual-purpose chickens is that they often have lower protein requirements, meaning that feed can be cheaper to formulate, and soybean meal, for example, can be replaced with alternative locally grown crops, bringing both financial and environmental benefits, as well as marketing opportunities[28,29]. A recent German trial found regionally grown fava beans to be a suitable alternative to soybean meal in the diet of three dual-purpose cross breeds[30].

One concern about the switch to dual-purpose breeds is that to produce the quantity of eggs or meat currently consumed, a higher number of animals will need to be used. However, there is a growing interest among consumers in plant-based alternative proteins, and a general trend in reducing consumption of animal sourced foods. A move towards dual-purpose breeds, coupled with a reduction of our reliance on animal sourced food, would allow to significantly improve hen and chicken welfare while supporting the much-needed transition towards a more sustainable food system.

The costs of rearing dual-purpose breeds are higher as they are considered less efficient than specialised breeds. Feed costs for the Lohmann Dual, for example, are predicted to be 50% more than for commercial layers[17]. Dual-purpose breeds have more moderate levels of production of eggs compared to conventional layers, and of meat compared to fast-growing broiler strains. Lohmann

Dual hens are said to produce 282 eggs by 72 weeks of age with a lighter weight than commercial layers (Lohmann Brown – 321 eggs by 72 weeks[i]). This has been estimated to result in 6€ lower profit per bird compared to the Lohmann Brown layer breed[31]. Commercial dual-purpose breeds perform better than native breeds in terms of growth[32,33], but not as well as fast growing broiler strains[33]. However, their growth, when fed a broiler diet, can be comparable to some slower growing broiler lines (Fig. 1), and coupled with their better egg production, makes them a commercially viable alternative[33]. German research in 2017 found that barn-reared dual-purpose birds were associated with an increase in production cost of €0.02 per egg[34]. The Bruderhahn (Brother Hen) Initiative in Germany propose that selling eggs with an additional cost of €0.04 per egg covers the additional costs of rearing and marketing the brother layers under organic production[35].

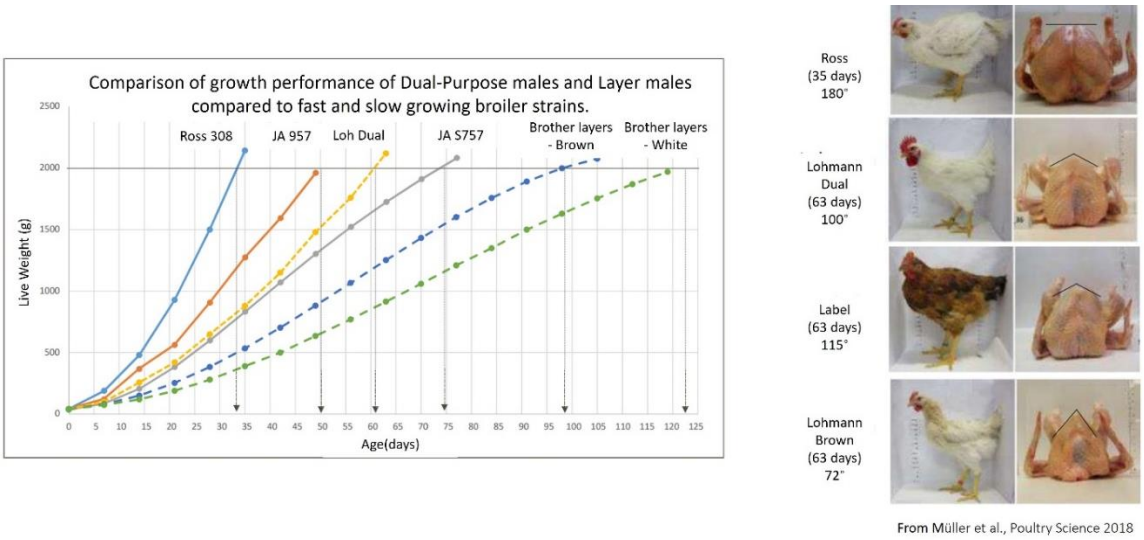

Figure 1. Growth performance and carcass appearance of dual-purpose and male layers compared with fast and slower growing broiler breeds. Slide presented at a French Webinar on Alternatives to Male Chick Culling, November 2022[36] and adapted from Müller et al. (2018)[33].

In terms of consumer perception, surveys in the Netherlands and Germany showed that 23-29% and 27% of respondents respectively indicated breeding dual-purpose breeds as their preferred alternative to male chick culling[15,37]. However, another study in Germany highlighted the importance of marketing of products from dual-purpose breeds as consumers generally have low knowledge of this alternative, but when given more information, most consider this a positive alternative[16]. Similarly, Swiss consumers' willingness to pay for products from dual-purpose breeds was related to consumers knowledge about poultry production[14].

As dual-purpose breeds have the potential to simultaneously address the major welfare problems in the laying and broiler industries as well as making male chick culling redundant, they are the preferred, and best-practice solution and likely to be the most future proof.

[i] www.lohmann-breeders.com

BROTHER LAYERS

Even though rearing male chicks from layer breeds for meat production is typically considered not to be economically viable and continues to remain a niche production, there has been a growing trend to keep them in recent years due to the public and legislative pressure to stop culling male chicks in some countries. In Germany for instance, it was estimated that in 2018 about 270,000 male layers were raised in the organic sector[38], and since the ban on culling day-old male chicks came into force at the start of 2022, it is estimated that 74% of all male chicks hatched in the first five months following the ban went on to be reared for meat[39].

In terms of welfare, there is little published research on the welfare of males from laying hen strains. Mortality rates are reported to be 1-2% per batch, and pododermatitis is not reported to be a problem[38]. There are anecdotal reports of higher aggression as the chickens get older, necessitating more enrichment, and, as the birds are kept for longer, there is the possibility that the birds will need re-vaccinations requiring some additional handling[38]. As the birds reach puberty at 13 weeks, there is an increased risk of aggression and injuries. In Germany, where rearing brother layers has become a more common practice since the introduction of the ban on chick culling, problems such as the lack of suitable rearing and slaughter facilities for these birds have resulted in additional welfare concerns (e.g. long transport to rearing facilities and again for slaughter)[40].

A study looking at the potential of male layers for poussin (traditionally young chickens slaughtered at weights under 750g) production found that male layers of various strains took longer to reach the intended slaughter weight of 650g than conventional fast growing broilers (broilers: 19 days, layers: 47-49 days), had a higher feed conversion ratio (broilers: 1:1.2, layers: 1:2.5), and had lower average proportion of valuable cuts (breasts and leg, broilers: 65%, layers: 62%)[41]. To rear male layers to higher target weights (1.3-1.5kg) resulted in even higher feed conversion ratios (of between 4 and 10[38]), resulting in operating costs five times greater than conventional broiler production[42].

The advantage of this solution for the industry is that the egg production does not decrease. However, a market is required for the meat from the male layer breeds. In Germany, it has been reported that most of the organic sector aim to switch to dual-purpose breeds[38,39], while in-ovo sexing is the likely direction of the conventional sector[39].

Importantly in terms of welfare, raising the male layers for meat does not reduce the production pressures on the female laying hens nor on fast growing broiler breeds, which has led to a number of welfare issues (detailed above). Further, the market for the meat of male layers would have to increase in Europe to make this alternative worthwhile. Potential problems of increased aggression and the lack of suitable rearing and slaughter facilities for male layers would have to be addressed. Conversely, male layers do not suffer from the problems caused by excessive growth, so have the potential for higher welfare if managed well in systems suited to their specific behavioural needs. More research is needed on what these animals need to live a good life in commercial conditions.

IN-OVO SEX DETERMINATION

One means by which to avoid the culling of day-old male chicks is to identify the sex of the chicks in-ovo and destroy the male chicks before hatching.

While this method can address any welfare concerns around the actual killing of day-old male chicks, it does not address the wider concerns about the effect of selection for high production in the egg and broiler industries. Furthermore, it is only an improvement on current methods if the destruction of the eggs is carried out at a point before which the chick is sentient and capable of feeling pain, and if the identification method poses no welfare risk to the eggs which go on to hatch. The method also needs to be highly accurate to ensure that all male eggs are identified and destroyed at this point, so that culling after hatching is rendered unnecessary. Sexing after hatching has an accuracy rate of 98.5% so a similar or higher accuracy rate would be the aim for any in-ovo sexing technique.

Perception of pain in the chicken embryo is impossible before Embryonic Day (ED) 7 as the afferent neurons, which carry sensory information, are not connected to the dorsal horn until this point[43]. A review of early research on neural development in chick embryos by Mellor in 2007[44] suggested no detectable EEG activity before day 13 but there has been little recent research. Due to the lack of experimental evidence on pain perception in ovo, the German Federal Office for Agriculture and Food recently commissioned a study into this[45]. Based on the findings, the report concluded that pain perception is not possible up to and including ED12. However, these findings ought to be treated with caution as the experimental studies on which the report is based have not yet been peer reviewed. The generalisability of the findings still has to be investigated, as only one breed (Lohman Selected Leghorn chicken eggs) was tested, and relatively low egg numbers were tested per experimental group[46–48]. Therefore, until these studies have been published, and further corroboratory evidence is demonstrated in other breeds, applying the precautionary principal would suggest that sexing and destroying the eggs before ED7 would ensure that these embryos do not suffer in the process, However, currently, methods are only commercially available starting from ED 9 (Table 2).

From an economic perspective, the earlier the eggs can be sexed, the better. Incubation costs can be reduced by earlier sexing, and ideally sexing before incubation would mean that the eggs could be sold as table eggs for human consumption. In addition, for any method to be commercially viable, it needs to be fast, precise and accurate, applicable to different breeds (and ideally, species), with a cost acceptable for the hatcheries and the consumers[17].

Consumer surveys in different EU countries show that in-ovo sex determination can be well accepted by consumers: over half of Dutch respondents indicated it was their preferred alternative to male chick culling[15], while various factors such as the method itself and the day of determination influenced German respondents' acceptance of this alternative[13,49]. In neither study, however, were the wider concerns about welfare issues due to the high specialisation of the egg and chicken meat production industries presented so it is not possible to know if this knowledge would alter respondents' preferences.

A variety of methods for in-ovo sexing have been investigated, which are detailed below, and industry methods in development or already commercially available are summarised in Table 2.

OPTICAL METHODS

The sex of the developing embryo can be determined by using optical and imaging techniques. Spectroscopy is the study of the interaction between electromagnetic waves (light and other

radiation) and matter. Examining the way that these electromagnetic waves are changed by this interaction provides valuable information about the composition, structure, and physical properties of substances. In the case of in-ovo sexing methods, spectroscopy is used to study whether gender specific differences can be identified by differences in which the electromagnetic waves change as they interact with the developing embryo. In some methods this can be done without any damage to the egg, while in others, the shell must be pierced.

- Hyperspectral Imaging: Hyperspectral imaging is a technology that measures and analyses signals from across the electromagnetic spectrum[50]. It provides information on the colour of the light as well as spatial information, at what depth the light is absorbed, meaning that it can provide extremely detailed information about an object. For in-ovo sexing, the egg is illuminated by a light source and a hyperspectral camera measures the spectral signal produced. This method is non-invasive as it does not require the shell to be pierced. Hyperspectral imaging has been used to detect gender specific differences in feather colour in brown eggs at ED14 with an accuracy of 97-99%[51,52]. Industry efforts are underway to use hyperspectral imaging on other features which may differ based on sex at a much earlier stage, but at the time of writing there is no published scientific literature on this.
- Point Spectroscopy: Point spectroscopy works similarly to hyperspectral imaging. It is a non-invasive method which provides a less detailed but clearer signal than hyperspectral imaging, so can potentially be more accurate. It was demonstrated that the accuracy of visible-near-infrared (vis-NIR) point spectroscopy to detect differences in feather colour in brown eggs exceeded that of hyperspectral imaging on ED13 at a lower cost, and could have a higher throughput without compromising on accuracy[52].
- Raman and Fluorescence Spectroscopy: Raman spectroscopy is a spectroscopic technique where the scattering of light emitted from an object gives a measure of the vibrational energy of the components of that object. Each molecule produces a unique Raman spectrum. Cells from male and female chick embryos have been found to differ in their blood biochemical composition as males have a higher haemoglobin content and these differences can be picked up by Raman Spectroscopy at ED3.5[17,53,54]. By combining Raman and fluorescent spectroscopy (a technique where the absorption and emission of light of a specific wavelength can provide information about an object), the accuracy rate was increased from 90%[54] to 93%[55]. More recently, a fluorescence spectroscopic method achieved an accuracy rate of 96% between ED3.5-5[56].The method is semi-invasive as it requires the outer shell to be pierced but the inner membrane can be left intact[53].
- Magnetic Resonance imaging: Magnetic resonance imaging (MRI) can detect certain features within the egg non-invasively, but these features were not found to correlate with the sex of the embryo[57]. However, industry has been successful in in-ovo sexing using MRI technology (see Table 2) but detailed information on the method is not yet available.

NON-OPTICAL METHODS

Various non-optical approaches have been looked at to determine their suitability for sexing the chick embryos in-ovo, from differences in morphology, to differences in hormone concentrations, or differences in DNA detected in blood or tissue cells.

- Biomarker analysis: Biomarker analysis involves taking a sample of blood, tissue or fluid from inside the egg to look for factors which can be measured, and which can accurately predict the gender of the developing embryo. Analysis of a sample of allantoic fluid inside the egg can distinguish males from females based on the higher levels of estrone sulphate in females on day 9[58] with a high accuracy (above 98%). Other approaches are based on the detection of specific genes of the W/Z sexual chromosome, through sampling small amounts of blood[59]. Sampling from inside the egg is an invasive method and can affect the hatching rate of the eggs.
- Gene editing: Due to recent advances in gene editing technology, scientists are able to remove, add, or change section of DNA in a highly targeted way. This CRISPR-Cas9 method can be used to determine the gender of chick embryos by, for example, adding a fluorescent protein to the DNA sequence of male chromosomes, which can then be detected after hatching[60]. Another method is to introduce a change to the Z chromosome (the male chromosome in birds) which, when activated via a blue light shone through the eggshell during incubation, causes the death of the homozygous male embryo, but not the heterozygous female embryo[61]. This could constitute a commercially viable method provided further research demonstrates no detrimental impact on welfare.

  As a general principle, Compassion considers that gene editing of farm animals should not be permitted other than in the most exceptional circumstances where an impact assessment shows that:
  - There will be no detrimental impact on animal health and welfare.
  - No less intrusive method of achieving the desired objective is available.
  - The desired objective does not entail facilitating the use of industrial livestock systems as these have a wide range of inherent disadvantages for animal health and welfare.
- Morphological differences: There are conflicting results about the possibility of using morphological characteristics of the egg to predict gender (such as egg length, diameter, shape width and volume)[62,63].

Some of these approaches have been developed further by the industry (see Table 2).

OTHER APPROACHES

Attempts to influence the sex ratio of the developing eggs have also been proposed. While there is little available information in the scientific literature on this, one industry method claims that by exposing the developing embryos to sound vibration and controlling the humidity of the environment, they are able to alter the gender expression of genetically male embryos. Their claim is that genetically male embryos develop female sexual characteristics – ovaries instead of testes - and are said to lay eggs at the same rate as genetically female hens[64]. The mechanism by which this occurs is said to be due to alterations on the DMRT1 gene[65]. Independent evidence to support this claim is not available, and while mutations on the DMRT1 gene can result in genetically male animals developing ovaries instead of testes, these animals did not ovulate or lay eggs at sexual maturity[66].

CONCLUSIONS

Culling of day-old male chicks is an industry practice no longer acceptable to consumers on both ethical and welfare grounds. From an animal welfare point of view, the best alternative is to shift to dual-purpose breeds with good welfare outcomes where the male chicks can be reared for meat. Where using dual-purpose breeds is not practicable, in-ovo sexing and the destruction of eggs containing male embryos before they become sentient is an acceptable alternative, provided certain conditions are met, including that the male eggs are destroyed before the embryo is capable of feeling pain (pain perception is not physically possible before ED7), the method is accurate, non-invasive, and does not impact the welfare of the surviving embryos. While the rearing of brother layers is another possible alternative, more research is needed ensure the welfare of these birds.

RECOMMENDATIONS

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- **Best practice**: use of **dual-purpose breeds** with good welfare outcomes where the male chicks can be reared for meat.
- Where using dual-purpose breeds is not practicable, **in-ovo sexing** and the destruction of eggs containing male embryos before they become sentient is an acceptable alternative.
  - ✓ ***Sexing must be performed before the embryo is capable of feeling pain*** according to the latest available science. Currently, research indicates that pain perception is not physically possible before embryonic day (ED) 7. We therefore advise those seeking to make the switch to adopt methods performed **before ED7** when they become commercially available. Until then, the earliest available methods should be used (currently available at ED9).*
  - ✓ The least invasive methods are preferred, and it is important that the sexing procedure does not cause damage to embryos which survive beyond the point of sentiency, and in particular does not cause death or welfare problems to chicks that go on to hatch.
  - ✓ The sexing method used should be highly accurate (at least equal to the 98.5% accuracy rate of post-hatch sexing methods).
  - ✓ Any males hatched as a result of sexing errors should be reared in higher welfare systems (i.e. at least to the European Chicken Commitment requirements).
  - ✓ The sexing method should be scalable and capable of being adopted by the industry.
- **Rearing the male layer chicks ("brother hens") for meat** in higher welfare systems that provide enough space and enrichment is also a possible solution, but a better understanding of the welfare implications of rearing those birds is needed before this is considered an acceptable alternative to the culling of male chicks.

** We continue to support those early pioneers who have already adopted in-ovo sexing methods up to ED14.*

Table 2. Overview of in-ovo sexing technologies - commercially available and in development. Text in green meets CIWF recommendations

Technology	Method	Day of sexing	Invasive	Reported accuracy	Breed	Speed	Stage
OPTICAL							
Raman Spectroscopy, AAT	Gender determination based on absorption spectra. Differences in haemoglobin content in blood vessels.	**Day 5**	Partly – shell perforated with CO_2 gas laser but inner membrane left intact		**All**		In development
Hypereye	Hyperspectral imaging – gender differences on germinal disk	**Pre-incubation**	No (No independent verification)	**99%**	**All**	Predicted: 50,000 eggs/hour	In development
CHEGGY, AAT	Hyperspectral imaging	Day 13	**Non invasive – no loss of hatchability**	>96%	Brown lines only	**Current: 20,000 eggs/hour**	**Commercially available**
Genus Focus, Orbem	Accelerated magnetic resonance imaging (MRI) with AI technology	Day 12	**Non invasive – no loss of hatchability**	> 98%	**All**	**Current: Up to 24,000 eggs/hour**	**Commercially available**
NON-OPTICAL							
Ella, In Ovo	Bio-marker analysis	**Day 9**	Yes – sample taken from inside egg with a needle		**All**		**Commercially available**
Plantegg	Detection of W/Z chromosome specific genes by PCR	**Day 9**	Partly – requires sample of allantoic fluid	**99.5%**	**All**	Current: 3,000 eggs/hour	**Commercially available**
Seleggt	Bio-marker – estrone sulphate levels differ between male and female chicks	**Day 9**	Partly – requires sample of allantoic fluid	**98.5%**	**All**	Current: 3,600 eggs/hour	**Commercially available**
GENE-EDITING							
eggXYt	CRISPR - fluorescent biomarker placed on male chromosome.	**Pre-incubation**	**Non-invasive**	**100%**	**All**		In development
Huminn	Lethal Z chromosome activated by blue light	**Pre-incubation**	**Non-invasive**	**100%**	**All**		In development

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