

# Moral “Lock-In” in Responsible Innovation: The Ethical and Social Aspects of Killing Day-Old Chicks and Its Alternatives

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Accepted: 13 August 2015

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**Abstract** The aim of this paper is to provide a conceptual framework that will help in understanding and evaluating, along social and ethical lines, the issue of killing day-old male chicks and two alternative directions of responsible innovations to solve this issue. The following research questions are addressed: Why is the killing of day-old chicks morally problematic? Are the proposed alternatives morally sound? To what extent do the alternatives lead to responsible innovation? The conceptual framework demonstrates clearly that there is a moral “lock-in”, and why the killing of day-old chicks is indeed an issue. Furthermore, it is shown that both alternative directions address some important objections with regard to the killing of day-old chicks, but that they also raise new dilemmas. It also becomes clear that the framework enables and secures anticipation, reflection, deliberation with and responsiveness to stakeholders, the four dimensions of responsible innovation, in a structured way.

**Keywords** Moral “lock-in” · Killing of day-old chicks · Animal ethics · Ethical matrix · Responsible innovation

## Introduction

Since the mid-nineteen eighties technological “lock-in” has become an important subject of growing academic enquiry in the field of innovation studies (David 1985; Arthur 1989), especially by economists working within an evolutionary tradition.

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The general idea of lock-in is that "...technologies and technological systems follow specific paths that are difficult and costly to escape" (Perkins 2003). Even if potentially superior alternatives are available, these technologies and technological systems often survive for a very long time. The famous examples in the literature are the triumph of the QWERTY keyboard layout over the Dvorak Simplified Keyboard layout (David 1985) and the race between the VHS and Betamax as a video cassette recorder standard (Arthur 1990). In the literature, lock-in is explained by the increasing returns of an initial lead in the competition between technologies (David 1985; Arthur 1989). "This arises because early adoption can generate a snowballing effect whereby the preferred technology benefits from greater improvement than its competitors, stimulating further adoption, improvement and eventual leadership" (Perkins 2003).

There are many ways in which locked-in technologies may be inferior to their alternatives. In this paper we will focus on *moral* "lock-in": the way the economic system can be locked-in to technology standards which are potentially morally inferior. In some cases there is a consensus on the potential for moral improvement that could be achieved through the development of alternative technologies. The question then becomes: What is holding back the development of these morally better technologies? Many debates about the transition to these new technologies only focus on the costs involved (Carrillo-Hermosilla 2013). Our hypothesis is that a kind of moral "lock-in" may explain the survival of morally inferior technologies.

Intensive animal farming for example has developed a number of morally controversial technologies. Many people, particularly from Western societies, are concerned about production animals (EC 2007; de Cock Buning et al. 2012). This is illustrated by numerous debates about modern animal farming. Beak trimming of chickens and housing of breeding sows are examples. In this paper we will focus on a clear case of a morally inferior practice with potential morally better alternatives: the killing of day-old male chicks in the egg sector (e.g. de Cock Buning et al. 2012). In response to the increasing demand for safe and cheap food in sufficient quantities, intensification and mechanization of poultry farming started in the mid-twentieth century. The number of chickens kept by one farmer has increased considerably since then. Efficiency and specialization were enabled by developments in feeding, breeding, housing of the animals and increased knowledge of veterinary medicine. Genetic selection enabled egg production by layer type chickens and chicken meat production using specialized meat type chickens. Therefore, male chicks from layer type chickens became less interesting for meat production. With the available sexing techniques, which made it possible to distinguish males from females immediately after hatching, it became common practice to kill these male chicks at 1 day of age. Societal opposition to this practice has prompted the development of innovations. Several alternatives to the killing of day-old chicks have been proposed (Leenstra et al. 2010), which raises the question whether these alternatives are morally superior. In this paper we will set up a framework to evaluate the technical and socio-ethical aspects of two alternative directions of more responsible innovations to solve this issue, selected on social desirability and technical potential (e.g. Leenstra et al. 2010; input from our panel of sector experts), compared to the current situation. One alternative direction aims at

dual use of chickens, which can be achieved in two ways. One option is to rear the layer type male chicks for meat. Another option is to use a less specialized type of chicken to produce both eggs and meat. The other alternative direction aims at in ovo sex determination. This can be done at different moments and with different techniques. The different moments of sex determination include before incubation and during the incubation period. The different techniques can be categorized into three approaches: using genetic modification (GM) in the breeding of laying hens in such a way that the hatching eggs containing males can easily be made visible with spectroscopy (GM in chickens to enable a non-invasive technique); taking a sample from the egg to find the difference between male and female eggs (invasive technique); and using spectroscopy on hatching eggs to determine sex (non-invasive technique). Sex determination before incubation is preferred (Leenstra et al. 2011), but seems rather difficult to achieve.

Each alternative has its advantages and disadvantages with respect to technical and socio-ethical aspects and each has a specific importance for various stakeholders. Solving one issue raised by the current situation throws up new issues. For example, by acknowledging arguments against the killing of such young animals and starting to rear the males, issues arise around the impact on the environment and marketing of the chicks. The issue of killing day-old chicks and its alternatives thus seems to be an example of a special type of moral “lock-in”. We will consider Responsible Innovation (RI), an emerging concept for balancing economic, socio-cultural and environmental aspects in innovation processes (EC 2011), as an approach to morally “un-lock” alternative innovations. By involving stakeholders in the innovation process and by considering ethical and societal aspects during this process, the socio-ethical acceptability and societal desirability of innovative products will increase significantly (von Schomberg 2013; Blok and Lemmens 2015).

The aim of this paper is to provide a conceptual framework that will help to understand and evaluate the social and ethical issues of alternative innovations to solve societal problems in general, and raised by the killing of day-old chicks and its alternatives in particular. We will address the following research questions:

1. Why is the killing of day-old chicks morally problematic?
2. Are the proposed alternatives morally sound?
3. To what extent do the alternatives lead to responsible innovation?

The next section starts with a technical and practical description of the egg sector, which explains the context, followed by a description of the alternatives to killing of day-old chicks. After this contextualization, the conceptual framework will be explained. This will be followed by a presentation of the analysis. The paper ends with the discussion, including the conclusions that address our research questions.

## **The Killing of Day-Old Chicks**

Before we go into the analysis of the ethical aspects, we will explain the current situation and proposed alternatives in more detail.

## Current Situation Within the Egg Sector

In the introduction it has already been explained that the intensification of poultry production was a response to the demand for safe and cheap food in sufficient quantities. Furthermore, specialized breeds have been developed in order to be as efficient as possible with regard to the input of resources and waste output per unit of production. This has led to products with a relatively low impact on the environment per unit of production (e.g. de Vries and de Boer 2010). Although this type of intensive poultry farming is applied in many Western societies and is emerging in developing countries as well, in this paper we will focus on the Dutch situation, because the issue is topical in the Netherlands (and in Germany, the main export market for the Dutch egg sector).

There are different actors in the production chain (Table 1). Two breeding companies own the pure lines of chickens that are needed to ensure genetic diversity and provide lines with certain specific traits. The first line of offspring is the grandparent stock, which produce hatching eggs that contain the parent stock. The latter produce the hatching eggs that contain the generation of the laying hens. After hatching, the chickens are sexed and the male chicks are killed. In the Netherlands about 45 million day-old chicks are gassed with CO<sub>2</sub> annually. The dead male chicks are then transported to a company that freezes and markets the chicks, mainly as feed for zoos and pet animals. The female chicks go to a rearing farm, where they reach maturity. At 18 weeks of age the hens go to the layer farm to start laying eggs. There are different housing types for laying hens, with associated average flock sizes. Because the birth rate of female- and male chickens is 50/50 %, for every laying hen produced in the Netherlands (regardless of the way the laying hens are kept later in life, such as in free range or organic systems), a male chick has also been produced, and killed.

## Alternatives to the Killing of Day-Old Chicks

### *Dual Use of Chickens*

Killing day-old chicks can be prevented by searching for an alternative where the males are killed when older. The chickens would then have a dual purpose: the males would produce meat and the females would produce eggs. This alternative can be achieved in two ways. One way is to rear layer type males to produce meat. This option would not affect the efficiency of egg production, but the efficiency of meat production would be relatively low. The feed conversion ratio at least doubles for laying type male chicks compared to broilers (e.g. Damme and Ristic 2003). This means that more resources would be needed to produce the same amount of meat. This inefficiency, combined with a less advantageous meat distribution (lower percentage of breast and leg meat) would result in a more expensive method of meat production (e.g. Murawska et al. 2005). The resulting higher cost price would lead to more expensive poultry meat (compared to broiler meat), or the extra costs would have to be compensated by a higher egg price. These higher prices would be unacceptable for Dutch retailers in the current intensive agriculture market (cf. Bos

**Table 1** Overview of the egg sector in the Netherlands (Bokma and Leenstra 2010; Hilkens and Klein Swormink 2011; PVE 2013)

	Starting point of the egg production chain:	
	2 breeding organizations (own pure lines and grandparent stock <sup>a</sup> )	
	41 breeder farms (parent stock)	Export:
	→ 137 million hatching eggs for laying hens <sup>b</sup>	19 million hatching eggs
	5 laying hen hatcheries	Export:
	→ 86 million day-old chicks	9 million day-old female chicks
	6 laying hen rearing farms	Export:
	→ 32 million young hens	4 million young hens
	1 processor of day-old chicks	Export:
	→ 43 million frozen day-old chicks <sup>c</sup>	35 million frozen day-old chicks
	1 destruction company	
	→ 2 million day-old chicks (insufficient quality)	
	1160 laying hen farms	
	→ 10.1 billion eggs	
Import:	85 egg packing stations	Export:
2.8 bln eggs	→ 12.9 billion eggs	9.7 billion eggs
	Retail, providing Dutch consumer	
	→ 3.2 billion eggs	

<sup>a</sup> Pure lines produce hatching eggs for grandparent stock, grandparent stock produces hatching eggs for parent stock. The pure lines and grandparent stock are kept at specialized farms

<sup>b</sup> Percentage of hatching about 80 %

<sup>c</sup> Providing all zoos in the Netherlands with day-old chicks as well as, for example, falconries and reptile shelters

et al. 2013). In addition to the effects on efficiency, product attributes, such as the structure and taste of the meat, would also be different (Damme and Ristic 2003; Murawska et al. 2005).

Another way is to breed a less specialized type of chicken (a dual-purpose chicken). Although there are no calculations available on the environmental impact of dual-purpose chickens, a study shows that the standard method of poultry meat production is the most efficient compared to alternative systems, when looking at indicators such as primary energy used (Leinonen et al. 2012). The differences between alternative systems and the standard system are, among others, the final slaughter age of the animals, the amount of feed intake per kg/bird, and stocking density, making it the most suitable comparison for dual-purpose breeds. With dual-purpose chickens, meat quality and egg quality would differ from the quality obtained from specialized chickens. The eggs would not differ in nutritional value but in the look of the shell, with a less uniform and less brown shell color (Leenstra et al. 2009). The meat would have a stronger taste, while needing about two times

the rearing period compared to broilers. Egg production would be about 20 % lower (Leenstra et al. 2010).

For both dual use alternatives, mainly small-scale projects are initiated and studied. These alternatives do already serve a niche market and are not expected to replace the specialized ways of production for poultry meat and eggs in the future (e.g. Leenstra et al. 2009). Broilers are still needed to meet the demand for poultry meat as meat consumption is expected to increase rather than decrease (Thornton 2010; FAO 2012). Moreover, there is the question of whether consumers would opt for the more expensive and different tasting meat of the layer type or less specialized chickens. The flavor of broiler meat is often preferred (Damme and Ristic 2003; Leenstra et al. 2009), though not always (Schäublin et al. 2005).

### *In Ovo Sex Determination*

Other alternatives to killing day-old chicks aim at preventing the male chicks from being born. Various proposals have been made for achieving this and the best option seems to be to determine the sex of the eggs before hatching, i.e. in ovo sex determination.

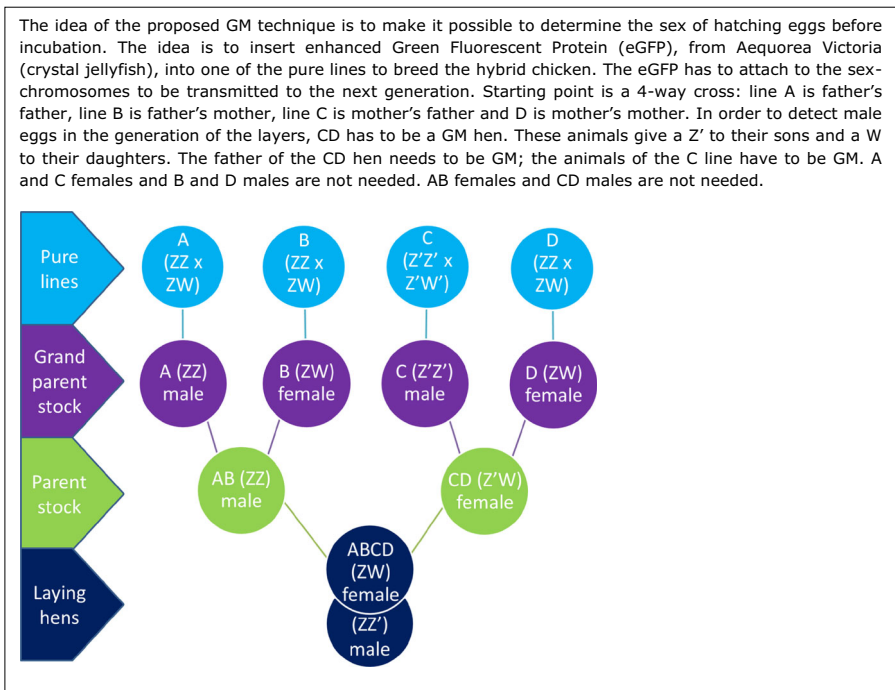
Although it is often stated that in ovo sex determination is not yet ready for practical use (e.g. Koenig et al. 2012), various researchers are exploring techniques with the aim of establishing an innovation to achieve this. The preferred method would be to determine sex before incubation, as embryonic development has then not yet started. It has been proposed that sex determination during incubation should be performed for preference in the first half of the incubation period, because it is assumed that the embryo does not yet have any pain perception at that stage (cf. Close et al. 1997; Weissmann et al. 2013). Techniques to determine sex in the second half of the incubation period have already been developed, but have not been put into practice.

In ovo sex determination would most likely affect practices in the hatcheries. The hatcheries would have to incorporate a technique to sex the eggs and remove them. The most difficult aspect of this is that it should be fast, reliable and cheap, and should not affect hatchability or the health and performance of the laying hens (cf. Kaleta and Redmann 2008). Labor demand would be reduced as sexing after hatching would no longer be needed. This would also mean less handling of the day-old laying hens and thus an enhanced animal welfare. In the case of sex determination of un-incubated eggs, detection might also be done at the breeding farms. The hatcheries would only have to incubate and hatch half of the hatching eggs, which would save energy and costs. In the case of sex determination during incubation, half of the eggs could be removed from the incubators during the incubation period, saving some energy and costs (the number of incubators cannot be reduced; only the hatchers can be reduced by half). The male eggs would be destroyed.

The following paragraphs will explain the techniques of the most promising (based on social desirability and technical and practical potential (e.g. Various Authors 2003; Leenstra et al. 2010; input from panel of sector experts) innovations for in ovo sex determination.

*GM of Chickens* The use of GM is a potential facilitator to enable sex determination before incubation. The use of eGFP to detect male eggs is explained in Fig. 1. The technique of inserting eGFP into chickens has been used successfully at the Roslin Institute (e.g. McGrew et al. 2004). However, a proof-of-principle for this specific goal, i.e. binding eGFP to sex-chromosomes, is needed. When the proof-of-principle works, this application of GM will mainly concern the breeding companies. These companies will have to breed a pure line with eGFP. It is, however, not yet known how this GM technique would affect the cost price (nor what effect implementation would have on the sector’s image).

*Taking a Sample from the Hatching Egg* Most scientific literature on in ovo sex determination is about invasive techniques where samples are taken from hatching eggs. Research has been done on sampling from the allantoic fluid to determine hormone levels. One paper, for example, reports on differences in estrogen levels being detected using techniques based on color differences of the samples. The male eggs in the layer industry can then be removed from the incubator on day 18 and do not have to be moved to the hatcher. This sampling of the eggs does not seem to have an effect on hatchability (Phelps 2001).



**Fig. 1** Explanation of the GM technique to enable early sexing of hatching eggs (personal communication Livestock Research 2013). ZZ, male chicken; ZW, female chicken; Z’ or W’, the chromosome is genetically modified

Other studies aim at sex determination in the first half of the incubation period. A number of researchers are working on techniques that require a sample from the egg around day 9. In Germany, for example, a technique uses samples from the allantoic fluid to measure estrone sulfate in the allantoic fluid at day 9 of incubation (Weissmann et al. 2013).

Steiner et al. (2011) report on a technique that can determine the sex of unincubated eggs. The technique involves sampling blastoderm cells to determine sex difference using DNA content by means of a certain type of spectroscopy.

*Spectroscopy on Hatching Eggs* Non-invasive techniques such as spectroscopy on hatching eggs are also being studied. The University of Leuven has reported a proof-of-principle for determining the sex of eggs around day 11. This technique is based on down color and is only applicable to eggs of brown chicken breeds.

### *Assumption Regarding Egg Sector*

Before continuing, we would like to explain an important assumption concerning this study. One could argue that the whole sector of egg production is problematic. It is therefore sometimes argued that the whole egg sector should be questioned when addressing the issue of killing day-old chicks. However, most people in society accept that animals are kept for the production of food (Rutgers et al. 2003; de Cock Buning et al. 2012). We assume that it is not realistic to stop the production of eggs completely, as worldwide consumption is increasing rather than decreasing, and demand for animal protein will increase especially in developing countries (Thornton 2010; FAO 2012). With these prospects it is not realistic to expect the production of eggs to be stopped completely, replaced entirely by plant-based imitation eggs or made substantially less intensive. From this starting point we have to look for alternatives within the egg production chain.

## **Conceptual Framework**

The problem of killing day-old chicks is a recurrent one. It might be valuable first to have a good understanding of the moral and social aspects of this issue. The issue has been ethically evaluated before (e.g. Woelders et al. 2007). However, developments in techniques and possible shifting ideas in society make it worthwhile performing a new analysis.

Different ethical theories are available. For example, consequentialist (e.g. Singer 1993) and deontological approaches (e.g. Regan 1983). Beauchamp and Childress (1994) define four principles, which are commonly used in bio-ethics: non-maleficence, beneficence, autonomy and justice. Mepham (2000) uses these principles to construct an ethical matrix, which combines consequentialist and deontological approaches to structure the different ethical aspects for different stakeholders. The ethical principles are represented by the principles of wellbeing,



autonomy and justice. These principles are judged for each stakeholder. The ethical matrix seems an appropriate tool for structuring the arguments.

Nevertheless, in order to analyze this problem properly, structuring of arguments alone is insufficient. Arguments differ for each situation (current situation vs. alternatives) and the interpretation and appreciation of arguments vary between stakeholders (such as the aspect of animal welfare) due to different interests and values. Elements from the reflective equilibrium method can help to analyze these aspects, as the model involves an analysis of moral intuitions, principles and facts (Bolt et al. 2005).

In this article, the ethical matrix is used as a basis to structure the different arguments and to show the various perspectives of the different stakeholders with regard to the arguments, which includes intuitions, perceptions and facts. The same procedure is followed to analyze the two alternative directions (dual use of chickens and in ovo sex determination). Unstructured data collection (i.e. the data depend on what kind of data is available) is used to collect the input. Input is derived from the available scientific literature and data from specialists and technical literature, together with expert input from stakeholders. Stakeholders were involved in this study by participation in a valorization panel.<sup>1</sup> The panel consisted of farmer representatives (i.e. people representing the breeding organizations, hatcheries and breeding farms, laying hen farmers). Furthermore, input from representatives of consumers, of retail and of animal protection organizations were included. Moreover, the research team consisted of researchers with expertise in various fields (animal science (including animal welfare), veterinary science, animal ethics, philosophy, management studies, innovation studies, poultry science and microbiology).

We distinguish four main stakeholders in our study: society (most members of which are also consumers), the egg sector, day-old chicks and the environment (as is common when working with the Ethical Matrix, cf. Mepham 2000) (Table 2). Society and the egg sector have their own interests and rank the importance of the various aspects differently in the ethical matrix. For example, the animal welfare aspect (the wellbeing of day-old chicks) is, in general, interpreted and valued differently by consumers compared to actors in the egg sector (e.g. Tuytens et al. 2010). The different stakeholders will rank the alternatives according to their interpretation and values, which means that there will be no consensus as to the preferred alternative. So-called value conflicts occur and it is a challenge to find a way of giving appropriate weight to the various opinions (cf. Taebi et al. 2014).

Before we start the analysis of the two alternative directions, it would be helpful to know why the current situation is problematic. Therefore, we will start the analysis by discussing the current situation, using the ethical matrix as the basis (Table 2).

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<sup>1</sup> The funding agency, Netherlands Organisation for Scientific Research (NWO) requires such a panel in order to stimulate the valorization of scientific knowledge in practice.

**Table 2** Ethical aspects for the stakeholders on the issue of killing day-old chicks and its alternatives filled out in the ethical matrix, based on (Mepham 2000)

Respect	Wellbeing	Autonomy	Justice
Society (consumers of eggs)	Acceptability Food safety	Consumer choice	Affordability Availability
Egg sector	Maintain profitability Adequate labor conditions	Freedom of management	Fair treatment in trade and law (level playing field, international competition)
Day-old chicks	Animal welfare	Integrity Naturalness	Intrinsic value
Environment <sup>a</sup>	Protection of the biota	Maintenance of biodiversity	Sustainability

<sup>a</sup> For this case we will only focus on the environmental impact with regard to use of resources and waste output as the other elements will be too extensive to discuss in this paper

## Analysis

### Current Situation: Killing Day-Old Chicks

#### *Society*

Many people do not know about the killing of day-old chicks and, when informed about the practice, most people do not like the idea (Leenstra et al. 2011). The problems regarding the acceptability of killing day-old chicks are the motive for this analysis. This low acceptability mainly relates to the use and treatment of animals, which will be explained in the paragraph *Status of day-old chicks*. Furthermore, when the consumer choice aspect is considered, it is clear that there is no choice for consumers. Although eggs are sold in different packages, showing the housing system or main feed ingredient for the laying hens, there are no eggs that are produced without killing day-old chicks. However, many people are not aware of this missing option or actively concerned about it.

Other aspects in the *society* row of the ethical matrix not only relate to the killing of day-old chicks but more to intensive animal production in general. Due to the intensive production method, which also includes the killing of day-old chicks, eggs are a relatively cheap and readily available source of animal protein (aspects of affordability and availability). Eggs are of high quality and are safe, as strict legislation exists in the Netherlands.

#### *Egg Sector*

To maintain profitability, animal production has become efficient and specialized over the last few decades. This intensification and specialization led to the practice of killing day-old chicks. A disadvantage relating to labor conditions is that most people in hatcheries who handle day-old chicks do not like this aspect of their work.

The current situation in the egg sector originates from the demand for efficient and cheap production of eggs, and has created a level playing field in which the Dutch egg sector can compete in the international market. The killing of day-old chicks is allowed in different countries and does not lead to disadvantages for trade. In principle, the sector is free to choose not to kill the male chicks. Adjustments in the sector to change this practice could have consequences for efficiency (e.g. use of resources and waste output) and product prices, and could raise new ethical dilemmas. However, in practice, there are as yet no alternatives that are economically and practically viable. A few initiatives have been undertaken to market layer males. This option only seems viable for a niche market, which shows there is a restricted freedom of management (Leenstra et al. 2009).

A consequence of implementing an alternative is that European zoos, falconries, etc. might lose an important source of feed for their animals, although they could probably order chicks. They could also start incubating the chicks themselves or find a suitable substitute (e.g. sausages from slaughter waste, specifically bred mice and rats, etc.).

### *Status of Day-Old Chicks*

As mentioned, the negative score for societal acceptability mainly relates to the use and treatment of animals, relating to animal welfare, animal integrity and intrinsic value. Reasons for people to disagree with killing day-old chicks include an objection to the large-scale killing of *young* animals which are a side-product of an intensive animal production chain; people disagree with the instrumentalization, technologization and rationalization of animals (CBD 2012). The chicks are used as objects instead of subjects. This is incompatible with the fact that most people grant animals moral status (Rutgers et al. 2003) or agree with the statement that animals have a right to life (Cohen et al. 2012). A common basis to granting moral status is to acknowledge that animals are sentient beings, which is also defined in EU regulations (EC 2009). Furthermore, the intrinsic value of the male chicks is not respected. In the Netherlands, the intrinsic value of animals is acknowledged in law [Dutch Animals Act, Section 1(3)], which means that animals are valued as an end in themselves. If the law were strictly applied, this could mean that it would not be permitted to do anything with animals. The explanation of the Act shows that it is not all that far-reaching and many interpretations are possible. Moreover, the production of animal-based food products is a justified reason to use animals [Dutch Animals Act, Section 2(10)].

With respect to the use of animals, other aspects can play a role, such as animal integrity and animal welfare. The Act refers to animal welfare by means of a definition of care of animals based on the Five Freedoms<sup>2</sup> ‘To the extent as may reasonably be expected’. This comment in the Act leaves much room for interpretation. It is a matter of debate to what extent animal welfare is at stake. It is frequently assumed that if killing is carried out quickly and without causing pain,

<sup>2</sup> The Five Freedoms were formulated by the Brambell committee in 1965, and formulated more broadly by the Farm Animal Welfare Council (FAWC).

then the killing of day-old chicks is not an animal welfare issue. The most commonly used method of killing chicks (i.e. gassing with CO<sub>2</sub>) is fairly quick, but there is no unanimous agreement that it does not raise welfare issues. Although, assuming the killing itself can be done in a way that is completely or almost completely welfare neutral, it is questionable whether the killing of such young animals is really not an animal welfare issue, because the animals are not able to complete a normal lifespan and their interests are at stake (Yeates 2009; Bruijnis et al. 2013). The latter argument requires a view on animal welfare where it is accepted that animal welfare is a concept based on interacting biological and normative viewpoints. The normative viewpoints determine what types of biological aspects are important and what is, or is not, acceptable (e.g. Schmidt 2011; Bruijnis et al. 2013). In this interpretation of animal welfare, the aspect of naturalness is also considered important.

Naturalness, in turn, closely relates to animal integrity. The concept of integrity is described by Rutgers and Heeger (1999) as: ‘The wholeness and completeness of the animal and the species-specific balance of the creature, as well as the animal’s capacity to maintain itself independently in an environment suitable to the species’. The day-old chicks do not have the chance to maintain themselves and develop according to species-specific needs when killed directly after hatching.

The purpose of the killing of animals is important for many people when deciding whether or not it is justified. The reason the male chicks are killed in the first place is that they are a side-product in an intensive animal production system (instrumentalization, rationalization). However, when people learn that the killed chicks from the Dutch egg sector serve as animal feed, they are more inclined to accept the killing of male chicks, as the animals are no longer waste, but serve a purpose (Leenstra et al. 2011). This argument is not valid for all people, as some may argue that this functionality does not compensate the violation of animal welfare, animal integrity or intrinsic value. This difference is largely determined by the moral values held by people, such as deontological or consequentialist values. Which values one holds depends, among other things, on sex and education (Cohen et al. 2012; Bobeck et al. 2014).

### *Environment*

The efficient way of producing eggs with low impact on the environment is a positive aspect of current egg production. The input needed to produce eggs is much lower than, for example, with a less specialized type of chicken. As a consequence, waste output and the impact on the environment per unit of production are relatively low (Leinonen et al. 2012).

### **Dual Use of Chickens**

For the alternatives that aim at dual use of chickens, the ideal situation, at first sight, would be for the whole poultry sector to switch to this alternative. However, that is not realistic because broiler meat production is needed to meet the demand for poultry meat (e.g. FAO 2012; personal communication panel of sector experts).

Therefore, broiler meat production would continue and meat from the egg sector would have to compete with broiler meat. The advantages and disadvantages of the alternatives involving dual use of chickens will be discussed below.

### *Society*

Assuming that the alternative of producing meat in the egg sector would only be a niche market (Dutch eggs are mainly produced for the German and Dutch markets), this would mean an improvement in consumer choice for both egg and chicken meat production. The products from dual use production would be more expensive (Leenstra et al. 2010; Schäublin et al. 2005), but as it would be a niche market, affordability would not be an issue. Food safety would not be affected or become a point of discussion and eggs would remain available.

### *Egg Sector*

As already stated, the option of the dual use of chickens would only be able to serve a niche market. For a certain group of poultry farmers it might be interesting to use laying hens of which the ‘brothers’ have not been killed in the hatchery. As long as the actors in the sector can choose such options, there will be no problems with trade or labor conditions. If the Dutch egg sector were forced to stop the killing of day-old chicks, the egg sector indicates they would probably be unable to compete and would move to other countries (personal communication panel of sector experts).

### *Status of Day-Old Chicks*

Dual use of chickens would end the practice of killing *day-old* chicks, thus largely solving the problem of objections to this practice. Certain aspects of animal integrity, naturalness and intrinsic value would be better respected as the animals would have the chance to live longer. However, this would bring new animal-related issues to the fore, such as the quality of life of the chicks. The housing and treatment of the animals would be considered very important. Other dilemmas relate to slaughter age and weight. At what age is it acceptable to slaughter the animals? And does it make a difference if the chicks are killed at a later stage for human food instead of being killed at 1 day of age for animal feed? Answers to these questions will differ, again depending on what moral values are most important, which is largely determined by a person’s background, knowledge, etc. (Cohen et al. 2012; Bobeck et al. 2014; Spooner et al. 2014).

### *Environment*

This aspect is contradictory, because it emerged that although dual purpose was preferred in the public questionnaire in 2008, at the end of the focus group consultations, one third opposed this type of production because of the inefficient use of resources (Leenstra et al. 2011). However, the battery cage system has been banned in the EU since 2012 because society no longer accepted that way of

keeping animals, although this ban is likely to increase the global warming potential (Dekker et al. 2011). Reasons of animal welfare or respect for animals can thus outweigh environmental concerns.

### **In Ovo Sex Determination**

The ideal situation for the alternatives that aim at in ovo sex determination would entail sex determination before incubation, which does not appear to be realistic in the short term. In contrast to the dual use of chickens, this alternative would not change the end products (eggs and meat) and would be more likely to serve the whole egg sector.

#### *Society*

The general public might see the idea of preventing the male chicks from being born as positive compared to killing young animals. This depends on what values people find most important. Some people might see this alternative as a way to maintain or further develop intensive animal production. Preventing males from being born as such does not change food safety. The technique used would, however, influence the perception of food safety. The use of genetic modification, regardless of how it is applied, is generally perceived as a risk for food safety (Lassen et al. 2006; Schuppli and Weary 2010). It probably does not matter to most people that GM is only used in the production chain and that the end product (eggs) is not genetically modified.

In ovo sex determination would not affect the availability of eggs. Furthermore, affordability would not be greatly affected because such techniques would only be implemented when they were feasible and would not cause disadvantages for the Dutch egg sector. This precondition is an important factor for the implementation of techniques that enable in ovo sex determination. The aspect of consumer choice might be improved, as eggs would then become available for which no day-old chicks had been killed. The technique using GM in the production process brings up new issues as GM is rather controversial (Lassen et al. 2006; Schuppli and Weary 2010). When there is discussion about using GM techniques on animals for food production, it raises many objections and often prompts accusations that moral boundaries will be exceeded (Lassen et al. 2006; Leenstra et al. 2011). These moral boundaries mainly relate to our dealing with animals and will be mentioned briefly in this paper. GM on animals for food production is currently forbidden by law in the EU (EFSA 2012).

#### *Egg Sector*

Maintaining profitability is a precondition when considering investments in new techniques. The investment should probably be made at the hatcheries. Return on this investment might come from a lower cost price, because fewer hatching eggs have to be hatched, or eggs might also be sold for a higher price to compensate the costs for investment. Changes in labor conditions would only occur at the hatcheries, where the chicks would no longer have to be sexed and the male chicks

would no longer have to be asphyxiated. Effects on trade and legislation would depend on the technique used. If approved by law, GM would have more implications for trade than the other techniques.

### *Status of Day-Old Chicks*

The option of in ovo sex determination does remove all objections to killing day-old chicks, as the chicks are prevented from being born. However, in ovo sex determination leads to new problems. For example, a side-effect might be that some buyers of day-old chicks would start to incubate eggs themselves to provide day-old chicks or buy specially bred mice or rats (Bokma and Leenstra 2010). People might have objections to the killing of chicken embryos. Furthermore, the GM technique would result in animals that are regarded as GM waste (i.e. the (grand)parents and male eggs that are genetically modified). One could ask whether there is any difference between killing animals for animal feed or for human food. How important is it that the eggs with embryos or the day-old chicks have a purpose or not? These questions relate to issues such as interfering in life, instrumental value versus intrinsic value of animals, respect for life, etc. Different people interpret and value these issues differently.

A number of arguments can be mentioned with respect to animal welfare. An advantage for the laying hen chicks, immediately after hatching, is that they do not have to be handled for sexing (because there are no hatched male chicks). On the other hand, people might question whether the techniques that use samples from the eggs during incubation affect the laying hens pre- or postnatally. Other concerns about animal welfare mainly relate to the option involving genetic modification. In general, people assume that GM animals encounter welfare problems. Studies indicate that eGFP does not impair animal welfare (cf. Huber et al. 2012), but the public's general perception is that it does. Other frequently used arguments relate to the integrity of the animals and naturalness (Frewer et al. 1997; Leenstra et al. 2011), although these are often based on values and arguments that are different from the objections based on integrity and naturalness that relate to the killing of day-old chicks. Different expressions are used, such as saying that such practices are 'going against nature' (Macnaghten 2004), that 'scientists are playing 'God'', or that the natural order of things is challenged, and people question to what extent humans should exercise control over animals (Schuppli and Weary 2010). The expression 'meddling with nature' is also used (Gaskell et al. 2000; Shaw 2002), with consumers tending to prefer natural entities above entities produced with human intervention (Heuvel et al. 2008). Furthermore, there is a certain infringement of respect for the intrinsic value, because the animal is changed (instrumentalized) further in order for it to be used as a production animal (rationalization of animal production).

### *Environment*

Consequences for the environment, in terms of energy use and emissions, will decrease due to the reduced capacity needed at hatcheries. With respect to the GM

option, people argue that safety mechanisms in nature are bypassed and GM is sometimes considered to present unpredictable risks to our environment (e.g. altering ecology through the release of modified organisms) (Schuppli and Weary 2010).

## Discussion and Conclusions

The aim of this paper is to address three research questions.

### Why is the Killing of Day-Old Chicks Morally Problematic?

This research question is relatively easy to answer. The framework we described earlier demonstrates clearly that the killing of day-old chicks is highly inhumane, mainly due to the violation of animals' interests. Important arguments include the fact that it involves the killing of animals, which do not have a chance to live and develop according to species-specific needs (the aspects of animal integrity and animal welfare). Another important issue is that, as it is not economically viable to raise male chicks for consumption, they are killed on a large scale because they are considered to be a side-product or even waste. Therefore, the practice of killing day-old chicks is a kind of instrumentalized and rationalized animal production (the aspect of no respect for intrinsic value) (Rutgers et al. 2003; CBD 2012). The conclusion that the killing of day-old chicks is morally problematic is in line with previous studies (e.g. Woelders et al. 2007).

How could such a morally problematic practice emerge? As explained earlier, in our Western society there has been a focus on producing large amounts of good-quality food that should be available to everyone at low cost. In the processes of specialization and the scaling up of production, the values of food security and food safety were leading, while values such as respect for animal integrity and animal welfare were not yet as important. The underlying moral reasoning was mainly consequentialist: the results of the leading values were important and the way of achieving those results was not considered. An argument that puts these processes into perspective is that the killing of day-old chicks is a side-effect. It only became possible in the second half of the twentieth century, because of the use of specialty breeds and the ability to sex day-old chicks.

Nowadays, animals receive more respect and are more often valued as ends in themselves (cf. Cohen et al. 2007). If one adds the fact that in the Netherlands and in most other Western societies there is no food shortage or much risk of such a shortage, one could ask whether it is justifiable to maintain such intensive livestock production. A big advantage of efficient production is that it is relatively environmentally friendly per unit of food produced. When comparing different types of meat, the production of chicken meat and eggs has a relatively low impact on the environment (de Vries and de Boer 2010). This is an important argument for maintaining this method of production, because worldwide the demand for animal protein is increasing due to population growth and the increased consumption of



animal protein. More extensive and more ‘animal-friendly’ animal production will increase the impact on the environment. Animal welfare and low environmental impact are difficult to compare; in certain situations one can do justice to both values. Looking at the Netherlands, where animal-related values are increasingly important, one could argue that a decline in the amount of animal protein consumed could enable responsible animal production. Based on this reasoning, the dual use alternatives would be an option to consider seriously. However, the real importance of the aspects of animal production related to animal welfare and associated issues should be demonstrated through support for more animal-friendly methods of animal production. It is then important, for example, to accept that products that are cheap and produced in an environmentally friendly way are in most cases less ‘animal-friendly’. One difficulty is that it is hard to inform consumers, as people do not always want to be informed (Boogaard et al. 2011b). Another difficulty is that, although people might be willing to pay more, this willingness is not the only factor that determines actual consumer behavior (cf. Boogaard et al. 2011a).

The killing of day-old chicks is more problematic than other types of killing in animal production because these chicks are not the main product and do not serve as food. The objection related to the chicks being a side-product or being waste is often lessened by arguing that these chicks are used as animal feed, at least in the Netherlands and to a large extent in Europe. To what extent does this argument justify the killing? There is no consensus on the answer to this question. Some people will argue that this is a good solution and these are probably the people who have a more consequentialist perspective. People who reason from a more deontological perspective will more often argue that this does not justify the killing, because in their view values such as fulfilment of the life-cycle are important. It may also be questioned to what extent the chicks are really needed as animal feed or whether this is a ‘retrospective justification’. One could argue (e.g. Society for the protection of animals) that the use of day-old chicks is only based on the fact that the chicks are available and not because they are really needed.

We now may conclude that in our case of the killing of day-old chicks the first condition for a moral “lock-in” is met: the practice is morally unacceptable. For the long term it might be desirable to search for more radical alternatives, for example the use of plant-based proteins as a substitute for eggs. In the short term it is desirable to adjust egg production to a more accepted way of production, at least for the countries where there are concerns about how production animals are treated (such as the Netherlands and Germany). This leads us to our *second research question* about the second condition for a moral lock-in.

### **Are the Proposed Alternative Directions Morally Sound?**

As discussed, both alternative directions address some important objections with regard to the killing of day-old chicks and have some advantages, but they also raise new dilemmas. Examples are the further instrumentalization of the alternative of in ovo sex determination, the questions raised about killing embryos, and the controversy regarding the option using a GM technique. The dual use alternative

raises environmental issues and the quality of life of the animals can be questioned. In none of these situations are all values entirely respected. As a consequence the alternatives are not completely morally superior to the existing practice, the second condition of a moral lock-in. This leads us to our third research question.

### **To What Extent do the Alternative Directions Lead to Responsible Innovation?**

In responsible innovation, the ethical acceptability and social desirability of an innovation, as well as its marketable products, are considered in a transparent process of stakeholder engagement, in which these stakeholders become mutual responsive to each other (von Schomberg 2013). This implies that not only traditional aspects, such as the economic viability of innovations, are considered in the innovation process, but also socio-ethical aspects. In order to assess the ethical desirability of innovations, four dimensions of responsible innovation should be taken into account, according to Owen and colleagues. During the innovation process, innovators should *anticipate* intended and potentially unintended future impacts of their innovations, *reflect* on the purposes, motivation and potential impact of their innovations, *deliberate* with multiple stakeholders about norms and future trajectories of their innovations, and finally *respond* to societal needs through participatory and anticipatory governance (Owen et al. 2013).

To what extent does our framework facilitate the assessment of the responsibility of innovation processes according to these four dimensions in general, and regarding the alternatives to the killing of day-old chicks described in this article in particular? The framework does facilitate the first two dimensions because it enables and secures anticipation and reflection in the innovation process in a structured way. The framework shows that both alternative directions try to anticipate the future impact by removing specific objections against the current practice of killing day-old chicks. These objections, such as the killing of young animals, discount the societal acceptance of the current situation. The framework also facilitates reflection on the alternatives and enables the assessment of how responsible the alternatives are. When reflecting on the alternatives, different values have to be weighed. This is rather difficult, for example respecting animal integrity versus food security, or weighing two different aspects of animal integrity when comparing the killing of a young animal with killing an embryo. In this respect, the framework does not help us to decide what the most responsible alternative is. This is also not to be expected, because we have to do with a highly complex problem, but it enables a structural reflection on the purposes and anticipation of the future consequences of alternatives. It raises questions such as how we should decide between the merits of environmentally friendly production and those of animal-friendly production.

Ideally, this reflection and anticipation should involve deliberation with multiple stakeholders. Although we only involved the stakeholders of our panel of sector experts in the assessment of the alternatives in this article and based our arguments on written reports and scientific data, it would be possible in principle. In this respect, the framework can facilitate collective deliberation with multiple

stakeholders on the alternatives in a structured way, although more empirical research is needed in order to assess the merits of our framework in practice.

The fourth dimension of responsible innovation includes responsiveness to societal needs through participatory and anticipatory governance, which can be understood as a democratic legitimization of certain innovation trajectories. In the case of alternatives to the killing of day-old chicks, it is certainly the case that actors in the egg sector are responsive to societal needs; an important societal need includes the demand for more animal-friendly production methods. At the same time, it is questionable whether actors in the egg sector are willing to share responsibility for innovation in the sector. On the one hand, companies are inclined to say that they are solely responsible for the innovations they invest in, while stakeholders such as NGOs are not inclined to take over this responsibility from the companies (cf. Blok and Lemmens 2015). On the other hand, it seems to be possible for companies to become responsive to societal needs without the participation of multiple stakeholders (Blok et al. 2015; cf. Blok 2014).

Although we did not apply participation and anticipatory governance in our framework and more research is needed in this respect, we can conclude that our framework can potentially enhance participation. It helps to assess future impacts and weigh different values involved in egg production, it clearly shows the complexity of the problem and the proposed innovations as potential solutions, and therefore it enables actors to make decisions collectively about the direction of future innovations. In the effort to realize responsible innovation in egg production, for instance, the framework enables us to make a distinction between what might be possible in the short term—searching within the current production system—and in the long term. When, in line with the Responsible Innovation approach, multiple actors agree to improve the current egg production system by developing the proposed alternatives, while at the same time acknowledging the drawbacks of these alternatives, this innovation trajectory can be considered to be more responsible. Nevertheless, although the alternatives do solve some important issues, they also raise as many or even more ethical issues. It is then questionable whether the alternatives can be seen as a responsible innovation in the long term. This provides us with an alternative explanation of a moral lock-in: although the existing practice is morally inferior, none of the alternatives is ethically sound either. Therefore, in order to morally “un-lock” an existing morally inferior practice, it is important to look for innovations that solve the more substantial problems. And such innovations need more time and will probably require more radical changes than the proposed alternatives.

**Funding** The work of this article has been funded by NWO (Netherlands Organisation for Scientific Research (grant number 313-99-015).

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## References

- Arthur, W. B. (1989). Competing technologies, increasing returns and lock-in by historical events. *Economic Journal*, *99*, 116–131.
- Arthur, W. B. (1990). Positive feedbacks in the economy. *Scientific American*, *262*, 92–99.
- Beauchamp, T. L., & Childress, J. F. (1994). *Principles of biomedical ethics*. New York: Oxford University Press.
- Blok, V. (2014). Look who's talking: Responsible innovation, the paradox of dialogue and the voice of the other in communication and negotiation processes. *Journal of Responsible Innovation*, *1*, 171–190.
- Blok, V., Hoffmans, L., Wubben, E., 2015. Stakeholder engagement for responsible innovation in the Private Sector: Critical Issues and management practices in the Dutch food industry. *Journal of Chain and Network Science* (forthcoming).
- Blok, V., & Lemmens, P. (2015). Critical reflections on the concept of responsible innovation. In B. J. Koops, J. van den Hooven, H. A. Romijn, T. E. Swierstra, & I. Oosterlaken (Eds.), *Responsible innovation: Issues in conceptualization, governance and implementation*. Dordrecht: Springer.
- Bobeck, E. A., Combs, D. K., & Cook, M. E. (2014). Introductory animal science—Based instruction influences attitudes on animal agriculture issues. *Journal of Animal Science*, *92*, 856–864.
- Bokma, M., & Leenstra, F. (2010). *De afzetmarkt voor eendagshaantjes in beeld*. Lelystad: Animal Sciences Group.
- Bolt, L. L. E., Verweij, M. F., & Van Delden, J. J. M. (2005). *Ethiek in praktijk*. Assen: Van Gorcum B.V.
- Boogaard, B., Bock, B., Oosting, S., Wiskerke, J. C., & van der Zijpp, A. (2011a). Social acceptance of dairy farming: The ambivalence between the two faces of modernity. *Journal of Agricultural and Environmental Ethics*, *24*, 259–282.
- Boogaard, B. K., Oosting, S. J., Bock, B. B., & Wiskerke, J. S. C. (2011b). The sociocultural sustainability of livestock farming: An inquiry into social perceptions of dairy farming. *Animal*, *5*, 1458–1466.
- Bos, J., Blok, V., & Tulder, R. (2013). From confrontation to partnership. The role of a Dutch non-governmental organisation in co-creating a market to address the issue of animal welfare. *International Food and Agribusiness Management Review*, *16*, 69–75.
- Bruijnjs, M. R. N., Meijboom, F. L. B., & Stassen, E. N. (2013). Longevity as an animal welfare issue applied to the case of foot disorders in dairy cattle. *Journal of Agricultural and Environmental Ethics*, *26*, 191–205.
- Carrillo-Hermosilla, J. (2013). Technological Lock-in. *The Encyclopedia of Earth*. <http://www.eoearth.org/view/article/156453/>. Accessed April 2015.
- CBD. (2012). *Definitieve advies Commissie Biotechnologie bij Dieren over aanvraag RBD222*.
- Close, B., Banister, K., Baumans, V., Bernoth, E. M., Bromage, N., Bunyan, J., et al. (1997). Recommendations for euthanasia of experimental animals—Part 2. *Laboratory Animals*, *31*, 1–32.
- Cohen, N. E., Brom, F. W. A., & Stassen, E. N. (2012). Moral convictions and culling animals: A survey in the Netherlands. *Anthrozoos*, *25*, 353–367.
- Cohen, N. E., van Asseldonk, M. A. P. M., & Stassen, E. N. (2007). Social-ethical issues concerning the control strategy of animal diseases in the European Union: A survey. *Agriculture and Human Values*, *24*, 499–510.
- Damme, K., & Ristic, M. (2003). Fattening performance, meat yield and economic aspects of meat and layer type hybrids. *Special Report in Worlds Poultry Science Journal*, *59*, 50–53.
- David, P. A. (1985). Clio and the economics of QWERTY. *American Economic Review*, *75*, 332–337.
- de Cock Buning, T., Pompe, V., Hopster, H., & de Brauw, C. (2012). *Denken over dieren—dier en ding, zegen en zorg Inventarisatie van publiekswaarden en verwachtingen van praktijken in 2011* (p. 67). Amsterdam: Athena Instituut, Vrije Universiteit Amsterdam.
- de Vries, M., & de Boer, I. J. M. (2010). Comparing environmental impacts for livestock products: A review of life cycle assessments. *Livestock Science*, *128*, 1–11.
- Dekker, S. E. M., de Boer, I. J. M., Vermeij, I., Aarnink, A. J. A., & Koerkamp, P. (2011). Ecological and economic evaluation of Dutch egg production systems. *Livestock Science*, *139*, 109–121.
- Dutch Animals Act, Ministry of Economic affairs. <http://wetten.overheid.nl/BWBR0030250>. Accessed October 7, 2014.
- EC, European Commission. (2007). *Attitudes of EU citizens towards animal welfare*. Special Eurobarometer.

- EC, European Commission. (2009). *The Treaty of Lisbon*. [http://ec.europa.eu/food/animal/welfare/policy/index\\_en.htm](http://ec.europa.eu/food/animal/welfare/policy/index_en.htm)
- EC, European Commission. (2011). *Horizon 2020—The framework programme for research and innovation*. Brussels.
- EFSA. (2012). *Genetically modified animals*. <http://www.efsa.europa.eu/en/topics/topic/gmanimals.htm>. Accessed July 2015.
- FAO. (2012). *Global trends and future challenges for the work of the organization*. Web Annex. [http://www.fao.org/docrep/meeting/025/gt\\_webannex\\_rc2012.pdf](http://www.fao.org/docrep/meeting/025/gt_webannex_rc2012.pdf). Accessed March 2014.
- FAWC, Farm Animal Welfare Council. (2014). <http://www.fawc.org.uk/freedoms.htm>. Accessed March 2014.
- Frewer, L. J., Howard, C., & Shepherd, R. (1997). Public concerns in the United Kingdom about general and specific applications of genetic engineering: Risk, benefit, and ethics. *Science, Technology and Human Values*, 22, 98–124.
- Gaskell, G., Allum, N., Bauer, M., Durant, J., Allansdotir, A., Bonfadelli, H., et al. (2000). Biotechnology and the European public. *Nature Biotechnology*, 18, 935–938.
- Heuvel, T., Renes, R., Gremmen, B., Woerkum, C., & Trijp, H. (2008). Consumers’ images regarding genomics as a tomato breeding technology: “Maybe it can provide a more tasty tomato”. *Euphytica*, 159, 207–216.
- Hilkens, W., Klein Swormink, B. (2011). *Pluimveehouderij, op de golven van verandering*. ABN Amro, Sector Advisory.
- Huber, R., Remuge, L., Carlisle, A., Lillico, S., Sandøe, P., Sørensen, D., et al. (2012). Welfare assessment in transgenic pigs expressing green fluorescent protein (GFP). *Transgenic Research*, 21, 773–784.
- Kaleta, E. F., & Redmann, T. (2008). Approaches to determine the sex prior to and after incubation of chicken eggs and of day-old chicks. *World’s Poultry Science Journal*, 64, 391–399.
- Koenig, M., Hahn, G., Damme, K., & Schmutz, M. (2012). Utilization of laying-type cockerels as “coquelets”: Influence of genotype and diet characteristics on growth performance and carcass composition. *Archiv Fur Geflugelkunde*, 76, 197–202.
- Lassen, J., Gjerris, M., & Sandoe, P. (2006). After Dolly—Ethical limits to the use of biotechnology on farm animals. *Theriogenology*, 65, 992–1004.
- Leenstra, F., Munnichs, G., Beekman, V., van den Heuvel-Vromans, E., Aramyan, L., & Woelders, H. (2011). Killing day-old chicks? Public opinion regarding potential alternatives. *Animal Welfare*, 20, 37–45.
- Leenstra, F., van Horne, P., & van Krimpen, M. M. (2009). *Verkenning van de marktkansen voor een combi-kip in Nederland*. Lelystad: Animal Sciences Group.
- Leenstra, F., van Horne, P., van Krimpen, M. M. (2010). Dual purpose chicken, exploration of technical, environmental and economical feasibility. In *XIIIth European Poultry Conference, Tours, France*.
- Leinonen, I., Williams, A. G., Wiseman, J., Guy, J., & Kyriazakis, I. (2012). Predicting the environmental impacts of chicken systems in the United Kingdom through a life cycle assessment: Broiler production systems. *Poultry Science*, 91, 8–25.
- Macnaghten, P. (2004). Animals in their nature: A case study on public attitudes to animals, genetic modification and ‘nature’. *Sociology*, 38, 533–551.
- McGrew, et al. (2004). Efficient production of germline transgenic chickens using lentiviral vectors. *EMBO Reports*, 5, 728–733.
- Mepham, B. (2000). A framework for the ethical analysis of novel foods: The ethical matrix. *Journal of Agricultural and Environmental Ethics*, 12, 165–176.
- Murawska, D., Bochno, R., Michalick, D., & Janiszewska, M. (2005). Age-related changes in the carcass tissue composition and distribution of meat and fat with skin in carcasses of laying-type cockerels. *Archiv Fur Geflugelkunde*, 69, 135–139.
- Owen, R., Stilgoe, J., Macnaghten, P., Gorman, M., Fisher, E., & Guston, D. (2013). A framework for responsible innovation. In R. Owen, J. Bessant, & M. Heintz (Eds.), *Responsible innovation*. Chichester: Wiley.
- Perkins, R. (2003). Technological “lock-in”. *Internet Encyclopaedia of Ecological Economics*. Accessed April 2015.
- Phelps, P. (2001). *Gender identification of chicks prior to hatch*. 50th Annual National Breeders Roundtable. Poultry Science, St. Louis, Missouri.
- PVE. (2013). *Vee, Vlees en Eieren in Nederland, Kengetallen 2012*. Zoetermeer: Productschap Pluimvee & Eieren en Productschap Vee & Vlees.

- Regan, T. (1983). *The case for animal rights*. Berkeley, Los Angeles: University of California Press.
- Rutgers, L. J. E., & Heeger, R. (1999). Inherent worth and respect for animal integrity. In M. Dol, M. Fentener van Vlissingen, S. Kasanmoentalib, T. Visser, & H. Zwart (Eds.), *Recognizing the intrinsic value of animals—Beyond animal welfare*. Assen: Van Gorcum B.V.
- Rutgers, L. J. E., Swabe, J. M., Noordhuizen-Stassen, E. N. (2003). *Het doden van gehouden dieren, ja, mits... of nee, tenzij?* Universiteit Utrecht, p. 118.
- Schäublin, H., Wiedmer, H., & Zweifel, R. (2005). *Schlussbericht Versuchsprojekt M 405—Vergleich der Mastleistungen und Fleischqualität van Hähnchen ausgewählter Legelinien mit einem extensiven Masthybriden*. Zollikofen: Aviform.
- Schmidt, K. (2011). Concepts of animal welfare in relation to positions in animal ethics. *Acta Biotheoretica*, 59, 153–171.
- Schuppli, C. A., & Weary, D. M. (2010). Attitudes towards the use of genetically modified animals in research. *Public Understanding of Science*, 19, 686–697.
- Shaw, A. (2002). “It just goes against the grain”. Public understandings of genetically modified (GM) food in the UK. *Public Understanding of Science*, 11, 273–291.
- Singer, P. (1993). *Practical ethics*. New York: Cambridge University Press.
- Spooner, J. M., Schuppli, C. A., & Fraser, D. (2014). Attitudes of Canadian citizens toward farm animal welfare: A qualitative study. *Livestock Science*, 163, 150–158.
- Steiner, G., Bartels, T., Stelling, A., Krautwald-Junghanns, M.-E., Fuhrmann, H., Sablinskas, V., & Koch, E. (2011). Gender determination of fertilized unincubated chicken eggs by infrared spectroscopic imaging. *Analytical and Bioanalytical Biochemistry*, 400, 2775–2782.
- Taebi, B., Correljé, A., Cuppen, E., Dignum, M., & Pesch, U. (2014). Responsible innovation as an endorsement of public values: The need for interdisciplinary research. *Journal of Responsible Innovation*, 1, 118–124.
- Thornton, P. K. (2010). Livestock production: Recent trends, future prospects. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365, 2853–2867.
- Tuytens, F. A. M., Vanhonacker, F., Van Poucke, E., & Verbeke, W. (2010). Quantitative verification of the correspondence between the Welfare Quality® operational definition of farm animal welfare and the opinion of Flemish farmers, citizens and vegetarians. *Livestock Science*, 131, 108–114.
- von Schomberg, R. (2013). A vision of responsible research innovation. In R. Owen, M. Heintz, & J. Bessant (Eds.), *Responsible innovation*. Chichester: Wiley.
- Various Authors. (2003). Avian sex determination and sex diagnosis. *World's Poultry Science Journal*, 59, 5–64. doi:[10.1079/WPS20030002](https://doi.org/10.1079/WPS20030002).
- Weissmann, A., Reitemeier, S., Hahn, A., Gottschalk, J., & Einspanier, A. (2013). Sexing domestic chicken before hatch: A new method for in ovo gender identification. *Theriogenology*, 80, 1–7.
- Woelders, H., Brom, F. W. A., & Hopster, H. (2007). *Alternatieven voor doding eendagskuikens—Technologische perspectieven en ethische consequenties*. Lelystad: Animal Sciences Group, Wageningen Universiteit and Research Centrum.
- Yeates, J. (2009). Death is a welfare issue. *Journal of Agricultural and Environmental Ethics*, doi:[10.1007/s10806-009-9199-9](https://doi.org/10.1007/s10806-009-9199-9).