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A PLEA TO IMPLEMENT ROBUSTNESS INTO A BREEDING GOAL: POULTRY AS AN EXAMPLE

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ABSTRACT. The combination of breeding for increased production and the intensification of housing conditions have resulted in increased occurrence of behavioral, physiological, and immunological disorders. These disorders affect health and welfare of production animals negatively. For future livestock systems, it is important to consider how to manage and breed production animals. In this paper, we will focus on selective breeding of laying hens. Selective breeding should not only be defined in terms of production, but should also include traits related to animal health and welfare. For this we like to introduce the concept of robustness. The concept of robustness includes individual traits of an animal that are relevant for health and welfare. Improving robustness by selective breeding will increase (or restore) the ability of animals to interact successfully with the environment and thereby to make them more able to adapt to an appropriate husbandry system. Application of robustness into a breeding goal will result in animals with improved health and welfare without affecting their integrity. Therefore, in order to be ethically acceptable, selective breeding in animal production should accept robustness as a breeding goal.

KEY WORDS: health, integrity, laying hen, robustness as a breeding goal, welfare

1. INTRODUCTION

There is only a limited number of internationally operating poultry breeding companies that have to provide laying hens worldwide. As a consequence, these companies face a wide variety of environmental conditions in which their laying hens have to perform (Knap, 2005). Differences in environmental conditions can be due to climate, housing facilities, disease pressure, exposure to different pathogens, and differences in feed quality and composition. Laying hens are kept from the cold, dry climates in Siberia to the hot, humid climates in Brazil, from battery cages to free range systems

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that could differ in hygienic circumstances, and are fed corn-based to soy-based diets. Laying hens kept under such different conditions must be able to cope with their environment and, therefore, require sufficient capacities to adapt. Furthermore, these laying hens are expected to produce a maximum number of eggs irrespective of environmental circumstances.

Traditional breeding has resulted in a rapid increase in egg production; in 1930 the average production was 116 eggs per hen per year, whereas nowadays the average production is increased to 300 eggs per hen per year (Preisinger and Flock, 2000). Furthermore, production became even more efficient by intensification; farms increased in size and animals were kept at a higher density (Sandøe et al., 2003).

The combination of breeding for increased production and the intensification of housing conditions have not been without consequences, especially for the animals. Laying hens have become more at risk for behavioral, physiological, and immunological disorders (Rauw et al., 1998) and consequently, for reduced animal welfare. Behavioral disorders include cannibalism,[1] feather pecking,[2] and absence of broodiness behavior[3] (Newberry, 2004, Price, 1999, Savory, 1995); physiological disorders include asymmetric growth[4] (Tuyttens, 2003, Yngvesson and Keeling, 2001) and osteoporosis[5] (Bishop et al., 2000, Whitehead et al., 2003); and immunological disorders include increased susceptibility against Marek's disease[6] (Dalgaard et al., 2003).

[1] Cannibalism is the act of consuming tissue of other members of the same species, whether living or dead, and at any stage of the life cycle. Cannibalistic behavior affects the well-being of attacked laying hens, as evidenced by injuries that, if extensive, result in death (Newberry, 2004).

[2] Feather pecking is characterized as non aggressive pecks towards the plumage of other birds. Generally two forms can be distinguished, i.e. gentle and severe feather pecking. Gentle feather pecking can be defined as repeated pecks at the tips and edges of feathers, mostly ignored by the receiver. Severe feather pecking causes feather damage and feather loss. Flocks with high incidence of severe feather pecking suffer from reduced welfare and higher mortality rates due to cannibalism (Savory, 1995).

[3] Broodiness behavior consists of termination of egg production, the incubation of eggs, and care of the young (Johnson, 2000).

[4] Fluctuating asymmetry is defined as small, randomly directed deviations from perfect symmetrical development in bilateral traits, resulting from the inability of individuals to undergo identical development on both sides of the plane of symmetry. Fluctuating asymmetry provides a useful measure of how well development processes cope with internal genetic and external environmental stressors during morphogenesis (Tuyttens, 2003).

[5] Osteoporosis in laying hens is defined as a decrease in the amount of fully mineralized structural bone, leading to increased fragility and susceptibility to fracture (Whitehead et al., 2003).

[6] Marek's disease is caused by a highly virulent herpes virus. Marek's disease causes paralysis and mortality in laying hens (Bumstead, 2003).

The traditional strategy to reduce these problems is preventive management. Preventive management can be divided in two procedures; physical and non-physical. A physical procedure to reduce feather pecking and cannibalism is beak trimming (Appleby et al., 2004) and non-physical procedures include decrease of light intensity, change of feed composition, environmental enrichment, and optimizing group size (Hester, 2005). To protect against harmful pathogens, vaccination can be used as a physical procedure, whereas high hygiene systems [specific pathogen free systems (SPF)] are used as a non-physical proceeding. Although much research has been focused on improvement of management factors, problems still occur in all types of poultry production systems. Furthermore, management factors used to reduce feather pecking and cannibalism, such as beak trimming and low light intensity, have been associated with welfare problems (Gentle, 1986; Jones and Hocking, 1999; Manser, 1996). Because of these welfare problems, beak trimming is, or will be in the near future, prohibited in parts of Western Europe.

Besides the traditional strategy of preventive management, another possibility is to adapt animals by selective breeding or even genetic modification. Selective breeding can be used to improve health and welfare related traits in laying hens (Jones and Hocking, 1999). Health can be enhanced by selective breeding for disease resistance. This may be effective in resistance to a wide range of pathogens and can be used to protect laying hens under different environmental conditions (Lamont, 1998). Welfare can be enhanced by selection against expression of undesirable behavior. Jones and Hocking (1999) argued that selection against feather pecking and cannibalism might provide powerful, welfare-friendly solutions.

Improving health and welfare by adapting the animal to the housing system, however, can result in violation of the integrity of the animal; for instance, breeding blind laying hens. It is technically possible to breed blind laying hens that do not show feather pecking or cannibalistic behavior. Although these laying hens are blind, they are healthy, able to find food and water, and produce a number of eggs according to the expectations (Ali and Cheng, 1985). These hens also seem well adapted to their situation and, assuming that blind hens do not suffer in any other way, they may live a better life than hens that are able to see. Many people, however, intuitively feel that this is a morally wrong approach to improve animal welfare (Sandøe et al., 1999). In this example, integrity of the laying hens was violated by selective breeding. By making use of genetic modification, violation of the integrity could even be worse.

In present poultry farming, increased occurrence of behavioral, physiological, and immunological disorders affect health and welfare negatively. Preventive management and selective breeding to reduce disorders, like beak trimming or breeding blind laying hens, can affect the integrity of laying hens. For future livestock systems it is, therefore, important to consider how to manage and breed laying hens. In this paper, we will focus on selective breeding of laying hens. We argue that in future livestock systems it is necessary that breeding goals[7] should not only be defined in terms of production, but that they should also include traits related to animal health and welfare. For this we introduce robustness as a breeding goal.

Robustness is a term that is rapidly becoming a main interest in animal production (Knap, 2005, Ten Napel et al., 2006). We like to explore the discussion on robustness as a breeding goal for animals kept in future livestock systems. The concept of robustness is related to the concepts of health, welfare, and integrity, but in our opinion, robustness is more comprehensive. We expect that robustness as a breeding goal will result in better health and welfare without affecting the integrity of the laying hen. Based upon this, we argue that it is ethically acceptable to use selective breeding in order to create animals that are able to function better in conventional agricultural systems.

2. THE CONCEPT OF HEALTH, WELFARE, AND INTEGRITY

Before going into detail about the concept of robustness, the concepts of health, welfare, and integrity will be explored. For the concept of robustness it is important to have a perception about the definitions and considerations behind the realization of the concepts of health, welfare, and integrity. The considerations are important for the implementation of the different concepts into a breeding goal for robustness.

2.1. *The Concept of Health*

Different approaches towards the concept of health can be found in the literature. The very basic definition of health is no more than the absence of disease (Gunnarsson, 2006; Nordenfelt, 2007). Boorse (1997 in Nordenfelt, 2007) defined disease as "a type of internal state that is an impairment of normal functional ability." This definition indicates that disease (and health) are linked to functional ability, i.e., biological functioning (Nordenfelt, 2007). For Boorse (1997), biological functioning is tied to the individual's survival and reproduction. This is, however, a very narrow concept of biological functioning. The broader concept of biological functioning, as a basis for the concept of health, is related to homeostasis, i.e., regulation of the internal environment of living organisms (Gunnarsson, 2006). In

[7] The definition of breeding goal will be elaborated in Section 3.1.

addition, an animal may be in pain and disabled by internal bodily causes (failure in regulating homeostasis) without reducing the probability of the animal's survival. This indicates that there are other possible goals than the one of pure survival (Nordenfelt, 2007). One goal related to health, and commonly used in the debate about animal welfare, is *quality of life*, which includes psychological aspects of health (Fraser et al., 1997). Gunnarsson (2006), however, mentioned that if health is defined as physical and psychological well-being, there will be problems associated with applying the definition to all animals, especially production animals. Gunnarsson (2006) stated that a health definition that puts priority to the physical and psychological well-being of a production animal is misleading in relation to the general purpose of livestock production. In livestock production, economical considerations are involved and can be decisive in the judgment of the animals' health. To achieve good health the animal has to be in harmony with itself and its environment, and has to be in a normal physical condition (free of diseases and other physical disorders) (Rutgers, 1993). Health could then be considered as ''the physical condition required to achieve welfare at an acceptable level'' (Brom, 1997 derived from Nordenfelt, 1987).

2.2. *The Concept of Welfare*

Welfare of farm animals is a major concern, in society, in livestock production, as well as in animal science (Kanis et al., 2004). Animal welfare, however, is a complex concept that is difficult to define operationally, and hence to evaluate empirically (Rowan, 1997). This has led to different welfare definitions.

Fraser et al. (1997) suggested that three main ideas are expressed in public discussion concerning animal welfare: feelings, functioning, and natural living. Fraser et al. (1997) also argued that a scientific approach to animal welfare has to take into account these ideas expressed in public discussion. Animal feelings are related to experiences of animals, i.e., mental harmony, whereas functioning is related to biological functioning, i.e., physical harmony. The concept of experience is based on the presence of positive experiences and the absence of negative experiences, whereas the concept of functioning is based on ''doing well,'' so that the animal is functioning as it should do (Stafleu et al., 1999). The idea that animals should live natural lives includes considerations of an animal's nature or *telos* (Appleby and Sandøe, 2002), which is related to the concept of integrity, and will be discussed later.

A definition of animal welfare related to the concept of experience is that ''animals should feel well by being free from prolonged and intense fear, pain, and other negative states, and by experiencing normal pleasures" (Fraser et al., 1997). Kanis et al. (2004) considered animal welfare as similar to "animal happiness," which can be seen as "the balance between an animal's positive and negative emotions or feelings over a certain time period." It is, however, impossible to ask an animal directly in which situation it feels comfortable and if its preferences are satisfied. Therefore, making use of the concept of experience in scientific studies is rather difficult. To make animal experiences more applicable, the concept of functioning can be used as a tool. The concept of functioning often involves ideas about evolutionary fitness, including successful breeding. When breeding is strongly affected by human intervention, as for production animals, it might be difficult to apply the concept of functioning (Appleby and Sandøe, 2002). The concept of functioning, however, can still be linked to scientific (biological, physiological, social functioning) animal production theories, or models. Definitions of welfare commonly used are often based on the concept of functioning; for instance, welfare definitions given by Broom (1993) "welfare of an animal is reflected by the success of its attempt to cope with its environment" and by Siegel (1995) "welfare depends on physiological ability to respond properly in order to maintain or re-establish homeostatic state or balance."

For scientific models, the concept of functioning is easier to demonstrate than what an animal experiences (Duncan and Fraser, 1997). Although the concept of functioning is more straightforward to quantify, the link between (biological) functioning and the animal's welfare is not always apparent, e.g., there is little consensus on the baseline that should be used in assessing measures and there is less agreement on which levels necessarily denote a better quality of life for the animal. Therefore, assessment of welfare involves a mixture of scientific knowledge and value judgments.

2.3. *The Concept of Integrity*

Integrity has been described by Rutgers and Heeger (1999) as the "wholeness and intactness of the animal and its species-specific balance, as well as the capacity to sustain itself in an environment suitable to the species." The principle of respect for the integrity of animals leads to considerations and arguments beyond animal health and welfare (Grommers et al., 1995). The integrity theory of King (2004) proposed that the value of animal life is such that animals should not be harmed or destroyed. The loss of life itself is conceived as the ultimate harm to the animal's integrity, i.e., to its "completeness."

Integrity gives notion to our own moral position, purposes, and perspectives with regard to animals (Vorstenbosch, 1993). Integrity is not strictly a describing term, but it rather refers to the way we think an animal has to be (Brom, 1997). In the former, we already mentioned the possibility to breed blind laying hens and that many people intuitively feel that this is a morally wrong approach to improve animal welfare. The moral notion that gives voice to this intuition is integrity (Bovenkerk et al., 2002). Another example is non-broody behavior in laying hens. Selection has resulted in strains of chickens that normally do not incubate eggs or brood chicks (Price, 1999). These laying hens seem to be well adapted to their situation and, probably, are still able to brood. However, they do not have the motivation to express their brooding behavior; it is just not natural to them. These two examples clearly show that it is important to consider the nature and biological needs of animals.

According to Rollin (1989), the nature and biological needs are related to the *telos* of an animal. He defined *telos* as "the unique, evolutionarily determined, genetically encoded, environmentally shaped set of needs and interests which characterize the animal in question." Each animal has a *telos* that is unique to its species, it can be seen as the "chickenness of the chicken" or the "pigness of the pig," which are essential to their well-being as speech is to us (Rollin, 1989). He stated that the animal's well-being is determined by the match between its needs and interest and the treatment it receives (Rollin, 1995). Although, the animal's *telos* is unique to its species, Rollin (1995) argued that changing the *telos* of an animal can be justified. He stated that there is no moral problem in making an animal happier or prevent it from suffering by changing its *telos*, unless changes endanger the animal itself, other animals, humans, or the environment. Verhoog (1992), however, insisted that *telos* is of direct moral relevance in itself and should not be violated or changed. He stated that selective breeding is morally questionable, because it represents interference with the natural species integrity and evolutionary development of animals. De Vries (2006), however, stated that selective breeding cannot change the genes of animals, let alone introduce new genes. According to him, integrity is only violated if new genes are introduced to the genome of an animal and, therefore, selective breeding cannot violate the animals integrity. In our opinion, this is too simple; selective breeding can violate the animals' integrity in extreme cases like breeding blind laying hens. We can use selective breeding to improve animals, but only if the animals' identity is preserved.

3. THE CONCEPT OF ROBUSTNESS

3.1. *Introduction to Robustness*

In the previous section we have explored the concepts of health, welfare, and integrity. All three concepts are related to the quality of life of an animal. To improve the quality of life of an animal in future livestock systems these concepts have to be integrated into a breeding goal. The breeding goal defines which traits have to be improved and how much weight is given to each trait. The breeding goal is the direction in which we want to improve the population (Cameron, 1997). The concepts of health and welfare primarily focus on the state of the animal (mentally and physically) in a specific situation. These concepts do not consider animal related traits and, therefore, could not be implemented into a breeding goal. Integrity considers animal related traits, namely, the presence of species specific characters, e.g., it's "completeness." It is, however, not possible to optimize the integrity of an animal, and therefore integrity cannot be improved by selective breeding. For this, we would like to introduce the concept of robustness. The concept of robustness includes individual traits of an animal that are relevant for health, welfare, and integrity. Because robustness includes individual traits, it can be integrated into a breeding goal.

The concept of robustness is defined in different fields, e.g., ecology, biological systems, statistics, and animal production. A broad definition of the concept of biological robustness is "the maintenance of specific functionalities of the system against perturbations, and it often requires the system to change its mode of operation in a flexible way" (Kitano, 2004). This definition can be used as a starting point for definitions of robustness in other fields, like animal production. Knap (2005) defined robust pigs as "pigs that combine high production potential with resilience to external stressors, allowing for unproblematic expression of high production potential in a wide variety of environmental conditions." Whereas Ten Napel et al. (2006) defined robustness in a broad sense as "the minimal variation in a target feature following a disturbance, regardless of whether it is due to switching between underlying processes, insensitivity or quickly regaining the balance," and in a narrow sense as "the ability to switch between underlying processes to maintain balance." The definitions of Ten Napel et al. (2006) are independent of species.

From these definitions, it can be concluded that the main characteristics informative for robustness of production animals are production and adaptation in a wide variety of environmental conditions. Production is important because it is one of the parameters related to the functioning of an animal. Besides, production is important because of its economical value. In the concept of robustness, adaptation can be seen as a mechanism of the animal that enables it to cope with internal or external disturbances, or with changes in the environment. Ideally, we would like to breed a strain of laying hens that can adapt to different environmental conditions. In practice, however, strains of laying hens can perform differently in different environments; this is called genotype by environment interaction (Falconer and Mackay, 1996). As mentioned earlier, there is a limited number of internationally operating poultry breeding companies that provide laying hens worldwide. For these companies, it is favorable to have animals that can function under a wide variety of environmental conditions.

Using the main characteristics informative for robustness, e.g., production, adaptation, and a wide variety of environmental conditions, we define a robust laying hen as "an animal under a normal physical condition that has the potential to keep functioning and take short periods to recover under varying environmental conditions." Functioning can be evaluated in terms of physiological, behavioral, and immunological traits. This definition of robustness includes different measurable characteristics and traits that make the concept of robustness applicable for breeding programs.

3.2. *Implementation of Health in the Breeding Goal for Robustness*

In the definition of robustness, "keep functioning" and "take short periods to recover" are referring primarily to health. The definition of Rutgers (1993), "the harmony between an animal itself and its environment, where the animal is free of diseases and other physical disorders," primarily focuses on "functioning." Whereas the definition of Gunnarsson (2006) "regulation of the internal environment of living organisms," primarily focuses on "take short periods to recover." Robust animals will be less sensitive to disease pressure and are expected to recover more quickly than less robust animals. Therefore, by implementing the concept of robustness as a breeding goal, the health of laying hens should improve simultaneously.

3.3. *Implementation of Welfare in the Breeding Goal for Robustness*

Together, the welfare definitions given by Broom (1993) and Siegel (1995) "welfare of an animal is reflected by the success of its attempt to cope with its environment" and "welfare depends on physiological ability to respond properly in order to maintain or re-establish homeostatic state or balance," respectively, corresponds with the definition of the concept of robustness. The distinction between animal welfare and robustness is that animal welfare is often measured by an animals' response to a current stressor, whereas robustness is based on the possibility to respond adequately to a stressor and is aiming at less disturbed functioning by challenge with a stressor. Implementation of robustness into a breeding goal should result in animals with improved coping abilities for conventional housing systems, and, therefore, should result in improved animal welfare.

3.4. *Implementation of Integrity in the Breeding Goal for Robustness*

As described earlier, the concept of integrity indicates how an animal has to be. We have to be aware that selective breeding can have either positive or negative side effects on the ability to function. Sometimes a change in genotype would be an advantage to both animals and humans (Sandøe et al., 1999). But in other cases it could have a negative side effect. These negative side effects are not only morally problematic due to undesired consequences for health and welfare. They are also problematic because two core elements in the concept of integrity, as described by Rutgers and Heeger (1999) are at issue, namely "the balance in species specifity" and "to sustain itself in an environment suitable to the species." According to Rollin (1995), changing the animal by selective breeding does not necessary lead to impoverishment of the *telos*. In line with this, the notion of integrity is a requirement for robustness. Therefore, improvement of health and welfare by implementation of the breeding goal of robustness should not be achieved by violation of the integrity or impoverishment of the *telos*.

4. APPLICATION OF ROBUSTNESS AS A BREEDING GOAL

As mentioned earlier, robustness embraces health, welfare, and integrity. Therefore, different traits can be implemented in the breeding goal of robustness. To utilize robustness as a breeding goal, the traits have to be (a) relevant, i.e., they have to say something about robustness, (b) simple, i.e., they have to be understandable for users, (c) sensitive, i.e., they have to react to changes in the system, (d) reliable, i.e., different measurements must lead to the same outcome, (e) it must be possible to establish a target value or trend, and (f) data have to be accessible. Robustness as a breeding goal can be used for different production animals. Each production animal has its species specific characteristics. In this paper, we will focus on traits interesting for improvement of robustness in laying hens. An overview will be given of traits that can be implemented into a breeding goal. These traits cover behavioral, physiological, and immune characters. In practical – commercial – context, selection for these robustness traits must be in balance with selection for production traits.

4.1. *Traits to Breed for*

Behavioral traits. To quantify behavioral aspects for robustness in laying hens, parameters like fear, social stress, feather pecking, and cannibalism could be used. The different behavioral parameters are related. For instance, fearful laying hens tend to show more feather pecking behavior (Jones et al., 1995), and severe feather pecking can lead to cannibalism. Methods used to assess fear in laying hens involve fear towards humans or towards a novel object. Whereas determining plumage and skin condition is a method to assess feather pecking behavior. Variation in fearful behavior (novel object test) and incidence of feather pecking exists between genetically different layer lines (Uitdehaag et al., 2007). Rodenburg et al. (2004) estimated heritabilities for fearful behavior (open-field test) and feather pecking behavior ranging between 0.35 and 0.60, and 0.10 and 0.24, respectively. The estimated heritabilities were based on individual measurements. More or less fearful and pecking behavior, however, will also depend on the social behavior of group members, e.g., plumage condition of a hen does not only depend on her own pecking behavior, but also depends on the pecking behavior of her group members. Therefore, it is important to use a breeding method that makes use of information of group members, rather than individual information (Ellen et al., 2007; Muir, 2003).

Immunological traits. Animal health data are rarely straightforward to use. Veterinary treatment records do not give a precise measure for disease (Sørensen et al., 2001), and diagnoses do not normally describe implications useful for robustness. Increasing robustness of animals is important to reduce occurrence of diseases. To reduce occurrence of diseases, animals need a well developed immune systems that adequately responds to invading pathogens. The immunological capacity of animals might be enhanced by genetic selection for disease resistance. Variation in immune competence exists between genetically different layer lines (Star et al., 2007a). Siwek et al. (2006) estimated heritabilities for natural antibodies determined in blood ranging between 0.11 and 0.42, whereas Bovenhuis et al. (2002) estimated heritabilities for specific antibodies ranging between 0.16 and 0.19. Furthermore, immune responses towards environmental stressors vary between layer lines (Star et al., 2007b). Therefore, genetic selection for immune traits may improve resistance to a wide range of pathogens and may be an effective strategy to protect laying hens under a wide variety of environmental conditions (Lamont, 1998).

Physiological traits. Genetic selection for production efficiency can have adverse effects on health. In poultry, for instance, this selection has unwittingly produced birds with poor structural bone mass (Bishop et al., 2000, Whitehead et al., 2003). Laying hens selected for high egg number and low maintenance requirements (which implies a small body mass) can become prone to osteoporosis towards the end of the laying cycle, because of the high metabolism of calcium for egg shell formation. Such birds have fragile bones and when caught and transported, fractures are common (Hughes and Curtis, 1997). Because selection for egg production has contributed to osteoporosis, this implies that susceptibility to osteoporosis has a genetic component. Bishop et al. (2000) found that traits describing bone strength are moderately to strongly inherited, where heritabilities range between 0.30 and 0.45. Therefore, selection for enhanced bone strength can be used to alleviate the problem of osteoporosis in laying hens.

4.2. *Potential for a Successful Result*

In our opinion robustness as a breeding goal can be successful to improve health and welfare of production animals in future livestock systems. Before robustness can be implemented into a breeding goal, large scale genetic research on the different traits has to be done. Large scale genetic research is for most traits labor intensive and expensive. For instance, behavioral measurements and collecting blood samples for immunological parameters have to be done at the individual level.

After determining the most promising traits, the next step will be the implementation of these traits into the breeding goal. Implementation of the traits is difficult and riskful, but the potential of success for robustness as a breeding goal depends on this implementation. One of the difficulties for the implementation is to decide which trait is more important than another, e.g., how much weight is given to each trait. It is, however, important to implement all traits, because the success of selective breeding for robustness depends on all traits and not on a single trait.

Genetic research for robustness traits and the implementation of these traits into the breeding goal have to be established by cooperation between science and breeders. Additionally, successful result of robustness as a breeding goal depends on the opinion and motivation of the farmer. The principle aspects of robustness may be different for each individual farmer (or breeder), but also reference values can change. Besides, in the future, other traits may arise that have to be implemented into the breeding goal of robustness. By implementation of new traits, it is, however, important that these traits concern the animal itself.

Finally, the potential for a successful result of robustness as a breeding goal depends on the economic value. In his decision-making, a farmer has to consider not just animal robustness, but also how to produce efficiently, at competitive cost.

5. QUESTIONS RELATED TO ROBUSTNESS

In this paper, we explored the discussion of robustness as a breeding goal for laying hens kept in future livestock systems. Although we think it is possible to implement robustness into a breeding goal, it still raises several ethical questions like: Is it acceptable to adapt animals to the production environment, rather than by changing their environments? Should animals be adapted to all environments, even the worst? And does selection for robustness affect the integrity of the animal?

When looking at the definition of robustness, a robust animal is an animal that has the potential to keep functioning and take short periods to recover under varying environmental conditions. This indicates that the animal has to function under a wide range of circumstances. It is, therefore, preferable to select for robustness traits that are common to different types of production environments. But, are we really aiming at adapting the animal to even the worst environment? No. The aim is to breed animals that can function well in a range of environments and not to breed animals specifically for the worst environments. However, even in the most optimal environments welfare of laying hens can be improved as illustrated by the fact that they show abnormal behavior. Increasing robustness by selective breeding, therefore, improves welfare by adapting animals to the production environment. This does, however, not take away the need for improvement of housing conditions.

Christiansen and Sandøe (2000) mentioned that breeding for animals that are better suited for intensive farming *instead* of adapting the farming system may be considered violations of animal integrity. This, however, is only the case in those situations where adapting the animal involves diminishing its ability to live a good life or by depriving the animal of natural abilities, such as being able to see. However, improving the ability to cope with stress and improving the ability to recover by using robustness as a breeding goal does not deprive natural abilities, and is, therefore, not a violation of animal integrity. Of course, we have to be aware that when selecting for robust laying hens it is unknown if problems negatively correlated with the genetic make-up underlying robustness will occur.

6. CONCLUSION

The aim of this paper was to develop the concept of robustness as a breeding goal. Improving robustness by selective breeding will increase (or restore) the animals' ability to interact successfully with the environment and thereby to make the animal better able to adapt to an appropriate husbandry system. This, in turn, is likely to improve both welfare and productivity, although this also depends on management and housing conditions.

The implementation and application of robustness as a breeding goal is desirable. We are convinced that this application will result in animals with improved health and welfare without affecting the integrity. Therefore, improving robustness by introducing this concept as a breeding goal is ethically acceptable.

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