Feeding Broiler Breeder Flocks in Relation to Bird Welfare Aspects

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Abstract

To ensure health and reproductive capacity of the birds, broiler breeders are fed restricted during the rearing period, and to a lesser extent also during the production period. Although restricted feeding improves health and thereby bird welfare, on the other hand the birds are chronically hungry and suffer from frustration of the feeding motivation, which has a negative effect on bird welfare. The aim of the current paper is to give an overview of the relation between feed restriction and broiler breeder welfare, and the role of feed (nutritional aspects as well as feeding management) as a possible tool to improve broiler breeder welfare. Possible strategies are 1) dietary dilution, by reducing the energy content and/or increasing the NSP content, by adding soluble (e.g. sugar beet pulp) or insoluble (e.g. oat hulls) fibres to the diet; 2) adding appetite suppressants (e.g. calcium propionate) to the diet; 3) scattering feed in the litter; 4) feeding twice a day, or 5) skip-a-day feeding. Some of these strategies, i.e. dietary dilution or adding appetite suppressants positively affect behavioural patterns of the birds, by reducing stereotypic pecking and eating motivation, and increasing the time spent sitting. These changes, however, can only be considered as indirect parameters of improved bird welfare. It is clear that nutritional strategies can be helpful in reducing hunger stress in broiler breeders. Nutrition, however, cannot fully solve the broiler breeder paradox. The main reason for this paradox is related to breeding goals, that are focussed on improving feed conversion and increasing breast meat percentage. On short term, using dwarf broiler breeder hens could be an alternative. On long term, future genetic selection should be directed on assigning economic values to welfare and including integrity traits in an extended breeding goal.

Introduction

The selection of broiler breeders for increased growth rate has resulted in an increased appetite by modulating central and peripheral mechanisms of hunger regulation. As a consequence, ad libitum feed intake in broiler breeders causes obesity. To ensure health and reproductive capacity of the birds, broiler breeders are fed restricted during the rearing period, and to a lesser extent also during the production period. Although restricted feeding improves health and thereby bird welfare, on the other hand the birds are chronically hungry and suffer from frustration of the feeding motivation which has a negative effect on bird welfare. The restricted feeding of broiler breeders during rearing is generally considered as one of the most important issues with respect to broiler breeder welfare (e.g., (Mench, 2002; De Jong and Guemene, 2011).

The aim of the current paper is to give an overview of the relation between feed restriction and broiler breeder welfare, and to assess the role of feed (nutritional aspects as well as feeding management) as a possible tool to improve broiler breeder welfare.

Growth potential, feed efficiency and reproduction

Over the past 30 years, the growth potential of commercial broilers increased drastically (Renema et al., 2007). Modern broiler strains grow 4.6 times the rate of a 1957 strain (Havenstein et al., 2003b). According to Havenstein (2003a) the 6 fold increase in carcass yield in 2001 stocks fed a 2001 diet compared to 1957 stocks fed a 1957 diet is 85-90% due to genetics, and 10-15% due to nutritional changes. This extreme increase in carcass yield is the result of increased growth potential of the broiler breeders. Ad libitum fed standard broiler breeder chicks consume about 200 g feed per day from week 11 onwards and weighed 4.5 kg at 18 weeks of age (Heck et al., 2004). To prevent serious health problems and to maintain a good production of eggs and chicks as a consequence of this increased growth rate, broiler breeders have to be fed restrictedly at a young age. Over the past 30 years, broiler breeder BW targets have undergone change, although the degree of change is small compared to the large increases in growth potential. As a result, the degree of feed restriction needed to maintain broiler breeder BW targets

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has increased. Over the period from 1979 to 2005 the ratio in BW between broiler breeders to broilers at 6 wk of age in female Hubbard birds decreased from 52% to 27% (Renema et al., 2007).

Decades of selection for meat production traits have impaired the reproductive abilities of broiler breeders (Siegel and Dunnington, 1985). Ad libitum feeding of broiler breeders results in a low egg production which has been associated with multiple ovulations caused by the presence of more than one hierarchy of ovarian yellow follicles during early lay (Hocking et al., 1989). Feed intake during rearing and body weight at sexual maturity seem directly correlated with the number of yellow follicles in the ovary (Hocking, 1993). Feed restriction is necessary to obtain an acceptable reproductive performance in broiler breeders. Restricting the quantity of feed during rearing, breeding period or both significantly reduces the weight of the ovary and the number of large follicles at sexual maturity, the incidence of erratic ovipositions, defective eggs and multiple ovulations (Yu et al., 1992; Hocking, 1993) and results in a lower mortality of the hens (Katanbaf et al., 1989). In addition, restricting the quantity of feed during the rearing period has several repercussions on the different levels of the hypothalamic—pituitary—gonadal axis (Bruggeman et al., 1998). Heck et al. (Heck et al., 2004) compared ad libitum and restricted fed broiler breeders. Restricted feeding delayed sexual maturity by 6 weeks and the peak of lay by 7 – 8 weeks. The maximal laying rates, however, were 83.3% for restricted fed hens, versus 57% for ad libitum fed hens. The restricted fed birds showed a good persistency, whereas the rate of lay of the ad libitum fed group rapidly decreased to only 20 to 25% after peak production. A significantly higher proportion of eggs were laid with multiple-yolk, soft or broken shells by the ad libitum fed hens than by the restricted fed hens, resulting in a reduced percentage of settable eggs in the former group. Mortality was 40.4% in the ad libitum fed hens versus 5.6% in the restricted fed hens.

Dietary energy and protein content

The main focus during the rearing period is to meet the target weight of the pullets. Less attention is given to chemical composition (protein and fat content) of these birds. Compared to broilers that were common 30 years ago, the modern broilers have 8.7% more breast fillet, while percentages of abdominal fat and total fat are reduced by 1.9% and 7.1%, respectively (Havenstein et al., 2003a). These changes in chemical composition are reflected in the broiler breeders as well. It is hypothesized that a reduction in abdominal and total fat content of broiler breeders might affect performance during the laying period. The key problem in the (Dutch) broiler breeder sector is the decreasing trend of hatchability. An inventory in practice showed that egg hatchability between 2002 and 2007 in the Netherlands reduced by 0.7% per year (Van Emous, non-published data). It is suggested that this reduced fertility could be related to a deficiency of fat reserves. Adipose tissues are responsible for the production of fertility hormones (oestrogen). Therefore, it can be imagined that a too low fat content negatively affect fertility parameters. Moreover, the current feed recommendations between 20 and 30 weeks of age do not meet the energy requirements, as recently calculated by Rabello et al. (2006). It is suggested that the birds have to prioritize their nutrient distribution to own body weight gain and plumage development, or to their progeny. This might explain the low viability of day-old broilers produced by modern broiler breeders at the onset of lay. It is also suggested that the low body fat reserves of the broiler breeders seemed to be related to the reduced persistence and hatchability during the second part of the laying period. Increasing the amount of feed, without changing the diet composition, seems not sufficient to solve the mentioned problems. Additional standard feed, thereby providing extra dietary protein, undesirably will stimulate muscle tissue development, which subsequently will increase the energy demand of the birds. Moreover, a negative relation between a high amino acid intake (e.g. lysine, and isolysine) and hatchability was shown (Coon et al., 2006). Therefore, it is expected that providing more energy to pullets and young broiler breeders, while simultaneously maintaining protein supply (by increasing energy to protein ratio), will stimulate body fat deposition and egg performance.

Consequences of feed restriction for bird welfare during rearing and production

The interaction between nutritional and reproductive traits is complex and continually changing with the introduction of new genetics. It is necessary to provide enough, but not excessive nutrient intake for maximum egg production. Female broiler breeders that are full fed have decreased total egg output (Robinson et al., 1991; Yu et al., 1992b) and adverse changes in ovarian function leading to multiple ovulation and poor fertility (Hocking, 2009). However, too severe feed restriction can result in a decrease in egg production as well (Wilson and Harms, 1986).

With respect to bird welfare, unrestricted feeding in broiler breeders leads to heavy body weights, associated with severe pathological conditions such as lameness and premature death, that have a negative effect on bird welfare (Mench, 2002). However, despite the positive effect on health and reproduction efficiency when adult, there is substantial evidence that the applied feed restriction, especially during rearing, has negative effects on broiler breeder welfare. In commercially applied restriction programs feed intake is restricted to about 25-33% of the intake of ad libitum fed birds of the same age during rearing (Savory and Kostal, 1996); (De Jong et al., 2002) and it is restricted to 50-90% of ad libitum intake of hens at the same age when they are in lay (Bruggeman et al., 1999). The restricted feeding regime results in a reduction of body weight of adult birds of approximately 40-50% of that of unrestricted fed birds (Katanbaf et al., 1989; Savory et al., 1996). Numerous studies have shown that feed restricted broiler breeders show behaviours indicative of frustration, boredom and hunger, like stereotypic object pecking, overdrinking and pacing (see (De Jong and Jones, 2006) and (D'Eath et al., 2009) for an overview). Stereotypic pecking is mainly observed after feeding, and may be directed at the litter, drinker, (empty) feeder, the walls of the pen or to other birds (Kostal et al., 1992; Savory and Maros, 1993; Savory and Kostal, 1996; De Jong et al., 2002; Hocking et al., 2002). Restricted fed birds spend considerable time on stereotypic pecking. For example, at eight weeks of age it has been observed that restricted fed broiler breeders spent about half of the observed time on stereotypic pecking at the empty feeder (De Jong et al., 2002). To prevent overdrinking, water intake is often restricted in practice. Pacing is mainly apparent before the birds are fed (Savory and Maros, 1993). The amounts of stereotypic pecking and pacing are positively correlated with the level of feed restriction (Savory and Maros, 1993; Hocking et al., 1996). It has also been reported that aggressive pecking, caused by feeding competition, is increasing in prevalence in commercial flocks of broiler breeders which is also detrimental for bird welfare (Jones et al., 2004). In addition, when feed is supplied birds may run over each other to reach the food which may cause skin damage (scratches, wounds) which has negative consequences for bird welfare (De Jong, unpublished observation).

It has been shown that feed restricted broiler breeders have a very high feed intake motivation. Using operant conditioning, it has been shown that the motivation to eat in broiler breeders kept under commercial restriction programmes was approximately four times as high as that of unrestricted fed birds that had been subjected to food withdrawal for 72 h (Savory et al., 1993). The compensatory feed intake (where previously restricted animals are allowed unrestricted access to food) of broiler breeder pullets is linearly related to the level of restriction they were subjected to (De Jong et al., 2003). Broiler breeder pullets fed commercial restriction programmes had a three times higher relative compensatory feed intake (feed intake/g metabolic weight) as compared to unrestricted fed birds. In addition, this very high level of feed consumption was maintained for several days and still two times higher than the intake during the feed restriction period after three weeks (De Jong et al., 2003).

Feed restricted broiler breeders may also show physiological signs of stress. Broiler breeders fed at commercially applied restriction levels showed chronically elevated plasma corticosterone levels (Hocking et al., 1996; Savory and Mann, 1997; De Jong et al., 2002). However, it is unclear yet whether these elevated plasma corticosterone levels reflect psychological stress, metabolic effects resulting from feed restriction or both (De Jong et al., 2003). Some studies also reported increased H/L ratios, indicative of chronic stress (Maxwell, 1993), in restricted fed birds (Hocking et al., 1993; Savory et al., 1993; Hocking et al., 1996). However, other studies could not find increased H/L ratios in restricted fed birds (Savory et al., 1996; Hocking et al., 1999; De Jong et al., 2002). Thus, although there is substantial evidence from behavioural studies that feed restriction is a potent stressor, there is poorer agreement between different studies when physiological indicators of hunger are considered (D'Eath et al., 2009).

Physiology of hunger feeling in broiler breeders

Jungle fowl spend 60% of their time on eating and foraging (Dawkins, 1989). Modern laying hens still spend up to 52% of their time on feeding related behavior (Aerni et al., 2000), showing that the behavior of the modern bird is very similar to that of its ancestor (Dawkins, 1989). As a consequence of restricted feeding, broiler breeder pullets, however, spend less than 15 min per day on eating (Savory and Maros, 1993; Savory et al., 1996; De Jong et al., 2002), indicating that these types of birds are not fulfilling their natural time budgets. The signs of stress and frustration, that are observed when broiler breeders are fed restrictedly, indicate that they are willing to consume more feed than they are offered (De Jong et al., 2002; De Jong et al., 2003). Feed intake and feed intake motivation are the result of a complex of different mechanisms, which involve regulation by the central nervous system, hormones and nutrient levels in blood and tissues (Boorman and Freeman, 1979; Forbes, 1988; Forbes, 1995; Forbes, 1999).

The motivation to consume feed can be induced by the emptying of the digestive tract. Information from mechanoreceptors in the wall of the crop, gizzard and intestines, and from specific chemoreceptors in the intestinal walls, is transferred to the central nervous system (Mei, 1985; Greenberg et al., 1989; Forbes and Barrio, 1992). The emptying of the digestive tract is mediated by gastro-intestinal hormones, which are produced when feed or specific nutrients are present in the intestinal tract. The release of these hormones reduces feed intake (Kuenzel, 1994) and slows down feed passage rate (Cuche and Malbert, 1999; Cuche et al., 2000). The gizzard, obviously, plays a regulatory role in feed passage and it is thought that accumulation of insoluble fiber in the gizzard triggers a temporary satiety (Hetland et al., 2004; Van Krimpen et al., Accepted for publication). High insoluble fiber diets accumulate in the gizzard, probably because the fiber has to be ground to a critical particle size before entering the small intestine (Hetland and Choct, 2003; Hetland et al., 2004).

The filling or emptying of the digestive tract is mediated by homeostatic plasma glucose levels (Edwards et al., 1986; Forbes, 1999) or gastro-intestinal hormones, such as cholecystokinin (CCK) and neuropeptide Y (NPY), which are produced when feed or specific nutrients are present in the intestinal tract. It has already been established that CCK, NPY, glucose (insulin) and corticosterone exert some of their effects on behavior and appetite through interaction with 5-HT and DA pathways e.g. (Morley and Blundell, 1988).

The mechanisms that determine the bird to start or stop eating, however, is only partially understood.

According to (Savory et al., 1981) maximum feed intake capacity in broiler breeders is more determining feed intake than nutrient levels in blood after feed consumption. Burkhart et al. (1983) concluded that selection for an increased growth rate in broilers has resulted in a reduction in satiety due to nutrient levels in blood and has leaded to feed intake levels at near-capacity of the digestive tract. Likewise, eating behavior of modern broilers is more controlled by physical satiety mechanisms than by hunger mechanisms (Bokkers and Koene, 2003). This indicates that diets that increase gastrointestinal filling, or decrease feed passage rate, might increase satiety levels in broiler chickens and their parents.

There are almost no indications that digestible nutrient levels in isocaloric and isonitrogenous diets with balanced amino acid profiles can affect satiety. Hocking et al. (2004a) suggested that diets with sugar beet pulp could improve satiety and welfare due to a higher water content in the digestive tract, as a consequence of an increased bulk capacity of the diet. In poultry, soluble fibers seem to more effective in increasing satiety, due to an increased digesta viscosity and reduced feed passage rate compared to insoluble fibers (Van der Klis et al., 1993; Smits et al., 1997).

In most species, including poultry, the neurotransmitters serotonin (5-HT) and dopamine (DA) play a role in the regulation of hunger, satiety, and eating (Denbow, 1999; Richards, 2003; Van Hierden et al., 2004a). Potential nutritional factors that influence feed intake behavior are tryptophan (TRP) and tyrosine (TYR) (Van Hierden et al., 2004b) that serve as biosynthetic precursors for 5-HT and DA, respectively (Groff and Gropper, 1999). Van Hierden et al. (2004a; 2005) showed that high levels of dietary TRP increased 5-HT and DA in the brains and consequently increased the time spent eating. The impact of specific dietary nutrients on the signals that determine feed intake regulation and satiety in the brains of laying hens, however, is still poorly understood.

Recently, we showed that dietary energy reduction affected serotonin turnover and dopamine turnover, whereas an increase of coarsely ground insoluble NSP's in the diet affected the levels of plasma glucose, corticosterone, and dopamine turnover (Van Hierden et al., 2002; Van Krimpen, 2008). Furthermore, significant effects of these nutritional factors were found on mean retention time of the digesta in the foregut (Van Krimpen et al., Accepted for publication). More research, however, is needed to understand the role of CCK, NPY, glucose, and corticosterone in initiating hunger, satiety, and feed intake behavior.

How to improve broiler breeder welfare?

During the past 20 years research has focused on practically applicable management strategies to reduce the negative effects of feed restriction while maintaining the desired growth rate. Generally applied measures were a changed feeding strategy or changed diet composition, which are discussed below.

Diet composition

Several studies have evaluated the use of low-density diets (qualitative restriction) as a possible method to reduce stress and hunger due to quantitative feed restriction in broiler breeders.

Savory et al. (Savory et al., 1996) tested diets diluted with unmolassed sugar beet pulp, two concentrations of oat hulls or sawdust up to 10 weeks of age. Although the incidence of stereotypic pecking significantly reduced, activity levels were not affected and the use of sugar beet pulp and sawdust even increased H/L ratios and plasma corticosterone concentrations. In a subsequent study, neither feeding motivation nor activity levels were affected by feeding diets with 15% oat hulls (Savory and Lariviere, 2000).

Hocking et al. (Hocking et al., 2004b) used diets diluted with 50 g/kg, 100 g/kg or 200 g/kg extracted sunflower meal, ground unmolassed sugar beet pulp or ground oat hulls during rearing and measured behaviour as well as H/L ratios. Body weights at 15 weeks of age decreased with increasing fibre concentrations. Results showed that diets with 50 g/kg sugar beet pulp or the highest concentration (200 g/kg) of oat hulls reduced stereotypic object pecking. H/L ratios were higher in the standard control diet as well as with the lowest (50 g/kg) concentration of fibres. In addition, birds fed the diets with sugar beet pulp showed a decreased prevalence of damaged pecking and cannibalism. Thus, the results indicate that welfare of birds fed the diets with 200 g/kg oat hulls or sugar beet pulp may be improved. The authors suggested that diets with sugar beet pulp were associated with higher water contents in the gastrointestinal tract, which might improve satiety and thus bird welfare.

De Jong et al. (De Jong et al., 2005a) tested four different diets during the rearing and laying period. The standard diet was either diluted with extracted sunflower seed meal, wheat bran, lucerne, wheat gluten feed, and palm kernel meal in two concentrations or with sugar beet pulp and oats. The diet with the lowest density (8.4 MJ/kg) appeared to reduce hunger and frustration in the first half of the rearing period, which was indicated by reduced stereotypic pecking behaviour. There were no differences between the diet diluted with sugar beet pulp and oats, or the other diluted diet with the same energy content. From this study it was concluded that for substantial improvement of broiler breeder welfare, more extreme diet modifications using higher fibre concentrations or combinations with appetite suppressants were required.

Others did not find any positive effects at all of high fibre contents in diluted broiler breeding diets (up to 6.6 MJ/kg) on behavioural and physiological indicators of welfare ((Zuidhof et al., 1995; Jones et al., 2004; Hocking, 2006). In contrast, a combination of calcium propionate (an appetite suppressant) and 400 g/kg oat hulls appeared to be a viable alternative to commercial quantitative feed restriction, which was indicated by a change in a couple of parameters indicative of hunger (Sandilands et al., 2006). Besides that stereotypic pecking was virtually absent in this treatment group. Also the time spent sitting significantly increased and feeding motivation (by measuring rate of eating) was reduced as compared to broiler breeders fed a quantitative restricted diet, suggesting improved welfare due to reduced hunger in these birds (Sandilands et al., 2005; Tolkamp et al., 2005; Sandilands et al., 2006). However, appetite suppressants may have their effect by causing the bird to feel ill and, as a consequence, have a reduced appetite (Hocking and Bernard, 1993). It can thus be questioned if bird welfare is indeed improved when these suppressants are used. Savory (Savory et al., 1996) only found a significant effect of appetite suppressants on stereotypic pecking but not on other welfare indicators.

Steenfeldt and Nielsen (2010) tested diets with high levels of soluble fibre or insoluble fibre in the rearing period, using scattered feeding. Levels of tail pecking were highest in birds fed control diets, lowest in birds fed the diet with soluble fibre and intermediate in birds fed diets with insoluble fibre. In addition, birds fed the control diet ate significantly more in a hunger test as compared to the two experimental diets. Stereotypic pecking was never seen in birds fed the diet with insoluble fibre and frequently seen in birds fed the control diet. However, birds fed the soluble fibre diet seemed to be scruffier in their plumage, probably due to the high water content of their litter, affecting their thermoregulation. They concluded that a high insoluble fibre content may improve the welfare of broiler breeders.

It is currently studied in our group if diets providing more energy to pullets, while simultaneously maintaining protein supply, will be helpful in reducing hunger in broiler breeder pullets.

Feeding management

Besides evaluating the effects of dietary dilution, the effects of changing feeding management have also been studied. De Jong et al. (De Jong et al., 2005b) studied if scattering the feed in the litter or feeding twice a day might have a positive effect on broiler breeder welfare. However, both feeding strategies did not have any positive effects on behavioural and physiological indicators of stress and hunger. In practice, skip-a-day feeding programmes are often used in the rearing period. It has been shown that skip-a-day

feeding did not impose more stress in the birds as compared to every day feeding, measured by behavioural observations and H/L ratios (Skinner-Noble and Teeter, 2009 in EFSA, 2010).

Other strategies to reduce the negative effects of feed restriction

Environmental enrichment during rearing may alleviate frustration of the feeding motivation. Hocking and Jones (Hocking and Jones, 2006) provided bunches of strings and bales of wood shavings from hatch or from 8 weeks of age onwards in commercial houses with broiler breeder females. Behaviour and the feather and skin condition were observed throughout rearing. Birds used the bales of wood shavings, but the bunches of string were not extensively used. However, providing the environmental enrichment did not reduce aggression due to competition for food and no positive effects of enrichment on feather and skin damage were found.

With respect to bird welfare the use of other genotypes of broilers, i.e. with a slower growth rate and dwarf breeds, will be other alternatives to reduce the negative effects of feed restriction (Jones et al., 2004; De Jong et al., 2005a; Decuypere et al., 2007). The dwarf genotypes only concern one sex (females), but numerically the problem of feed restriction concerns many more females than males and it thus may be a solution for a large part of the broiler breeder population. However, they will correspond only to a specific market demand, because their use is approximately 20% in all Europe, but is around 85% in France (EFSA, 2010), and the use of dwarf or other slower growing genotypes is unacceptable for economic reasons in many cases. Decuypere et al. (Decuypere et al., 2006) suggest that future genetic selection might attempt to uncouple control of ovarian follicular growth factors from selection for rapid growth – thereby allowing breeders to be fed at a higher level without penalising reproductive performance.

Interpretation of the results

Assessing the effects of changed feeding strategies or changed diet compositions involves the use of indirect indicators of animal welfare, like stereotypic and redirected pecking behaviour, increased activity levels, or physiological indicators of stress like increased corticosterone levels or H/L ratios. However, the meaning of these indicators for hunger can be interpreted differently as extensively discussed by (D'Eath et al., 2009). Therefore, more research will be necessary, both to develop alternative feeding strategies or diets as well as to develop methods to measure a subjective feeling like hunger.

Concluding remarks

The paradox in broiler breeders is that they are selected for fast growth and efficient meat production, supported by a virtually voluntary feed intake, whereas fast growth is negatively correlated to reproduction effectiveness. To prevent negative effects on reproduction, broiler breeders are fed restricted. This induces a second paradox; acceptable reproduction and health versus hunger, stress and impaired welfare. The main reason for this paradox is related to breeding goals, that are focussed on improving feed conversion and increasing breast meat percentage. Nutritional strategies cannot solve this paradox, but can be helpful in reducing hunger stress in broiler breeders. Strategies that seemed to have a positive effect on broiler breeder welfare are (1) Dietary dilution, by reducing the energy content and/or increasing the NSP content, by adding soluble (e.g. sugar beet pulp) or insoluble (e.g. oat hulls) fibres to the diet; and (2) Adding appetite suppressants (e.g. calcium propionate) to a diluted diet. Changed feeding strategies, like scattering feed in the litter or feeding twice a day seemed not to have a positive effect on bird welfare.

A qualitatively feed restriction allows the birds to consume more feed which might increase mechanical satiety. It remains unclear whether certain feeding strategies will increase chemostatic satiety. In some experiments, dietary dilution had no positive or even adverse effects on birds behaviour. Other studies, however, showed that these feeding strategies positively affected behavioural patterns of the birds, like a reduction in stereotypic pecking and eating motivation, and an increase in time spent sitting. These changes, however, can only be considered as indirect parameters of improved bird welfare. More research will be necessary, both to develop alternative diets as well as to develop methods to measure a subjective feeling like hunger.

Using dwarf broiler breeder hens is another alternative to overcome the dilemma, because dwarf hens combine relatively good reproductive fitness with ad libitum feeding. Future genetic selection might attempt to uncouple control of ovarian follicular growth factors from selection for rapid growth, which seems a structural solution for solving these paradox. Another possibility is to accept lower broiler

productivity by assigning economic values to welfare and including integrity traits in an extended breeding goal.

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