Motivation of Hens to Obtain Feed During a Molt Induced by Feed Withdrawal, Wheat Middlings, or Melengestrol Acetate[1]

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ABSTRACT Traditionally, molting was initiated by withdrawing feed. However, public criticism of feed deprivation, based on the perception that it inhumanely increases hunger, has led the poultry industry to ban the practice. Thus far, alternatives have not been demonstrated to ameliorate the increase in hunger that led to the ban on inducing molting by feed deprivation. Incorporating melengestrol acetate (MGA), an orally active progestin, into a balanced layer diet induces molting and increases postmolt egg quality. Hy-Line W-98 hens (n = 60) were randomly assigned to a balanced layer ration (control), a balanced layer ration containing MGA, or a 94% wheat middlings diet (wheat) for 20 d, or were feed deprived for 8 d. Hens were trained to peck a switch to receive a feed reward based on a progressive ratio reinforcement schedule. Motivation of hens to acquire feed was measured as the total number of pecks recorded in 15 min on d 0, 4, 8, 12, 16, and 20. On d 20, abdominal fat pad and digesta-free gizzards were weighed. The number of pecks in the feed-deprived group was greater than controls by d 4 and remained greater at d 8, when these hens were removed from the experiment. Hens in the wheat group that were rewarded with a layer diet pecked more than controls from d 8 to 20. Hens in the MGA group pecked for a reward at the same rate as control hens throughout the experiment. Hens fed the wheat diet had heavier gizzards compared with control and MGA-fed hens. Hens fed MGA had greater abdominal fat pad compared with wheat and control hens. Hens molted using a diet containing MGA have a similar motivation to obtain feed as control hens; therefore, this alternative does not appear to increase hunger. However, hens molted with a wheat middling diet appear to be as motivated to obtain feed as did the feed-deprived hens.

Key words: molting, hunger, laying hen, well-being, motivation

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INTRODUCTION

Inducing hens to molt increases egg quality and egg production, and extends the productive life of hens. Until recently, an acceptable method of molting included a 10- to 14-d period of feed deprivation. Due to consumer concerns, in 2000, McDonald's Corp. (purchaser of over 1 billion eggs each year) stated that they would no longer purchase eggs produced by hens that had undergone a feed deprivation-induced molt (Gast and Ricke, 2003). Therefore, recent research has examined alternative molting procedures that do not include a feed deprivation period, attempting to address hen well-being while remaining practical for producers.

The current alternatives with potential for application include feeding diets with altered nutrient content. These include low-nutrient-density diets such as 94% wheat middlings diet (Biggs et al., 2004), or diets with alterations in mineral content (i.e., low calcium, low sodium, or high zinc; Douglas et al., 1972; Nesbeth et al., 1976; Berry and Brake, 1987). These alternatives appear to address hen well-being by providing hens with some type of feedstuff during the molting process. However, these alternative practices have been shown to increase hen paralysis, or can result in kidney and adrenal damage, dehydration, and extreme loss of BW (Siegle, 1961; Lumijarvi et al., 1966; Douglas et al., 1972; Nesbeth et al., 1976; Biggs et al., 2004; Kim et al., 2006). Only a limited number of experiments have assessed hen well-being during an induced molt with an alternative feedstuff. For example, Biggs et al. (2004) found no difference in the social behavior of hens fed 94% wheat middlings compared with hens that were not fed for 10 d.

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Recently Koch et al. (2005a,b) developed a method of molting using melengestrol acetate (**MGA**) that allows the hen ad libitum access to a nutritionally balanced ration. This new method results in regression and rejuvenation of the reproductive tract and increases postmolt performance. The need exists, as with any alternative to traditional molt, to evaluate whether the alternative diet allows the hen to feel fully satiated. Determining hen well-being is complex, making the data obtained from particular experiments difficult to interpret. Using operant conditioning, an animal can be trained to perform a specific task to receive a reward in a manner designed to measure the animal's motivation. This method has been extensively used in swine to determine motivation and preferences (Hocking et al., 1993; Roberts et al., 1997; De Jong et al., 2002). In addition, the method has been adapted to the poultry industry to test the motivation of broiler breeders to obtain feed during periods of feed restriction (Savory et al., 1993, 1996; Savory and Lariviere, 2000).

Behavioral data collected during a previous experiment (our unpublished data) showed that feed-deprived hens and hens fed wheat middlings exhibited elevated activity, measured by angular velocity (degrees turned by the hen per s) compared with hens fed a layer ration containing MGA or control hens fed a layer ration. These data indicated that feed-deprived and wheat-fed hens were more active. We hypothesized that this activity was indicative of the hens experiencing increased hunger, and thus we designed the following experiment.

The objective of the experiment was to determine how the motivational state of hens changed in response to induced molting using 3 molting methods: a wheat middlings diet, a balanced layer diet including MGA, and feed deprivation.

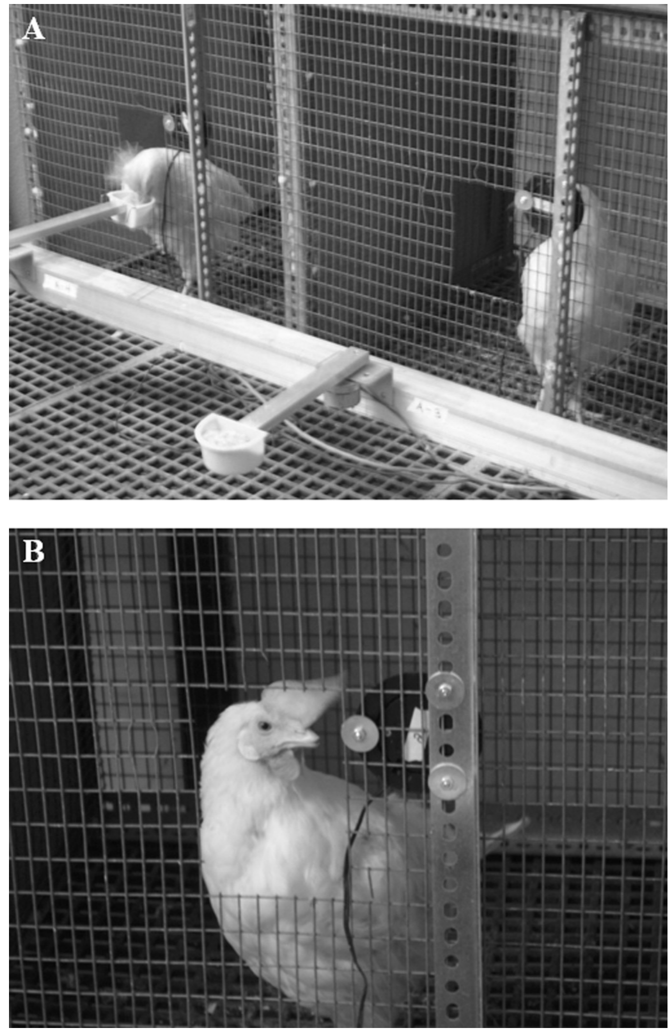

Figure 1. Test apparatus used for motivation testing. A) Two testing pens separated by a partition. The hen on the left is obtaining a reward (feed pan is in the feeding position) following activation of the switch, and the hen on the right is in the processes of activating the switch (the feed pan in the nonfeeding position); B) The switch is located to the hen's left relative to the opening in the pen.

MATERIALS AND METHODS

Hy-Line W-98 laying hens (n = 160) at 68 wk of age were housed 2 per cage with 774 cm^2 of floor space per bird and exposed to 18 h/d of light in 1 of 4 identical rooms. Hens were fed a corn and soybean meal-based diet, balanced to meet National Research Council requirements (NRC, 1994) and provided ad libitum access to water for 12 wk before the start of the experiment. All procedures involving animals were approved by the West Virginia University Animal Care and Use Committee (No. 05-0803).

Feeding Motivation: Training and Testing

The operant system for measuring feeding motivation consisted of 2 banks of five 53 × 53 × 53 cm testing pens (10 pens total), each containing a red switch, 5.5 cm in diameter (Jelly Bean Switch, 100JBR, Ablenet Inc., Roseville, MN), located next to a 8.8- × 13.2-cm opening in the wire (Figure 1). All pens contained a solid partition to limit the view of adjacent pens. The opening allowed a standing hen to extend her head out of the pen and eat from the feed pan. The feed pan was fixed to the end of a metal arm, which rotated in a horizontal plane driven by an electric motor (6RPM, CRA103-ND, Digi-Key Corp., Thief River Falls, MN). The hen was trained to peck at the switch, sending a signal through a circuit box that lengthened and amplified the signal, then to a switch box (Switch and Sense 8, Measurement Computing Corp., Middleboro, MA) to the computer. The computer recorded the number of pecks and, according to the programmed reward schedule, turned on the motor (through the switchbox and a solid-state relay) for the amount of time required to turn the arm 180° from the nonfeeding position to the feeding position. It remained in that position for 3 s to allow the hen access to feed. The motor was again activated automatically after 3 s and the arm turned back to the nonfeeding position.

Training began at 70 wk of age and consisted of a 20-min session every other day for 7 wk, ending 2 wk before treatments were applied. Training began by placing the hen in the testing pen with free access to the stationary feed pan in front of the pen. Once the hens were success-

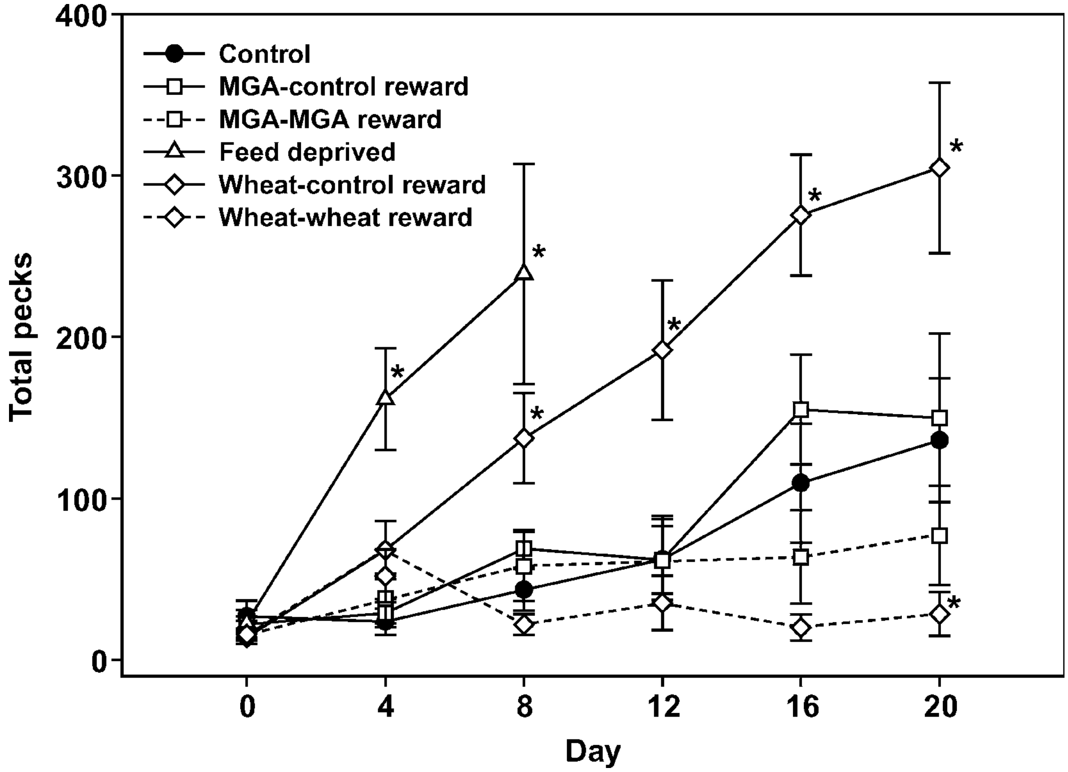

Figure 2. The total number of pecks performed in 15 min on d 0, 4, 8, 12, 16, and 20 by hens receiving the control diet, melengestrol acetate diet (MGA) with MGA reward, MGA with control reward, wheat middlings diet with wheat reward, wheat middlings diet with control diet reward, or undergoing feed deprivation. *Means ± SEM were different from control ($P < 0.05$).

fully eating from the stationary feed pan, they were trained on a fixed reward schedule of 1 peck to 1 feed reward. Hens were considered successfully trained if they received at least 8 feed rewards in 2 consecutive training sessions. A total of 160 hens entered the training program, after which 60 of the most successfully trained were selected to be included in the motivation testing.

Testing of the hens began at 79 wk of age, when treatments began, and was conducted on d 0, 4, 8, 12, 16, and 20. On the test day, 1 h after the lights came on, hens were removed from their home cage and placed in the testing pen for 15 min. During this time they were rewarded on a progressive ratio schedule that required 1 peck at the switch for the first feed reward, and then 1 additional peck for each successive reward. Savory et al. (1993) showed that this progressive ratio schedule was a sensitive indicator of variation in feeding motivation. During the session the total number of pecks and the number of feed rewards received were recorded for each hen.

Feeding motivation was determined separately using the treatment diet or the control diet, due to possible differences in palatability. All hens were trained in the operant task using the control diet (layer ration). During testing, the control hens (n = 10) and the feed-deprived hens (n = 10) were always rewarded with the control diet. There were 2 groups of wheat hens: one group received the wheat middlings diet as their feed reward (n = 10; wheat-wheat reward), whereas the other group received the control diet (n = 10; wheat-control reward). Similarly, there were 2 groups of MGA hens, one of which received the same diet as their reward (n = 10; MGA-MGA reward), whereas the other received the control diet (n = 10; MGA-control reward).

Before the start of the experiment hens were randomly assigned to 1 of 4 experimental diets. Experimental diets consisted of a layer ration balanced to meet NRC requirements (control; n = 10; Koch et al., 2005a; NRC, 1994), a balanced layer ration containing 7.27% MGA in propolyene glycol (MGA; n = 20; Koch et al., 2005a), a wheat middlings diet containing 94% wheat middlings, 4.87% limestone, 0.38% dicalcium phosphate, 0.30% salt, and 0.45% vitamin and mineral premix (wheat; n = 20). Hens in the MGA, wheat, and control treatments were fed experimental diets for 20 d, whereas feed-deprived hens had feed withheld for 8 d of the experiment (feed deprived; n = 10). With the exception of hens in the feed-deprived treatment, all hens had ad libitum access to feed. Total feed intake was determined for each group, once for the duration of experiment.

Tissue Collection

Hens were weighed following motivation testing on d 0, 4, 8, 12, 16, and 20. On d 20 all remaining hens (i.e., excluding feed-deprived hens) were euthanized to obtain abdominal fat pad and digesta-free gizzard weights.

Statistics

Effects of treatments and rewards on feeding motivation were determined by repeated-measures ANOVA utilizing the GLM procedure of SAS (version 8.2, SAS Institute, Cary, NC). The treatments included control, MGA-control reward, MGA-MGA reward, feed deprived, wheat-control reward, and wheat-wheat reward. If there was a treatment by day interaction, treatment means were separated utilizing the PDIFF option of the LSMEANS procedure. Effects of treatments on BW were determined by repeated-measures ANOVA utilizing the GLM procedure of SAS. The treatments included control, MGA, feed-deprived, and wheat. Means were separated utilizing the PDIFF option of the LSMEANS procedure. Effects of treatments on gizzard and abdominal fat pad weights were determined by ANOVA utilizing the GLM procedure of SAS. Treatments included control, MGA, and wheat (only collected on d 20). Means were separated utilizing the PDIFF option of the LSMEANS procedure of SAS.

RESULTS

During the motivation tests, hens in all treatments pecked the switch at the same rate on d 0 ($P > 0.80$) at the initiation of the experiment (Figure 2). Compared with control hens, feed-deprived hens pecked at a greater rate on both d 4 and d 8 ($P < 0.0003$, Figure 2). Hens on the wheat diet that were rewarded with the layer ration pecked more to obtain a feed reward from d 8 to 20 compared with control hens ($P < 0.01$, Figure 2). On the last day of testing, the wheat hens rewarded with feed containing 94% wheat middlings (their treatment diet) performed fewer pecks than control hens ($P < 0.004$, Figure 2). Control hens and MGA hens, regardless of their reward, pecked at a similar rate throughout the experiment ($P > 0.12$, Figure 2).

At the initiation of the experiment, hen weight was the same among groups ($P > 0.70$, Figure 3). On d 4 both the feed-deprived hens and the wheat-fed hens weighed less than the control hens ($P < 0.001$, Figure 3). Feed-deprived hens exhibited a continued decrease in BW up to d 8, when they were removed from the study. On d 8, both MGA- and wheat-fed hens weighed less than control hens ($P < 0.01$, Figure 3). Due to a gradual decrease in BW for control hens and a gradual rebound in BW for MGA- and wheat-fed hens, the latter 2 groups only tended to weigh less on d 16 ($P < 0.07$) and did not differ in BW for the remainder of the experiment ($P > 0.30$, Figure 3). Feed intake was 111.3, 117.0, and 112.4 g/d per hen for the control, MGA, and wheat groups, respectively.

Necropsy at d 20 showed that wheat-fed hens had heavier gizzards than either MGA-fed or control hens (32.5 ± 0.7, 24.1 ± 0.8, and 24.3 ± 0.7 g, respectively; $P < 0.0001$). Abdominal fat pad weight was greatest in MGA-fed hens compared with either control or wheat-fed hens (48.6 ± 6.3, 15.1 ± 2.3, and 9.4 ± 1.8 g, respectively; $P < 0.0001$).

DISCUSSION

The feeling of hunger is a subjective state and thus difficult to fully assess. However, many researchers have risen to this challenge (e.g., Dawkins, 1983; Lawrence and Illius, 1989; Savory and Lariviere, 2000). The basis for their work is that the feeling of hunger is the underlying drive that motivates an animal to seek out and consume feed. It is clear that what motivates an animal to consume feed can also be influenced by external factors; however, measuring an animal's motivation to obtain feed by requiring it to work for its feed largely minimizes any external influence and focuses the measure on the internal drive of hunger. The current study demonstrated that feeding a diet containing MGA does not increase hunger, as measured by the motivation of hens to acquire feed. This measure of hunger appears to be quite sensitive-the group of feed-deprived hens experienced a 555% increase in motivation following 1 wk of feed deprivation.

Feeding low-nutrient-density feedstuffs to allow hens to consume feed and experience gut fill has been proposed as an alternative to feed deprivation (Biggs et al., 2003, 2004). The idea is that the hen continues to be deprived of energy and nutrients with the outward appearance that the hen's well-being is improved over that of hens that are deprived of feed. However, gut fill triggers only some aspects of satiety. In this study, when utilizing the control diet as a reward, hens molted with a 94% wheat middlings diet experienced a 318% increase in motivation by d 8 and had surpassed the maximum motivation achieved by the restricted hens by d 20. In a comparison of hens molted utilizing a similar 94% wheat middlings diet with hens molted by feed deprivation, there were no differences in the frequency of a variety of behaviors performed (Biggs et al., 2004). The marked increase in motivation in the wheat-fed hens in the current study and the lack of difference in behavior of hens molted with a similar diet (Biggs et al., 2004) when compared with hens deprived of feed, leads us to suggest that alternatives to feed deprivation that feed low-nutrient-density feedstuffs are not different than feed deprivation in terms of animal well-being and do not address the root cause for changing the guidelines to ban feed deprivation.

Although diet dilution (i.e., adding oat feed, straw, or wheat middlings) is thought to ameliorate hunger by increasing gut fill, the observed failure of wheat middlings to prevent an increase in hunger is not surprising. Adding bulk (i.e., oat feed) to a broiler breeder diet did not decrease a bird's motivation to obtain feed (Savory and Lariviere, 2000). The same is true for swine, in that adding bulk (i.e., straw) to a nutrient-restricted diet did not decrease a pig's motivation to obtain feed (Lawrence et al., 1989; Roberts et al., 1993, 1997). Past research has shown that increasing the nutrient and energy content of these bulk diets did result in decreased motivation of the pigs to obtain feed (Lawrence et al., 1989; Roberts et al., 1993, 1997).

Others have attempted to measure hen well-being when subjected to alternative methods to induce molting by determining feed intake, hen BW, and internal organ weights. Current alternatives result in a dramatic decrease in feed intake, as seen when feeding low-sodium diets (59% decrease; Nesbeth et al., 1976), high-zinc diets (20% decrease; Shippee et al., 1979), and wheat middlings, in which intake

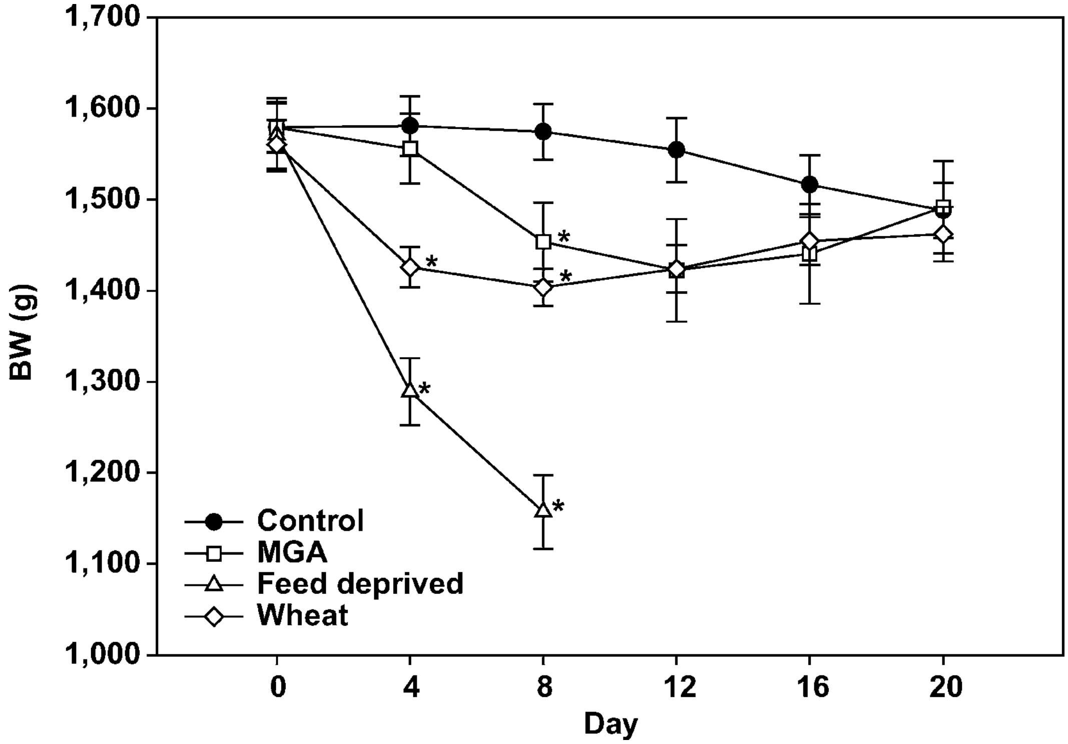

Figure 3. Hen BW on d 0, 4, 8, 12, 16, and 20 for hens receiving control, melengestrol acetate (MGA), or wheat diets, or feed deprived. *Means ± SEM were different from control ($P < 0.05$).

decreased for the first week (Biggs et al., 2003). Associated with a decrease in feed intake is a decrease in hen BW; a low-sodium diet caused a 19% loss of original BW (Nesbeth et al., 1976) and a 94% wheat middlings diet caused 13% loss (Biggs et al., 2003, 2004). Therefore, these alternative methods may not truly address hen well-being, and the degree of hunger resulting from the alternatives has not been determined. Several studies in other situations (i.e., feed-restricted broiler breeders) have tried to characterize hunger by determining an animal's motivation to obtain feed (Hocking et al., 1993; Savory et al., 1993; Roberts et al., 1997; De Jong et al., 2002).

Tests used to assess the motivation of an animal to obtain feed have been used to make an objective decision on their state of well-being and are a better measure than feed intake or changes in BW or organ weights. Operant conditioning has previously been used to determine the motivation of feed-restricted broiler breeders (Savory et al., 1993), boars (Lawrence et al., 1988, 1989), sows (Bergeron et al., 2000; Ramonet et al., 2000), and gilts (Roberts et al., 1997). Using operant conditioning to measure motivation has resulted in the conclusion that adding bulk to the diet does not increase satiety in swine (Lawrence et al., 1989; Bergeron et al., 2000; Ramonet et al., 2000). Roberts et al. (1997) concluded that adding bulk to the diet did increase satiety but only if nutrient requirements were met. Motivation testing has shown that broiler hens placed on a restricted diet are more motivated to work for feed than nonrestricted hens, as evidenced by their pecking the operant a greater number of times in a 16-min period (Savory et al., 1993). Feeding motivation of restricted broiler hens has been shown to be almost 4 times greater than that of hens fed ad libitum (Savory et al., 1993). In the current study, hens deprived of feed for 1 wk were more than 5 times more motivated to acquire feed.

To meet the demands of high productivity, broilers and layers have a high level of motivation to obtain feed. Once feed is obtained, the motivation subsides and the birds perform other non-feed-related behavior. However, if the drive cannot be satisfied, a high degree and chronic form of stress is likely to occur. Toates (1987), Hughes and Duncan (1988), and Dellmeier (1989) provide comprehensive reviews of how thwarting of motivation leads to impaired well-being. The evidence reviewed by these authors relies on observations that animals prevented from performing internally drive-motivated behaviors (e.g., hunger or sleeping) succumb to performing stereotypic and aberrant behaviors, exhibit altered physiology, express learned helplessness, and may have impaired productivity. Thus, impaired well-being associated with the thwarting of highly motivated behaviors, such as feeding behavior, need not be associated with a painful experience to be considered a welfare problem. Indeed, the sensation of pain is regulated by its own set of receptors, termed nociceptors, which are activated by specific stimuli, such as thermal, mechanical, or chemical. Our discussion on hen well-being is thus focused on the thwarting of a highly motivated behavior and does not address the issue of whether feed deprivation activates the nociceptor system.

Previous research has shown that pregnant sows that were placed on feed restriction were more motivated to obtain feed than those provided ad libitum access to feed

(Lawrence and Illius, 1989; Lawrence et al., 1989). In fact, increasing the degree of restriction or increasing the period of restriction leads to increased motivation of the animal to obtain feed. Sows placed on 60% feed restriction are considered extremely hungry (i.e., motivated) because many will exert more energy to work for the reward than the amount of energy they obtain from the reward (i.e., working at an energy deficit; Huston, 1991).

Savory et al. (1996) compared qualitative vs. quantitative feed restriction in broilers and found that the addition of high-fiber bulk to a diet decreased its palatability. Thus, motivation testing using a less palatable feed as a reward would create misleading data and suggest that broilers were less motivated to obtain feed (i.e., less hungry). Wheat middlings are a high-fiber feed and the wheat middling diet provided to hens to induce a molt is designed to provide gut fill with few calories. To prevent the collection of misleading data, we tested the hens in the motivation test with the control diet (layer ration) as a reward. This method of testing creates another challenge in interpretation because it has been shown that motivation can be increased when the reward is better than expected. However, because the wheat-fed hens had been consuming the control diet for 77 wk (before the start of the experiment) and the control diet was used as the reward during training, it is unlikely that it was better than expected (Flaherty, 1982). It is also unlikely that the hens were working to obtain more feed beyond their needs because they were losing weight and thus had a real need to obtain more nutrients. Often, animals will eat in response to external stimulation, such as the presence of a highly palatable or novel food, even when hunger is not at a high level. The advantage of our experimental design is that with each reward the hen was required to work harder for the next reward. These methods largely eliminate trivial eating, which would occur if feed were free choice. By testing hens with both the control diet and their experimental diet, we could make a more informed interpretation. This experimental design proved to be critical because the data presented support the suggestion that hens fed wheat middlings and rewarded with the same are unmotivated to obtain the wheat middlings. These data can be interpreted to mean that the hens are gaining little hedonic value by eating wheat middlings. Taste preferences of poultry dictate what they will and will not eat; for instance, hens are known to avoid salty feeds. Ganchrow et al. (1990) provide data indicating that as early as 1 d of age, chicks show aversion to some flavors, such as quinine and citrus. Alternatively, the nonpreference of hens in this study for the wheat middlings diet could be due to a phenomenon known as nutritional wisdom. The existence of nutritional wisdom attributes proper diet selection to account for nutritional deficiencies. For instance, an animal on a diet low in calories would select a higher caloric diet over a lower caloric diet. Provenza (1995) suggests that cattle have such an ability to eat according to their needs. Further, he contends that neural mechanisms between the senses and the viscera can increase the hedonic value of a feed to enable proper nutrition of the individual. The hens in our study did appear to become more proficient at operating the operant through successive trials. This was true for all but the hens fed wheat middlings and rewarded with wheat middlings. Thus, a palatable feed that was rewarding to the hen may have enhanced her responses through the trial. However, it is still apparent that hens fed wheat middlings but rewarded with the control diet were much more motivated to obtain feed because, compared with hens in other treatments also receiving control feed as a reward, their responses were more than 2 times greater on d 16 and 20. In our study, when provided with the opportunity to work for a layer ration, hens maintained on wheat middlings actually surpassed the motivation level of hens that were not fed for 8 d.

As expected, hens that were deprived of feed for 8 d lost 26% of their starting BW. The hens fed wheat middlings initially lost 10% of their BW, which is similar to the loss reported by others (Biggs et al., 2004; Mazzuco and Hestor, 2005). Hens fed MGA lost 8% of their initial BW by d 8. Both the MGA- and wheat-fed hens were no longer lighter than the controls by d 12 or for the remainder of the experiment. Although both the wheat- and MGA-fed hens initially lost BW, the reason for the change in weight appears to be quite different in these 2 groups. Previously, we demonstrated that feeding MGA to induce a molt would result in a loss of 5% of the hen's initial BW simply from regression of the reproductive tract (Koch et al., 2005a). In addition, because the MGA-fed hens are consuming a diet that meets their requirements but are not producing eggs, they are able to partition nutrients to replenish body reserves. Indeed, MGA hens had abdominal fat that was more than 3 times greater than that in control or wheat-fed hens. It would be interesting to investigate whether the greater abdominal fat helps or hinders productivity during the second cycle of laying. It is worth noting that, during the first 6 wk following an MGA-induced molt, both internal and external egg quality is improved and hens produce eggs at a rate consistent with expected second-cycle performance (Koch et al., 2005a,b). Hens fed a wheat middlings diet initially consumed less than they had previously (Biggs et al., 2003), potentially as a result of low palatability, followed by a period of greater feed intake than before the molt, potentially from extreme hunger and accommodation of the gastrointestinal tract to the bulk diet. In this study we observed a marked increase in the gizzard weight of wheat-fed hens compared with control and MGA-fed hens; it is likely that the entire digestive tract, including digesta, weighed more in the wheat-fed hens and contributed to the recovery of BW by the end of the experiment.

The need for an alternative to feed deprivation as a method to induce a molt has dramatically increased with the recent change to the United Egg Producers guidelines recommending that feed deprivation no longer be used to induce a molt (United Egg Producers, 2006). The 2 most important factors in evaluating a potential alternative are that the alternative method induce a molt sufficient to allow for an increase in egg quality following the molt, and that the alternative method does not increase hunger in the hen. Previously, we demonstrated that incorporating an orally active progestin into a balanced layer diet would cause reversible regression of the reproductive tract (Koch et al., 2005a). Furthermore, both the internal and external quality of the eggs produced by hens molted utilizing MGA is dramatically increased compared with nonmolted controls (Koch et al., 2005b). In this study we add the final piece, demonstrating that utilizing MGA to induce a molt does not increase hunger in the molted hen, unlike alternatives that involve feeding bulk low-nutrient-density diets, which increase hunger in the molted hen at least as much as in hens completely deprived of feed.

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