ISSN 1819-1878

Asian Journal of Animal Sciences

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OPEN ACCESS Asian Journal of Animal Sciences

ISSN 1819-1878
DOI: 10.3923/ajas.2021.43.52

Review Article
Deprivation of Feed for Better Broiler Performance: A Review

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Abstract

For many years, broilers were genetically selected and fed to gain more weight in a shorter time with better feed conversion. This led to increased mortality due to ascites and skeletal abnormalities and increased feed conversion ratio. The fast growth rate found to be not suitable for the chick's age because the development of some internal organs like the heart and lungs does not follow the speed of gaining more weight which led to heart and lung failure. This also happens to the long bones, these bones cannot hold the heavy small chick, which causes long bone deformities. Consequently, controlling broilers' feed consumption idea arises as a suggested method to decrease mortality due to ascites, sudden death syndrome and skeletal deformities. Hence, early feed restriction becomes a new paradigm in broiler nutrition for more than thirty years. Feed restriction is also claimed as a strategy to reduce feed costs. The main focus herein is to review early feed restriction; its definitions and methods, its effects on broiler chickens performance and its suggested effects on the economy of broiler production.

Key words: Broiler chickens, starter period, quantitative feed restriction, qualitative feed restriction, compensatory growth

Citation: Alkhair, S.M., 2021. Deprivation of Feed for Better Broiler Performance: A Review. Asian J. Anim. Sci., 15: 43-52.

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Competing Interest: The author has declared that no competing interest exists.

INTRODUCTION

Research in broiler nutrition has changed what had been considered as facts or routine activities in poultry nutrition and management. It was believed that ad libitum feeding is necessary for the fast broiler modern strains to meet their maximum growth potential. Due to the efforts of the researchers who think out of the box, it was approved that: fasting broilers for hours or even for intermittent days in certain circumstances is better than ad libitum feeding for growth and economics too[1,2]. Restricted feeding aimed to slow early growth rate of young broilers. These feeding programs synchronize the speed of growth of different body organs and decrease bad effects of rapid growth[3,4]. Investigators studied various methods of feed restriction during the first three weeks of age to evaluate its effects on broiler performance and health. These methods reduced or alleviate the incidence of some metabolic diseases such as ascites, lameness, mortality and sudden death syndrome, moreover, they improved broilers' efficiency of feed utilization and decreased the feeding cost[5-10]. Physical and diet dilution feed restriction methods are also applied during the finisher period[11-13]. Feed restriction also has been commonly used to optimize lean carcass tissue, control body weight and reduce reproductive problems in both meat-type and egg-type chickens and to prevent excessive fat deposition[14,15]. The severity of feed restriction, length of restriction and age at marketing are the main factors to take into account in a feed restriction program[16]. Dozier *et al.*[17] attributed the inconsistent results of feed restriction programs in the literature to differences in bird management, lighting, strain and ventilation. This review article is intended to review the definitions and methods of feed restriction, early feed restriction, effect of feed restriction on the economy of broiler production, compensatory growth and the effects of different feed restriction methods during the starter period on broiler chicks' performance.

DEFINITION OF FEED RESTRICTION

Feed restriction means, feeding chicks with a diet that do not meet the nutritional requirements for normal growth or reducing the amount of feed needed for normal growth[18]. It is achieved by limiting feeding time, or reducing the amount of feed offered to the birds, or changing the quality of feed by reducing protein or energy or both. In the latter feed restriction method, ad libitum feeding is offered, because low nutrient density of feed reduces growth even if the chicks fed ad libitum. Feed restriction is defined by many authors, Plavnik and Hurwitz[19] defined physical feed restriction as the supply of a calculated amount of feed per bird, which is often just enough to meet maintenance requirements. As defined by Ballay *et al.*[20] and Yu and Robinson[21] quantitative and qualitative feed restriction are feeding strategies of poultry nutrition in which time, duration and amount of feed are limited and have an impact on whether a bird is capable of achieving the same body weight as unrestricted birds. Leeson and Zubair[22] defined quantitative feed restriction as means of limiting the amount of feed daily given to the animals whereas qualitative restriction is related to nutrient dilution in the diet.

METHODS OF FEED RESTRICTION

Feed restriction is divided into two main groups: Quantitative, in which the quantity of feed is reduced and qualitative, in which the quality of feed is changed. These methods have been reviewed by Urdaneta-Rincon[16] and Sahraei[23].

Quantitative restriction: Quantitative feed restriction has been used for different purposes, such as reduction of broiler mortality and reduction of long bone abnormalities[24]. It has been observed that it reduces mortality and culling[21,25], improves feed conversion ratio[26,27] and allows a complete recovery of body weight if the degree of restriction was not too severe and slaughter ages were extended beyond 6 weeks[26].

Physical feed restriction: In the physical method graded levels of feed are measured from the ad libitum feed intake. Application of physical feed restriction requires regular weighing of birds, calculating daily feed intake of restricted chicks and providing sufficient feeder space to prevent the unequal growth of birds within a flock[15].

Feed removal: Fasting broilers for many hours during the day or skip-a-day feed removal has been reported to decrease early growth and reduce the incidence of ascites without affecting final body weight[20,28]. Reduced feed intake in this method is achieved by removing feed for 8-24 hrs during the starter period. Oyedeji and Atteh[29] reported a reduction in feed intake after exposing the birds to fasting on every other day. They also showed that skip-a-day feeding for 3 weeks starting at day-old would improve carcass quality and reduce sudden death syndrome which is often associated with birds that are on ad libitum feed intake.

Lighting: It is known that reducing the hours of light or developing intermittent lighting schedules will lead to reduced feed consumption of broiler chicks[30,31]. Although, lighting programs are not classified in the literature as a feed restriction method, this type of controlling feed intake achieves the goals of feed restriction. Several studies, however, indicated that intermittent lighting programs with reduced photoperiods could increase the growth and improve feed conversion of white broiler chickens[32,33]. Research concerning broiler performance demonstrated that, reducing the hours of light or developing intermittent schedules resulted in positive performance parameters, like improved feed utilization[30,31,34]. It also reduces the incidence of leg abnormalities[31] and mortality, specifically sudden death syndrome[35].

Qualitative feed restriction: Qualitative feed restriction requires changing the nutritional value of the diet or incorporation of chemical drugs. It is performed by using diets with low energy or protein content or both, this is accomplished by adding non-digestible ingredients and addition of appetite suppression drugs.

Diet dilution: Many researchers have used diet dilution because of the advantage of attaining a more consistent growth pattern within a flock[36]. The use of diluted diets relies upon the fact that broiler chicks eat close to their physical intake capacity[15,37]. Diet dilution is accomplished by lowering the level of either protein or energy or both. When broilers fed with low nutrient dense diets they will increase their feed intake in an attempt to maintain nutrient intake [11].

Chemical method: In order to depress feed intake of broilers, chemicals or pharmacological agents are used. The following drugs are used to suppress feed intake: Phenylpropanolamine hydrochloride which is known as an anorectic drug[38], monensin sodium, an ionophore which at low concentrations acts as a coccidiostat, but it causes anorexia at higher doses[38,39]. Acetic and propionic acids[40] and calcium propionate[41] are also used to depress appetite. This qualitative method of feed restriction has the benefit of evenly distributing the feed among birds and so reducing the variation in growth that can occur with physical feed restriction programs.

EARLY FEED RESTRICTION

Early feed restriction depends on compensatory growth phenomena. In which restricted birds compensate for the weight lost during restriction period when feed restriction is over, depending on duration of feed restriction and the age of restriction[4]. As stated by Leeson and Summers[4]: "If growth rate is to be reduced, then based on needs to optimize feed usage, nutrient restriction must occur early in the grow-out period. As the bird gets older, a greater proportion of nutrients is used for maintenance and less is used for growth. Therefore, reducing nutrient intake in the first 7 days will have little effect on feed efficiency, because so little feed is going towards maintenance." Feed restriction during early age is found to improve the efficiency of feed utilization, reduce mortality due to metabolic diseases, heat stress and reduce culls due to skeletal abnormalities. It also improves growth characteristics with lower fat accumulation[19,42].

EFFECT OF FEED RESTRICTION ON THE DEPOSITION OF ABDOMINAL FAT IN BROILER CHICKENS

Consumer awareness for healthy food makes the poultry industry to focus on healthy weight-to-age broiler chickens. The abdominal fat pad in broiler chickens is the most undesired character. To produce healthy broiler meat, numerous studies have been conducted to minimize fat deposition or even fat synthesis in broilers. The deposition of abdominal fat in broiler chickens is related to age and the growth curve. Mathematic models have shown that the maximum abdominal fat weight is observed in 43-day-old broilers, whereas maximum abdominal fat gain expressed as carcass and live weight percentages occurs on the 15th and 19th day of age, respectively[43,44]. There is an inherent increase in abdominal fat with an increased growth rate. So, different growth rates have resulted in different fat weights. Early feed restriction studies conducted to reduce fat deposition in broiler chickens were based on the following suggestions:

- Abdominal fat is laid down during the early stages of growth
- Fatness at an early age may affect adiposity at adulthood. It is hypothesized that this will suppress or delay adipocyte proliferation and this is expected to be accompanied by lower adiposity in older broilers
- The level of feeding during early ages can alter different processes involved in adiposity (hyperplasia and hypertrophy)
- Most of the growth of the adipose tissue occurs mainly during the second to third weeks of age in broiler chickens, that is why restricted feeding is applied during this age

Many studies revealed that the differences in fat deposition in terms of weight or carcass percentages are not significant. The fact that there was no significant reduction in abdominal fat deposition suggests that even feed-restricted broiler chickens are still overeating[36]. A similar conclusion was reached by Fontana et al.[25] and Deaton[26].

EFFECT OF FEED RESTRICTION PROGRAMS ON THE ECONOMY OF BROILER PRODUCTION

Generally, the economical broiler production depends on many factors such as strain of the bird, quality of feed, the management practices applied, type of housing (closed, semi-open, open) and vaccination. About 60-70% of broiler production cost is in feed ingredients, so minimizing feed cost will increase profit. Improvement in broiler production profitability could be achieved by improvement in the performance of broilers by offering quality balanced diets suitable to age and purpose of production. The most important is to improve the efficiency of feed utilization to ensure excellent use of nutrients. The inconsistency of the results reported in studies conducted to evaluate the effect of feed restriction programs in broiler performance make it difficult to consider which method, duration, severity or age at the commencement of feed restriction is suitable for profitable broiler production. In general, feed restriction could be an economical method of broiler production because, addition of inter-filler materials such as fiber sources, sand and charcoal instead of the expensive energy and protein ingredients in the ration will reduce feed cost. It also could be of economic importance if the next situations achieved:

- Restricted chicks consumed lesser amount of feed during the restriction period without reducing final body weight from that of ad libitum fed chicks and consumed the same amount of control feed intake after the restriction is over.
- Restricted chicks gained greater final body weight than the ad libitum fed chicks consuming the same amount of feed of ad libitum chicks
- Restricted chicks showed improved efficiency of nutrient utilization
- If the amount of fat deposited in the abdomen is reduced, then nutrients are directed to the production of real weight (carcass weight)
- If feed restriction reduced mortality and culls due to ascites, sudden death syndrome or skeletal deformities.

COMPENSATORY GROWTH

The animal growth rate follows a conventional growth curve when conditions are favorable. Early restricted birds are characterized by improved feed efficiency due to decreased maintenance requirements[4], that is why those birds in most cases achieved the body weight in a short period of time. Compensatory growth is defined as the abnormally rapid growth relative to age within a breed of an animal after early growth retardation. Restricted animals whose growth has been reduced have a higher growth rate than that which is normal in animals of the same chronological age. This accelerated growth rate relative to age has termed by Bohman (1955) as compensatory growth[45]. The reduction in maintenance costs would then allow for comparatively more energy for growth upon re-alimentation, thus contributing to the compensatory growth responses.

FACTORS THAT INFLUENCE COMPENSATORY GROWTH

Wilson and Osbourn[45] identified the factors that influence the ability of animals to exhibit compensatory growth during the period of re-alimentation. These factors include the duration, timing, nature and severity of restricted nutrition, degree and pattern of the re-alimentation condition and genetic factors. These factors are:

Duration and timing: Many studies have shown that the longer the period of feed restriction, the more difficult for restricted broilers to compensate for the reduction in weight gain[18,21]. It is recommended by most workers to restrict feeding for not more than seven and five days for male and female broilers, respectively, to allow for full body weight recovery[29]. More consistent results of compensatory growth have been obtained in studies that have extended the growth period to 47-56 days old[42,36,46]. The lack of recovery in body weight by the restricted birds was likely due to the prolonged period of restriction, giving no time for the birds to compensate for the weight loss[29,44,47].

The severity of feed restriction: Severity of feed restriction means: the length of restriction period or the level to which nutrient density is reduced or the age at which the chicks deprived of feed or the percentage at which feed is reduced below ad libitum intake. Milder feed restriction permits more realistic recovery[48,36].

Degree and pattern of re-feeding condition: Jones and Farrell[49] demonstrated that dietary supplementation with lysine and/or methionine during the re-alimentation period resulted in higher final body weight and leaner carcasses. More consistent results of compensatory growth have been obtained in studies that have extended the growth period to 7 weeks or more[46].

Genetic factors: Male broilers have a greater ability to exhibit compensatory growth following a period of feed restriction than females. The results of feed restriction showed that males could exhibit complete compensatory growth when subjected to similar conditions but not females[48,46]. Generally, researchers found that different strains respond differently to restriction feeding program.

FACTORS AFFECTING THE INITIATION OF COMPENSATORY GROWTH

As mentioned earlier, the inconsistency of results of feed restriction is due to the different conditions under which feed restriction is applied. Complete compensatory growth was reported by many authors and the failure of young chicks to compensate the weight lost during feed restriction also reported by many. The main factors that influencing initiation of compensatory growth are:

Age at the commencement of feed restriction: Leeson and Summers[1] stated that, in young birds 80% of feed is used for growth and the remainder 20% is used for maintenance. That is why early ages are preferable for feed restriction application. If the restriction occurs after the 21st day, broilers will not have enough time to recover the weight loss[13]. Another reason for early feed restriction is because there are about 3 to 4 weeks of ad libitum intake. This period is thought to be enough for the chicks to compensate for the weight loss.

Market age and re-alimentation period: Age at marketing is another factors to consider in a feed restriction program. Many authors reported that severe feed restriction programs require in many cases long re-alimentation periods about three weeks after the restriction program is stopped.

REASONS FOR GROWTH COMPENSATION AFTER FEED RESTRICTION

The ability of restricted chicks to show full body weight recovery has been attributed to many reasons:

- The energy that supports growth compensation may come from the reduced requirement for maintenance energy related to a lower body weight and metabolic adaptation, so energy is directed toward growth in the subsequent ad libitum feeding period[14,18]
- Greater feed intake relative to body weight and its associated digestive adaptations may also be contributing factors to growth compensation. Increased feed intake has been demonstrated by many researchers as the main mechanism that drives compensatory growth[14]
- Occurrence of compensatory growth after restricted feeding is also attributed to improved feed conversion during re-alimentation. Improvement in feed efficiency associated with early feed restriction has been attributed to higher metabolic efficiency associated with maintaining a smaller body[50,36,51,10]
- Digestive adaptation to feed restriction is also a suggested reason for growth compensation. The relative enlargement of digestive organs, especially the gizzard, crop, pancreas and liver which enhances feed intake and help support compensatory growth[22]

Most studies that have reported complete growth compensation used either milder under nutrition programs or apply it for short period or when the periods after restriction is over were enough to compensate weight lost during the restriction program. Generally, complete compensatory growth was reported at the following ages: Santoso *et al.*[42] at 56 days, Santoso[52] at 56 days, Nirmala[46] at 49 days and Ozkan *et al.*[3] at 56 days old.

REASONS FOR FAILURE OF RESTRICTED CHICKS TO EXHIBIT COMPENSATORY GROWTH AFTER FEED RESTRICTION

Many studies reported no compensatory growth of restricted chicks. Birds were not able to fully compensate body weight by 21 days, because, as reported by Leeson and Zubair[22], it usually takes male birds about 20 to 25 days to compensate for the weight loss after restricted feeding. It could be concluded that, broilers subjected to prolonged feed restriction periods, sever feed restriction feeding programs or short re-alimentation periods may not be able to compensate for the weight loss.

EFFECT OF DIFFERENT FEED RESTRICTION METHODS DURING THE STARTER PERIOD ON BROILER CHICKS' PERFORMANCE

Physical feed restriction

Performance during feed restriction period: Many researchers revealed that body weight of restricted chicks during the restriction period is usually inferior to full fed ones. This situation is observed in chicks subjected to physical feed restriction in the 1st, 2nd and the 3rd weeks of life. This inferior performance is due to the inability of young chicks to adapt to restricted feeding especially during the first and sometimes the second week of life, because of their immature digestive system. It also may be due to insufficient amounts of nutrients offered during the restricting program. In some cases, it meets only maintenance requirements. Hence none is available to build body tissues. This situation is reported by may authors who found that body weight of restricted chicks is lower than that of full fed ones during feed restriction period[51,53-55]. A similar conclusion was reached by van der Klein *et al.*[56] who found that body weight of restricted chicks is lower but not significant. This period is also characterized by lower feed intake compared to full fed chicks[57,58]. When restriction is mild the differences in performance between chicks are not significant even if the restricted chicks showed numerically inferior performance. Lippens *et al.*[5] found no significant difference in feed intake. Similar findings were reported by Urdaneta- Rincon and Leeson[36] and Ozkan *et al.*[3].

Performance at the end of the breeding period: When feed restriction is over, in some cases, restricted chicks increase their feed intake to reach that of full fed ones and sometimes gained more weight than full fed chicks. If the restriction is mild (e.g: applied for short time during the starter period, or reduction of the ad libitum intake was at a low percentage), restricted chicks may reach the full fed chicks' final body weight or the differences will not be significant. If the restriction is severe and the re-alimentation period is short, restricted chicks may not recover the weight lost during the restriction period even if they increased feed consumption or gained more weight than full fed ones. Various studies reported lower market weight in feed restricted vs. full fed chicks[36,10,59,55,18]. Contrasting results have been reported by many authors[27,60-62]. Many authors found that, physical feed restriction improves feed conversion ratio. This improvement may be the reason for the ability of restricted chicks to recover the weight that have been lost during the restriction period. The improved feed conversion ratio was reported by Zhan *et al.*[10], Urdaneta-Rincon and Lesson[36] and Saleh *et al.*[51].

Carcass and carcass cuts weight: Physical feed restriction during the starter period found to affect carcass and carcass cuts weight in certain circumstances, while in some cases do not have any effect on it, according to the severity of feed restriction. Vargas *et al.*[63] and Mohebodini *et al.*[64] found that carcass and cuts weight were depressed by feed restriction. Different results have been reported by Shariatmadari and Torshizi[65], Nirmala *et al.*[46] and Jalal and Zakaria[54]. They reported no significant differences in carcass yield. On the other hand, Tůmová *et al.*[66] and Jahanpour *et al.*[62] found increased carcass weight of restricted chicks compared to control ones.

Limiting feeding time

Performance during feed restriction: Reduction in body weight during restriction period (the first three weeks of life) was reported by Mahmood *et al.*[9] and Acheampong-Boateng *et al.*[53]. Earlier studies demonstrated the same results[67]. Different results were observed by Saleh *et al.*[68] who found no effect of feed removal on body weight. Body weight reduction is also combined with an increased limitation of feeding time[2,5,69,70]. Reduced feed intake due to feed removal is also reported by Mahmood *et al.*[9]. Insignificant differences in weight gain was observed by Zhong *et al.*[71], Zubair and Leeson[50] and Netshipale *et al.*[70]. Insignificant differences in feed conversion ratio were reported by Dozier *et al.*[17] and Khajali *et al.*[72]. Better performance of restricted chicks was observed by many authors. Lee and Leeson[27] observed higher weight gain of restricted chicks than ad libitum fed ones. Better feed conversion ratio is also observed by Deaton[26], Zhong *et al.*[71], Lee and Leeson[27] and Mahmood *et al.*[9].

Performance at the end of the breeding period: Inconsistencies in results appear in the studies concerning feed removal as a feed restriction method. This is due to differences in fasting hours and age at commencement. The insignificant differences in performance at the end of the breeding period between the control and fasted chicks were demonstrated by De Silva and Kalubowila[69] and Alkhair *et al.*[73] who found no significant differences in feed intake between control and 3 hrs fasted chicks. Fasted chicks found to be able to compensate for loss of weight resulting from short periods[17,72,73]. While Boostani *et al.*[74] found that feed removal for 8 hrs during the day allow complete compensatory growth at 42 days old. Acheampong-Boateng *et al.*[53] found that fasted chicks could not recover from the slow growth during restriction period and they were lighter than the control chicks.

Carcass and carcass cuts weight: No significant differences in carcass and thigh weight were observed by Camacho *et al.*[6], Mohebodini *et al.*[64] and Boostani *et al.*[74]. Teimouri *et al.*[75] found lower carcass and breast weight than that of control ones.

Diet dilution

Performance during the restriction period: Diet dilution requires energy and/or protein dilution while keeping the other nutrients within the recommended levels. So, the increased consumption of feed observed by restricted chicks is an attempt to maintain nutrient requirement[56,76,77].On the other hand, Cornejo *et al.*[45] reported no effect on feed intake, while Mohebodini *et al.*[64] found that chicks subjected to feed restriction (diet dilution) consumed lesser feed compared to control ones. Similar results reported by Somaia *et al.*[77] but the differences were not significant. In some cases, when dilution is achieved by adding wheat bran, restricted chicks showed reduced intake due to the increased volume of the diluted diet. Reduced body weight during the restriction period is observed by Rezaei and Hajati[78]. Other authors reported that diet dilution do not affect weight gain[44,57,55]. Different results of the effect of diet dilution during the starter period on feed conversion ratio were reported by many authors. Hassanabadi[79] found no effect of diet dilution on feed conversion ratio, while the better ability of nutrient utilization was observed by Zubair and Leeson[50] and Urdaneta-Rincon and Leeson[36].

Performance at the end of the breeding period: No statistical differences were observed in body weight between restricted and control chicks during the re-alimentation period[49,14,80,62]. Some studies revealed negative effects on body weight, such as, Jang *et al.*[57] who reported lower body weight of restricted chicks at 35 days old. Rezaei *et al.*[76] and Rezaei and Hajati[78] also found reduced body weight of restricted chicks with increased levels of diet dilution. Feed intake following feed restriction (diet dilution) tended to be lesser than control ones[64]. Despite the reduction in feed consumption after feed restriction is over, in some experiments, restricted chicks compensate for the loss in body weight during restriction period[58,77,73]. This may be due to the improved feed conversion ratio exhibited by early restricted chicks[51,10]. Ozkan *et al.*[3] found that, after feed restriction was stopped, the restricted chicks showed accelerated weight gain.

Carcass characteristics: Carcass, thigh and drumstick weight were not affected by diet dilution during the starter period[5,77,78]. Butzen *et al.*[55] found no significant differences in carcass weight of male and female restricted broiler chicks. The insignificant differences in carcass and cuts weight were also demonstrated by Teimouri *et al.*[75]. On the other hand, Tumova *et al.*[66] reported higher carcass weight of restricted chicks compared to control ones. Other different results were observed by Azarnik *et al.*[81] who found that feed restriction reduced carcass weight, breast weight and thigh weight.

CONCLUSION

The continuous advances in broiler nutrition revealed valuable progress in broiler production. Due to the efforts of the researchers who think out of the box, research in broiler nutrition had changed what was considered as facts or routine activities in poultry nutrition and management. One of which is ad libitum feeding which was considered necessary for the fast broiler modern strains to meet their maximum growth potential. Despite the inconsistent results of the effect of early feed restriction on broiler performance, restricted feeding could be a promising nutrition paradigm. Further studies are necessary to reach a consensus on the optimal method of the application of early feed restriction under various conditions.

SIGNIFICANCE STATEMENT

This review helps the researcher to uncover the reasons behind the rise of the concept of early feed restriction of broiler chicks as a new paradigm in poultry nutrition instead of ad libitum feeding for a meat type bird. This review will help the researcher to build a complete overview of the effects of different quantitative and qualitative feed restriction methods on broiler performance, during the restriction period and at the end of the rearing period as well.

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