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Economic and productive performance of broilers subjected to quantitative feed restriction

Desempenho econômico e zootécnico de frangos de corte submetidos à restrição alimentar quantitativa

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ABSTRACT: Nutrition today accounts for approximately 75% of broiler production costs due to the large variety of ingredients contained in poultry feed. Commercial chicken breeds have been genetically selected for rapid weight gain, among other characteristics, thereby stimulating their voracious feeding behavior. However, this greater feed intake has not seen an attendant increase in the digestion capacity of the birds' digestive system, thus interfering with feed conversion. The objective of this study to compare the performance of feed conversion, mortality rates, daily weight gain, carcass rejections, carcass and parts yields and the cost of ad libitum feeding of broiler chickens with those achieved through quantitative feed restriction (Cobb broiler diet table and 10% less than recommended in the table). The treatments were tested in three consecutive batches on a poultry farm with three aviaries. The results obtained indicated that quantitative feed restriction improves feed conversion and reduces daily weight gain and mortality rates, but affects neither carcass rejection rates nor carcass and parts yields. As for production costs, the kilogram of live chicken was 5.69% lower among birds that received controlled feed, following the diet recommended for the breed, and 7.38% in birds that received a 10% quantitative feed restriction compared to the Cobb broiler diet table. The results of this study indicate that the use of quantitative feed restriction programs, despite the lower daily weight gain of broiler chickens, can offer advantages because lower mortality rates and enhanced feed conversion compensate for this loss, thus significantly reducing production costs.

KEYWORDS: feed conversion; production cost; poultry.

RESUMO: Atualmente a nutrição, com o aumento dos ingredientes utilizados na ração, representa aproximadamente 75% do custo de produção na criação de frangos de corte. As linhagens utilizadas na avicultura de corte foram selecionadas geneticamente, entre outras características, para rápido ganho de peso, gerando um aumento da voracidade das aves pelo alimento. Esse maior consumo de ração não foi acompanhado pelo aumento da capacidade de digestibilidade do trato digestório, interferindo na conversão alimentar. O objetivo deste trabalho foi comparar a conversão alimentar, mortalidade, ganho de peso diário, condenações, rendimento de carcaça e cortes e os custos de frangos alimentados à vontade e com restrição quantitativa (consumo tabela Cobb e menos 10% da quantidade recomendada pela tabela Cobb). Numa granja com três aviários, com capacidade de alojamento de 9.000 aves cada, foram testados os tratamentos em três lotes consecutivos. Os resultados obtidos demonstraram que a restrição alimentar quantitativa melhora a conversão alimentar, reduz o ganho de peso diário, a mortalidade, não interferindo nas condenações e no rendimento de carcaça e cortes. Quanto aos custos de produção, observou-se uma redução no quilograma de frango vivo de 5,69% nas aves que receberam ração controlada conforme a recomendação da linhagem e 7,38 nas aves que receberam restrição de 10% em comparação a tabela Cobb. Diante dos resultados encontrados nesse trabalho, a utilização de programas de restrição alimentar quantitativa, embora tenha se verificado um menor ganho de peso diário das aves, podem ser utilizados com vantagens pois a redução na mortalidade e a melhora na conversão alimentar compensam essa perda, reduzindo significativamente o custo de produção.

PALAVRAS-CHAVE: conversão alimentar; custo de produção; frangos de corte.

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INTRODUCTION

Broiler performance has improved markedly in recent decades, mainly due to genetic enhancement programs (Hartcher; Lum, 2020). The emergence of increasingly nutritionally demanding breeds poses challenges in regard to the use of feed (Zampiga; Calini; Sirri, 2021). Moreover, genetic enhancement has resulted in birds consuming more nutrients than their digestive tract can assimilate (Ravindran; Abdollahi, 2021). Therefore, this rapid weight gain is also accompanied by an increase in body fat deposition, high mortality rates, high incidence of metabolic diseases and skeletal disorders (Abo Ghanima *et al.*, 2021).

Quantitative feed restriction in broilers has been adopted as a management tool to improve zootechnical indicators and reduce production costs. Dissanayake and David (2017), Bordin *et al.* (2021) and Melo *et al.* (2021), have stated that quantitative feed restriction is an alternative to improve feed efficiency, curtail the accumulation of abdominal and body fat, and reduce bird mortality rates caused by metabolic disorders The practice of early feed restriction is based on the theory of compensatory gain, which is defined as the compensation and/or recovery of weight after periods of fasting, through higher feed efficiency. Ye *et al.* (2022) reported that early feed restriction was effective in improving feed conversion and reducing the amount of fat in the broiler carcass.

Thus, the objetive of this study to compare feed conversion, mortality rates, daily weight gain, carcass disposal, carcass yield, parts yield and production costs of broiler batches fed ad libitum and subjected to different quantitative feed restriction programs.

MATERIAL AND METHODS

The study was carried out in three conventional broiler chicken sheds at an experimental poultry farm belonging to Agrodanieli Indústria e Comércio Ltda, located in the municipality of Tapejara, state of Rio Grande do Sul, Brazil. The project was approved by the Animal Use Ethics Committee (023/2017). Nine thousand mixed birds of the Cobb 500® breed were housed in each shed. The birds in the first aviary (AV1) were fed ad libitum, while those in the second aviary (AV2) received controlled feed, according to the reference table of the poultry breed, and those in the third aviary (AV3) were subjected to quantitative feed restriction, receiving 10% less feed than that listed on the afore mentioned table (Table 1).

Quantitative feed restriction was started at 15 days old and each treatment was tested in three consecutive batches. The birds were handled as recommended by the Cobb broiler management guide. Table 2 describes the lighting program used in this experiment. Starting on day 15 and up to slaughter, feed was provided in the dark at 09:00 pm and light in the sheds was turned only after 10:00 pm, thereby preventing the birds from pecking at each other and squabbling at the feeders. This light program, starting at 15 days of age, was adopted to ensure the broilers would eat at night, when temperatures are milder, thus avoiding thermal stress, since the three batches were reared during the summer in conventional aviaries with positive pressure.

The birds were given pelleted feed, whose nutritional composition varied according to five different ages, as described in Table 3.

All the birds were fed ad libitum until their 14th day of age, after which AV2 and AV3 received controlled feed (see Table 1), starting on day 15. Controlled feed was weighed daily before feeding, with the amount adjusted daily according to the number of live birds remaining in each shed. Feed conversion was calculated by dividing the feed consumed by the body weight of the birds.

Table 1. Daily weight gain per bird, in grams, from 15 to 42 days of age, recommended for the breed (AV2) and subjected to 10% feed restriction (AV3).

Days	Daily feed consumption Cobb Mixed Broiler Dietary Table	10% Feed restriction
15	78	70
16	85	76.5
17	91	81.9
18	103	92.7
19	110	99
20	114	102.6
21	118	106.2
22	123	110.7
23	128	115.2
24	133	119.7
25	137	123.3
26	144	129.6
27	150	135
28	156	140.4
29	160	144
30	164	147.6
31	167	150.3
32	170	153
33	174	156.6
34	177	159.3
35	179	161.1
36	182	163.8
37	186	167.4
38	190	171
39	193	173.7
40	197	177.3
41	203	182.7
42	208	187.2

Table 2. Lighting schedule used in the treatments of broiler chickens.

Age	Lights on	Lights off	Hours of light	Hours of dark
0 to 7 days	19:00	18:00	23	1
8 to 15 days	0:00	18:00	18	6
15 to 42 days	22:00	18:00	20	4

Table 3. Nutritional levels of the diets provided in the treatments.

Energy and nutrients, %	Pre initial	Initial	Growth 1	Growth 2	Final
EMAn1, kcal/kg	2950	3010	3060	3100	3130
Crude Protein	23.5	22.5	20	18.5	17.8
Dig. Lys	1.32	1.22	1.1	1.04	0.99
Dig. Met+Cys	0.98	0.99	0.99	1.00	1.02
Dig. Thr	0.63	0.63	0.63	0.63	0.63
Dig. Trp	0.11	0.11	0.11	0.11	0.11
Dig. Val	0.08	0.08	0.08	0.08	0.08
Met+Cys/Lys	0.74	0.75	0.75	0.76	0.77
Thr/Lys	0.64	0.64	0.64	0.64	0.64
Trp/Lys	0.17	0.17	0.17	0.17	0.17
Val/Lys	0.72	0.73	0.74	0.76	0.76

Prior to slaughter, the birds were subjected to six hours of fasting, and slaughtering occurred at 42 days of age. The broilers were stunned by cerebral concussion and immediately bled out through a jugular vein cut, after which they were scalded, plucked and eviscerated. The carcass and parts yield were evaluated by a single trained person, who examined 1% of the birds from each aviary according to the standard established by the slaughterhouse of the integrator company. Carcass yield was determined by weighing the broiler before and after evisceration. To determine the parts yield, the thighs, drumsticks, breast and wings were removed surgically and weighed. Commercial carcass and meat yields were expressed in relation to body weight at slaughter. The carcass rejection rate was assessed based on the number of birds from both aviaries fully and partially rejected by the Federal Inspection Service (S.I.F.). The economic evaluation of the treatments was based on feed conversion and mortality rates of the batches.

The data were subjected to the Kruskal-Wallis test followed by Dunn's post hoc test of multiple comparisons to compare the different groups. Data were considered significantly different when the probability (p) was less than 5%, using GraphPad Prism 8.0.1 software.

RESULTS AND DISCUSSIONS

Table 4 describes the zootechnical results obtained in this experiment. A 10% feed restriction presented the best feed conversion and lowered mortality rates, but also resulted in lower daily weight gain compared to the batch that was fed as recommended in the Cobb broiler management guide and the one that received feed ad libitum.

The hypothesis that restricting feed would better feed conversion in broilers was confirmed in this study. The data found here are in agreement with those reported by Bordin *et al.* (2021), who found that 10% and 20% of feed restriction represented savings of 100 and 252 grams of feed per kg of chicken produced, respectively. Pesenatto *et al.* (2015) evaluated the effects of feed conversion in broilers subjected to different feeder settings and reported significant gains when feeder opening size was reduced. Today, most poultry equipment manufacturers have reduced feeder size and integrator companies recommend reducing the volume of feed in poultry feeders to less than 1/3 of their capacity, starting at 20 days of age, in order to reduce feed supply and thereby enhance feed conversion. Increased feed intake reduces the digestibility of starch because it can cause excessively rapid feed passage rates (Herwig *et al.*, 2019). Moreover, feed restriction slows the passage rate of digesta sufficiently to increase its digestibility (Ravindran; Abdollahi, 2021). In this study, ad libitum feeding may have increased the passage rate of digesta through the gastrointestinal tract, reducing its exposure time to digestive enzymes and nutrient absorption in the intestinal mucosa, which may explain the increase in feed conversion. Moreover, birds subjected to feed restriction show higher energy and protein efficiency due to metabolic acceleration of the tissues (Buyse; Decuypere, 1996), as well as changes in hormone production such as a rapid increase in plasma levels of insulin (Yambayamba; Price, 1996), triiodothyronine (T3), growth hormone and insulin-like growth factor (IGF 1) (Kuhn *et al.*, 1996). In addition, digestive tract organs are heavier (Solmaz *et al.*, 2015), changes occur in the production

Table 4. Effect of quantitative feed restriction on the zootechnical performance of broilers.

Parameters evaluated	Ad libitum feeding	Cobb dietary table	10% less than Cobb table
Feed conversion ratio	1.82 [a]	1.72 [ab]	1.69 [b]
Mortality rate	5.23 [a]	3.52 [ab]	3.19 [b]
Daily weight gain (in grams)	69.30 [a]	65.69 [ab]	60.50 [b]
Yield %	72.90 [a]	74.74 [a]	73.29 [a]
Wings %	8.20 [a]	8.39 [a]	8.44 [a]
Thighs %	22.89 [a]	23.48 [a]	23.00 [a]
Breast fillets %	21.51 [a]	24.37 [a]	22.50 [a]
Whole breast %	28.35 [a]	30.31 [a]	29.62 [a]
Total carcass rejections %	1.76 [a]	1.71 [a]	2.00 [a]
Cellulitis %	0.19 [a]	0.27 [a]	0.31 [a]
Dermatitis %	0.31 [a]	0.32 [a]	0.37 [a]

[a,b]Different letters on a line indicate significant differences (n = 3, Kruskal-Wallis test, Dunn's multiple comparison test, $p < 0.05$).

of digestive enzymes (Tarek *et al.*, 2022) and in enterocyte morphology (Zubair; Lesson, 1994), and there is greater expansion of nutrient carriers on the surface of enterocytes (Yu; Robinson, 1992). Teeter and Smith (1985) reported an increase in the digestibility of dry matter, crude protein, fat and starch in response to 75% feed restriction compared to poultry under ad libitum feeding. These authors also evaluated the increase in consumption through forced feeding and found a marked reduction in the digestibility of all the fractions evaluated as consumption increased. Scott (2005) stated that poultry maximize consumption to maintain their growth but not necessarily to maximize their digestion.

The broilers in AV1 and AV2 showed the same daily weight gain, while that of the birds in AV3 differed significantly. These findings coincide with those of Melo *et al.* (2021), Mora, Andrés and Cuéllar (2000) and who also reported lower weight gain in birds in response to increasing levels of quantitative feed restriction. Susbilla *et al.* (1994), who applied more severe feed restrictions of 15%, 30% and 45%, as well as no feed restriction, observed that restriction decreased daily weight gain, but improved feed conversion, demonstrating that the use of feed restriction must go hand in hand with an analysis of economic viability, since the body weight of poultry is reduced.

As for viability (Table 04), it was found that increasing quantitative feed restriction decreased mortality rates. In recent decades, genetic selection for rapid weight gain has increased the mortality rate of broilers, mainly through ascites, sudden death and skeletal disorders, worsening feed conversion (Alkhair, 2021). Yu and Robinson (1992) and Fontana *et al.* (1992) found that the use of moderate quantitative feed restriction programs in poultry rearing reduces mortality and improves feed conversion in broilers. In addition, Gobane *et al.* (2021), Ozkan, Plavnik and Yahav (2006) and Balog *et al.* (2000) reported that quantitative feed restriction synchronizes the bird's rapid growth with the development of its main organs, reducing the harmful effects of rapid weight gain.

In comparison to broiler batches fed ad libitum, the quantitative feed restriction programs (Cobb diet table and 10% less than the table) did not interfere statistically ($p<0.05$) in carcass and parts yields, according to data reported by Mello *et al.* (2021). However, Junior *et al.* (1999), stated that broilers subjected to severe feed restriction of over 20% showed reduced carcass and parts yields. As for poultry carcass rejection, there was no statistical difference between the different treatments in terms of total rejects, and condemnation due to cellulitis and dermatitis, as demonstrated in other studies (Saleh *et al.*, 2004).

From the standpoint of economic performance (Table 5), feed restriction reduced production costs when compared with those allowed ad libitum feeding.

Feed restriction programs have the potential to reduce the incidence of metabolic disorders and carcass fat deposition and to improve feed efficiency in broiler production, leading to savings in production costs (Azouz, 2019; Tsiouris *et al.*, 2014). Dissanayake and David (2017) reported a 34% increase in broiler chicken profits due to an improvement of 210 grams in feed conversion, greater weight gain and better carcass yield of birds subjected to 10% feed restriction when compared to birds fed ad libitum. Lana *et al.* (1999), who did not identify changes in carcass and parts yield in response to feed restriction programs, suggested that this restriction is recommended mostly when feed costs are high and chicken prices in the producer market are low. Also, according to Robinson *et al.* (1992), the best time to apply a feed restriction program is starting in the second week of age, because in their first week of life, chicks are too fragile to withstand the stress of fasting, which can cause changes in satellite cells, thereby diminishing skeletal muscle hypertrophy (Velleman *et al.*, 2010). The results of feed restriction methods indicate that compensatory weight gain varies according to the level of restriction and the period during which animals were subjected to restricted feeding. Studies on the subject are needed

Table 5. Effect of quantitative feed restriction on the cost per kg of mixed broilers weighing 2.8 kg.

Parameters	Ad libitum	Cobb table	10% Restriction
Feed conversion	1.820	1.720	1.690
R$/Kg of feed	2.040	2.040	2.040
R$/Kg of broiler	3.713	3.509	3.448
Mortality rate %	5.230	3.520	3.190
R$/chick	1.530	1.530	1.530
R$/Kg of chicken	0.029	0.019	0.017
Cost R$ (feed + chick)	3.741	3.528	3.465
Cost reduction/Kg of live broiler	0.000	0.213	0.276
% Cost reduction in R$/Kg live broiler	0.000	5.69	7.38

to clarify the advantages and disadvantages of these restrictions on the zootechnical performance of broilers, as well as the maximum and minimum restriction levels. The data found this study indicate that the quantitative feed restriction programs used here provide financial gains and optimize production costs when compared to those obtained through ad libitum feeding. Thus, in addition to the direct gains in feed conversion and mortality rates, gains are also achieved in the poultry production process, which includes the correct shipment of feed to farms, avoiding leftover feed at the end of each broiler batch, optimizing freight costs and losses in the nutritional quality of leftover feed that is generally fed to the next batch. The adoption of quantitative feed restriction programs associated with an automation system for weighing birds in aviaries also allows the development of software for real time monitoring of feed conversion, mortality rates and daily weight gain, enabling poultry farmers and the agribusiness to make more confident decisions.

The data obtained in this study are highly promising and should contribute significantly to reducing broiler chicken production costs. Furthermore, the adoption of quantitative feed restriction programs will allow for the implementation of a real-time batch production data management system, increasing confidence in decision making.

CONCLUSIONS

Quantitative feed restriction in broilers, using 10% less feed daily than recommended by the strain table from 15 days of age, although it caused a lower daily weight gain, significantly improved feed conversion and mortality, generating a considerable reduction in production costs.

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