Effect of Quantitative Feed Restriction during the Growing Period on Growth Performance and Economical Efficiency in Broiler Chickens

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Abstract. *Five hundred broilers chickens were used to study the effect of quantitative feed restriction during the growth period on the zootechnical performance and economical efficiency. Chickens were raised collectively during the starter period and a part of the growing period. At 24days of age, chickens were divided into three groups: control group, fed ad libitum, and two experimental groups (R1 and R2) restricted, respectively, to 10% and 20% of the daily feed intake of the control between 32 and 42 days of age. At 43 days, chickens of R1 and R2 were re-fed ad libitum until the end of the raising (49 days) where 13 randomly selected chickens from each group were slaughtered to record the weight of the heat carcass. Results showed that the average final live weight and the average heat carcass weight were similar in the three groups. Restricted animals recovered, through compensatory growth, the weight to reach the level of the control group. Quantitative feed restriction allowed to save 641.1g and 1282.1g feed per chicken, respectively, in R1 and R2 groups. The quantitative feed restriction provides a significant economy in feed costs, a reduction in carcass cost price and, consequently, a significant improvement in farmers income.*

Introduction

The poultry sector in Algeria has seen significant development in recent decades. Population growth and changes in feeding habits that have accompanied the country's urbanization are the main determinants of this development (Kaci, 2015). The strong development of the poultry sector contributes to job creation and reduction of animal protein deficits (Kaci, 2009). The national poultry industry is undergoing changes that create new constraints. Indeed, the basic factors necessary for its operation (maize and soybean, biological materials, veterinary products, etc.) are exclusively imported (Mouhous et al., 2015). The foreign currency resources allocated annually to this sector are very important and constantly increasing (Belaid-Gater et al., 2021b).

Under these conditions, the formulation of the feed is made almost exclusively with corn and soybean meal. The value of imports of these two raw materials amounts annually to about 1 billion US dollars (Mouhous et al., 2021). As feed is the most important component of expenses in broiler farming (more than 60%), the cost price per kilogram of chicken is highly impacted and dependent on the fluctuation of corn and soybean meal prices on the world market (Belaid-Gater et al., 2019).

The high growth rate of chickens increases the deposition of fat in the carcasses, which leads to human health problems, metabolic and skeletal disorders in poultry, feed wastage through ad libitum feeding and high mortality (Baghbanzadeh & Decuypere, 2008). Also, the syndrome of sudden death (Khurshid et al., 2019) and ascitis (Kalmar et al., 2013) are common and well-known health and safety complaints in fast-growing broilers..

Broiler farmers are looking for high productivity with reduced production costs. This objective is closely related to the quantitative feed restriction practiced in broilers to induce compensatory growth, improve feed utilization efficiency and reduce maintenance requirements in the growth and finishing phases (Teimouri et al., 2005) but also to reduce the incidence of metabolic diseases (Sahraei, 2014). This restriction decreases the fat content in the carcass and decreases the incidence of disease associated with a high growth rate, such as ascites (Afsharmanesh et al., 2016). This will ultimately result in lower feed and production costs, resulting in higher quality, leaner and cheaper meat with lower mortality rates (Zubair & Leeson,1996a; 1996b). In addition, recent studies on the topic, such as those of Trocino et al. (2020), report that feed restriction stimulates activity during and after the restriction phase without any relevant effect on the stress state of the chickens.

In this sense, the aim of this study was to investigate, under the real conditions of local production, the

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effect on the growth, slaughter and economical performance of broilers, of a phase of quantitative feed restriction during the growth period.

Materials and Methods

Presentation of the experimental site

This experiment was carried out in a poultry house of the Institute of Technologies and Specialized Agricultural Means (ITMAS) located in the province of Tizi-Ouzou (Algeria). The study started on February 3, 2019, (installation of the birds) and finished on March 23, 2019, i.e., a 49-day period. The house is an open type building with a total surface of 129 m^2 and the occupied surface is 90 m^2. It is provided with a natural ventilation system assisted by three small ventilators and three small extractors. The heating is provided by a pancake brooder of 1450 kcal. The temperature inside the building has changed inversely with the age of the chickens and has decreased from 33°C to 21°C. The humidity level recorded varied between 50% and 70%. The lighting was combined (natural and artificial). Feed distribution was manual, with feeders adapted to the age of the chickens. The chickens were watered ad libitum and manually at the starter period and automatically during the growing and finishing periods.

Feeds and animals

Five hundred day-old chicks (mixed sexes) of Cobb 500 strain were delivered from a private hatchery located in the same area. The rearing period was divided into three periods. The start period was from the 1st to the 13th day of age, the growth period from the 14th to the 42nd day of age and the finishing period from the 43rd to the 49th day of age. Three different diets were used in this experiment: a starter diet (crumbled) a growth diet (pellet) and a finish diet (pellet). These three diets are available on the local market, in high demand and used by many breeders, and manufactured and marketed by a private feed factory in the region. During the starter period (13 days) and the first 11 days of the growing period (24 days), all birds were raised collectively in the same and conventional broiler rearing conditions. At 24 days of age, the chickens were divided into three equal groups taking into account the number of chickens (163 chickens each) and the total weight of the group. The control one (C) was fed ad libitum and the two experimental groups R1 and R2 were subjected to quantitative dietary restriction for 11 consecutive days (from 32 to 42 days of age) with two levels of restriction, respectively, 10% (R1) and 20% (R2) of the daily intake of the control group. Ad libitum re-feeding with the finishing feed began at 43 days of age of the chickens and ended on the last day of the experiment, i.e., at 49 days of age. The field conditions were reproduced, i.e., how broilers are raised in local production conditions. In addition, during the animals' distribution, the groups were as homogenous as possible, including the proportion of males and females.

Measures performed or calculated

Mortality monitoring wascarried out daily. During the seven weeks of the experiment, weekly monitoring of individual body weight was carried out. A daily control of the quantities of consumed feed (quantities distributed – quantities refused) was carried out per group and per period: before restriction (adaptation period from 24th to 32nd day), during restriction (from 32nd to 42nd day) and after restriction (from 43rd to 49th day).

The economic efficiency (AD = Algerian Dinar) was calculated according to the model of Harouz-Cherifi et al. (2018).

Economic efficiency (%) = [(Weight gain income in AD/kg – Total feed cost in AD/kg) / Total feed cost in AD/kg] × 100.

Weight gain income, AD /kg = total weight gain (kg) * price per kg live weight (in AD).

Total feed cost (feed loads) = the total amount of feed consumed (kg/chicken) * price per kg of feed.

Gross margin (AD) = Weight gain income (AD) - Total feed cost (AD).

Cost/benefit ratio = Total cost of feed consumed/ gross margin.

The price of the feed, which was bought on the local market, was 52 AD /kg.

Slaughter

At the end of the experiment, 13 randomly selected chickens from each group were slaughtered without fasting. The total live weight per slaughter cage and the weight of the hot carcass were recorded.

Chemical analysis

The raw materials of which the feed is composed are corn grain, soybean meal, wheat bran, soybean oil, synthetic amino acids (DL-Methionine, L-Lysine), salt, phosphate, calcium, mineralovitamin complex andan anticoccidian (Coccidiostat).

The chemical analyses of diets (Table 1) covered dry matter, crude ash, crude protein (NA652-1992), fat (NA654-1992), calcium (AFNOR) and phosphorus (NA657-1992).

Statistical analysis

The different results were expressed by means ± standard error of means. The recorded and/or calculated data were subjected to an analysis of variance using software R 3.6.1(www.r-project.org), with the restriction level as the only variation factor. Analysis of variance was used to assess the effects of feed restriction on growth performance and slaughter parameters. Significant differences between the means of the various variables were determined by using the Duncan test. The results were considered different when the value of p was lower than 0.05.

Table 1. Chemical composition (% DM) of the three types of diets used in the test

Parameter	Starter diet	Growth diet	Finishing diet
Dry matter	83.83	88	89.5
Crude ash	5,4	5.6	5.6
Organic matter	94.6	94.4	94.4
Crude protein (N×6.25)	21,49	21.74	20.66
Crude fat	4.4	4.87	3.7
Calcium	1.1	0.93	0.7
Phosphor	0.68	0.74	0.6
Metabolizable energy(kcal/kg)[a]	3811.42	3832.62	3807.43

DM: Dry matter
N: nitrogen
[a]: Estimate from the equation of Zarghi et al. (2010):
ME (MJ /kg DM) = 16.063-0.115EE-0.027CP.

Results

The crude protein, calcium and phosphorus contents of the starter diet are higher than those recommended by the Cobb 500 strain guide (Table 1). The growth diet contains a crude protein content (Table 1) that is 1.75% higher than the standards recommended in the strain guide. The protein concentration of the finishing diet also exceeds the nutritional recommendations of the strain by 2.66%. Calcium and phosphorus levels in the growing diet exceed the nutritional recommendations of the strain guide (Vantress, 2018). For the finishing diet, the phosphorus content is higher than the recommended intake according to the strain guide (Vantress, 2018), in contrast to the calcium content.

During the restriction period (11 days), as expected and contrary to the pre-restriction period, daily consumption per chicken was significantly lower in restricted groups R1 and R2 compared with the control group(p = 0.002;Table 2). After the return to ad libitum feeding (post-restriction period), there was an increase in feed intake in the chickens that were restricted, resulting in a similar average feed daily intake in the three groups during this period.

The average live weights (Table 3), obtained at the end of the trial (49 days of age), are similar between group C and groups R1 and R2, respectively, 3416.34 g, 3456.38 g and 3432.10 g ($p > 0.05$). However, the highest level of compensatory growth was noted for the most severe level of restriction with an average daily gain (ADG) of 95.43 g/day during the post-restriction period, $P = 0.022$(Table 4).

In terms of absolute values, the feed conversion seems to be at the same level in the three groups or even more interesting in the restricted groups with an overall feed conversion ratio (at 49 days) of 1.77 for group R1, 1.78 for group R2 and 1.90 for the control group (Table 4).

No mortality was recorded in the different groups during the trial. Throughout the restriction phase, the chickens' health status was good, and only two chickens died in group R1 on the last day, probably due to the stress of handling (the final weighing).

The average hot carcass weight (Table 5) was similar in the three groups (C, R1 and R2).

The parameters in Table 6 were calculated according to the model of Harouz-Cherifi et al. (2018) as précised in Material and Methods, without a statistical study.

The feed restriction, at the end of the growth period, resulted in an improvement of 20% and 42% in economic efficiency, respectively, for groups R1 and R2, compared with that of the control one (Table 6). Similarly, restriction reduced the total feed cost per chicken by 9.52% and 19.97% for groups R1and R2 respectively, compared with the control one. This reduction is explained by the amount of feed saved due to the restriction of 10% and 20% of the control's consumption, which are 641.1 g and 1282.1 g per chicken, respectively.

Table 2. Average daily feed consumption per chicken (g/d) according to the level of restriction before, during and after restriction

Period \ Groups	C	R1	R2	SEM	P
Before restriction (1–31days)	151.04	150.22	144.65	8.23	0.949
During restriction (32–42days)	210.89b	177.85a	169.89a	5.77	**0.002**
After restriction (after 43days)	186.29	183.01	200.63	5.53	0.404

C: Control. R1:Group with 10% of restriction. R2: Group with 20% restriction.
Values followed by different letters on the same line are significantly different.

Table 3. Comparison of average live weight (g) according to restriction level and period

Period \ Groups	**C**	**R1**	**R2**	**SEM**	**P**
Before restriction (1–31 days)	1673.46	1665.80	1652.80	13.99	0.152
During restriction(32–42 days)	2305.91a	2247.62b	2258.60b	19.73	0.038
After restriction (after 43 days)	3416.34	3456.38	3432.10	18.94	0.682

C: Control. R1: Group with 10% of restriction. R2: Group with 20% restriction.
Values followed by different letters on the same column are significantly different.

Table 4. Average daily gain (ADG) and the feed conversion ratio (FCR) according to the level of feed restriction

Average Daily Gain (ADG) (g/d)				
Groups \ periods	**Before restriction**	**During restriction**	**After restriction**	**Global ADG**
C	85.16	91.91	66.98a	70.13
R1	84.07	89.72	85.44b	70.97
R2	72.50	92.13	95.43b	70.46
SEM	11.67	09.37	17.63	2.13
P	0.113	0.336	0.022	0.174
Feed Conversion Ratio (FCR)				
Groups \ periods	**Before restriction**	**During restriction**	**After restriction**	**global FCR**
C	1.62	1.91	2.24	1.90
R1	1.52	1.97	2.04	1.77
R2	1.81	1.61	2.76	1.78
SEM	1.64	1.13	1.96	1.56
P	0.167	0.052	0.057	0.178

C: Control. R1: Group with 10% of restriction. R2: Group with 20% restriction.
Global ADG and global FCRwere calculated for all the experimental period (before, during and after restriction).

Table 5. Effect of feed restriction on hot carcass weight (g) of chickens

Group	**C**	**R1**	**R2**	**SEM**	**P**
hot carcass weight (g)	2549.16	2732.72	2670.90	53.10	0.367

C: Control. R1: Group with 10% of restriction. R2: Group with 20% restriction.
Values followed by different letters on the same line are significantly different.

Table 6. Production economy per 49-day-old chicken in the three groups (C, R1 and R2)

Parameters	**C Group**	**R1 Group**	**R2 Group**
Average live weight of a day-old chick (g)	49.7	49.7	49.7
Average live weight at 49 days (g/chicken)	3416.4	3456.4	3432.1
Total weight gain (kg)	3.37	3.41	3.38
Selling price AD-Euro/kg live weight	250–2.11	250–2.11	250–2.11
Income as live weight gain AD-Euro/kg	842.5–7.1	852.5–7.18	845–7.12
Total feed consumed/chicken (kg)	6.41	5.8	5.13
Price per 1kg of feed (AD-Euro)	52–0.44	52–0.44	52–0.44
Total feed/chicken cost (AD-Euro/kg)	333.3–2.81	301.6–2.54	266.8-2.25
Economical efficiency (%)	153	183	217
Gross margin (AD-Euro)	509.2–4.29	550.9–4.64	578.2–4.87
Cost/benefit ratio	0.65	0.54	0.46

C: Control. R1: Group with 10% of restriction. R2: Group with 20% of restriction. AD: Algerian Dinar, (01 euro=118.7 DA during the essay period).

The restricted groups also enabled an improvement in the income per kg of meat produced, with a reduction of 31.72 AD for R1 and 66.56 AD for R2 for each kg of meat produced. In addition, restricted groups R1 and R2 had better cost/income ratios than the control one.

Discussion and Conclusion

Chemical composition of the feeds

According to Larbier and Leclercq (1992), fillet yields are better when the requirements for a minimum feed conversion are optimized during the first two rearing phases. According to thesame authors, when growing chickens are provided with the required energy, the excess of protein moderately reduces the appetite without affecting growth and raises the protein level by 1 point (10 g/kg diet) resulting in a 3% increase in water consumption.

According to Drogoul et al. (2004), for a given energy concentration, the crude protein and amino acid content of the diet decreases as the age of chickens increases. A combined and balanced intakeof calcium and phosphorus in the feedis necessary for bone growth; calcium plays a determining role in phosphorus availability (Narcy et al., 2009).

In addition, nutritionists use wide safety margins to ensure adequate phosphorus intake, which is crucial for skeletal integrity and growth performance in broilers (Flaten et al., 2003).

According to Waldenstedt (2006), the calcium content must be less than 0.70% after 28 days of the age of chickens. Globally, the nutrient intakes of the three types of diets, especially nitrogen, exceed the recommendations, which have negative repercussions on the costs of these diets, generate significant nitrogen rejections and indicate the lack of adequate knowledge regarding the formulation aspect at the level of the feed mills.

Feed consumption and growth performance

The resultsof daily consumption per chicken are in agreement with those reported in the literature (Novele et al., 2008; Malpotra et al., 2017). Those of increased feed intake in chickens that were restricted are in agreement with those recorded by Zomrawi et al. (2019). However, the opposite was recorded by Bouallegue & Aschi (2015) who explained their results by the severity of the level of restriction applied, with the restricted chickens receiving the same amount of feed for 8 successive days while those of the control group gradually increased their consumption. Our results were caused by the low level of restriction applied in this experiment. Chickens from groups R1 and R2 were restricted for 11 successive days. The amounts consumed by these chickens were calculated on the basis of the daily consumption of those in the control group. The control chickens gradually increased their consumption. The difference in average daily consumption recorded per restricted chickens during the 11 days of restriction ranged from 350 g to 450 g less compared with those which were fed ad libitum.

The results of the mean live weights, obtained at the end of the trial (49 days of age), are in agreement with those reported by Khetani et al. (2009) who reported that restricted chickens expressed compensatory growth after re-feeding ad libitum. When animals are restricted, a negative effect on body weight growth occurs; restricted animals grow less than animals fed ad libitum. However, this effect will disappear during the ad libitum feeding period due to compensatory growth. Compensatory growth has been reported by the literature (Lee & Leeson, 2001; Jang et al., 2009). Thus, the level of feed restriction or/and duration of restriction showed a negative correlation with the growth of restricted chickens (Urdaneta-Rincon & Leeson, 2002).

The average daily gain (95.43 g/day), during the post-restriction period, is slightly higher than recommended, at the same time, by the Cobb 500 strain guide, and confirms the results recorded by Leeson and Zubair (1997).

The average final live weight at 49 days (3434.94 g) recorded in this study was better than those (2760 g) reported by Mouhous et al. (2012) recorded at 57 days of age in private farms in the same region (Tizi-Ouzou) or those reported by Mouhous et al. (2014) for the Béjaia region, which borders Tizi-Ouzou. However, it is slightly lower than the average weight of the Cobb 500 strain and is the weight recommended by the strain guide at 49 days, i.e., 3506 g.

The results of health status are in agreement with those reported in the literature regarding the reduced mortality rate and sudden restriction death syndrome (Bhat & Banday, 2000; Urdaneta-Rincon & Leeson, 2002; Boostani et al., 2010). In addition, this restriction did not affect the chickens' welfare according to Belaid-Gater et al. (2021a). Jang et al. (2009) reported a significant increase in cytokine levels of blood in the feed-restricted groups, which could positively impact the health and welfare of the chickens. This was noted even when the quantitative feed restriction was strict (less than 75% of the ad libitum amount).

The results of the feed conversion were similar to those reported by several authors, notably Sahraei (2012) and Bouallegue and Aschi (2015). The value of the overall feed conversion ratio recorded for the two restricted groups (1.77) was slightly better than the performance of the Cobb 500 strain (1.82) recommended, at the same age as the chickens, by the strain guide.

The average hot carcass weight is very interesting and indicates that the experimental chickens managed to regain growth during their re-feeding ad libitum period after feed restriction and to reach the weight of the control group with reduced feed intake. Jayasiri et al. (2019) also reported this type of result.

For indication, the average carcass yield in the restricted groups was 78.44% compared with 74.61% in the control one. The recommended yield for chickens of this strain at this age by the Cobb 500 Guide is 75.42%. Lee & Leeson (2001) suggest that there was no loss in meat yield if chickens achieve compensatory growth during their re-feeding period after feed restriction.

Economical efficiency

The results of the economic study of this experiment showed the advantage of the feed restriction and confirmed the results of the bibliography, notably those of Sahraei (2012), Zomrawi et al. (2019), Trocino et al. (2020). They were in agreement with those of Proudfoot & Hulan (1982) and Jayasiri et al. (2019), who reported that chickens restricted and then fed *ad libitum* had a higher benefit than those fed ad libitum without restriction (control).

In conclusion, the results of this experiment confirm the advantages of quantitative feed restriction in broiler farming. Applied at two levels (10% and 20%) during the late growing period (32 to 42 days of age), it did not affect the health status or zootechnical performance of the chickens. It induced sufficient compensatory growth to reach a final live weight and hot carcass weight similar to the control group with an appreciable economy of feed consumed.

The quantitative feed restriction mainly results in a significant economy of feed costs in broiler production, which is very profitable for the breeders but also, indirectly, for the consumers.

Conflict of Interests

The authors declared that there is no conflict of interests.

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