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Productive performance, body chemical composition, and deposition of 42-day-old quail for meat subjected to quantitative dietary restriction

Desempenho produtivo, composição e deposição química corporal aos 42 dias em codornas de corte submetidas à restrição alimentar quantitativa

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Abstract

This study aimed to assess the effect of quantitative dietary restriction during refeeding on the performance, body chemical composition, and deposition, weight gain of organs and carcass parts of quails reared for meat (*Coturnix coturnix coturnix*). A total of 144 quails, between 11 to 42 days old, were distributed in a completely randomized design, 4x2 factorial scheme, at four levels of feed restriction (*ad libitum*, 30%, 50% and 70% restrictions on the daily intake *ad libitum*) for both genders. Therefore, there was eight treatments with three replicates and six birds each. At the tenth day of age, the animals were housed in cages, where remained for four days under adaptation. Dietary restriction was applied between the days 15 and 35 while refeeding was carried out from day 36 to 42. Compensatory weight gain (CWG), i.e. weight gain of organs and carcass parts, and feed efficiency (FE) were improved for quails under feed restriction. Fat (F), crude protein (CP), protein deposition rate (PDR) and fat in females (FDf) and carcass retained energy in females (CREf) increased linearly as restriction levels decreased. Maximum estimates of feed intake for males (MFIm), compensatory weight gain for males (CWGm) and females (CWGf), feed efficiency for males (FEm), protein deposition for males (PDm) and carcass retained energy in males (CREm) were obtained with restriction levels of 43.56%, 30.56%, 63.93%, 62.63%, 80.25%, 1.94% and 09.34% if compared to *ad libitum*, respectively. As a result, we concluded that according to quantitative feed restriction level, significant increases in feed efficiency and body weight gain, as well as decreases in carcass fat throughout quail refeeding period. As for gender, given the existing sexual dimorphism, females lost greater body weight than males under dietary restriction, besides showing higher protein and fat gains in the carcass and an enhanced feed efficiency during refeeding.

Key words: Body chemical composition. Compensatory weight gain. Feeding levels. Organs. Carcass parts.

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Resumo

Neste estudo objetivou-se avaliar o efeito da restrição alimentar quantitativa sobre o desempenho, composição e deposição química corporal, ganho de peso de órgãos e partes da carcaça de codornas de corte (*Coturnix coturnix coturnix*) no período de realimentação. Foram utilizadas 144 codornas, de 11 a 42 dias de idade, distribuídas em delineamento inteiramente casualizado, em arranjo fatorial 4x2, com quatro níveis de restrição alimentar (ad libitum e restrição alimentar quantitativa de 30%, 50% e 70% da ingestão diária dos animais ad libitum) e gênero, totalizando oito tratamentos, com três repetições e seis aves cada. Foram alojadas aos 11 dias de idade em gaiolas, permanecendo quatro dias em adaptação. Dos 15 aos 35 dias foi aplicada a restrição alimentar e a realimentação de 36 a 42 dias. O ganho de peso compensatório (GP), consequentemente de órgãos e partes da carcaça e a eficiência alimentar (EA) foram melhores em codornas submetidas à restrição alimentar. A gordura (GD), proteína bruta (PB) corporal, taxa de deposição de proteína (TDP) e gordura em fêmeas (TDGF) e energia retida na carcaça em fêmeas (ERCF) aumentaram linearmente à medida que diminuíram os níveis de restrição. As estimativas de máximo consumo de ração para machos (CRM) e fêmeas (CRF), ganho de peso compensatório para machos (GPM) e fêmeas (GPF), eficiência alimentar para machos (EAM), taxa de deposição de proteína para machos (TDPM) e energia retida na carcaça em machos (ERCM) foram obtidas com níveis de restrição alimentar de 43,56%, 30,56%, 63,93%, 62,63%, 80,25%, 1,94% e 9,34% em comparação a ingestão ad libitum, respectivamente. Conclui-se que dependendo do nível de restrição alimentar quantitativa, ocorre melhora significativa na eficiência alimentar, aumenta o ganho de peso corporal e diminui a quantidade de gordura na carcaça no período de realimentação de codornas de corte. Já para gênero, devido ao dimorfismo sexual existente, as fêmeas perderam maior peso corporal do que os machos na restrição e apresentaram maiores ganhos de proteína e gordura na carcaça e melhor eficiência alimentar no período de realimentação.

Palavras-chave: Composição química corporal. Ganho de peso compensatório. Níveis de alimentação. Órgãos. Partes da carcaça.

Introduction

The European quail strain (*Coturnix coturnix coturnix*) is one the most used for meat production. These animals reach an adult weight between 200 and 300 g (DU PREEZ; SALES, 1997), and slaughtering at 42 days of age is recommended (ABREU et al., 2014). This strain is well known for its rapid body growth until 21 days of age; thereafter, weight gain starts to decrease since protein and water deposition rates are declined, followed by an increase in fat content in carcass and organs. Overall, significant differences are observed between genders regarding body weight and nutrient deposition rates in the carcass (DU PREEZ; SALES, 1997).

For birds, reducing feed supply in a given period (quantitative) or decreasing the amount of nutrients in the diet (qualitative) are techniques targeting at minimizing body fat accumulation and promote improvements in dietary efficiency (ROSA et al., 2000), which associated to a compensatory weight gain without compromising slaughter weight (PLAVINIK; HURWITZ, 1985). Another relevant factor of these techniques would be the reduction of feed costs, thus increasing the profitability of the production system, without compromising the carcass yield (LANA et al., 1999).

During dietary restriction, poultry growth rates are slowed down, being afterwards offset by refeeding (FONTANA et al., 1992). After a period of reduced growth, such increasing rates are defined as compensatory gain (YU et al., 1990). This procedure promotes a lower deposition of fat and larger of lean tissue in the carcass (OMOSEBI et al., 2014).

Such compensatory gain only occurs when animals are submitted to a short period of dietary restriction. Nevertheless, long intervals and severe levels of nutrient restriction can cause growth retardation or even permanent damages to the poultry, thus compromising a weight gain recovery

during refeeding period (PLAVINIK; HURWITZ, 1985). For instance, a few studies have been carried out on broiler chickens and turkeys, which underwent feed restriction at an early growth stage without jeopardizing body weight at slaughter age (OSBOURN; WILSON, 1960; AUCKLAND; MORRIS, 1971).

Given the above, several studies have been performed focusing on determining the best levels of feed restriction, besides defining in which rearing phase it should be applied. These investigations also aim to evaluate further benefits from such dietary restrictions on animal production, with the purpose of improving carcass quality without affecting poultry productive and economic performance. Thus, this research was conducted to evaluate the effect of a quantitative feed restriction on productive performance, body chemical composition and deposition, weight gain of organs and carcass parts of male and female quail (*Coturnix coturnix coturnix*) during the refeeding phase (*ad libitum*).

Material and Methods

The experiment was carried out following the guidelines stated by the Committee of Ethics in Animal Experimentation of the State University of Maringá, in Brazil.

Animals and diets

One hundred and forty-four quails for meat (*Coturnix coturnix coturnix*), 72 males and 72 females, were conventionally reared from 1 to 10 days old, receiving water and feed *ad libitum*. Thereafter, the animals were divided into boxes lined with rice straw where remained from 11 to 42 days of age for the experiment period.

The experimental design was a completely randomized, in a 4x2 factorial scheme consisted of four feeding levels and two genders, totalling 8 treatments with three replicates containing six quails each. At 11 days of age, the birds were housed in galvanized wire cages, which was considered an experimental unit.

The first four days consisted of an adaptation period to the experimental cages, within which birds received feed *ad libitum*; yet water was supplied freely throughout the entire experiment. From 15 to 35 days of age, the animals underwent four feeding levels, which were *ad libitum* and quantitative dietary restrictions (DR) of 30%, 50% and 70% of the total consumed daily for each animal. These restriction levels were estimated based on *ad libitum* consumption measured the previous day; therefore, all units were daily checked. Later, from 36 to 42 days of age, a refeeding phase started, that is, feedstuff was provided *ad libitum* for all treatments.

Feeds were formulated based on corn and soy bran, considering the values of feed chemical composition according to Rostagno et al. (2011), in order to meet quail nutritional requirements at each rearing phase (Table 1).

Table 1. Percent chemical and energetic composition of the feeds for quails in early growth (1 to 14 days of age) and final growth (15 to 42 days of age).

	Meat-type quail	
	Initial phase	Final phase
Ingredients	Quantity (kg/100kg)	
Maize	40,95	52,79
Soya bean meal (45%)	49,75	39,31
Soya bean oil	4,75	3,25
Dicalcium phosphate	1,56	1,60
Sodium chloride	0,46	0,46
Limestone	0,36	0,28
DL-Methionine	0,67	0,66
L-Lysine HCL	0,68	0,80
L-Threonine	0,42	0,41
L- Tryptophan	0,006	0,04
Vitamin and mineral mixture[1]	0,40	0,40
Total	100,00	100,00
Calculeted values		
Metabolisable Energy (Kcal/kg)	2996	3034
Crude protein (%)	27,49	23,51
Calcium (%)	0,64	0,61
Available phosphorus (%)	0,41	0,41
Sodium (%)	0,20	0,20
Potassium (%)	1,02	0,86
Chlorine (%)	0,31	0,31
Methionine + digestible cystine (%)	1,32	1,23
Digestible lysine (%)	1,87	1,73
Digestible threonine (%)	1,25	1,11
Digestible tryptophan (%)	0,30	0,28

[1]Mineral-vitamin mix (replacement levels per kg of product); Vit. A – 4,500,000 IU; Vit. D3 – 1250,000 IU; Vit. E – 4,000 mg; Vit. B1 = 278 mg; Vit. B2 – 2,000 mg; Vit. B6 – 525 mg; Vit. B12 – 5,000 mcg; Vit. K3 = 1,007 mg; Calcium Pantothenate – 4,000 mg; Niacin – 10,000 mg; Choline – 140,000 mg; Antioxidant – 5,000 mg; Zinc – 31,500 mg; Iron – 24,500 mg; Manganese – 38,750 mg; Copper – 7,656 mg; Cobalt – 100 mg; Iodine – 484 mg; Selenium – 127 mg; 2 BHT (Butyl Hydroxy Toluene).

Evaluation of performance

The quails were weighed at 36 and 42 days of age and, simultaneously with this period, experimental feed provided to the animals and respective leftovers were weighed for determination of weight gains (being compensatory for treatments under feed restrictions – 30, 50 and 70%), feed consumption (g) and food efficiency (%). The weight gain was determined by the difference between final (42 days of age) and initial (36 days of age) weights of each experimental unit. Yet feed efficiency was estimated by the relationship between the average weight gain per bird in one replication and the average feed intake per bird.

Weighing of organs and carcass parts

Organs and carcass parts of one animal per replication were weighed at the beginning and at the end of refeeding (36 and 42 days of age). Birds were selected based on mean weight (± 5%) of each experimental unit. After selection, the animals fasted for six hours for posterior weighing. Next, they underwent electrical stunning and further occipital bone displacement apart from the atlas bone. After bleeding, birds were scalded (53-55 °C) for 10 seconds, manually plucked, eviscerated by abdominal incision, and the organs were removed for weighing. The following organs were weighed: heart, liver, small intestine, gizzard, both wings

together, legs and leg quarters, back and chest. In addition, the length of the small intestine was measured by means of a measuring tape.

Body chemical composition and deposition

The chemical composition of nutrients in quail carcasses was determined by a method described by Sakomura and Rostagno (2007), slaughtering one bird per repetition at 36 and 42 days of age. Prior to slaughter, animals were selected by the mean weight (± 5%) of each experimental unit, identified with numbered plastic rings attached to the left foot. Then, they were submitted to six hours of fasting for complete emptying of the gastrointestinal tract. Subsequently, we performed the weighing of animals, submitting them to electrical stunning and further occipital bone displacement from the atlas bone.

After slaughter, the carcasses with feathers, viscera, feet, and head were frozen and then ground in an industrial meat grinder. Afterwards, the samples were homogenized, weighed and taken to a forced ventilation oven at 55 ºC, where remained for 72 hours for a pre-drying. Later, they were weighed, ground in a knife-type mill and transferred to the laboratory for analytical determinations. Dry matter (DM), crude protein (CP), ethereal extract (EE) and mineral matter (MM) were evaluated. The methods for the aforementioned analyses are detailed in the AOAC (1990).

We used the methods described by Fraga et al. (2008) for estimations regarding protein and fat deposition rates (g/ day), protein deposition efficiency (g) and carcass-retained energy (CRE, in kcal/ day). For CRE, the equation proposed by Sakomura (2004) was employed where the estimated energy values were 5.66 for protein and 9.37 for fat (kcal/g).

Statistics

Parameters investigated here were analyzed by means of SAS statistical software version 8.2 (SAS, 2001). The data were subjected to analysis of variance and subsequent polynomial regression ($p<0.05$) and, when factors interacted, a split analysis and linear regression were performed ($p<0.05$).

Results

Poultry performance

The levels of dietary restriction (DR) showed significant interaction ($p<0.05$) among each other and between genders for the parameters feed consumption (FC), weight gain (WG) and feed efficiency (FE). The interaction points out that the DR levels and gender acted independently on poultry performance during refeeding (36 to 42 days of age).

There was a quadratic effect ($p<0.05$) for feed intake by males (MFIm) and females (MFIf), compensatory weight gain in males (CWGm) and females (CWGf) as well as feed efficiency for males (FEm) during refeeding (36 to 42 days of age), due to dietary restriction levels between 15 and 35 days of age. Female feeding efficiency (FEf) showed a linear behaviour, as shown in Table 2.

The maximum estimates MFIm (206.75 g), MFIf (232.84 g), CWGm (70.63g), CWGf (77.90g) and FEm (38.29%) were reached under restriction levels of 43.56%, 30.56%, 63.93%, 62.63% and 80.25% of ad libitum feeding, respectively (Figure 1).

Females submitted to 70% feed restriction showed the best result for FE, from which lower values of DR provided a decrease in FEf, because of a significant linear behaviour ($p<0.05$).

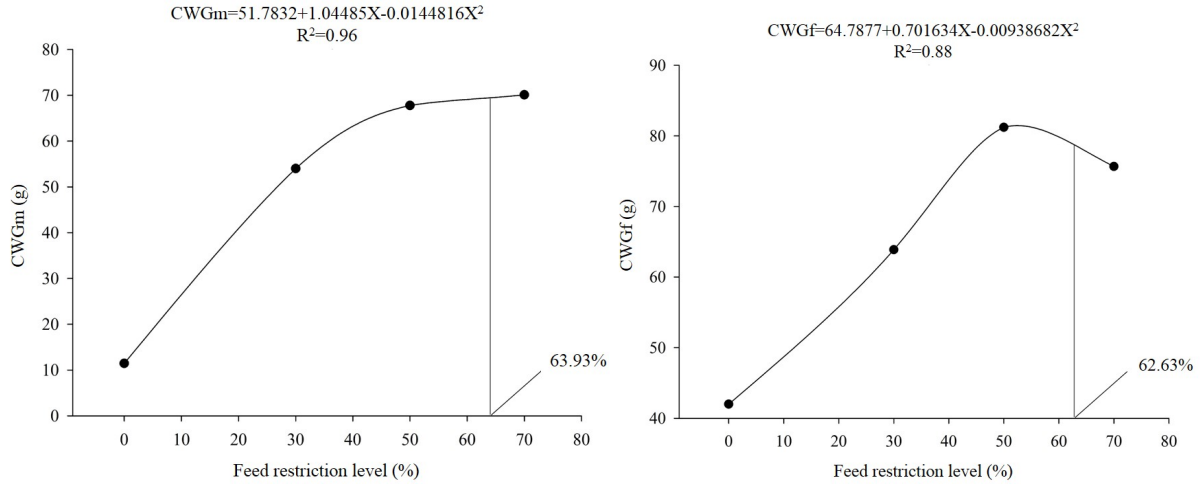
At this stage, the results of quail performance indicated that birds under no dietary restriction had lower feed consumption if compared to those previously submitted to certain restriction levels. The higher the restriction to which birds had been subjected, the lower the feed intake was in refeeding phase.

Table 2. Performance of quails for meat production at 42 days old, which were submitted to feed restriction levels of 30%, 50% and 70% *ad libitum* intake from 15 to 35 days of age and refed from 36 to 42 days of age.

Feed restriction levels	FI (g/bird)		WG (g/bird)		FE (%/bird)	
	M	F	M	F	M	F
70% restriction	186,22	185,00	70,11	75,67	37,83	41,43
50% restriction	200,33	208,67	67,78	81,22	33,87	39,06
30% restriction	205,11	242,44	54,00	63,89	26,43	26,33
Ad libitum	145,11	199,44	11,44	42,00	7,81	21,11
Mean	184,19	208,89	50,83	65,69	0,265	0,320
CV (%)	8,97		9,85		12,22	
Regression equation				R^2	Effect	
FIm = 104,919 + 3,60859DR – 0,0319697DR²				0,76	Quadratic	
FIf = 71,7754 + 4,63874DR – 0,0334DR²				0,54	Quadratic	
CWGm = 51,7832 + 1,04485DR – 0,0144816DR²				0,96	Quadratic	
CWGf = 64,7877 + 0,701624DR – 0,00938682DR²				0,88	Quadratic	
FEm = 36,4484 + 0,186925DR – 0,00473123DR²				0,94	Quadratic	
FEf = 51,7435 – 0,316178DR				0,82	Linear	

Coefficient of variation (CV); coefficient of determination (R^2); feed intake (FI); weight gain (WG); feed efficiency (FE); males (M); females (F); feed intake of males (FIm) and of females (FIf); compensatory weight gain of males (CWGm) and of females (CWGf); feed efficiency of males (FEm) and of females (FEf); levels of dietary restriction (DR).

Figure 1. Compensatory weight gain of males (CWGm) and females (CWGf) of quails for meat production at 42 days old, which were submitted to feed restriction of 30%, 50%, and 70% *ad libitum* intake from 15 to 35 days old and refed from 36 to 42 days of age.



After 35 days of age, the body weight of females submitted to restriction and *ad libitum* feeding showed differences between 20 and 55%, being lower for animals under more severe levels. After 42 days of age (refeeding), male and female under 70% DR presented body weights of 20 and 35% lower than control, respectively. Under 50% restriction, females reached a 10% lower body weight than those animals under 30% restriction. Moreover, males under 30% restriction had a body weight equal to those of the control group – *ad libitum* (Table 3).

Table 3. Mean body weight at 35 and 42 days of age for males and females of quails for meat production submitted to 30%, 50%, and 70% feed restriction related to an *ad libitum* intake from 15 to 35 days of age and refed from 36 to 42 days old.

Feed restriction levels	BW (g/bird) at 35 days of age			BW (g/bird) at 42 days of age		
	M	F	Mean	M	F	Mean
70% restriction	104,89	97,22	101,06	175,00	172,89	173,95
50% restriction	130,89	124,56	127,73	198,67	246,52	222,60
30% restriction	167,67	175,11	171,39	221,67	239,00	230,34
Ad libitum	209,67	223,56	216,62	221,11	265,56	243,34
Mean	153,28	155,11	154,20	204,11	230,99	217,56

Mean body weight (BW); males (M); females (F).

Compensatory weight gains of quail organs and carcass parts

Regarding CWG of organs, there was no significant interaction ($p<0.05$) during refeeding (from 36 to 42 days of age). However, there was a linear effect particularly for liver, small intestine and gizzard as dietary restriction increased from 15 to 35 days of age (Table 4).

Table 4. Compensatory weight gain of quail organs at 42 days of age which underwent feed restriction of 30%, 50%, and 70% *ad libitum* intake from 15 to 35 days old and refeeding from 36 to 42 days.

Feed restriction levels	Heart (g)	Liver (g)	SI (g)	SIL (cm)	Gizzard (g)
70% restriction	1,74	3,02	5,27	14,75	1,57
50% restriction	0,91	2,06	3,22	6,42	1,23
30% restriction	0,83	1,70	3,48	10,75	1,13
Ad libitum	0,44	0,96	2,03	7,83	0,28
Mean	0,98	1,94	3,5	9,94	1,05
CV (%)	111,75	47,84	42,53	9,71	60,40
Regression equation				R^2	Effect
Liver = 3,68354-0,0280234DR				0,96	Linear
SI = 6,03879-0,0405872DR				0,83	Linear
Gizzard = 2,15953-0,0177259DR				0,93	Linear

Coefficient of variation (CV); coefficient of determination (R^2); small intestine (SI); small intestine length (SIL); levels of dietary restriction (DR).

CWG for parameters heart and small intestine length showed no significant difference among restriction levels of feeding. Furthermore, there was no significant interaction ($p<0.05$) between dietary restriction and gender for the parts of the carcass assessed (Table 5). On the other hand, a CWG linear increase ($p<0.05$) was observed for wings, legs and leg quarters, back and chest of quails throughout refeeding period (36 to 42 days of age), according to the increase of feed restriction levels from 15 to 35 days of age.

Body chemical composition and deposition

Table 6 shows a significant difference ($p <0.05$) for the variables crude protein, water and fat, where fat presented an interaction between levels of feed restriction and gender.

Table 5. Compensatory weight gain of carcass parts of quails for meat production at 42 days of age, which were subjected to feed restrictions of 30%, 50% and 70% *ad libitum* intake from 15 to 35 days old and refeeding from 36 to 42 days of age.

Feed restriction levels	Wings (g)	Legs and legs quarters (g)	Back (g)	Chest (g)
70% restriction	4,01	13,13	11,86	27,53
50% restriction	2,15	9,67	8,14	19,98
30% restriction	1,77	7,15	3,93	19,47
Ad libitum	1,60	1,24	3,85	4,88
Mean	2,38	7,80	6,95	17,97
CV (%)	41,23	43,57	67,95	33,60
Regression equation			R^2	Effect
Wings = 4,34660-0,0314190DR			0,71	Linear
Legs and legs quarters = 18,2455-0,167178DR			0,99	Linear
Back = 14,2721-0,117234DR			0,83	Linear
Chest = 37,0128-0,304779DR			0,92	Linear

Coefficient of variation (CV); coefficient of determination (R^2); levels of dietary restriction (DR).

Table 6. Body chemical composition (fresh matter) of quails for meat production at 42 days old, which were subjected to feed restriction of 30%, 50% and 70% *ad libitum* intake from 15 to 35 days of age and refeeding from 36 to 42 days old.

Feed restriction levels	CP (%/bird)	F (%/bird)		A (%/bird)	W (%/bird)
		M	F		
70% restriction	18,66	6,72	6,26	3,10	70,60
50% restriction	18,65	7,55	7,99	3,06	69,98
30% restriction	18,81	8,56	9,03	3,06	68,47
Ad libitum	19,43	8,57	11,18	3,10	66,45
Mean	18,89	7,85	8,61	3,05	68,88
CV (%)	3,14	10,96		5,37	1,63
Regression equation			R^2	Effect	Interaction
CP = 18,1862 + 0,0112343DR			0,17	Linear	NS
Fm = 6,15028 + 0,0271682DR			0,36	Linear	S
Ff = 4,322273 + 0,0686684DR			0,90	Linear	S
W = 72,6931 – 0,0611355DR			0,69	Linear	NS

Coefficient of variation (CV); coefficient of determination (R^2); crude protein (CP); fat (F); ashes (A); water (W); males (M); females (F); fat for males (Fm) and for females (Ff); levels of dietary restriction (DR); significant (S); non-significant (NS).

Fat results displayed a linear behaviour for both males and females ($p < 0.05$). The higher the amount of feed provided, from 15 to 35 days of age, the greater the content of body fat found in females and in males at 42 days of age. It is noteworthy that females accumulated higher amounts of fat in the carcass than did the males.

Dietary restriction also influenced CP content, which increased linearly ($p < 0.05$) in the carcasses as restriction decreased, until *ad libitum* feeding. Likewise, body water rose linearly ($p < 0.05$), but unlike CP, the higher the feed restriction level, the higher the amount of water found in carcasses.

Table 7 presents a significant interaction ($p < 0.05$) between gender and restriction levels for protein deposition rate (PDR) and fat (FDR), as well as for CRE.

For males, PD and CRE showed a quadratic behaviour ($p < 0.05$) (PDm and CREm) during

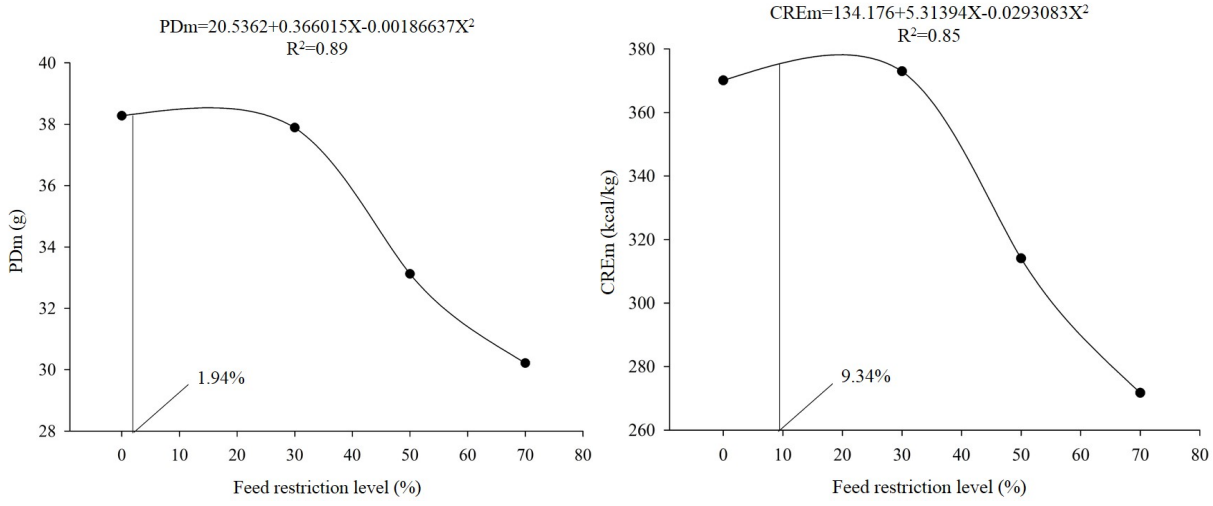
refeeding as a function of an interaction between gender and restriction levels from 15 to 35 days of age. The maximum estimates for PDm (38.48 g) and higher amount of CREm (375.05 Kcal / kg) were reached at restriction levels of 1.94% and 9.34%, respectively (Figure 2).

Table 7. Chemical deposition of protein, fat, and energy retained in the carcass (fresh matter) of quails for meat production at 42 days old under feed restriction of 30%, 50% and 70% *ad libitum* intake from 15 to 35 days of age and refed from 36 to 42 days of age.

Feed	PDR (g/bird)		FDR (g/bird)		CRE (kcal/kg/bird)	
restriction levels	M	F	M	F	M	F
70% restriction	30,21	29,31	10,75	9,97	271,69	259,27
50% restriction	33,12	35,49	13,51	15,02	314,07	341,67
30% restriction	37,89	39,45	16,92	19,37	372,98	404,75
Ad libitum	38,27	44,01	16,38	26,14	370,10	494,06
Mean	34,87	37,07	14,39	17,62	332,21	374,94
CV (%)	3,03		11,67		5,46	
Regression equation				R^2	Effect	
PDm = 20,5362 + 0,366015DR – 0,00186637DR²				0,89	Quadratic	
PDf = 24,2124 + 0,163301DR				0,97	Linear	
FDm = 9,18001 + 0,0833498DR				0,56	Linear	
FDf = 3,28195 + 0,229485DR				0,93	Linear	
CREm = 134,176 + 5,31394DR – 0,0293083DR²				0,85	Quadratic	
CREf = 167,793 + 3,31431DR				0,96	Linear	

Coefficient of variation (CV); coefficient of determination (R^2); protein deposition rate (PDR); fat deposition rate (FDR); carcass retained energy (CRE); male (M); females (F); protein deposition in males (PDm) and in females (PDf); fat deposition in males (FDm) and in females (FDf); carcass retained energy in males (CREm) and in females (CREf); levels of dietary restriction (DR).

Figure 2. Body protein deposition (PDm) and carcass retained energy (CREm) in males of quails for meat production at 42 days of age under feed restriction of 30%, 50% and 70% *ad libitum* intake from 15 to 35 days old and refed from 36 to 42 days of age.



As for females, there was a linear increase ($p < 0.05$) in PD (PDf), FD (FDf) and CRE (CREf) derived from a decrease in the level of feed restriction. The same linear effect was observed for fat deposition in males (FDm).

In general, females showed higher results for PDR, FDR and CRE when compared to males. However, for both genders and at lower dietary restriction, there were higher values for the same variables.

Discussion

During restriction period, weight gains were reduced, consequently, nutrient requirements for body maintenance varied. As a result, in refeeding, these variations enhanced efficiency in the use of nutrients provided by the diets for growth (LIPPENS et al., 2000). This outcome can be clearly visualized in this study. Here, the best results for weight gain and feed efficiency were obtained during refeeding of birds previously submitted to feed restriction. Confirming this statement, we may highlight that the maximum CWGs for males and for females were found in birds under restriction levels of 63.93% and 62.63%, respectively.

As can be expected increasing body weights of birds should be proportional to larger organs, so that functional problems could be avoided. Therefore, in being refed, quails submitted to feed restrictions showed not only a CWG increase but also weight gains in organs and carcass parts. In this study, liver, small intestine, gizzard, wings, legs and leg quarters, back and chest CWG increased linearly in refeeding feed restriction was raised.

Interestingly, feed efficiency in males reached an optimal threshold at a high degree of feed restriction of 80.25%. Yet for females, this effect was linear, i.e. the higher the restriction, the better the nutrient use efficiency for growth in refeeding period. This indicates that birds under dietary restriction have their nutritional needs altered as a survival strategy, which makes it more efficient later in the refeeding (LIPPENS et al., 2000).

Within the seven-day refeeding period, only quail males under the lowest feed restriction level (30%) were able to achieve body weight similar to that of birds fed *ad libitum* (Table 3). In particular, we may highlight that the lower the feed restriction, the faster the bird recovers its body weight in refeeding. Robinson et al. (1992) observed that longer refeeding periods for broilers decreased the difference between weight gain of birds under restricted diet and those animals fed *ad libitum*, thus outlining possible advantages of this technique in poultry.

Animal body growth is established by deposition of four chemical components: protein, fat, water and ashes (EDWARDS JUNIOR et al., 1973; SAKOMURA et al., 2000). In quails, growth is fast until around 21 days of age, where deposition rates are higher for protein and water in the carcass. After this age, it slows down with an increase in fat deposition, mainly in the viscera, including in ovary (SILVA et al., 2009; GRIESER et al., 2015).

For most animals, increased body fat deposition is common with age, being related to a number of nutrients (proteins, carbohydrates, and fats) available for organism synthesis (SILVA et al., 2009). Such deposition is reduced when the capacity of consumption is only sufficient to maintain lean tissue growth. On the other hand, as the consumption capacity increases, fat deposition rises (REGINATTO et al., 2000). In addition, a larger volume of ingested feed can be poorly digested and absorbed by digestive tract due to a decrease in digestive enzyme efficiency (SAKOMURA et al., 2004).

However, protein deposition is controlled by animal genetics, being limited daily regardless of the diet (SILVA et al., 2009). According to Gonzáles and Sartori (2002), diet may increase protein in the carcass, or as stated by Ruts (2002), it decreases because in diets with deficient contents of amino acids essential to meet the nutritional requirements of animals, organism begins to catabolize body protein. The availability of nutrients in a diet changes the rates of lipogenesis, modifying body deposition of fat and protein (KESSLER et al., 2000).

The greater the severity of dietary restrictions, the smaller the body fat content during refeeding. Sugeta et al. (2002) demonstrated similar findings to ours in an experiment with broiler chickens, in which animals remained under feed restriction from 8 to 14 days of age and were then fed *ad libitum* up to 42 days. These authors reported that birds under a 70% feed restriction showed a lower body fat content at 42 days compared to a control group fed 30% feed restriction.

Quail growth curves presented marked differences between genders, in which females had higher growth than did males (SILVA et al., 2009). Overall, this contrast in body weight starts around the third and fourth week of age, being attributed to the ovaries and liver of females (OGUZ et al., 1996). Males and females of quails for meat production can be differed in several respects, such as weight at maturity, composition and deposition rates of body chemical nutrients, varying according to the growth stage (GOUS et al., 1999). In this study, such differences between males and females interfered with the results regarding FC, WG, EE, PDR, FDR, and CRE. Furthermore, we observed a significant interaction between both parameters (gender and feed restriction levels).

Conclusion

We can conclude that the level of quantitative dietary restriction provides an improvement in feed efficiency, increase in body weight gain and decrease for fat accumulated in the carcass during refeeding period of quails for meat production. As for gender, given the existing sexual dimorphism, females lost more body weight than did males, both under the same restriction, besides presenting higher protein and fat gains in the carcass and enhanced feed efficiency while refeeding.

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