

# EFFECTS OF DURATION AND LEVEL OF FEED RESTRICTION ON PERFORMANCE AND MEAT QUALITY OF BROILER CHICKENS

## EFFECTOS DE LA DURACIÓN Y NIVEL DE RESTRICCIÓN ALIMENTICIA SOBRE LA PRODUCCIÓN Y CALIDAD DE LA CARNE DE POLLOS DE CARNE

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### ADDITIONAL KEYWORDS

Abdominal fat. Marshall broilers. Cost benefit. Feed:gain ratio.

### PALABRAS CLAVE ADICIONALES

Grasa abdominal. Broilers Marshall. Coste/beneficio. Conversión alimenticia.

### SUMMARY

Two hundred and sixteen unsexed 14 days-old Marshall broiler chicks were used in a 3x3 factorial experimental design to test the effect of restricting feed intake of birds by 0 %, 20 % and 40 % levels for 2, 4 and 6 weeks after two weeks of the starter phase. The unrestricted (control) treatments were fed *ad libitum* throughout the experiment. The experiment lasted for 42 days. Data were collected and calculated on weight gain, feed:gain, feed intake, mortality, proximate composition of meat and cost-benefit analysis. Data obtained were subjected to a 2-way analysis of variance. Results showed significantly higher ( $p < 0.05$ ) final weights in the unrestricted birds (control) compared to the restricted birds. Interaction between duration of restriction and level of restriction indicated that weight gain and feed intake significantly ( $p < 0.05$ ) reduced as duration and level of feed restriction increased. Feed:gain was significantly ( $p < 0.05$ ) different across the treatments with birds restricted at 40 % for 6 weeks having the best feed:gain (1.91). The mortality recorded was not significant ( $p > 0.05$ ) across duration and level of restriction. Abdominal fat decreased with increasing duration and level of restriction with birds on 40 % level and 6 weeks duration of restriction having the lowest fat content (0.20 %). Crude protein content of the breast muscle significantly increased while crude fat content of the breast muscle significantly decreased with duration and level of restriction. Crude fat content was lowest at 40 % level and 6

weeks duration of feed restriction. As level and duration of feed restriction increased, feed cost/kg reduced. Birds restricted at 40 % level for 2, 4 and 6 weeks durations respectively had better cost benefit than birds restricted at 0 and 20 % levels for 2, 4 and 6 weeks durations. It can be concluded that the best feed:gain, lower abdominal fat, higher protein and better cost benefit was achieved in birds restricted at 40 % for 6 weeks.

### RESUMEN

Durante 42 días, 216 pollos broiler Marshall, de 14 días, fueron empleados en un diseño experimental factorial 3x3 para estudiar el efecto de la restricción de la ingestión de alimento en 0, 20 y 40 %, durante 2, 4 y 6 semanas en la fase de iniciación. El tratamiento control (no restringido) recibió alimentación *ad libitum* durante todo el experimento. Se obtuvieron datos sobre ganancia de peso, alimento/peso, ingestión, mortalidad, composición de la carne y relación coste beneficio. Los datos obtenidos se sometieron a un análisis de varianza de dos vías. Los resultados mostraron mayor peso final ( $p < 0,05$ ), en las aves sin restricción, la interacción duración\*nivel de restricción indicó que tanto la ganancia de peso como la ingestión, se redujeron cuando aumentaron la duración y nivel de restricción. La relación alimento/ganancia fue diferente ( $p < 0,05$ ) entre tratamientos siendo la mejor (1,91) en las aves con restricción de 40 % durante 6 semanas. No hubo

diferencias ( $p>0,05$ ) en la mortalidad registrada. La grasa abdominal disminuyó al aumentar la duración y nivel de restricción, alcanzando el menor contenido (0,20 %) en los niveles más intensos de restricción. El contenido proteico de la pechuga aumentó y su contenido graso se redujo al aumentar el tiempo y nivel de restricción. El contenido graso fue igualmente menor en los niveles más intensos de restricción. Cuando la restricción se hacía mayor, el coste por kg producido se reducía. Las aves con restricción del 40 % tuvieron en todo el tiempo mejor relación coste beneficio que las de control y las de restricción del 20 %. Se puede concluir que con la restricción del 40 % durante seis semanas se consigue mejor transformación de alimento, menor grasa abdominal, mayor cantidad de proteína, y mejor relación coste beneficio.

## INTRODUCTION

Increased cost of feeding and early fat deposit are few of the problems of poultry farmers (Smith, 1990). It is generally assumed that when birds eat more, they have higher body weight at market age (Urdaneta-Rincon and Leeson, 2002). Feeding strategies in growing broiler chickens should be aimed at optimizing lean carcass tissue, feed conversion ratio (FCR) and body weight gain (Gous and Cherry, 2004; Teimouri *et al.*, 2005). Nutrient restriction is usually employed to tackle problems that accompany early-life fast growth rate in broilers, such as increased body fat deposition, high incidence of metabolic disorders, increased mortality, and high incidences of skeletal diseases (Crouch, 2000; Saleh *et al.*, 2005; Rezaei *et al.*, 2006). Early feed restriction in broilers is practiced to induce catch-up growth and efficiency of feed utilization (Hocking *et al.*, 2002; Teimouri *et al.*, 2005). Response to feed restriction, however, depends on the duration of feed restriction. Prolonged feed restriction diminishes the potential of compensatory growth (Gous and Cherry, 2004; Leeson and Summers, 2005). Feed restriction programs have shown the potential to reduce the incidence of such problems can be used to modify birds

growth patterns by decreasing their maintenance requirements, which should improve feed efficiency (Urdaneta-Rincon and Leeson, 2002).

Feed restriction has been adopted in broiler production to avoid rapid growth rate, which is associated with ascites, lameness, mortality, and poor reproductive results (Mench, 2002; Tolcamp *et al.*, 2005). In addition, feed restriction in the early stage is beneficial for improving the feed efficiency and decreasing the breeding cost (Zubair and Leeson, 1994). Although early feed restriction reduces growth performance, compensatory growth in the refeeding period will be attained to accelerate organism growth to reach the weight of animals (Hornick *et al.*, 2000; Pinheiro *et al.*, 2004).

Excessive fat deposition is one of the main problems faced by the broiler industry these days, since it does not only reduce carcass yield and feed efficiency but also causes rejection of the meat by consumers (Kessler *et al.*, 2000) and causes difficulties in processing (Chambers, 1990). Recent reports on feed restriction during the growing period in broiler chickens indicate that restricting feed intake lowers body weight and carcass fat and improves feed efficiency with compensatory growth during refeeding (Al-Taleb, 2003).

Response to feed restriction, however, depends on the duration of feed restriction. Prolonged feed restriction diminishes the potential of compensatory growth (Leeson and Summers, 2005). This study is aimed at identifying the duration and level of restriction that will bring about lean carcass tissue, feed efficiency and cost benefits in broiler production.

## MATERIALS AND METHODS

Experimental site. The study was carried out at the Poultry Unit of the Teaching and Research Farm Directorate (TREFAD), Federal University of Agriculture (FUNAAB), Abeokuta, Ogun State. It receives a mean

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precipitation of 1037 mm per annum.

Experimental birds and management. A total of two hundred and sixteen (216) day old Marshall broiler chicks with average weight of 45-55g each, purchased from a reputable hatchery were used for the study. On arrival, they were given water containing glucose as anti-stress before feeding. The chicks were brooded for two weeks using charcoal pot as a heat source. At the beginning of the experiment, the birds were randomly distributed into nine treatments with 3 replicates of 8 birds per replicate. Daily routine management practices were carried out such as supply of clean water, feed, observing for sick birds, checking for mortalities and appropriate record keeping. Administration of vaccines, antibiotics and multivitamin supplement was given when necessary. The experiment lasted for 42 days. The study protocol was approved and conducted in accordance with the Animal Ethics Committee guidelines of Federal University of Agriculture, Abeokuta, Nigeria (FUNAAB, 2013).

Experimental diet. The composition of the diet is shown in **table I**. The ingredient composition (%) of the diet was on *as-fed* basis. The diet was based on feed composition used for growing rabbits on the Federal University of Agriculture Abeokuta, Teaching and Research Farm, which was developed in line with the recommendations of Aduku (2004) and Merck (2011). The major ingredients (i.e. maize, groundnut cake and soy bean meal) were milled through a screen mesh size of 2.5 mm in a hammer mill. Other ingredients were already in milled forms at the point of purchase. The various ingredients were individually weighed out in their milled form into a rotary feed mixer and mixed to get the experimental diet. The experimental feed was mixed in the research feed mill. The feed was fed in mash form. Three levels of quantitative feed restriction were used (0- *ad libitum*, 20 and 40 %) and three feeding restriction durations of 2, 4 and 6 weeks respectively. The birds were

distributed randomly into nine treatments. Weekly feed supply of each chick was predicated on the findings of Aduku (2004). The birds were subjected to 2 weeks of restriction at 0, 20 and 40 % levels of feed requirement, respectively, 4 weeks of restriction at 0, 20 and 40 % levels, respectively and 6 weeks of restriction at 0, 20 and 40 % levels, respectively.

Experimental design. The experimental

**Table I.** Composition of the experimental feed. (Composicion del pienso experimental).

Feed ingredients	Composition (%)
Maize	45.00
Soy bean meal (44% CP)	15.00
Fish meal (72% CP)	1.00
Groundnut cake	12.50
Wheat offal	21.50
Oyster shell	1.50
Bone meal	2.50
Lysine	0.25
Methionine	0.25
Salt	0.25
Vit./ Min. Premix*	0.25
Total	100.00
Analysis results	
Dry matter (%)	87.50
Crude protein (%)	21.74
Metabolisable energy (Kcal/kg)	2850.85
Crude fibre	4.90
Ether extract (%)	4.01
Ash (%)	3.93
NFE (%)	53.46
Lysine (%)	5.91
Methionine (%)	5.31
Calcium (%)	1.49
Phosphorus (%)	0.57
Ca:P	2.62
Protein:Energy	0.008

\*Composition per kg diet: Vit A: 40000IU; Vit D: 80000IU; Vit E: 40000 ng; Vit k<sub>3</sub>: 800 mg; Vit B<sub>1</sub>: 1000 mg; Vit B<sub>2</sub>: 6000mg; Vit B<sub>3</sub>: 500 mg; VitB12: 25 mg; Niacin: 6000 mg; Panthothenic acid: 2000 mg; Folic acid: 200 mg; Biotin: 8 mg; Mn: 300000 mg; Fe: 8000 mg; Zn: 20000 mg; Co: 80mg; I: 400 mg; Se: 40 mg; Choline: 800000 mg.

design used was 3×3 factorial design. There were two factors of feed restriction. Duration of restriction was at three periods (2, 4 and 6 weeks) while level of restriction was at three levels (0, 20 and 40 % of total feed intake).

Data collection. The birds were weighed per replicate at the start of the experiment and subsequently on weekly basis. Weight gain was taken by calculating the difference between the final body weight and previous body weight. Feed intake was recorded weekly for each treatment per replicate while left-over feed was subtracted from the total feed given to the birds in order to determine feed intake. Feed: gain ratio was calculated as feed intake per g body weight gain.

The total number of dead broilers during the experimental trial were recorded and expressed as percentage (%) of total number of birds alive at the start of the experiment.

Abdominal fat measurement and chemical analysis. At 56 days, two birds whose weight were close to the mean replicate weight were selected from each replicate, fasted overnight, slaughtered, manually defeathered and eviscerated and cut into retail parts. The abdominal fat pad was excised, weighed and expressed as a

percentage of liveweight. Proximate analysis of the compounded ration and breast muscle were analyzed according to the method of (AOAC, 1995).

Cost benefit determination. The prevailing market prices of the feed ingredients at the time of the experiment were used to estimate the unit cost of the experimental diet. Feed cost per kilogramme and cost per kilogramme of weight gain were calculated. The percentage feed cost saving of broilers on restriction compared to the *ad libitum* fed broilers was also determined.

Statistical analysis. All data collected were subjected to a two-way analysis of variance in 3×3 factorial experimental design using a statistical package (SPSS, 1999). Significant (p<0.05) differences among variables were separated using Duncan's Multiple Range Test (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

The results of the experiment (**table II**) indicated that the control group had significantly higher performance than the restricted group. The results also indicated that the growth of broiler chicken is related to the feed intake supporting the evidence

**Table II.** Main effect of duration and level of feed restriction on Marshall broiler performance. (Efectos de la duracion e intensidad de la restricción alimenticia sobre el rendimiento de pollos broiler Marshall).

Parameters	Duration of feed restriction (weeks)				Level of feed restriction (%)			
	2	4	6	SEM	0	20	40	SEM
Initial weight(g)	174.15	174.28	170.13	8.27	175.93	171.37	171.25	8.25
Final weight (g)	1945.56 <sup>a</sup>	1822.22 <sup>ab</sup>	1713.33 <sup>b</sup>	45.29	2097.78 <sup>a</sup>	1683.33 <sup>c</sup>	1700.00 <sup>b</sup>	45.29
Total feed intake (g)	3939.33 <sup>a</sup>	3791.06 <sup>a</sup>	3403.09 <sup>b</sup>	98.68	4173.63 <sup>a</sup>	3712.15 <sup>b</sup>	3247.71 <sup>c</sup>	98.68
Daily feed intake (g/b)	93.79 <sup>a</sup>	90.26 <sup>a</sup>	81.02 <sup>b</sup>	2.34	99.37 <sup>a</sup>	88.34 <sup>b</sup>	77.32 <sup>c</sup>	2.34
Total weight gain (g/b)	1771.41 <sup>a</sup>	1641.94 <sup>b</sup>	1543.20 <sup>b</sup>	26.78	1921.78 <sup>a</sup>	1511.96 <sup>b</sup>	1528.75 <sup>b</sup>	26.78
Daily weight gain (g/b/d)	42.18 <sup>a</sup>	39.24 <sup>b</sup>	36.74 <sup>b</sup>	0.63	45.76 <sup>a</sup>	36.00 <sup>b</sup>	36.40 <sup>b</sup>	0.63
Feed: gain	2.22 <sup>ab</sup>	2.30 <sup>a</sup>	2.21 <sup>b</sup>	1.04	2.17 <sup>b</sup>	2.45 <sup>a</sup>	2.12 <sup>b</sup>	1.04
Mortality(%)	2.77	4.16	4.16	1.99	4.16	2.77	4.16	1.99

<sup>a,b,c,d</sup>Means in the same row not sharing common superscript are significantly different (p<0.05). SEM: Standard error mean.

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that the body weight gain of broiler chickens could be inhibited by feed restriction (Washburn and Bondari, 1978). Lippens *et al.* (2000) and Urdaneta-Rincon and Leeson (2002) have argued that improvement in feed efficiency noted with the use of feed restriction programmes is due to reduced overall maintenance requirements because birds subjected to a period of feed restriction tend to have smaller body weights before they reach market weight thus they require less for this purpose. Urdaneta-Rincon and Leeson (2002) postulated that compensatory growth and associated reduction in

maintenance feed requirements provide a promising method of reducing feed cost of broiler chickens. In this study, feed restriction reduced the growth of the birds according to the intensity of the duration and level (**table III**). However, it was apparent that the feed allocation allowed for some growth and maintenance. Body weight and feed intake at the end of the experiment were progressively reduced by increasing duration and level of feed restriction. In this study, reduction of final body weights for birds restricted for 6 weeks at 40 % might have been at least due to birds not being

**Table III.** Interactive effect between duration and level of feed restriction on Marshall broiler performance. (Efecto interactivo entre la duración y nivel de restricción alimenticia sobre el rendimiento de pollos broiler Marshall).

	Duration (weeks)	Level			SEM
		0	20	40	
Initial weight (g/b)	2	178.30	173.32	170.83	9.46
	4	177.83	172.5	172.5	8.26
	6	171.67	168.3	170.42	8.37
Final weight (g/b)	2	2133.30 <sup>a</sup>	1886.70 <sup>ab</sup>	1816.70 <sup>ab</sup>	45.29
	4	2083.30 <sup>a</sup>	1733.30 <sup>b</sup>	1650.00 <sup>bc</sup>	63.74
	6	2076.70 <sup>a</sup>	1541.47 <sup>bc</sup>	1511.00 <sup>c</sup>	79.31
Total weight gain (g/b)	2	1955.00 <sup>a</sup>	1713.38 <sup>ab</sup>	1964.87 <sup>b</sup>	98.68
	4	1905.47 <sup>a</sup>	15608 <sup>c</sup>	1477.5 <sup>d</sup>	44.32
	6	1905.3 <sup>a</sup>	1373.17 <sup>d</sup>	1341.58 <sup>d</sup>	48.32
Daily weight gain (g/b/d)	2	46.55 <sup>a</sup>	40.79 <sup>ab</sup>	39.19 <sup>b</sup>	2.34
	4	45.37 <sup>a</sup>	37.16 <sup>c</sup>	35.18 <sup>d</sup>	1.82
	6	45.36 <sup>a</sup>	32.69 <sup>d</sup>	31.93 <sup>d</sup>	1.15
Total feed intake (g/b)	2	4043.04 <sup>b</sup>	3940.26 <sup>c</sup>	3834.70 <sup>d</sup>	26.78
	4	4248.51 <sup>a</sup>	3781.91 <sup>e</sup>	3342.70 <sup>g</sup>	18.42
	6	4229.27 <sup>a</sup>	3414.28 <sup>f</sup>	2565.74 <sup>h</sup>	10.07
Daily Feed intake(g/b/d)	2	96.26 <sup>b</sup>	93.81 <sup>c</sup>	91.30 <sup>d</sup>	0.63
	4	101.15 <sup>a</sup>	90.04 <sup>e</sup>	79.58 <sup>g</sup>	0.53
	6	100.69 <sup>a</sup>	81.29 <sup>f</sup>	61.09 <sup>h</sup>	0.58
Feed: gain	2	2.06 <sup>c</sup>	2.30 <sup>abc</sup>	2.33 <sup>bc</sup>	1.04
	4	2.23 <sup>ab</sup>	2.42 <sup>a</sup>	2.26 <sup>c</sup>	1.01
	6	2.22 <sup>ab</sup>	2.48 <sup>abc</sup>	1.91 <sup>d</sup>	0.08
Mortality (%)	2	4.16	0	4.16	1.99
	4	4.16	4.16	4.16	3.66
	6	4.16	4.16	4.16	3.69

<sup>a,b,c,d</sup>Means in the same row not sharing common superscript are significantly different (p<0.05). SEM: Standard error mean.

able to compensate after the more severe feed restriction. Studies have shown that the longer the period of undernutrition, the more difficult it is for broiler chickens to compensate for reduction in live weight (Yu and Robinson, 1992). Zubair and Leeson (1994) have concluded that this effect is simply related to reduce maintenance energy needs of a smaller body mass at any time up to the time of growth compensation. Feed: gain ratio was superior for birds subjected to higher level and longer period of feed restriction (40 % for 6 weeks) compared to the ones on *ad libitum*. These results are consistent with previous reports (Palo *et al.*, 1995 and Camacho *et al.*, 2004).

Pokniak and Cornejo (1982) and Pokniak *et al.* (1984) reported improved feed efficiency, but they noticed no significant difference in body composition between previously restricted and full-fed chickens at 8 weeks of age. Most notably, Plavnik and co-workers (Plavnik and Hurwitz, 1985; Plavnik *et al.*, 1986 and McMurtry *et al.*, 1988) obtained improved feed efficiency, reduced body fat and abdominal fat and no reduction of final body weight in broiler chickens subjected to severe early feed restriction (70 %). The body composition of broiler chickens can be significantly altered by protein level of the diet and frequency of

feeding. Some investigators have reported a reduction in mortality rate following feed restriction (Bowes *et al.*, 1988; Arce *et al.*, 1992). This could provide the greatest economic incentive for implementing early feed restriction by allowing for more birds to be marketed from a flock. In this study, mortality was not significantly affected by the feed restriction programme and did not follow a particular pattern so it cannot be established if it was caused by restriction. This is similar to results reported by Oyedepi and Atteh (2005). However, the present results (**table IV**) are contrary to the findings of Saleh *et al.* (2005) who reported that level of feed had effects on mortality of the broiler chickens.

In this study, abdominal fat was greatly reduced with severity of restriction. This might be due to fat mobilization for energy supply and abdominal fat might be mobilized more easily during a fasting period. A reduction in abdominal fat content with concomitant reduction in body weight were found by Plavnik and Hurwitz (1986) and Jones and Farrell (1992). Other investigators have reported reductions in abdominal fat pad due to early life feed restriction but a small reduction in final body weight (Lippens *et al.*, 2000). Beane *et al.* (1979) reported that feed efficiency was improved, but the

**Table IV.** Main effect of duration and level of feed restriction on abdominal fat and proximate composition of breast muscle of Marshall broilers. (Efecto de la duración y nivel de restricción alimenticia sobre la grasa abdominal y composición de la pechuga de pollos broiler Marshall).

Parameters	Duration of feed restriction (weeks)				Level of feed restriction (%)			
	2	4	6	SEM	0	20	40	SEM
Abdominal fat	0.54 <sup>a</sup>	0.47 <sup>b</sup>	0.34 <sup>c</sup>	0.07	0.52 <sup>a</sup>	0.50 <sup>a</sup>	0.33 <sup>b</sup>	0.07
Crude protein	18.22 <sup>c</sup>	19.59 <sup>b</sup>	22.82 <sup>a</sup>	0.37	18.71 <sup>b</sup>	20.44 <sup>a</sup>	21.49 <sup>a</sup>	0.37
Crude fat	17.61	17.49	17.02	0.19	17.95 <sup>b</sup>	17.42 <sup>b</sup>	16.74 <sup>a</sup>	0.19
Ash	5.22 <sup>a</sup>	5.01 <sup>ab</sup>	4.70 <sup>b</sup>	0.12	5.18 <sup>a</sup>	5.09 <sup>a</sup>	4.66 <sup>b</sup>	0.12
Nitrogen free extract	31.00 <sup>b</sup>	32.20 <sup>a</sup>	33.00 <sup>a</sup>	0.40	33.20 <sup>a</sup>	32.00 <sup>b</sup>	31.60 <sup>b</sup>	0.41

<sup>a,b,c</sup>Means in the same row not sharing common superscript are significantly different (p<0.05). SEM: Standard error mean.

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amount of abdominal fat in male broilers was significantly increased. Feed-restricted birds have been shown to have lower carcass fat content at market age than birds fed *ad libitum* (Cabel and Waldroup, 1990). Summers *et al.* (1990) and Jones and Farrell (1992) did not find changes in carcass composition of birds after feed restriction conditions; however, Plavnik and Hurwitz (1985, 1989) and Plavnik *et al.* (1986) reported a decrease in fat pad on birds restricted from 6 to 12 days of age, without adverse effects on growth. The same effect of restriction on the amount of carcass fat was found by Plavnik and Hurwitz (1985), but with lower body weight gain in relation to the *ad libitum* birds, perhaps due to the restriction severity (70 % of the *ad libitum* feed intake). Fontana *et al.* (1992) reported a larger abdominal fat deposition in the carcass of restricted birds after refeeding. According to Pinchasov and Jensen (1989), fat pad is more directly influenced by nutrition than total carcass fat. Most of these studies reported improved

feed efficiency and a reduction of body fat and abdominal fat, but with final body weight somewhat reduced. There are exceptions; for example Yu *et al.* (1990) found no significant difference in overall feed efficiency between restricted and full-fed broilers. Zubair and Leeson (1994) showed that feed-restricted birds usually had a numerically smaller abdominal fat pad. This agrees with the current results. Feed restriction brought about the reduction of abdominal fat as reported by Griffiths *et al.* (1977), Arafa *et al.* (1983) and Pinchasov *et al.* (1985). However, this study proves that abdominal fat is a perfect indicator to estimate meat fat content.

At 56 days of age, compared with the *ad libitum* broilers, crude protein (CP) content of breast muscle was higher in feed-restricted broilers, whereas the ash content varied across the treatments. The results are consistent with previous reports (Gondret *et al.*, 2000; Gondret and Lebret, 2002). During feed restriction, broilers con-

**Table V.** Interactive effect of duration and level of feed restriction on abdominal fat and proximate composition of breast muscle of Marshall broilers. (Efecto interactivo entre la duración y nivel de restricción alimenticia sobre la grasa abdominal y composición de la pechuga de pollos broiler Marshall).

	Duration (weeks)	Level			SEM
		0	20	40	
Abdominal fat pad (% LW)	2	0.59 <sup>ab</sup>	0.41 <sup>ab</sup>	0.40 <sup>a</sup>	0.07
	4	0.66 <sup>a</sup>	0.59 <sup>a</sup>	0.37 <sup>ab</sup>	0.1
	6	0.57 <sup>a</sup>	0.41 <sup>ab</sup>	0.20 <sup>b</sup>	0.13
Crude protein (%)	2	17.60 <sup>d</sup>	18.41 <sup>cd</sup>	18.65 <sup>cd</sup>	0.37
	4	18.31 <sup>cd</sup>	19.44 <sup>bcd</sup>	21.05 <sup>b</sup>	0.48
	6	20.23 <sup>bc</sup>	23.24 <sup>a</sup>	25.00 <sup>a</sup>	0.65
Crude fat (%)	2	17.40 <sup>abc</sup>	16.92 <sup>bcd</sup>	16.73 <sup>cd</sup>	0.19
	4	18.29 <sup>a</sup>	17.88 <sup>ab</sup>	16.29 <sup>d</sup>	0.21
	6	18.16 <sup>a</sup>	17.46 <sup>abc</sup>	17.20 <sup>abcd</sup>	0.33
NFE (%)	2	33.20 <sup>ab</sup>	31.11 <sup>bc</sup>	32.10 <sup>bc</sup>	0.4
	4	31.22 <sup>abc</sup>	32.43 <sup>bc</sup>	30.43 <sup>bcd</sup>	0.54
	6	33.55 <sup>a</sup>	32.00 <sup>bc</sup>	31.67 <sup>abc</sup>	0.71

<sup>a,b,c,d</sup>Means in the same row not sharing common superscript are significantly different ( $p < 0.05$ ). SEM: Standard error mean.

sume less protein than the control and it has been observed that total protein depend on quality and quantity of protein supplied in the diet (Iyayi and Tewe, 1998). Lower pro-

tein consumption may improve mineral metabolism. This assumption was based on the finding of Hulan *et al.* (1980) who found that lower protein consumption would reduce leg abnormality. The findings of Robinson *et al.* (1999) also showed that lowering growth at an early age would allow the bone grow faster at optimum rate. Niret *et al.* (1996) and Katanbaf *et al.* (1988) found that restricted chicks had heavier digestive tract. Cherry *et al.* (1978) showed that chickens with heavier relative digestive tract weight had slower gastro-intestinal clearance than those with lighter digestive tract. A slower clearance of feed from the intestinal tract allows the nutrients (i.e. minerals) greater exposure to the absorptive cells and consequently influences the efficiency of nutrient utilization. This study showed that birds restricted for 6 weeks duration had lowest fat content in breast muscle. The study also showed (**table V**) that the lower the abdominal fat and breast muscle fat content, the higher the protein. In general, duration of feed restriction increased ash content at 2 and 4 weeks within increasing levels but reduced at 6 weeks with increasing levels.

Feed restriction affected the live weight of broiler chickens at 56 days of age. Chickens on 20 % restriction attained little compensation in live weight but did not achieve up to the control birds while those on 40 % restriction did not. Thus, 20 % restriction was beneficial in terms of saving feed. It may, therefore, be a useful tool to reduce the cost (**table VI**) of starter feed, without any adverse effect on the final body weight of the chickens. However, generally from this study, total feed cost per bird was reduced by increasing durations and levels of feed restriction.

It can be concluded that the best feed:gain, lower abdominal fat, better mea quality and better cost benefit was achieved in birds restricted at 40 % for 6 weeks. The diet therefore produced lean meat at reduced

**Table VI.** Effect of duration and level of feed restriction on cost benefit of Marshall broilers. (Efecto de la duración y nivel de restricción alimenticia sobre la relación coste/beneficio de pollos broiler Marshall).

	0	Level 20	40
Cost of chicks (US\$)			
2	21.68	21.68	21.68
4	21.68	21.68	21.68
6	21.68	21.68	21.68
Feed consumed (kg/bird)			
2	0.03	0.03	0.03
4	0.03	0.02	0.02
6	0.02	0.02	0.02
Feed price/kg (US\$)			
2	0.46	0.46	0.46
4	0.46	0.46	0.46
6	0.46	0.46	0.46
Total feed cost (US\$)			
2	45.07	47.35	47.14
4	43.92	42.15	38.06
6	42.74	37.25	28.59
Labour and Drugs (US\$)			
2	19.35	19.35	19.35
4	19.35	19.35	19.35
6	19.35	19.35	19.35
Total cost of production (US\$)			
2	86.10	88.39	88.17
4	84.95	83.18	79.09
6	83.77	78.28	69.63
Sale price per kg/live weight (US\$)			
2	7.42	7.10	7.10
4	7.42	7.10	7.10
6	7.42	7.10	6.97
Cost/ kg/ live weight (US\$)			
2	178.06	170.32	170.32
4	178.06	170.32	170.32
6	178.06	170.32	167.23
Revenue/kg/ live weight (US\$)			
2	91.96	81.94	82.15
4	93.11	87.14	91.23
6	94.29	92.04	97.60



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cost which can be of advantage to the producer and beneficial to the consumer.

### CONCLUSION

Restricting feed intake from 2 to 4 and 6 weeks significantly reduced final body weight gain with no evidence of compensatory gain. Feed intake following restriction was also significantly reduced at all ages. Feed conversion following restricted feed intake was improved. Feed:gain was better in birds restricted at 6 weeks at 40 %. Mortality was not significant throughout the trial and did not follow a

particular pattern so it cannot be established if it was caused by restriction. Duration and level of feed restriction affected performance and abdominal fat pad. However, chickens on 20 and 40 % *ad libitum* feeding did not 'catch-up' with those on *ad libitum* feeding in terms of live weight.

Feed restriction had effect on nutrient content of breast muscle except ash and NFE. Crude protein increased while other nutrients decreased as feed restriction increased. Crude fat content was lowest at 40 % level of restriction. Hence, restricting feed at 40 % for 6 weeks is recommended based on better feed:gain and meat quality.

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