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Effects of Dietary Regimens and Brown-Egg Pullet Strain on Growth and Development

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Abstract: This study consisted of; two strains of brown-egg pullets, the Hy-Line (HB) and H&N (BN) Brown were raised on three different dietary regimens resulting in a 2 x 3 factorial design. The three different regimens were a standard Step-down Protein Regimen (SDP) comprised of a 20% CP Starter, 0-6 week, 18% CP Grower 1, 7-12 week and 16% CP Grower 2, 13-18 week; a Step-up Protein Regimen (SUP9) comprised of a 12% CP Starter, 0-9 week, 16% CP Grower 2, 10-16 week and 18% CP Grower 1, 17-18 week and a Step-up Protein Regimen (SUP12) comprised of a 12% CP Starter, 0-12 week, 16% CP Grower 2, 13-16 week and 18% CP Grower 1, 17-18 week. The pullets were housed in an environmentally controlled rearing facility with trideck battery cages. Feed consumption and body weights were measured bi-weekly and mortality was recorded daily. At 17 week of age a sample of 20 pullets from each strain and regimen combination were randomly selected and brought to the laboratory for body composition analysis. At 18 week the HB and BN strains only differed in livability with the HB having a 4.2% greater ($p<0.05$) liveability than the BN pullets. There was a stepwise reduction ($p<0.05$) in total protein intake from the SDP, SUP9 and SUP12, however, energy, Ca, P and lysine consumption were comparable. The SUP9 and SUP12 feeding regimens resulted in significantly ($p<0.05$) lower BW than the SDP regimen pullets. The SUP12 regimen significantly reduced sternum length below that obtained with the SDP or SUP9 program 11.0 vs. 11.2 and 11.3 cm, respectively. Tibial breaking strength was no different between the strains or regimens. This study shows that pullets reared on SUP regimens would have lower body weights with few differences in body composition percentages. Indicating that reduced dietary protein and energy would result in smaller pullets with comparable body composition.

Key words: Chicken, pullet, growth, step-up protein, step-down protein

INTRODUCTION

With the commercial egg industry facing high feed costs, lower protein and energy consumption by reducing pullet rearing feed expenses could help reduce costs. Step-down protein feeding regimens are still the norm for the egg industry in the growing program for pullets (Anderson, 2007). However, Step-up protein feed regimens have been shown to provide for the pullet optimal growth with the lowest possible feed cost (Anderson *et al.*, 1995; Leeson, 1986). Blaylock (1956), and Christmas *et al.* (1982) showed that reduced dietary protein from 18-12% at 16 weeks during the rearing period had no effect on the age at which sexual maturity was reached or on subsequent egg production. They showed that protein could be reduced to 12% at 16 week without detrimental effects on body weight, sexual maturity, or egg production. Douglas *et al.* (1985) and Connor and Burton (1971), examined different feeding programs for dietary protein on 20-week body weights and subsequent egg production. They determined that 18-20 week body weights were significantly reduced when dietary protein was provided at a level of 15% or less. They ultimately concluded that 12% crude protein pullet diets were adequate for pullet development and the ensuing layer performance. Despite not having significant effects on performance parameters, the low protein diets used by Christmas *et al.* (1982), Douglas *et al.* (1985) and Connor and Burton (1971), delayed the onset of sexual maturity and reduced body weight at the onset of egg production.

Leeson and Summers (1978, 1979) and Bish *et al.* (1984) examined step-down protein regimens for rearing egg-type pullets. They compared a conventional step-down diet regime containing 18, 15 and 13% Crude Protein (CP) to a split-diet consisting of a concentrated energy ration and a concentrated protein ration provided free-choice in separate feeders in the same pen step-up and feeding regimes 12, 16 and 19% CP, respectively. The split-diet pullets consumed increasing levels of protein as they matured, which was opposite compared to conventional layer pullet feeding programs. In both studies, step-up fed pullets, those fed increasing protein, had lower body weights, but subsequently higher egg production than conventionally fed pullets. Pullets grown on the step-up protein regime were significantly lighter and consumed less total protein, in comparison to the birds on the step-down regime. Leeson and Summers (1984a) confirmed that step-up protein dietary regimens resulted in reduced body weight, egg weight and egg production. No effect on feed consumption or other performance parameters were observed for the step-up protein groups. However, Bish *et al.* (1984) found that egg production and weight for the step-up groups were slightly reduced and feed consumption did not differ from the pullets on the step-down protein regimes.

Anderson *et al.* (1995) examined the impact of high and low energy step-up protein growing regimens in brown egg layer pullets in comparison to a standard step-down protein feeding program. Pullets from both step-up protein regimes weighed significantly less than those on the step-down protein regime. Pullet frame sizes were smaller in the step-up fed pullets when compared to the step-down regimens. Age at sexual maturity and egg production were significantly delayed in both step-up protein groups but mortality was not affected. The feed consumption for the step-up feeding group was significantly lower than that from the other two groups.

The manner in which we feed commercial egg layers needs to be examined due to the changes the primary breeders have made through genetic selection and increased feed costs facing the layer industry. The strains of chickens used for commercial production are smaller with higher productivity (Anderson, 1992). He also showed that the brown egg producing strains have different growth and feed intake. With strain differences it would be important to know if strains of brown egg pullets had a similar growth response as white egg strains to alternative rearing programs. Nutritional and physiological research is needed to provide information relating to strain, alternative rearing programs which may lower feed costs and more importantly, change the way pullets grow, develop and their subsequent productive potential. High fiber low energy ingredients can be used to reduce dietary costs which may result in reduced feed cost to raise pullets. Therefore, the objectives of this research was to compare the development of two different commercial brown-egg layer strains grown on a conventional rearing program, step-down protein, to ones grown on two different step-up dietary regimens, a step-up protein regime with the starter fed for 9 week and a step-up protein regime with the starter fed for 12 week. The different time span for the starter would potentially restrict early development for a longer period with greater savings in feed.

MATERIALS AND METHODS

Hatching eggs from two commercial brown-egg layer strains the H & N "Brown Nick" (BN) and Hy-Line Brown (HB) were obtained and hatched at the NCDA & CS Piedmont Research Station at Salisbury, NC, USA. The birds were brooded and grown in an environmental control facility containing 4 banks of triple-deck brood-grow cages. The chicks were wing banded for identification and randomly assigned to 10 blocks, each containing 6 replicates of 6 cages each containing 10 pullets for grow out. This represented a total of 3600 pullets. The two strains by three dietary regimens were assigned in a randomized complete block factorial arrangement. The six treatment groups were randomly assigned such that each treatment group was assigned to each block. The vaccination and lighting programs were in accordance with standard industry husbandry practices outlined by Anderson (1992). The three rearing dietary regimens consisted of a commercial Step-Down Protein Regimen (SDP) and two Step-Up Protein regimens differentiated by the week of age that the pullets were transitioned from the low protein starter (Table 1). The first Step-Up Protein regimen transitioned to Grower 2 feed at 9 week (SUP9) and the second regimen transitioned at 12 week of age (SUP12). Data on body weight and feed consumption were collected from 0-4 week of age and then at 2 week intervals throughout the remaining 18 week grow period. Three randomly selected birds per cage or 18 birds per replicate were measured for body weight at each period. A random sample of 120 pullets were selected by wing band number at 17 week from each strain and feeding regime (2 pullets/replicate) to be euthanized and dissected to provide data on body dimensions and composition. The selected pullets were weighed then the sternum was measured in mm from the "Cranial process of the crest" to the posterior tip of the "Sternal crest" using a tape measure (Camberlain, 1943). The shank length was measured from the foot pad to the hock joint using a caliper measuring in mm as done by Anderson *et al.* (1995). After the these measurements the pullets were euthanized and body component weights were collected for blood, feather, head and neck, shank and foot, fat pad, wings, leg quarters, breast, liver, gizzard and small intestine. Blood weight was measured by the difference between the live weight and bird weight after electric stunning followed by a 3 min bleed after an outside cut to the jugular vein and carotid artery. The whole carcass was weighed after complete feather removal and feather weight was calculated by subtraction from the bled carcass. The body components were separated using the reference of Camberlain (1943). The head and neck were removed at the "Cranial Central Articular Surface" anterior to the thoracic vertebrate and weighed. The shank and foot were separated at the hock joint. Wings were separated at the head of the humerous. Leg quarters were separated at the juncture of the thoracic vertebrate and the Ilium of the pelvic and the whole breast included the sternal ribs. The liver was removed and weighed. The gizzard was removed split and cleaned of contents then weighed. The small Intestine (jejunum and ileum) was excised then rinsed to remove the contents and weighed.

Table 1: Rearing diet regimes[1]

Diet type	Age fed (week)	Crude protein (%)	Metabolizable energy (kcal/kg)
Step-down Protein (SDP)			
Starter	0-6 week	20	2970
Grower 1	7-12 week	18	2970
Grower 2	13-18 week	16	2970
Step-Up Protein Low Energy Starter Fed for 9 week (SUP9)			
Starter	0-9 week	12	2750
Grower 2	10-16 week	16	2970
Grower 1	17-18 week	18	2970
Step-up Protein Low Energy Starter Fed for 12 week (SUP12)			
Starter	0-12 week	12	2750
Grower 2	13-16 week	16	2970
Grower 1	17-18 week	18	2970

[1]See Table 2 for calculated composition and laboratory analysis

Table 2: Diets with calculated and laboratory analysis

Ingredients	Starter	Low energy starter	Grower 1	Grower 2
	(%)			
Corn	58.65	44.30	62.03	65.57
Soybean meal	28.35	3.92	23.11	17.27
Wheat midds	4.63	10.00	5.93	7.88
Oats	5.00	36.79	5.00	5.01
Limestone	1.18	1.67	1.65	1.78
Methionine	-	0.26	0.06	0.13
Dical	1.69	1.82	1.73	1.70
Salt	0.25	0.40	0.25	0.25
Vit. premix[1]	0.1	0.10	0.10	0.10
Min. premix[2]	0.05	0.05	0.05	0.05
Gentian Violet	0.05	0.05	0.05	0.05
Tracer	0.05	0.05	0.05	0.05
Lysine	-	0.60	-	0.21
Calculated analysis				
Protein (%)	20.00	12.00	18.00	16.00
ME (Kcal/kg)	2970	2750	2970	2970
Calcium (%)	0.90	1.10	1.08	1.10
T. Phosphorus (%)	0.70	0.70	0.69	0.69
Lysine (%)	1.10	0.95	0.95	0.95
TSAA (%)[3]	0.66	0.65	0.65	0.65
Laboratory analysis				
Protein (%)	20.16	12.09	18.06	16.28
ME (Kcal/kg)	2945	2765	2945	2953
Ca (%)	1.40	1.30	1.70	1.40
T. Phosphorus (%)	0.67	0.62	0.68	0.61

[1]Vitamin premix contained the following per kg of diet; vitamin A, 9.4 IU; cholecalciferol, 2 IU; vitamin E, 0.022 mg; thiamine, 3.674 mg; riboflavin, 6 mg; pantothenic acid, 10 mg; niacin, 35 mg, biotin, 100 ug; folic acid, 3292 ug; vitamin B_{12}, 15.2 ug.
[2]Mineral premix contained the following per kg of diet; manganese, 75 ppm; iron, 56 ppm; copper, 0.3 ppm; zinc, 60 ppm; cobalt, 0.075 ppm; iodine, 0.075 ppm. [3]Total sulphur amino acids

After the body component weights were collected the left tibia was removed and evaluated according to procedures outlined by Crenshaw *et al.* (1981). Briefly, the bones were cleaned of excess tissue and the tibia breaking strength was determined using an Instron, Model 1122[1]. The bones were supported by two fulcra points 27 mm apart and force was applied mid-shaft at a constant rate of 300 mm/min. The breaking strength was recorded automatically by a 50 kg load cell. Weights of the liver, spleen, gizzard, small intestine and fat pad were then collected from these birds. This data was then transformed to represent a percentage of body weight prior to analysis.

Data from the rearing period was analyzed using the General Linear Model Program (GLM) by SAS® (SAS Institute, 2004) using the replicate means. Data are presented as the means with a pooled SEM for each parameter. Percent liveability was converted to Arc Sin prior to analysis and the differences were applied to the actual means. The body component weights were converted to a percentage of the live body weight prior to analysis. Where the means for the main effects were significantly different, the significant differences present were separated using Duncan's new multiple range test ($p<0.05$).

Table 3: Impact of reverse feeding programs and strain on body weight, total feed consumption and livability in brown egg pullets

	18 week body weight (g)	Total feed cons. (kg/pullet)	Livability (%)
Strain			
Hy-Line Brown	1782	7.191	96.2^{a}
H & N "Brown Nick"	1826	7.255	92.0^{b}
Pooled SEM	±20	±0.058	±0.8
Diet regimen			
SDP	1860^{a}	7.278	93.8
SUP9	1782^{b}	7.232	93.4
SUP12	1770^{b}	7.160	95.1
Pooled SEM	±25	±0.071	±1.0

^{ab}(p<0.05)

RESULTS

Strain: The 18 week BW and total Feed Consumption (FC) were similar between the HB or BN strains. Livability was significantly better (p<0.05) in the HB pullets than in the BN with percentages of 96.2 and 92.0, respectively (Table 3). There were no differences between the strains intake of protein, energy, amino acids and minerals (Table 4). Pullet BW, skeletal dimensions and organ components that were examined at 17 week of age (Table 5) showed that the HB pullets had a sternum length of 113 mm vs. the BN that had a sternum length of 110 mm, however, shank length was not influenced by strain. The other skeletal parameters of bone strength and ash were not significantly different between the strains. The body component weights at 17 weeks are shown in Table 6, of which only breast weight was significantly different between the strains with the HB having a 0.7% heavier breast than the BN. There were no interactions between strain and rearing dietary regimen throughout this study.

Dietary regimen: The 18 week BW of the pullets fed the SDP pullets were heavier than either the SUP9 or the SUP12 at 1860, 1782 and 1770 g, respectively as shown in Table 3. These BW differences were manifested at 4 week and the SUP 9 and SUP12 regimens resulted in lighter weight pullets throughout the rearing period. Only the SUP12 pullets were significantly (p<0.05) lighter than the SDP throughout the rearing period (Fig. 1). By week 14 through week 16 the SUP9 group had recovered some of the BW from the SDP group and was not significantly different. However, by week 18, after the pullets had been on the grower diet for 6 weeks, both the SUP9 and SUP12 BW were not different from each other but were lighter than the SDP pullets. Total feed consumption and livability were not different between the 3 dietary regimens (Table 3). Overall protein consumption was highest in the SUP pullets at 1.26 kg, while both the SUP9 and SUP12 regimens were significantly lower at 1.15 and 1.01 kg, respectively with the SUP12 pullets having the lowest (p<0.05) protein intake (Table 4). Metabolizable Energy (ME), Lysine and TSAA, Calcium and Phosphorus consumption rates were not significantly different between the three dietary regimens.

The pullets reared on the SDP dietary regimen were heavier (p<0.05) at 17 weeks, than both SUP9 and SUP12 regimen pullets. When body dimensions were examined only the only the SUP12 regimen had a shorter sternum length and only different from the SUP9 pullets. Shank length, tibia breaking strength, nor tibia ash were different between the pullets on the three dietary regimens.

Table 4: Impact of reverse feeding programs on protein, energy and mineral intake in brown egg pullets through 18 week of age

	Protein consumption (kg)	ME (Kcal)	Lysine (g)	TSAA (g)	Calcium (g)	Phosphorus (g)
Strain						
Hy-Line Brown	1.14	213.7	69	47	77	49
H & N "Brown Nick"	1.15	215.9	70	47	78	50
Pooled SEM	±0.12	±9.3	±3.2	±2.1	±3.6	±2.2
Diet regimen						
SDP	1.26^{a}	215.6	71	47	77	50
SUP9	1.15^{b}	215.3	70	47	76	49
SUP12	1.01^{c}	213.5	68	46	79	48
Pooled SEM	±0.03	±6.3	±2.0	±0.3	±2.3	±1.4

Table 5: Effect of strain and dietary regimen on sternum length, shank Length, tibia breaking strength and tibia ash at 17 week of age

Source[1]	17 week body weight (g)	Sternum length (mm)	Shank length (mm)	Tibia breaking strength (kg/cm^{2})	Tibia ash (%)
Strain					
Hy-Line Brown	1554	113^{a}	99	22.2	43.3
H & N "Brown Nick"	1568	110^{b}	100	22.8	39.4
Pooled SEM	±49	±1	±1	±1.1	±4.0
Diet regimen[2]					
SDP	1618^{a}	112^{ab}	100	23.2	39.3
SUP9	1555^{b}	113^{a}	100	22.5	40.0
SUP12	1510^{b}	110^{b}	99	21.8	44.6
Pooled SEM	±62	±1	±1	±1.4	±4.0

[1]None of the Strain x Diet regimen interactions were significant. [2]SDP = Step-down Protein; SUPLES = Step-up Protein Low Energy Starter Fed to 9 Week; SUP12 = Step-up Protein Low Energy Starter Fed to 12 Week. ^{abc}($p \leq 0.05$)

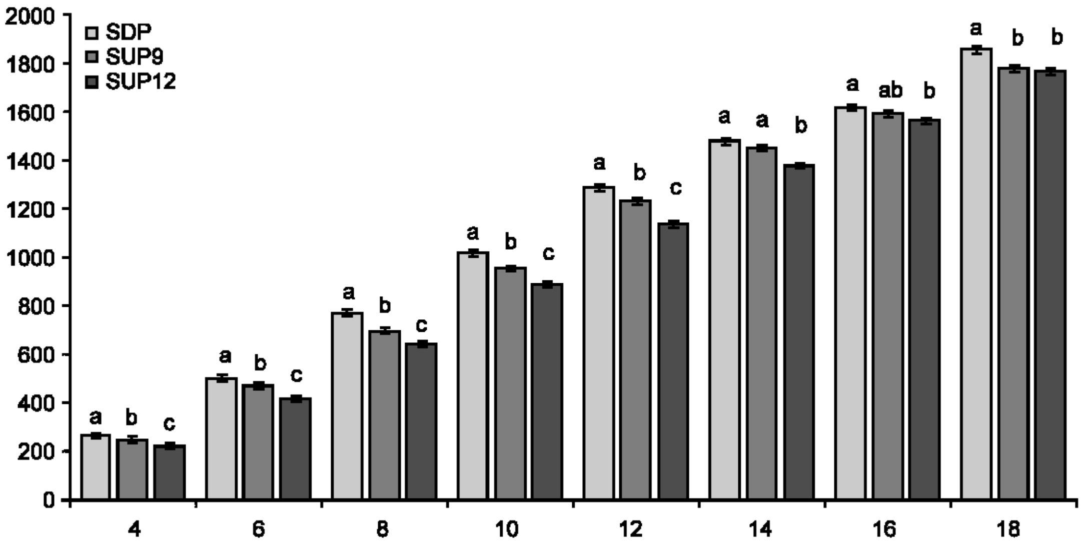

Fig. 1: Impact of reverse feeding programs body growth by period in brown egg pullets from 4-18 weeks

Table 6: Effect of strain and dietary regimen on body component weights as a percentage of body weight at 17 week of age

Source[1]	Blood	Feather	Head and neck	Shank and foot	Fat pad	Wings	Leg quarters	Breast	Liver	Gizzard	Small intestine
Strain	%	%	%	%	%	%	%	%	%	%	%
Hy-Line Brown	3.06	6.5	8.3	11.6	2.2	8.9	32.2	24.6^{a}	1.26	2.30	1.35
H & N "Brown Nick"	3.06	6.6	8.2	11.5	2.6	8.9	32.0	23.9^{b}	1.22	2.29	1.33
Pooled SEM	±0.09	±0.2	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.02	±0.04	±0.03
Diet regimen[2]											
SDP	3.0	6.1	8.2^{b}	11.5^{b}	2.4	8.8	32.5^{a}	24.3^{ab}	1.18^{b}	2.19^{b}	1.35
SUP9	3.0	6.6	8.1^{b}	11.4^{b}	2.3	8.8	31.8^{b}	24.6^{a}	1.24^{ab}	2.39^{a}	1.37
SUP12	3.2	6.9	8.5^{a}	11.8^{a}	2.5	9.0	31.9^{b}	24.0^{b}	1.30^{a}	2.30^{a}	1.29
Pooled SEM	± 0.11	± 0.2	±0.1	±0.1	±0.2	±0.1	±0.2	±0.2	±0.02	±0.05	±0.04

[1]None of the Strain x Diet regimen interactions were significant. [2]SDP = Step-down Protein; SUPLES = Step-up Protein Low Energy Starter Fed to 9 Week; SUP12 = Step-up Protein Low Energy Starter Fed to 12 Week. [abc]($p \leq 0.05$)

The Head and Neck and the Shank and Foot percent of BW were significantly greater (p<0.05) in the SUP12 regimen pullets than either the SDP or SUP9 pullets. Leg Quarters were a greater percentage (p<0.05) in the SDP regimen pullets than in either the SUP9 or SUP12 pullets. The Whole Breast from the SUP9 pullets had the greatest percent (p<0.05) of body weight while the pullets in the SUP12 with the SDP regimens being intermediate. The SUP12 regimen pullets had a greater percent liver than the SDP regimen pullets with the SUP9 Regimen resulting in pullets with an intermediate percent liver. Gizzard percentage of BW was greatest for the SUP9 pullets at 2.39% and the SUP12 pullets at 2.30% and the SDP pullets had the lowest gizzard 5 of BW at 2.19%. The small intestine percentage of body weight was not influenced by the dietary regimen.

DISCUSSION

Strain: The growth and development of the two strains of brown-egg layers BN and HB were similar as indicated by both the 17 and 18 week BW indicating that they grew in a similar manner consuming comparable volumes of feed. Indicating that the skeletal and organ development occurs in a similar fashion in both strains. Livability was greatest in the HB pullets by 3.9%. The majority of the mortality occurred in the first two weeks, suggesting that the effect may have been due to outside factors other than strain such as hatching egg age, or breeder flock husbandry rather than genetic differences. However, sternum length was shorter in the BN than in the HB by 0.3 cm. The shorter keel length apparently influenced the breast weight which was a lower (p<0.05) percentage of BW in the BN pullet. These findings were consistent with those reported by Anderson *et al.* (1995) using the same strains. This data most likely indicates that selection in these two strains has remained consistent with similar goals. Even though the sternum length was longer for the HB this did not translate into a heavier pullet. Since there was a lack of relationship between BW and sternum length this would suggest that sternum length is a poor indicator of pullet development as concluded by Leeson and Summers (1984b) supporting the assertion by Anderson *et al.* (1995) that BW remains the best indicator of pullet development that skeletal dimensions were not applicable after 105 d of age.

Dietary regimen: The SUP9 and SUP 12 Regimens resulted in pullets which were lighter in BW ($p<0.05$) than the SDP pullets at both 17 and 18 week, these results are consistent with numerous other reports (Lee *et al.*, 1971; Leeson and Summers, 1979, 1980; Doran *et al.*, 1983; Robinson *et al.*, 1986; Anderson *et al.*, 1995). The weight differences observed in this study developed early in the rearing period and were sustained throughout. This may have been the result of the decreased bulk density of the starter in the SUP9 and SUP12 diet regimens which would have enhance gut fill and reduce total protein intake. After the pullets were placed on the grower diet, growth increased and by 18 week the SUP9 and SUP12 pullets did not differ in BW. This data indicates that the pullets can be grown on a low protein starter for extended periods. Both the SUP9 and SUP12 consumed less ($p<0.05$) total protein than the SDP pullets of 1.15, 1.01 and 1.26 kg, respectively. The SUP feeding regimens may be a means of reducing feed costs when protein costs are high. Since all diets were formulated for mineral intake there were no differences between the SDP, SUP9 and SUP12, mineral intake as supported by the fact that bone strength and ash content were not different between the regimens. The body component of the offal as a percentage of BW for the head and neck and shank and foot were much higher ($p<0.05$) in the SUP12 which were the smaller pullets. The Leg Quarter was lighter for the SUP9 and SUP12 pullets than the SDP birds, however, this was the opposite for the breast weight with the SDP pullets having an intermediate percent of body weight between the SUP9 at 24.6% of body weight and the SUP12 pullet at 24.0%. The liver weight in the SUP9 and SUP12 pullets were the heaviest in the presence of lower protein intake where the percentage liver was larger ($p<0.05$) than the liver in the SDP pullets. The absolute liver weight was not different (data not shown) between the 3 groups. This would explain the percentage difference since both of the SUP pullet groups had the lowest body weight. The Gizzard percentages were higher in the SUP9 and SUP12 regimens with the highest fiber content. This indicates that the muscular grinding in the gizzard was greatest due to the increased fiber content with a diet containing 36.79% oats. The other organs were the same as the SDP pullets. This study shows that pullets can be effectively grown on SUP Regimens with no detrimental impact on development during the pullet rearing period.

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