Dietary Manipulation of Lean Tissue Deposition in Broiler Chickens

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ABSTRACT : Two experiments were conducted to examine the effect of graded levels of dietary chromium and leucine, and different fat sources on performance and body composition of broiler chickens. The results showed that chromium picolinate at 0.5 ppm significantly ($p<0.05$) lowered the carcass fat level. Gut weight and carcass water content were increased as a result of chromium treatment. Body weight, plucked weight, carcass weight, abdominal fat pad weight, breast yield and feed efficiency were unaffected by chromium treatment. Leucine did not interact with chromium to effect lean growth. Dietary leucine above the recommended maintenance level (1.2% of diet) markedly ($p<0.001$) reduced the breast muscle yield. The addition of fish oil to broiler diets reduced ($p<0.05$) the abdominal fat pad weights compared to birds on linseed diets. Fish oil is believed to improve lean growth through the effects of long chain polyunsaturated fatty acids in lowering the very low-density lipoprotein levels and triglyceride in the blood, in the meantime increasing glucose uptake into the muscle tissue in blood and by minimizing the negative impact of the immune system on protein breakdown. The amount of fat in the diet (2% or 4%) did not affect body composition. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 5 : 692-698)***

Key Words : Body Composition, Chromium, Leucine, Fish Oil, Linseed Oil, Lard, Safflower Oil

INTRODUCTION

Reducing fatness in chicken meat is a current industry goal. The objective is to provide a leaner product for the consumer, whilst at the same time reduce production cost. Changing the nutrient composition of the diet provides an opportunity for reducing production costs and decreasing carcass fat content. Feed restriction regimes and alterations in the protein to energy ratio of feed have some success in increasing leanness in broilers (van Weerden, 1989), but their commercial practice is very limited.

Dietary manipulations that may be of practical implications in the poultry industry include using a) chromium as a supplement (Wenk, 1995), b) branched chain fatty acids such as leucine, isoleucine and valine to change muscle protein synthesis (Chua et al., 1979; Morgan et al., 1981), and c) fat sources enriched in n-3 fatty acids and conjugated linoleic acid (Farrell, 1995; Chen and Hsu, 2004).

In the current study, two experiments were conducted to examine the potential of manipulating lean tissue deposition of broiler chickens by including different levels of chromium and leucine, and using different types of fats in broiler diets.

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MATERIALS AND METHODS

Experiment 1: Eeffect of dietary chromium and leucine on protein deposition in broilers

Husbandry : Mixed sex broiler chickens (300) were supplied by Baiada Poultry, Tamworth, NSW Australia. Upon arrival at the University of New England (UNE) 216 healthy day old chicks were weighed and housed in electrically heated brooders. These brooders consisted of wire mesh floors with galvanized cage partitions with slide-in excreta trays, and external feeders and water troughs. At 21 days of age the birds were moved to Harrison carry-on cages (4 birds per cage for 54 pens). These wire mesh cages were also fitted with external galvanized feeders, external water troughs and slide-in excreta trays. Brooders and cages were located in an insulated room. Room temperature was maintained between 23-28°C. The floor was wetted each morning to increase the humidity in the rooms and to keep the dust levels to a minimum. The floor was regularly swept to remove spilt feed and excess dust and feathers. Excreta trays were cleaned and water troughs scrubbed and refilled regularly. Birds in the weight range of 47-53 g were accepted for the experiment, birds outside this weight range were rejected. Birds were thereafter weighed weekly. Birds showing obvious sickness or leg weakness (such as tibial dischondroplasia), which hindered their ability to access water or food, were euthanised by cervical dislocation.

Experimental design : This experiment was a 3×3 factorial design, including three levels of chromium (0, 0.5 and 1.0 mg/kg) and three levels of leucine (1.2-control, 1.88, 2.40%). Overall there were nine separate diets (Table 1) which were randomized between 216 mixed-sex broilers (24 birds/diet).

Table 1. Experimental diets for Experiment 1

Diet No.	Diet Id.	Diet design
1	Control	Control
2	L1	Control+1.88% leucine
3	L2	Control+2.40% leucine
4	Cr1	Diet 1+0.5 mg/kg chromium
5	Cr1L1	Diet 2+0.5 mg/kg chromium
6	Cr1L2	Diet 3+0.5 mg/kg chromium
7	Cr2	Diet 1+1.0 mg/kg chromium
8	Cr2L1	Diet 2+1.0 mg/kg chromium
9	Cr2L2	Diet 3+1.0 mg/kg chromium

Diets and feeding : Both starter and finisher diets were formulated by Inghams Enterprises Pty Ltd. Leppington, NSW. using the feed formulation software Agridata (Table 2). Chromium was obtained from Ridley AgriProducts (Tamworth, NSW) as chromium picolinate and synthetic leucine from Masashi Australia (Melbourne, Vic). The mixed feed was cold-pelleted. The freshly pelleted diets were placed in a dry room to cool down and become isoanhydrogenous with the surroundings. This process was carried out to balance the water content of the food and to reduce the risk of bacteria or mould spoiling the feed. The AME and crude protein content were 12.59 MJ/kg and 21.79% for starter diets, and 12.58 MJ/kg and 18.92% for finisher diets. Birds were fed the starter diets for the first three weeks. At 21 days of age the birds were transferred onto the finisher diets until slaughter. During the trial feed was available *ad libitum*. Feed was removed from the feed troughs 24 h before the trial was terminated. Water was also provided *ad libitum* throughout the trial and access was continued until slaughter.

Measurements : All birds were weighed upon arrival, and at weekly intervals until slaughter. Feed intake was recorded weekly and feed conversion ratio (g feed/g gain) calculated Mortalities were recorded and weekly feed on offer was adjusted accordingly. At 6 weeks of age the birds were fasted overnight in preparation for processing. Birds were killed by cervical dislocation and transported to the processing room in labelled plastic buckets. Each bird was weighed. and then immersed in 67°C water for 40-50 seconds. The animal was then plucked using a custom made. automated chicken plucker fitted with 15 cm rubber fingers. The weight of each plucked bird was recorded. The bird was then manually eviscerated with care taken to collect the entire abdominal fat pad. The fat pads and visceral weights were recorded. From the carcass. both breast muscles were removed and weighed. The carcass and filleted breast muscles were placed in labelled polythene bags and stored at -23°C for further analysis.

A subset (25%) of the 216 birds was randomly selected from each treatment for body water and fat content measurements. Moisture analysis was carried out on a 50 g subsample. Each frozen carcass was cut into 25 mm×25 mm strips on a band saw then refrozen. A homogenate was created after each carcass was doubly minced. Processing through the mincer twice resulted in a uniform homogenate. Subsamples were taken as a representation of the total carcass for moisture and fat analysis. The moisture content was measured using a Dynavac Freeze Driers and the fat content was determined using Soxlet extraction method (AOAC, 1980).

Experiment 2: Effect of fat sources on lean tissue deposition in broilers

Husbandry : Day old birds (48) were randomly housed in individual temperature control brooders in a climate control room. The temperature of the room was maintained between 31.5-33.5°C, with a relative humidity of 55%. As a safety precaution the brooders were fitted with 40 watt light bulbs. which switched on through a thermostat control if the room temperature fell below 31°C. The birds were

Table 2. Diet formulation for starter and finisher diets (Experiment 1)

Ingredients	Starter diet			Finisher diet		
	1,4,7	2,5,8	3,6,9	1,4,7	2,5,8	3,6,9
Wheat (11.5% CP)	50.04	49.44	49.84	61.35	60.85	60.35
Barley (10% CP)	10.00	10.00	10.00	9.00	9.00	9.00
Rice pollard (13% CP)	6.00	6.00	6.00	4.00	4.00	4.00
Cottonseed	4.00	4.00	4.00	4.00	4.00	4.00
Meat and bone meal (50% CP)	10.00	10.00	10.00	8.13	8.13	8.13
Soyabean meal (48% CP)	15.00	15.00	15.00	10.00	10.00	10.00
Lime	0.50	0.50	0.50	0.40	0.40	0.40
Tallow	3.03	3.03	3.03	1.83	1.83	1.83
DL methionine	0.23	0.23	0.23	0.18	0.18	0.18
Lysine	0.31	0.31	0.31	0.23	0.23	0.23
Bicarbonate soda	0.18	0.18	0.18	0.14	0.14	0.14
Salt	0.10	0.10	0.10	0.15	0.15	0.15
Choline	0.08	0.08	0.08	0.02	0.02	0.02
Premix (vitamins and minerals)	0.50	0.50	0.50	0.50	0.50	0.50
Synthetic leucine	0.00	0.60	1.20	0.00	0.50	1.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 3. The fatty acid composition of different fat resource tested in Experiment 2

Fatty acid	Common name	Fat source			
		Linseed	Tallow	Safflower	Fish*
12:0	lauric	-	0.1	-	-
14:0	myristic	-	3.2	0.1	3.7
16:0	palmic	6	24.5	6.5	12.6
18:0	stearic	4	19	2.4	2.3
20:0	arachidic	-	0.1	-	-
16:1, n-7	palmitoleic	-	3.3	-	9.3
18:1, n-9	oleic	16	42.6	13.1	22.7
20:1, n-9	gadoleic	-	0.6	-	7.5
22:1, n-9	erucic	-	-	-	6.2
18:2, n-6	linoleic	15	2.6	77.7	1.5
18:3, n-3	alpha-linolenic	59	0.7	-	0.6
18:3, n-6	gamma-linolenic	-	0.2	0.2	-
20:4, n-6	arachidonic	-	0.4	-	1.4
20:5, n-3	EPA	-	-	-	12.9
22:5, n-3	adrenic	-	-	-	1.7
22:6, n-3	DHA	-	-	-	12.7

* Cod oil (source = Tacon, 1990).

maintained in this room until week three when they were transferred to larger individual cages. Handling of the birds was as per Experiment 1 with the exception that the birds were weighed at three weeks intervals (weeks three and six).

Experimental design : Experiment two was a 2×4 factorial design. Two different increments (2% and 4%) of four fatty acid sources (linseed oil, lard, safflower oil and fish oil) were used in formulating the eight diets. Six birds were designated to each diet. Linseed in this experiment was considered the control diet as it contained little linoleic acid and EPA and DHA are not present. The tallow diet consisted of a higher proportion of saturated fats than the other diets. The tallow diet did, however, contain traces of arachidonic acid and high content of it's linoleic acid as the c-9, t-11 isomer. Safflower oil was used as a rich source of linoleic acid (over 77% of total fatty acid content). Fish oil treatments were trialed as they supply high levels of the omega-3 fatty acids EPA and DHA. The commercial fish oil used in this experiment had an unknown fatty acid composition. The composition of four fatty acid sources is listed in Table 3.

Diets and feeding : Both the starter and grower diets were formulated at the University of New England using FEEDMANIA software package (Table 4). The difference between diets was the differing fat sources and levels. The AME and crude protein were 12.31 MJ/kg and 21.19% for starter diet, and 12.34 MJ/kg and 20.81% for finisher diet. Feed and water were available to the birds *ad libitum*.

Measurements : During this experiment feed intake and feed conversion ratio (FCR) were determined every three weeks. The birds were weighed upon arrival, at three weeks (when cages and rooms were changed) and at slaughter. The same body parameters were measured as a representation of growth in the animal. All of the birds were processed on the same day. The techniques employed were the same as those used in Experiment 1. Liveweight, carcass weight, abdominal fat pad, breast muscles, and visceral weight were measured.

Statistical analysis of data

Data from both experiments were analyzed using Statgraphics statistical analysis software (Manugistica Software, MD, USA). Any effects of diet which were likely to have occurred by chance less than five times in 100 test repeats (i.e., $p<0.05$) were declared statistically significant. Duncans multiple range test was used to separate means and test for specific treatment effects.

RESULTS

Chromium and leucine

Levels of leucine or chromium did not affect feed

Table 4. Diet formulations for starter and finisher birds in Experiment 2

Diet fat level (%)	Starter		Finisher	
	2	4	2	4
Ingredient				
Sorghum (9% CP)	41.21	39.21	46.32	41.32
Barley (9% CP)	15.00	15.00	10.00	10.00
Rice Pollard (13% CP)	5.30	5.30	5.00	8.00
Cottonseed	5.00	5.00	10.00	13.00
Meat and bone meal (50% CP)	3.00	3.00	3.00	3.00
Soyabean meal (48% CP)	24.80	24.80	20.00	17.00
Limestone	1.50	1.50	1.70	1.70
Dicalcium phosphate	0.70	0.70	0.60	0.60
DL methionine	0.40	0.40	0.30	0.30
Lysine	0.28	0.28	0.20	0.20
Threonine	0.11	0.11	0.03	0.03
Salt	0.20	0.20	0.35	0.35
Premix (vitamins and minerals)	0.50	0.50	0.50	0.50
Fat (lard, safflower, linseed or fish oil)	2.00	4.00	2.00	4.00
Total	100.00	100.00	100.00	100.00

Table 5. Effect of chromium and leucine on Feed Conversion Ratio (FCR), body weight and body components (g) of broiler chickens. Values are least square means

Treatment	N	FCR	Body Wt.	Carcass Wt.	Gut Wt.	Fat pad	Breast Wt.
Chromium							
Cr0	18	1.695	2,061	1,718	198[a]	26.2	308
Cr1	18	1.724	2,028	1,685	2,013[a]	24.1	302
Cr2	18	1.724	2,116	1,756	210[b]	27. 8	308
P value		0.28	0.21	0.29	0.01	0.11	0.74
Leucine							
L0	18	1.754	2,097	1,752	200	24.4	329[a]
L1	18	1.754	2,097	1,742	204	26.3	308[b]
L2	18	1.724	2,011	1,662	205	27.3	281[c]
P value		0.07	0.15	0.11	0.42	0.25	0.01

[a, b, c] Different superscripts in separate columns within a treatment differ significantly at p<0.05.

Cr0 = 0 mg Cr/kg feed; Cr1 = 0.5 mg Cr/kg feed; Cr2 = 1.0 mg Cr/kg feed; L0 = 1.20% leucine; L1 = 1.88% leucine; L2 = 2.40% leucine.

FCR: Feed conversion ratio.

Table 6. Effect of chromium and leucine on water and fat content (%) of broiler carcass (values are least square means)

Treatment	N	Water	Fat
Chromium			
Cr0	18	64.3	15.3[a]
Cr1	18	65.3	13.8[b]
Cr2	18	64.8	14.7[c]
P value		0.13	0.03
Leucine			
L0	18	64.93	14.2
L1	18	64.61	14.8
L2	18	64.75	14.7
P value		0.82	0.43

[a, b, c] Different superscripts in separate columns within a treatment differ significantly at p<0.05.

Cr0 = 0 mg Cr/kg feed; Cr1 = 0.5 mg Cr/kg feed; Cr2 = 1.0 mg Cr/kg feed; L0 = 1.20% leucine; L1 = 1.88% leucine; L2 = 2.40% leucine.

conversion ratio (FCR). There was no significant difference in FCR between the nine diets (p>0.05). The average FCR for all of the birds at 6 weeks of age was 1.724. There were no interactions between the diets and body weight, plucked weight or the carcass weight. The average bird weighed 2,068.5 g at 42 days. The mean plucked weight was 1948.8g with no significant difference between treatments. Carcass weight in this experiment included the head and feet although these are removed during commercial processing. There was no significant effect (p>0.05) of chromium or leucine on carcass weight.

Chromium included at 1 mg/kg level increased the average gut weight of the birds from 198.2g of the controls to 210.2 g (p<0.05). Neither Cr nor leucine had a significant effect on fat pad weight (Table 5). Chromium had no effect on breast tissue yield, but supplementation of leucine reduced (p<0.001) breast muscle weight. Birds fed leucine at the level of 2.40% digestible leucine had 15% lighter breast muscles less than control birds.

Leucine had no significant effect on the water and fat content of the carcass (Table 6). The addition of 1.88% Cr increased the average water percentage by 1% unit (p>0.05). Feeding chromium reduced (p<0.05) carcass fat content, but there was no significant interaction between chromium and leucine treatments.

There was no effect of dietary fat source and level on feed efficiency and body weight, the plucked weight or carcass weight of the birds (Table 7). The average viscera weight at 42 days was 206 g. The type of fat in the diet and the inclusion level in the diet did not influence (p>0.05) the viscera weight.

The abdominal fat pad weighed an average of 22.9 g. Birds fed diets containing the fish oil had lower (p<0.05) fat pad weight than those fed the other diets. Birds fed the linseed oil had the highest fat pad weight. Overall, the inclusion level of fat in the diet did not affect the fat pad weight and the breast yield (p>0.05). The fat pad of birds fed the diet containing fish oil was 19.6 g and 21.6 g for the inclusion level of 2% and 4%, respectively, with the corresponding values for linseed treatments being 28.7 g and 26.8 g.

DISCUSSION

This study shows that altering the dietary concentration of organic chromium and leucine in broiler diets affected deposition of fat. Chromium added as chromium picolinate at 0.5 mg/kg decreased carcass fat deposition (as measured by chemical fat content) without a commensurate change in carcass weight, breast weight or water content. This observation is consistent with reports in pigs (Amoikon et al., 1995; Wenk, 1995). The mechanism of action is not properly understood, but is thought to be due to potentiation of insulin function through both enhanced secretion and an increase in cellular sensitivity to insulin, possibly through increased insulin receptor numbers (Buse, 1981). Chromium (Cr) is involved in normal glucose metabolism and is necessary for optimal insulin function and glucose uptake by insulin-sensitive cells (Amoikon et al., 1995). Chromium deficiency can lead to a diminished

Table 7. Effect of fat source and inclusion level on feed conversion ratio (FCR) body weight and weight of body components (g) of broiler chickens (LSM's)

Treatment	n	FCR	Body Wt.	Plucked Wt.	Gut Wt.	Fat pad Wt.	Breasts Wt.
Fat inclusion level (%)							
2	24	1.449	2,143	2,037	206	22.3	353
4	24	1.471	2,128	1,998	205	23.4	344
P value		0.709	0.82	0.55	0.88	0.64	0.58
Fat source							
Fish oil	12	1.471	2,131	2,043	201	20.6[c]	350
Lard	12	1.449	2,176	2,048	204	21.8[b]	357
Linseed	12	1.471	2,066	1,945	204	27.8[a]	337
Safflower	12	1.449	2,169	2,034	214	21.7[b]	349
P value		0.17	0.66	0.64	0.61	0.07	0.86
Fat inclusion level vs. fat source							
2% Fish oil	6	1.449	2,177	2,131	206	19.6	365
2% Lard	6	1.449	2,148	2,022	208	18.9	337
2% Linseed	6	1.471	2,003	1,889	204	28.7	337
2% Safflower	6	1.449	2,245	2,106	206	22.6	373
4% Fish oil	6	1.492	2,084	1,955	196	21.6	334
4% Lard	6	1.449	2,205	2,075	200	24.6	377
4% Linseed	6	1.449	2,129	2,001	203	26.8	337
4% Safflower	6	1.449	2,094	1,962	222	20.7	325
P value		0.14	0.46	0.32	0.55	0.51	0.26

[a, b, c] Data bearing different superscripts in a column within a treatment differ significantly at $p<0.05$.

FCR: Feed conversion ratio.

responsiveness of tissues to insulin (Mertz, 1979). Animals deficient in chromium have impaired pancreatic beta-cell functions and an altered glucose tolerance curve similar to that seen in non insulin-dependent diabetes in humans (Striffler et al., 1995). Other factors associated with insufficient chromium levels are increased levels of circulating insulin, impaired growth, higher percentage of body fat, lower lean body mass and increased mortality rate. Lindemann et al. (1994) reported an increased sensitivity of skeletal muscle to insulin as a result of chromium supplementation in pigs. A significant difference was noted in both carcass composition and feed utilization between chromium supplemented and control animals.

Supplementation with chromium did not affect the growth rate and feed conversion ratio of broilers in the current study. Similar results were also reported for rats (Striffler et al., 1995), and growing pigs (Amoikon et al.; 1995, Lindemann et al., 1995; Wenk, 1995). However, chromium supplementation has been reported to improve growth and feed conversion during periods of stress (Mowat, 1993; Kitchalong et al., 1995; Wenk, 1995). Stress alters nutrient metabolism and ultimately increases the dietary requirements for specific nutrients. Chromium may be at sub-optimal levels in normal diets, principally because of marginal deficiency in cereal grains. Stress, which increases rate of carbohydrate utilisation, may create a demand for chromium and thus a deficient state (Lindemann et al., 1995). Lack of response to chromium supplementation in growth and feed conversion in this study was not surprising because all birds in this trial were housed and fed without stresses. However, as noted above, chromium supplementation was effective in that it did have an effect on fat deposition.

The branched chain fatty acids such as leucine, isoleucine and valine to change muscle protein synthesis (Chua et al., 1979; Morgan et al., 1981). It is hypothesized that these amino acids alter the sensitivity of muscle protein synthesis to insulin (Garlick and Grant, 1988). The precise mode(s) of action is not known, but in the case of leucine is it proposed that its effect on protein synthesis is exerted during mRNA translation and seems to involve alteration of the rate of peptide chain initiation (Buse, 1981). Recent work in athletes has demonstrated that the β-hydroxy β-methylbutyrate (HMB), a metabolite of leucine, enhanced gains in strength and lean body mass associated with resistance training (Slater and Jenkens, 2000). In the current study, however, additional dietary leucine had no influence on efficiency of feed use and had no impact on carcass fat content although additional leucine significantly reduced breast muscle weight. It was surprising that leucine had these effects. Reduction in growth was unexpected until it was realised that the branched chain amino oxidase complex is not specific for leucine, but has similar affinity for isoleucine and valine. Moreover, it has been shown in rats (Block and Harper, 1984) that excess dietary leucine decreases the circulating concentration of iso-leucine and valine, by increasing the activity of branched chain amino acid oxidase (and BCAA oxidation) in muscle, and branched chain keto acid dehydrogenase in liver. Given that chickens are susceptible to marginal deficiencies in isoleucine, it is possible that in this study, excess leucine has generated a functional decrease in isoleucine availability and through this mechanism reduced muscle weight gain. It was surprising that this occurred with no significant change in body weight, or in feed conversion efficiency.

Type of dietary fat has been reported to alter glucose and lipid metabolism in broiler chickens (Newman et al., 2002). The difference is mainly related to the contents of n-3 fatty acids and conjugated linoleic acid. These polyunsaturated fatty acids including docohexaenoic acid (in fish oils) have been reported to promote cell proliferation and reduce apotosis rate (Tang et al., 1997). Early research demonstrated that high dietary polyunsaturated fatty acid levels (over 1.4% of the diet) reduced fat deposition in broilers (Pinchasov and Nir, 1992). In the current study, the effect of linseed oil, lard, fish oil and safflower oil included at 2% and 4% levels had no effect on body weight, carcass weight, gut weight or feed efficiency in male broilers. Birds receiving diets fortified with fish oil developed significantly smaller abdominal fat pads than birds receiving the linseed oil treatment. This effect is possibly through the influence of polyunsaturated fatty acids, eicosapentanoic acid (EPA) and docosahexanoic acid (DHA) in lowering the circulating very low density lipoprotein (VLDL) levels. These complexes are normally delivered to tissues for fat storage, including the abdominal fat pad. Fish oil has been reported to improve feed efficiency in broilers (Farrell, 1995). It is thought that the n-3 fatty acids in fish oil may reduce the catabolic response induced by the immune system (Chin et al., 1994), reducing protein turnover levels and effectively promoting lean growth. Linoleic acid is generally converted to arachidonic acid which is a precursor for the eicosanoids-local messenger molecules which regulate the rates of protein synthesis and degradation (Reeds, 1987). This is supported by the findings of Newman et al. (1998) that fish oil increases glucose uptake into the muscle tissue and decreases plasma triglyceride concentration in broiler chickens.

In summary, the studies have shown that (a) moderate level of chromium can reduce carcass fat content in broilers, and (b) fats containing high levels of polyunsaturated fatty acids, i.e., eicosapentonoic acid (EPA) and docosahexanoic acid (DHA), can reduce abdominal fat pad weight in broilers. The current industry practice does not have any particular provision for chromium in the least cost feed formulation. Various fats and oils are considered equivalent energy sources with the exception that linoleic acid, an essential fatty acid for poultry, is explicitly recognised in diet formulation. The chicken carcass contains 13-17% fat and any decrease in the fatness of broilers is favourable in terms of production cost and meat quality. It is important that provisions be made for chromium levels and some polyunsaturated fatty acids in practical feed formulations to take advantage of their effect on energy utilisation and carcass fat content. However, more research is required to further assess 1) the role of organic chromium in stressed and unstressed broilers and 2) the effect of graded leucine in conjunction with other branched chain amino acids, polyunsaturated fatty acids (i.e., EPA and DHA) and conjugated linoleic acid in the diet on protein deposition and energy metabolism in broilers.

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