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PROJECT LEADER: Sandra G. Velleman

Posthatch Feed Restriction Effects on Broiler Muscle Growth

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Researcher Contact Details
Name: Sandra G. Velleman
Address: 1680 Madison Ave.

Phone: 330-263-3905
Fax: 330-263-3949
Email: Velleman.1@osu.edu

In submitting this report, the researcher has agreed to the Poultry CRC publishing this material in its edited form.

Poultry CRC Ltd Contact Details
PO Box U242
University of New England
ARMIDALE NSW 2351

Phone: 02 6773 3767
Fax: 02 6773 3050
Email: admin@poultrycrc.com.au
Website: http://www.poultrycrc.com.au

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Executive Summary

This project was designed to determine if altering the time of administering immediate posthatch feed restrictions in developing broiler chicks could function as a means of improving breast meat quality by reducing the transdifferentiation of adult myoblasts (satellite cells) to adipose cells and maximizing satellite cell mediated growth. Satellite cells in broilers have maximal activity the first week posthatch and by moving the feed restriction to the second week posthatch after the period of satellite cell activity could maximize muscle mass accretion. A series of *in vivo* and *in vitro* experiments with isolated broiler satellite cells were conducted with the following the outcomes:

1. The effect of feed restrictions being administered the first week posthatch or the second week posthatch was compared *in vivo.*

2. Morphological changes and gene expression changes that occur in the broiler breast muscle with feed restrictions administered the first week posthatch were eliminated by moving the feed restriction to the second week posthatch.

3. Feed restrictions administered the first week posthatch increased fat deposition in the broiler breast muscle.

4. Fat deposition in the breast muscle was reduced when the feed restriction occurred during the second week posthatch.

5. *In vitro* studies with isolated broiler breast muscle satellite cells showed that the proliferation and differentiation of satellite cells was altered by suboptimal nutrition which will affect muscle mass accretion in the bird.

6. Suboptimal nutrition *in vitro* resulted in the transdifferentiation of satellite cells to an adipogenic lineage and apoptosis of the cells.

7. There are differences in response to nutrition *in vitro* from broiler satellite cells isolated from muscles of different fiber types.

The *in vivo* and *in vitro* trials conducted in this CRC-funded project suggest a high potential for manipulating satellite cell activity and cellular fate through nutritional management during the immediate posthatch period. Studies are in progress to determine the effect of different diets *in vivo* on broiler breast muscle growth and development.

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INTRODUCTION

The *per capita* consumption of poultry products has increased during the past decade and is expected to continue to rise worldwide (Roegnik, 1999). This increased demand has caused breeders and producers to maximize growth including lean carcass development, especially the breast muscle, which is the most economically valuable part of the carcass. Muscle formation is a complex process resulting in the development of muscle fibers and muscle fiber bundles. After hatch, muscle growth occurs through a myogenic stem cell population, termed satellite cells. Satellite cells are multipotential cells that can form muscle, fat, or bone cells (Askura et al., 2001). Although the primary cellular fate pathway for satellite cells is to form muscle, they can be induced to follow other cellular outcomes which will have a detrimental impact on muscle accretion and meat quality. Investigations on factors influencing satellite cell activity in poultry, broilers, and turkeys have shown that the immediate posthatch nutritional regimen can affect satellite cell activity, and muscle growth and development (Plavnik and Hurwitz, 1988; Halevy et al., 2000, 2003; Mozdziak et al., 2002; Velleman and Mozdziak, 2005; Velleman unpublished).

In commercial poultry operations, it is common during the immediate posthatch period for chicks to rely on nutrients from the yolk during shipping. In addition, control of metabolic disorders such as those resulting in leg problems and ascites has led to the industry recommendation of early feed restriction (Arce et al., 1992; Acar et al., 1995). The logic is that short term feed restriction applied early in life would allow the chicken to restore balance between supply and demand organs (Katanbaf et al., 1988; Acar et al., 1995). Final processing body weights would be achieved through compensatory gain. The phenomenon of compensatory gain in poultry has been studied for years (Auckland, 1972; Cherry et al., 1978; Malone et al., 1980; Ferket and Sell, 1989; Washburn, 1990) with mixed results. It appears that factors such as timing, duration and intensity of the restriction all impact the compensatory response of the bird. It is unclear, however, if muscle generated from a post restriction recovery period is the same as that of muscle from birds reared in unrestricted conditions.

Chicks and turkey poults without feed for the first 48 h after hatch have reduced growth and small intestinal development (Noy and Sklan, 1997; Geyra et al., 2001). In addition to the chick and turkey poults having reduced growth, muscle growth is also decreased (Halevy et al., 2000, 2003, Mozdziak et al., 2002). Posthatch muscle growth is due to the hypertrophy of existing muscle fibers mediated by myonuclear accretion. These new nuclei are from the incorporation of satellite cell myonuclei into existing myofibers. Feed-deprived turkey poults and chicks exhibit reduced satellite cell mitotic activity (Halevy et al., 2000; Mozdziak et al., 2002). Thus, it is likely that the reduction in muscle growth from posthatch feed deprivation is through modifications in satellite cell mediated muscle hypertrophy.

The first week posthatch appears to be the most intense period of satellite cell activity (Plavnik and Hurwitz, 1988; Halevy et al., 2000). Halevy et al. (2000) reported, based on 48 h starvation periods during the first week posthatch in chicks, that the timing of the starvation period influenced muscle and body growth potential. Feed deprivation over the first 2 days posthatch had the greatest effect on growth compared to deprivation periods beginning at day 4 or 6 after

hatch. Plavnik and Hurwitz (1988) showed that feed restriction during the second week posthatch results in growth retardation that is fully recoverable. In vitro culturing of chick breast muscle satellite cells has shown that satellite cell activity peaks 2 to 3 days after hatch in cells isolated from fed birds (Halevy et al. , 2000) which supports the in vivo findings and the importance of the first week posthatch in muscle growth.

In summary, to achieve optimal muscle mass accretion and maintain meat quality requires the appropriate immediate posthatch nutritional regimen. Breast meat yield and quality are the primary profit centers for the commercial poultry industry. Changes in meat quality, especially the amount of fat deposition, will have a significant economic impact as breast meat leanness is a primary consideration by consumers for purchasing poultry breast meat.

OBJECTIVES

The development of skeletal muscle occurs as a result of the proliferation and differentiation of myoblasts that fuse to form multinucleated myotubes. During the immediate posthatch period, muscle growth occurs through hypertrophy. This is a period of maximal satellite cell activity and is affected by the nutritional status of the chicks. For example, Mozdziak et al. (2002) showed that chick satellite cell mitotic activity is reduced in feed deprived chicks. Velleman (unpublished) has shown that maintaining the chicks on a 20% feed restriction during the first 2 weeks posthatch reduced breast muscle yield and body weight throughout the 42 day duration of the study. Futhermore, the expression of genes associated with the proliferation (replication of muscle cells) and differentiation (formation of muscle fibers) of the satellite cells is significantly altered, resulting in the formation of extensive intramuscular fat depots. The feed restriction resulted in an increase in proliferation and decrease in differentiation, and altered morphological structure of the breast muscle. These data show the importance of the immediate posthatch period and appropriate nutritional regimen. Alterations in the nutritional regimen will change breast muscle development and yield, and affect meat quality. Since the newly hatched chicks exhibit such rapid growth after hatch, it is important to develop feed regimens that maximize genetic potential for breast muscle yield and quality while maintaining skeletal development. Based on other studies, the first week posthatch appears to be the most intense period of satellite cell activity (Plavnik and Hurwitz, 1988; Halevy et al., 2000). Halevy et al. (2000) reported, based on 48 h starvation periods during the first week posthatch in chicks, that the timing of the starvation period influenced the muscle and body growth potential. Feed deprivation for the first 2 days posthatch had the greatest effect on growth. Therefore, the working hypothesis for the proposed research is that muscle growth potential is at a maximum level during the first week posthatch due to peak levels of satellite cell activity, and the immediate posthatch nutritional regimen during this period is critical in determining satellite cell activity and cellular fate. The goal of the proposed research is to determine the appropriate immediate posthatch nutritional regimen in order to maximize muscle mass accretion and

maintain meat quality including the appropriate structure of the breast muscle and lean composition.

To determine the optimal dietary conditions to maintain satellite cell activity, the following experimental diet treatments and objectives were used:

1. Control full-fed diet; and 0 to 7 day 20% restriction followed by full fed diet. This aim tested the hypothesis that muscle satellite cells are at maximal activity in the first week posthatch and their activity and cellular fate is determined by nutritional regimen. At hatch the chicks were separated into treatment groups. At each sampling period, body weight and breast muscle weight were recorded. Breast muscle samples were harvested for histological analysis and gene expression studies.

2. Control full-fed diet; and a 0 to 7 day full fed followed by a 20% restriction from 8 to 14 days and then placed on a full feed diet. This aim tested the hypothesis that after the first week posthatch, growth can be restricted by a feed restriction without any permanent effect on muscle growth or cellular fate. Separation of the chicks at hatch and sampling were the same as described for specific aim 1.

The results from objectives 1 and 2 yielded valuable new information to the poultry industry on dietary feed restriction programs and the effect on breast muscle yield, proliferation, differentiation, fat deposition, and the structural organization of the muscle.

METHODOLOGY

Trial 1

Birds and Feed Restriction

Fertile Ross broiler 308 line eggs were shipped to The Ohio State University, Ohio Agricultural Research and Development Center Poultry Research Farm and hatched. At hatch (d 0), the chicks were divided into a fed (control) group on a standard commercial regimen and a 20% feed restriction group. The feed restricted group of chicks were kept on the restricted diet for 7 days and then returned to a full fed standard commercial diet. Immediately after the separation into the experimental groups, 8 chicks from each group were sacrificed with body weights and breast muscle weights recorded, and a sample removed for histological analysis of muscle structure. The remainders of the breast muscle were immediately frozen and stored at -70 ◦C for RNA analysis. Every day for the first 7 days after hatch, 8 birds from each group were sacrificed, body weight and breast muscle weights recorded, and a sample removed for histology. The remainder of the muscle was quick frozen and stored at -70 ◦C for RNA analysis.

After the 7 day feed restriction period, the birds were returned to a standard commercial diet for the duration of the study through 42 days of age. At this time, 8 birds from each group were sacrificed every 4 days with body weight and breast muscle recorded, and samples collected for histology and RNA analysis.

Histology

Histological analysis was conducted to determine muscle fiber structure, extracellular matrix spacing between fiber bundles, and presence of intramuscular fat depots.

After the removal of the skin from the breast region, a sample of the breast muscle was obtained by carefully dissecting approximately a 0.3 to 0.5 cm wide section of the muscle following the orientation of the muscle fibers for a length of about 3 cm. The muscle samples were placed in 10% (vol/vol) buffered formalin fixative (pH 7.0) at 4 °C for at least 17 h. After fixation, the samples were dehydrated through a series of graded alcohols as previously described by Jarrold et al. (1999), cleared in Pro-Par Clearant (Anatech, Battle Creek, MI) for 1 h with one change at 30 min, and then infiltrated with paraffin at 55 °C for 4 h with one change at 1 h using a Leica TP1020 tissue processor (Leica, Nussloch, Germany). The samples were then embedded in paraffin, and the resulting paraffin blocks were cross sectioned at 5 µm and mounted on Starfrost Adhesive slides (Mercedes Medical, Sarasota, FL).

Prior to staining with hematoxylin and eosin, the muscle tissue sections were incubated at 55 °C for 30 min, and then rehydrated, 2X for 10 min in Pro-Par Clearant, 2X for 2 min in 100% ethanol, 2 min in 95% ethanol, 2 min in 70% ethanol, 2 min in 50% ethanol, and 2 min in distilled water. After rehydration, the slides were placed in Gill's #2 hematoxylin (Fisher Scientific, Pittsburgh, PA) for 4 min. Sections were rinsed in gentle running tap water for 10 min and transferred to eosin Y (0.5 g of eosin Y and 2.5 mL of glacial acetic acid and brought to 500 mL in 70% ethanol) (Fisher Scientific) for 2 min. After being stained, the slides were rehydrated back through the graded series of ethanol and Pro-Par Clearant.

The stained muscle sections were analyzed for muscle morphology with an Olympus XI 70 microscope (Melville, KY) equipped with an Olympus Magna Fire digital camera linked to a computer with Image Pro Software (Media Cybernectics, Silverspring, MD). Each slide from each breast muscle sample contained a minimum of 4 sections, and 5 microscopic fields were evaluated from each section.

Gene Expression Analysis

The following genes were analyzed for their expression: MyoD, myogenin, MRF4, syndecan-4, glypican-1, PPARγ, and C/EBPα. MyoD, myogenin, and MRF4 are muscle specific transcriptional regulatory factors. MyoD is necessary for the proliferation of satellite cells. Myogenin is required for the differentiation of satellite cells into myotubes. MRF4 is thought to be involved in the activation of satellite cells. Both syndecan-4 and glypican-1 are differentially expressed during proliferation and differentiation with syndecan-4 playing a role in proliferation and glypican-1 in differentiation. PPARγ and C/EBPα are adipogenic specific genes. The

expression of these genes was measured by real-time quantitative polymerase chain reaction (PCR). The primers used are the following:

Table 1: Primer sequences for real-time PCR

Primer	Sequence[1]	Product size
MyoD	5'-GACGGCATGATGGAGTACAG-3' (Forward)	201 bp
	5'-AGCTTCAGCTGGAGGGAGTA-3' (Backward)	
Myogenin	5'-GGCTTTGGAGGAGAAGGACT-3' (Forward)	184 bp
	5'-CAGAGTGCTGCGTTTCAGAG-3' (Backward)	
MRF4	5'-AGGCTCTGAAAAGGAGGACTGT-3' (Forward)	307 bp
	5'-AGGCTGCTGGAAGCCGACGACT-3' (Backward)	
SYN 4	5'- CCAACAGCAGCATCTTTGAA-3' (Forward)	234 bp
	5'-GATGGGTTTCTTCCCAAGGT -3' (Backward)	
GPC 1	5'-ACATCGGGAATGATGTGGAT-3' (Forward)	208 bp
	5'-AAGAGGAGGAAGGCAGAAGG-3' (Backward)	
PPARγ	5'-CCACTGCAGGAACAGAACAA-3' (Forward)	249 bp
	5'-CTCCCGTGTCATGAATCCTT-3' (Backward)	
C/EBPα	5'-CAGTGGACAAGAACAGCAACGA-3' (Forward)	227 bp
	5'-CCTTCACCAGCGAGCTTTCG-3' (Backward)	
GAPDH	5'-GAGGGTAGTGAAGGCTGCTG-3' (Forward)	200 bp
	5'-CCACAACACGGTTGCTGTAT-3' (Backward)	

[1]Primer sequences were designed from the following GenBank accession numbers: MyoD, L34006: Myogenin D90157; Syndecan-4 (SYN 4), NM001007869; Glypican-1 (GPC 1), L29089; MRF4, GU223068; peroxisome proliferator-activated receptor gamma (PPARγ), NM_001001460, CCAAT/Enhancer-binding protein alpha (C/EBPα), NM_001031459.1, glyceraldehyde-3-phosphate dehydrogenase (GAPDH), U94327.

The amplified sequences were confirmed by DNA sequence analysis. The real-time PCR analysis was done as previously described in Liu et al. (2006). In brief, total RNA was extracted from each individual breast muscle using TRI Reagent (Molecular Research Center, Cincinnati, OH). The isolated RNA was reverse transcribed into a cDNA using Maloney murine leukemia virus transcriptase (Promega, Madison, WI). The real time quantitative PCR to measure the expression of each gene was performed using the DyNAmo Hot Start SYBR Green qPCR kit (Finnzymes, Ipswich, MA). The final PCR products were analyzed on a 1.5% agarose gel to check for amplification specificity. Standard curves were constructed for MyoD, myogenin, MRF4, syndecan-4, glypican-1, and glyceraldehyde-3-phosphate with serial dilutions of the purified PCR products from each gene. The amount of cDNA for each gene was interpolated from the corresponding standard curve. The expression of MyoD, myogenin, MRF4, syndecan-4, and glypican-1 was normalized to GAPDH expression.

Statistical Analysis

The student's *t*-test was performed at each sampling time to evaluate the differences between the means. Differences were considered significant at $P < 0.05$.

CHAPTERS

(Publications resulting, accepted pending revisions, and submitted papers will be included in this section. All figures are copyrighted to Poultry Science)

For the manuscripts published, the pdf version of the published manuscripts will be uploaded separately to Smartsheet. Submitted manuscripts will be uploaded in Word format.

Published manuscripts:

Velleman, S.G., Coy, C.S., and Emmerson, D.A. 2014. Effect of the Timing of Posthatch Feed Restrictions on Broiler Breast Muscle Development and Muscle Transcriptional Regulatory Factor Gene Expression. Poult. Sci. (in press).

Powell, D.J., McFarland, D.C., Muir, W., Cowieson, A., and Velleman, S.G. 2013. The effect of nutritional status on myogenic satellite cell proliferation and differentiation. Poult. Sci. 92:2163-2173.

Powell, D.J., McFarland, D.C., Muir, W., Cowieson, A., and Velleman, S.G. 2014. The Effect of Nutritional Status and Muscle Fiber Type on Myogenic Satellite Cell Fate and Apoptosis. Poult. Sci. 93:163-173.

Accepted manuscript pending revisions:

Powell, D.J., McFarland, D.C., Muir, W., Cowieson, A., and Velleman, S.G. 2014. The Effect of Nutritional Status and Muscle Fiber Type on Satellite Cell Myogenic Gene Expression. Poult. Sci.

Submitted:

Velleman, S.G., Coy, C.S., and Emmerson, D.A. 2014. Effect of the Timing of Posthatch Feed Restrictions on the Deposition of Fat during Broiler Breast Muscle Development. Poult. Sci.

DISCUSSION of RESULTS

In broilers, satellite cells are maximally active immediately posthatch and responsive to nutritional regime (Halevy et al., 2000; Mozdziak et al., 2002; Velleman et al., 2010; Kornasio et al., 2011; Powell et al., 2013). During the immediate posthatch period, muscle growth occurs through the hypertrophy of existing fibers. The satellite cells are responsible for this hypertrophy. During the immediate posthatch period of rapid muscle growth, the birds are placed on a restricted diet under some circumstances. After the period of the feed restriction, it is assumed that body weight and skeletal muscle growth will reach normal levels through compensatory growth mechanisms. Compensatory growth may not be sufficient to overcome changes in satellite cell mitotitc activity resulting from feed manipulations immediately after hatch. Feed depriving chicks early after hatch has been shown to decrease satellite cell proliferation and result in decreased muscle weight at market age (Halevy et al., 2000). Velleman et al. (2010) showed after a 2 week immediate posthatch 20% feed restriction that the morphological structure, expression of the myogenic specific genes, and fat deposition in the pectoralis major muscle was altered. These changes in the muscle are likely the result of the reduction in nutrient levels altering the mitotic activity of the satellite cells.

To confirm the effect of nutrition on broiler satellite cells, Powell et al. (2013) cultured isolated broiler pectoralis major satellite cells in culture medium with varying concentrations of the sulfur amino acids Met and Cys. This would compromise total protein synthesis as Met is the first limiting amino acid in most poultry protein feedstuffs (Scott et al., 1982). Both satellite cell proliferation and differentiation were decreased with reduced concentrations of Met from the control. In support of the nutritional sensitivity of satellite cells reported by Powell et al. (2013), satellite cell sensitivity to nutritional regime has been reported by others (Halevy et al., 2000, 2003; Mozdziak et al., 2002; Pophal et al., 2003).

In broilers, satellite cells have maximal mitotic activity immediately after hatch and are sensitive to nutrition in terms of their proliferation and differentiation. The present study addressed whether the timing of the early posthatch feed restriction would reduce feed restriction effects on the morphological development of the pectoralis major muscle, and effects on the expression of the myogenic transcriptional regulatory factors regulating muscle cell proliferation and differentiation.

The results from the present study demonstrated that using feed restrictions to slow broiler growth can alter pectoralis major muscle development based on the timing of when the feed restriction was administered after hatch. Feed restricting the birds during the first week posthatch resulted in changes in endomysial and perimysial connective tissue spacing. The endomysium surrounds individual muscle fibers and perimysium surrounds muscle fiber bundles. In addition, the vascular supply to the muscle tissue and water-holding capacity are also properties linked to primarily the perimysium which can compose up to 90% of the intramuscular connective tissue (Velleman and McFarland, 2014). When individual muscle fibers and muscle fiber bundles lose connective tissue spacing, muscle damage results (Dransfield and Sosnicki, 1999; Velleman et al., 2003) likely affecting meat quality. The pectoralis major muscle is an anaerobic glycolytic muscle containing fast twitch type IIb fibers.

The byproduct of glycolytic anaerobic respiration is lactic acid. Lactic acid is removed from the pectoralis major muscle through the circulatory system (Bangsbo et al., 1991). As hypothesized by Velleman et al. (2003), the amount of capillary supply available to the muscle is dependent upon the connective tissue spacing. With limited connective tissue spacing, the area for capillary beds is reduced. Decreased capillaries in the muscle to remove lactic acid will further decrease muscle pH as lactic acid will be maintained. Increased lactic acid in the muscle will result in muscle damage and degradation that will subsequently affect meat quality. Having the feed restriction during week 2 after hatch resulted in pectoralis major muscle with connective tissue spacing similar to the control full fed birds.

The expression of the myogenic specific transcriptional regulatory factors MyoD, myogenin, and MRF4 was measured. These genes are only expressed by muscle cells. Since the myoblasts are withdrawn from the cell cycle after multinucleated myotubes and fibers form embryonically, the only muscle cell type able to express these transcription factors after hatch is the satellite cells. The expression of MyoD, myogenin, and MRF4 is at its peak levels during the first week posthatch especially the first 4 days after hatch. As reported by Halevy et al. (2000), the first 4 days after hatch for broilers is the period of time that there is maximal satellite cell mitotic activity and cellular sensitivity to nutritional regime. The week 1 feed restriction resulted in increased MyoD expression and decreased myogenin and MRF4 expression. The increase in MyoD and MRF4 expression indicates increased proliferation of the muscle cells. However, myogenin expression is required for differentiation. The reduction in myogenin expression suggests that the cells are not receiving the appropriate signals to differentiate into mature muscle (Velleman et al., 2010). The increase in proliferation as suggested by the elevation in MyoD and MRF4 expression may be due to the muscle cells compensating for the decrease in differentiation. Velleman et al. (2010) using a 2 week immediate posthatch 20% feed restriction reported similar effects on MyoD and myogenin expression. Moving the feed restriction to week 2 removed all effects on the expression of the myogenic specific transcriptional regulatory factors.

In summary, the results demonstrate that the timing of when a feed restriction is applied after hatch can affect the development of the pectoralis major muscle in broilers at the cellular or tissue level even when the absolute weight is not reduced which has important implications for muscle functional and quality characteristics. These data showed that the appropriate nutritional regime after hatch is required for optimal proliferation, differentiation, and morphological development of the pectoralis major muscle. The effect of feed restrictions affecting muscle development likely extends beyond just the proliferation, differentiation, and morphological structure as satellite cells are multipotential stem cells. Broiler pectoralis major satellite cells, as shown by Powell et al. (2014), with altered nutrition will transdifferentiate to an adipogenic lineage.

Feed restrictions administered the first week posthatch result in increased expression of the adipogenic genes primarily during the first week after hatch and increased fat deposition. Moving the feed restriction to week 2 removed all the effects on the expression of the adipogenic genes and the control full fed birds were observed to have more extensive fat depots within the pectoralis major muscle. These data demonstrate that the appropriate nutritional

regime after hatch is important in regulating fat deposition occurring within the broiler pectoralis major muscle. The possible transdifferentiation of satellite cells to an adipogenic cellular lineage is important for broiler producers to recognize in order to maintain the lean product quality associated with chicken breast meat.

RECOMMENDATIONS

The data collected from this project demonstrates the importance of nutritional regime on the cellular fate of the adult myoblast (satellite cell) population and the direct effect on breast muscle structure and the deposition of fat. Since the satellite cell is a stem cell sensitive to nutritional cues, and can transdifferentiate to an adipogenic lineage as well as have altered proliferation and differentiation, research needs to be focused on the development of specific diets and nutritional management strategies to optimize the activity of broiler breast muscle satellite cells during the immediate posthatch period.

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Plain English Compendium Summary

Sub-Project Title:	**Posthatch Feed Restriction Effects on Broiler Muscle Growth**
Sub-Project No.:	2.1.3
Researcher:	Sandra G. Velleman
Organisation:	The Ohio State University
Phone:	330-263-3905
Fax:	330-263-3949
Email:	Velleman.1@osu.edu
Sub-Project Overview	In commercial poultry operations, it is common during the immediate posthatch period for chicks to rely on nutrients from the yolk during shipping. The logic is that a short term feed restriction applied early in life will help in the control of metabolic disorders such as those resulting in leg problems and ascites. The thought is that the birds will regain final processing weight after the restriction is removed through compensatory gain. The compensatory response of the birds is dependent upon the timing, duration, and intensity of the restriction. The research conducted under the Poultry CRC funding addresses whether the breast muscle generated from a feed restriction is the same as that of breast muscle from birds reared in unrestricted conditions.
Background	In commercial poultry operations, it is common during the immediate posthatch period for chicks to rely on nutrients from the yolk during shipping. In addition, control of metabolic disorders such as those resulting in leg problems and ascites has led to the industry recommendation of early feed restriction. Final processing body weights would be achieved through compensatory gain. It appears that factors such as timing, duration and intensity of the restriction all impact the compensatory response of the bird. It is unclear, however, if muscle generated from a post restriction recovery period is the same as that of muscle from birds reared in unrestricted conditions.
Implications	According to the Australian Bureau of Agricultural and Resource Economics the per capita consumption of chicken meat in Australia was 35.9 kg/person in 2007-2008 with the production value estimated to be $1.637 billion AUD with an industry retail value of $3.5 billion AUD (Australian Commodity Statistics, 2008).

	During the past decade the number of chickens slaughtered and chicken meat produced in Australia has risen from 340.9 to 470.6 million birds slaughtered and the amount of meat produced has increased from 487,929 to 800,100 tons. These increases are expected to continue. The trend of increased broiler meat consumption is occurring throughout the world (USDA, 1997). A driving force leading to this increase in consumer consumption is that chicken breast meat is regarded as the ideal lean meat for a healthy diet. Coupled with the associated health value of chicken breast meat is its affordability and ease of preparation. These factors truly make chicken breast meat an ideal meat for the consumer. Although growth rate, feed conversion, and the amount of muscling have improved in meat-type chickens, the incidence of meat quality problems has increased. Problems with meat quality are the result of changes in muscle morphology and biochemistry with the end consequence being muscle fiber defects like the pale, soft, and exudative condition. Another concern with regard to meat quality is reducing the leanness by changing the cellular fate of satellite cells from muscle forming cells to adipogenic cells. Muscle satellite cells have their maximal activity during the first week posthatch as shown in preliminary studies described in the literature review. The period of intense satellite cell activity coincides with chicks relying on nutrients from the yolk during shipping and industry recommended early feed restrictions. Preliminary results demonstrate that the muscle generated from chicks on an immediate posthatch feed restriction is not the same in terms of intramuscular fat and morphologic structure compared to ad libitium fed chicks. Reductions in meat quality due to increased intramuscular fat will decrease the associated health values with the consumption of chicken breast meat. It was the goal of the proposed research to identify the appropriate immediate posthatch nutritional regimen to maximize muscle growth and maintain or improve breast meat quality.

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