GROWTH AND IGF-I RESPONSE TO BREAST MUSCLE SELECTION BY ULTRASOUND AND DIETARY PROTEIN PROGRAMS IN PEKIN DUCKS

By

ANTOINE GEORGES FARHAT

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Department of Animal Science
Mcgill University
Montréal
Canada

0-612-55327-2

ABSTRACT

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Antoine Farhat

GROWTH AND IGF-I RESPONSE TO BREAST MUSCLE SELECTION BY ULTRASOUND AND DIETARY PROTEIN PROGRAMS IN PEKIN DUCKS

Four experiments were conducted to determine the reproductive, metabolic, growth and IGF-I response to ultrasound selection for increased breast muscle thickness (MT) in Pekin ducks. Selection for body weight had a negative ($P < 0.05$) effect on the reproductive performance while the selection for greater breast muscle thickness resulted in egg production, fertility and hatchability similar to those of the control line (C). Males from the MT line reached market weight at 6 wk but the breast muscle thickness improved from 6 to 7 wk. Compared to females from the C line, MT females had higher ($P < 0.05$) carcass yield, plasma glucose, and body protein; lower fat and plasma uric acid; and no difference ($P > 0.05$) in plasma triglycerides and total cholesterol. Males responded more efficiently to increasing dietary protein than females, and males selected for greater MT can be slaughtered at an earlier age when a high protein feeding program (HP) was followed. Males receiving HP had greater ($P < 0.05$) pectoralis muscles yield, longer keel bone, and lower breast skin and total skin fat yields. Female dissection data show similar ($P > 0.05$) effects of high and medium protein programs. Increasing dietary protein reduced ($P < 0.05$) carcass fat and increased ($P < 0.05$) crude protein (CP). In vivo breast muscle measurement correlated positively ($P < 0.05$) with body weight, pectoralis yield, and keel bone length. Birds with higher pectoralis yield tended to have more CP and less fat in their carcasses. A low correlation (r=0.19) was found for the caliper measurement of breast skin plus fat thickness and carcass fat. We determined the metabolic differences between lean and fat male and female ducks, associated metabolic parameters and body composition, and assessed the difference between two feeding solutions for the determination of metabolic endogenous losses. There was a positive correlation between breast muscle:total breast muscle thickness ratio (MT/TOT) and plasma IGF-I and with nitrogen retention. The MT:TOT correlated negatively with carcass fat and positively with carcass CP. Estimation of carcass fat or CP content were presented in prediction equations from carcass DM and ash content. The ducks with greater breast muscle thickness had higher ($P < 0.05$) plasma IGF-I concentration than the control ducks, and the high protein program resulted in higher ($P < 0.05$) plasma IGF-I. Males exhibited higher ($P < 0.05$) IGF-I than females, and IGF-I concentrations decreased ($P < 0.05$) with age from 42 to 49 d. Plasma IGF-I of the High MT:TOT ratio ducks were more negatively affected by feed deprivation. These ducks had similar ($P > 0.05$) plasma IGF-I concentrations to low ratio ducks during fasting, but had higher ($P < 0.05$) concentrations when fed. Collectively, these data contribute to an understanding of the response of growth and IGF-I response to the ultrasound selection for greater breast muscle thickness and dietary protein, complemented with the assessment of the selection on the reproductive and metabolic performance of the ducks. These results are of original value in the field of growth and carcass improvement in Pekin duck production.

SOMMAIRE

Docteur en Philosophie Zootechnie

Antoine Farhat

EFFETS DE LA SÉLECTION POUR MUSCLES PECTORAUX PAR ULTRASONS ET PROGRAMMES DE PROTÉINE ALIMENTAIRE SUR LA CROISSANCE ET IGF-I DE CANARDS PÉKIN

Nous avons étudié chez les canards Pékin l'influence de la sélection pour l'épaisseur des muscles pectoraux (EM) sur les performances reproductive et métabolique, la croissance, et la concentration plasmatique de IGF-I. La sélection pour poids maximum a eu un effet négatif ($P<0.05$) sur la performance reproductive tandis que la sélection pour EM a donné des effets similaires à ceux de la lignée témoin (T). Les mâles de la lignée EM peuvent être abattus à l'âge de 6 semaines sur la base de poids vif, mais l'épaisseur des muscles pectoraux continue à s'accroitre entre 6 et 7 semaines d'âge. Les femelles de la lignée EM ont eu un rendement de carcasse, une concentration de glucose plasmatique, et une protéine brute (PB) corporelle plus élevés ($P<0.05$); cependant, le gras corporel et l'acide urique plasmatique ont été inférieurs ($P<0.05$) à ceux de T. Les deux lignées n'ont eu aucune différence en triglycéride et cholestérol total plasmatiques. Les mâles ont été plus efficaces que les femelles avec l'augmentation de PB alimentaire, et ceux de la lignée EM ont atteint l'âge d'abattage plus tôt quand ils ont reçu le programme le plus haut en protéine (HP). Les mâles qui reçurent HP ont eu un rendement des muscle pectoraux et de la longueur du bréchet plus élevé ($P<0.05$), et un rendement de peau et de gras plus bas ($P<0.05$) que celui des programmes de PB moyen (MP) et de PB bas. Les effets de la PB alimentaire pour les femelles ont été similaires entre HP et MP pour les rendements

des organes disséqués. L'augmentation de la PB alimentaire a réduit le gras et amelioré la PB corporelle. La corrélation entre les mesures de l'épaisseur des muscle pectoraux *in vivo* et le poids vif, le rendement des muscles pectoraux, et la longueur du bréchet a été positive. Les canards qui ont montré un rendement des muscles pectoraux supérieur tendirent à avoir plus de PB et moins de gras corporel. Les différences métaboliques ont été étudiées entre les canards maigres et les canards plus gras. Nous avons associé les paramètres métaboliques et la composition corporelle, et comparé deux méthodologies alimentaires pour la détermination des pertes métaboliques endogènes. Une corrélation positive est apparue entre l'épaisseur des muscles pectoraux:l'épaisseur totale de la poitrine (EM:ETP) et IGF-I plasmatique ainsi qu' avec l'azote corporel retenu. L'association de EM:ETP a été négative avec le gras corporel et positive avec le PB corporel. Des équations pour les estimations du gras et PB corporels ont été développées, basées sur les valeurs de matière sèche et cendres corporelles. Les canards de la lignée EM ont eu des taux de IGF-I plasmatique plus hauts (P<0.05) que ceux de T, et l'augmentation de la PB alimentaire a amelioré ces concentrations. L'IGF-I du plasma des mâles a été plus élevée (P<0.05) que celle des femelles, et cette concentration a diminué (P<0.05) avec l'âge entre 42 et 49 jours. Les canards avec EM:ETP plus élevé ont montré un effet plus marqué de la privation d'aliments sur les taux de IGF-I plasmatiques. Ils avaient des concentrations de IGF-I similaires à celles des canards avec EM:ETP inférieur (P<0.05) pendant la période de privation d'aliments, mais leurs concentrations ont atteint des niveaux plus élevés (P<0.05) après la ré-alimentation. Collectivement, ces résultats permettent de comprendre les effets de la sélection pour l'épaisseur des muscles pectoraux et les programmes de protéine alimentaire sur la croissance, la concentration du IGF-I plasmatique, et la détermination de ces effets sur la performance reproductive et métabolique des canards. Ces études ont une valeur originale dans le domaine de l'amélioration de l'efficacité de croissance et de la qualité de la carcasse de canards Pékin.

RESUMEN

Doctor en Filosofía Ciencia Animal

Antoine Farhat

RESPUESTA EN EL CRECIMIENTO Y EL NIVEL DE IGF-I EN EL PLASMA DE PATOS PEKINESES SELECCIONADOS CON EQUIPOS DE ULTRASONIDO Y ALIMENTADOS CON DISTINTOS PROGRAMAS DE PROTEINA

Cuatro experimentos fueron realizados para determinar la respuesta reproductiva, metabólica, de crecimiento, y nivel de IGF-I a la selección hecha con equipo de ultrasonido para mejorar el grosor del músculo (GM) pectoral del pato Pekín. La selección basada sólo en peso vivo tuvo un efecto negativo ($P<0.05$) en el comporta-miento reproductivo mientras que la selección dirijida a un grosor mayor del músculo pectoral produjo no afectó la reproducción y el comportamiento reproductivo fué similar a lo observado en la línea control (C). Machos de la línea de GM llegaron a peso de mercado a las 6 semanas aunque el grosor del músculo pectoral siguio aumentando entre las 6 y 7 semanas de edad. Comparadas a las hembras de la línea C, las hembras seleccionadas GM tuvieron una mejora significativa ($P<0.05$) en el rendimiento de canal, glucosa en el plasma, y proteínas del cuerpo; menor grasa y ácido úrico en el plasma; sin diferencias ($P>0.05$) en el nivel de triglicéridos y colesterol en el plasma. Los machos respondieron mejor que las hembras a un aumento de la proteína en la dieta, y los machos seleccionados por GM podrían ser faenados a una edad más temprana si son alimentados con niveles altos de proteína (AP). Los machos alimentados con AP desarrollaron

músculos pectorales más grandes, un hueso de quilla más largo, y un menor contenido de grasa en la piel y una piel más delgada en el pecho (P<0.05). Los resultados de la disección de las hembras fueron similares (P>0.05) con programas de dietas con AP y proteína media. Aumentando la proteína en la dieta se reduce (P<0.05) la grasa y aumenta la proteína bruta (PB) en la canal (P<0.05). Se encontró una baja correlación (P<0.05) entre las medidas calibradas (caliper) del grosor de la piel más la grasa y la grasa de la canal. También establecimos las diferencias metabólicas entre los patos machos y hembras, magros y gordos o grasos, los parámetros metabólicos asociados a la composición corporal, y también evaluamos la diferencia entre dos soluciones de ayuno en la alimentación básica para la determinación de las pérdidas metabólicas endógenas. Hubo una correlación positiva (P<0.05) entre el radio del grosor del músculo pectoral(excluyendo la capa de grasa)/ grosor total del músculo pectoral (GM/GTM) y el nivel de IFF-I en el plasma y retención de nitrógeno. El radio de GM/GTM se correlaciona (P<0.05) negativamente a la grasa y positivamente con PB de la canal. Estimaciones del contenido de grasa o PC de la canal fueron presentadas con equaciones derivadas del contenido de materia seca y cenizas. Los patos con músculo pectoral más grande tuvieron un contenido mayor (P<0.05) de IGF-I en el plasma que los patos controles, y el programa de alimentacion basado en un alto nivel de proteína resultó con patos con alto nivel (P<0.05) de IGF-I en el plasma. Los machos resultaron con niveled de IGF-I más alto que las hembras, y el nivel de IGF-I disminuyó (P<0.05) con el incremento de la edad de los 42 a los 49 días. Los niveles de IGF-I en el plasma de los patos con un radio alto entre GM/GTM fueron más afectados con el ayuno o deprivación del alimento. Estos patos

tuvieron niveles de IGF-I en el plasma similares (P>0.05) a los patos con un radio bajo de GM/GTM durante el ayuno aunque el nível fué más alto cuando estaban alimentados. En su conjunto, estos datos contribuyen al entendimiento de la respuesta de crecimiento y los nivels de IGF-I en el plasma, a la selección por mayor tamaño de pechuga (músculo pectoral) con el uso de un aparato de Ultrasonido y el uso de altos niveles de proteína; es complementada con la evaluación del efecto de la selección en la reproducción y el comportamiento metabólico de los patos Pekineses. Estos resultados son una contribución original en el área del crecimiento y mejora en la canal en la producción de patos Pekineses para consumo humano.

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GUIDELINES CONCERNING THESIS PREPARATION
Faculty of Graduate Studies and Research, McGill University

This thesis is presented as a series of five papers corresponding to section C of the "GUIDELINES FOR THESIS PREPARATION" (Revised August 1998) from the Faculty of Graduate Studies and Research at McGill University.

Section II, IV, and V are in preparation for submission for publication. Section III has been submitted and Section VI has been accepted for publication as indicated on the title page of the Section. These Sections are authored by Antoine Farhat and Eduardo R. Chavez. Dr. Chavez was the student's supervisor.

The general idea of this project comes from the outcome of a previous research work co-supervised by Drs. E. R. Chavez and S. P. Touchburn.

The contribution of the author of this thesis included the detailed ideas of the project, experimental designs and analyses, and writing publications. All the phases of the work conducted have been discussed with Dr. Chavez.

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Poultry meat consumption is expected to surpass pork (Roenigk, 1999) and continues to increase due to many factors including price (Leeson, 1997), healthier meat than pork and beef (Chu *et al.*, 1995), and flexibility for further processed ready-to-cook home replacement (Zeidler, 1998). Chicken breeds with high breast meat yield have been introduced into the industry to satisfy the trends in consumption (Leeson, 1997). Breast muscle of poultry is the most important part of the carcass and attempts to increase its percentage continues through selective breeding and nutrition.

The duck industry is mainly concentrated in South and East Asia where 75 % of the world's domesticated ducks are found (Hetzel, 1986) with 60 % in China (Turcotte, 1995). Recently, this industry gained more interest in Europe and North America with the improvement of breeding programs and feeding efficiency (Stevens and Sauveur, 1986) where feed represents 63 % of production cost (Vernam, 1998), and the increasing business opportunities in the most populated region of the world (Dunn, 1998). However, selection for growth rate in poultry is known to be associated with increased carcass fat. Duck fat distribution is mainly subcutaneous which makes it a permanent part of the product because it cannot be removed during processing (Leeson and Summers, 1997). Breast meat yield is considered as important as growth rate and feed efficiency in the duck industry (Baeza and Leclercq, 1998). Heritability of breast muscle percent of body weight ranges from 0.44 to 0.66 (Clayton and Powell, 1979).

Several selection approaches have been adopted to improve the breast muscle yield including carcass dissection of sibs and progeny (Powell, 1986), the use of a needle probe (Pingel and Heimpold, 1983), and the use of a real-time ultrasound scanner (Dean *et al.*, 1987; Lavallée, 1998). Similar to other means of selection for a certain trait, ultrasound scanning of breast muscle is expected to result in differences in the reproductive performance, carcass composition, and nutritional requirements. Ducks selected by ultrasound for greater breast muscle thickness had lower live body weight than those selected for body weight, but were heavier than the control line (Lavallée *et al.*, 1998).

Male and female Pekin ducks are usually reared together under the same feeding program despite the differences in growth rate (Normand *et al.*, 1996a; Farrell, 1990), feed efficiency (Leeson and Summers, 1997), and body composition (Normand, 1997). Carcass composition can be greatly influenced by protein in the diet (Fisher, 1984). In chickens, the breast muscle yield tended to correlate negatively with abdominal fat in males (Bartov and Plavnik, 1998), but not in females (Bartov, 1998).

Lean chickens selected for low abdominal fat were suggested to require more protein in their diet because they favoured protein synthesis compared to the fat chickens (Touchburn *et al.*, 1981). Lean chickens selected for low VLDL were the leanest when fed high protein diets and showed a considerable increase in fatness when fed diets low in protein (Whitehead *et al.*, 1990). Lean and fat chicken lines have similar metabolizable energy (Leclercq and Saadoun, 1982), but the lean line deposited more protein than the fat line (Geraert *et al.*, 1988). Plasma parameters associated with leanness and fatness were comprehensively characterized in lean and fat chickens (Griffin *et al.*, 1982, Whitehead and Griffin, 1984; Leclercq, 1988), and partly in ducks (Ksiazkiewicz *et al.*, 1993; Baeza *et al.*, 1997).

Insulin-like growth factor-I mediates many of the growth hormone anabolic effects (Guler *et al.*, 1988). It was suggested to play a role in the regulation of muscle growth in sheep (Pell and Bates, 1993), pigs (Clutter *et al.*, 1995), mice (Barton-Davis *et al.*, 1998), and chickens (Kocamis *et al.*, 1998). However, IGF-I in Pekin ducks, in general, and in lean and fat ducks, in particular, was not characterized.

Collectively, there is no information on the response of growth, carcass characteristics, and metabolic profile to ultrasound selection for greater breast muscle thickness and dietary protein.

The objectives of the experiments presented in this thesis were:

1- To study the effect of selection for breast muscle thickness in Pekin ducks on the reproduction of F1 and growth performance of the F2 progeny.

2- To compare the growth performance, ultrasound breast measurements at 6 and 7 wk, blood chemistry, and carcass analysis of male and female Pekin ducks, from the line selected for greater breast muscle thickness and control line, under mixed-sex and sex-separated rearing programs.

3- To determine the metabolic differences in terms of metabolizable energy and nitrogen retention between lean and fat male and female ducks, to test the effect of fasting and feeding on blood parameters, to associate metabolic parameters and body composition, and to assess the difference between two feeding solutions for the determination of metabolic endogenous losses.

4- To determine the appropriate program (starter, grower, and finisher rations) in terms of dietary protein for male and female Pekin ducks selected for greater breast muscle thickness, to examine the possibility of reducing the growth period, to determine the effect of dietary program, age, and sex on the yield of carcass components and carcass composition, and to establish the association between ultrasound measurements and blood parameters with carcass characteristics.

5- To examine the effects of genetic line, dietary protein, sex, age, and the feed-deprived or fed state on plasma IGF-I in Pekin ducks.

SECTION I

I. LITERATURE REVIEW

LITERATURE REVIEW

1.1- Introduction

1.1.1- White Pekin Ducks

All domestic ducks except Muscovy are descended from the wild green-headed mallard Anas Platyhrynchos (Hetzel, 1986) and were first domesticated in Southeast Asia. Today 18 breeds are recognized in the UK (May and Hawksworth, 1982) and 14 in the US (American Poultry Association, 1989) where the White Pekin is the most common. Duck production in North America commercially started with the introduction of Pekin ducks from China in 1873 (Scott and Dean, 1991). It is expected that the duck industry will shift to added-value product and the demand for high carcass quality with less fat and more lean meat will increase following the general global trend toward healthier eating (Stimpson, 1998).

1.1.2- Characteristics of Pekin ducks

Pekin ducks are fast growing and slaughtered at 7 wk of age with a body weight over 3.2 kg (Farhat *et al.*, 1999). Recently, there was an increasing interest in the growth potential of meat type ducks because of their high early growth (Knížetová *et al.*, 1995) and exceptional capacity for compensatory growth (Dean, 1972). However the duck carcass is characterized with high fat content mainly subcutaneously distributed (Normand *et al.*, 1996b). Plavnik *et al.* (1982) observed that at market age, Pekin duck carcasses contain 30 % fat compared to 15 % fat in broiler chickens. Pekin ducks at 8 weeks of age and broiler chickens at 7 weeks of age had, respectively, 1.1 % (Lühmann and Vogt, 1975) and 3.6 % (Metzler *et al.*, 1987) abdominal fat as a percentage of live weight. Among others, Leeson and Summers (1980) reported that the percentage of abdominal and total carcass fat increases with increasing age of broiler chickens. A positive linear association was observed between total body lipids and abdominal fat in lean and fat lines of chickens (Whitehead, 1988). In poultry production, shortening of processing time depends on muscle growth (Gille and Salomon, 1998). Thus, the sooner the breast muscles which are the most economically important part of the carcass develops, the younger the bird's market age, and hence the less fat would have been deposited.

Torges (1986), working with Muscovy ducklings, found that regardless of age or weight, females always had greater amounts of abdominal fat than males. Male Pekin ducks were leaner than females at 6 and 10 wk of age (Abdelsamie and Farrell, 1986).

1.2- Sex Differences

Male and female Pekin ducks grow and develop differently (Abdelsamie and Farrell, 1986). Males were reported to be heavier than females while there was no difference between the two sexes in breast muscle thickness measured with ultrasound (Lavallée, 1998). Female chickens had about 0.4 and 0.7 % more abdominal fat than males at seven and eight wk of age, respectively (Heath, 1981). The author suggests that if these birds were grown for 9 wk, the difference between males and females will be even greater. However, female Pekin ducks had approximately 2 % more carcass fat than males at 6 and

10 wk, and that difference became negligible at 16 wk of age (Abdelsamie and Farrell, 1986). Heath (1981) suggested that it is possibly more beneficial for the females to be marketed earlier because their abdominal fat was more influenced than males by growing them an extra week. His argument for growing sexes separately could be to market the male earlier in the case of Pekin ducks because the males carcass fat was more affected by age (Abdelsamie and Farrell, 1986). The lack of a pronounced sexual dimorphism in Pekin ducks as well as the cost of sexing ducklings at hatching are reasons that justify rearing males and females together. However, many factors tend to favor separated rearing of ducklings, including the consumer demand for uniformity of carcass and further processed items, the difference in body weight between males and females (Normand *et al.*, 1996a), the low feed efficiency during the 7th wk of growth, and the possibility of reducing the growth period (Farhat *et al.*, 1999). Pekin males possess a faster growth rate than females (Farrell, 1990), better feed efficiency (Leeson and Summers, 1997), and lower fat content in their carcasses (Normand *et al.*,1996b). In general, chickens are reared together despite the documented differences in nutrient requirements between male and female (Douglas and Harms, 1959). The growth rate of male chickens was improved on 20 and 22 % dietary CP in their finisher, but the growth rate of the females was not affected when the dietary protein was reduced to 18 % CP (Payne and Lewis, 1963). However, Waldroup *et al.* (1990) concluded that male and female broiler chickens can be fed the same diets when the feeding periods are adjusted by sex. Similarly to chickens, ducks can increase their feed consumption to meet their energy requirements (Dean, 1986). However, chickens did not select the appropriate diet to maximize growth when offered free choice of different diets varying in protein and energy levels (Siegel *et*

al., 1997). As the market age of ducklings is being reduced, the birds have less time for compensatory growth (Dean, 1986), and diets have to be tailored to their requirements. Poultry species are influenced by the energy:protein ratio of their diet (Siregar *et al.*, 1982b; Dean, 1986; Farhat *et al.*, 1999). Feeding males and females a single dietary program may not provide the male ducklings with the appropriate dietary protein that enables them to perform to their maximum genetic potential. The market age and weight of most Pekin ducks grown in this region are 49 d and 3.2 kg, respectively. In previous studies (Normand, 1997), it was observed that the growth rate of the two sexes starts to differentiate at 5 wk of age. The same studies revealed a sharp decrease in feed efficiency after 6 wk of age, which is most probably related to the higher energy requirement for maintenance and the deposition of fat. A limiting factor in marketing Pekin ducks at 6 wk of age may be the insufficient breast muscle development. An early development of breast meat can be addressed by nutritional means and selection of ducks for greater breast muscle thickness earlier than the traditional market age.

1.3- Duck Nutrition

Ducks are economically less important than broiler chickens, laying hens, and turkeys in the poultry production of the developed world. For this reason, little research has been done on the nutrition of this species, and formulation of diets for ducks depends on data reported for chicken despite the existence of differences in digestive physiology between the two species (Elkin, 1987). However, research on the duck nutrition was greatly promoted by the remarkable development of duck industry that accompanied globalization and the opening of business opportunities of Western firms in Asia (Dunn, 1998).

Ducks raised for meat production are generally fed starter, grower, and finisher diets during their growing period and require a high-quality diet for the first two weeks of age. Two phase feeding program resulted in the same performance as three phase program, but the latter increased N supply through the feed and had better processing quality (De Buisonjé, 1999).

1.3.1- Energy and Protein Requirements

Being characterized by their capacity for compensatory growth, Pekin ducklings were able to reach maximum body weight and overcome a 30 % growth depression at 14 d of age (Dean, 1972). Siregar *et al.* (1982a) grew Pekin ducklings from day-old to 14 d after hatching on diets containing 3035 kcal ME/kg and a range of crude protein (CP) contents from 18 to 24 %. Growth rate and feed efficiency were not affected, but as percent CP declined, carcass fat increased. Different combinations of dietary CP were used in formulating a starter diet fed from 1 to 14 d of age and a grower-finisher diet fed from 15 to 56 d of age. Feed efficiency was the same on all diets, but the highest growth rate was achieved dy feeding 18.7 % CP throughout the growth trial (Siregar *et al.*, 1982a). Following their first experiment, Siregar *et al.* (1982b) fed ducks from 2 to 8 wk of age on diets that varied in protein and energy levels. Dietary CP as little as 12 % showed no significant effect on growth rate or feed efficiency to 56 days of age. In a similar study, however, Dean (1986) observed low yield of feathers and cannibalistic feather pecking on low protein diets. Siregar *et al.* (1982b) showed that growth rate of Pekin ducks on diets with ME of 2748 to 3512 kcal/kg, was the same, whereas the highest growth rate and the best feed efficiency were achieved on the two diets with 3250 and 3512 kcal ME/kg.

Leeson and Summers (1997) set dietary specifications for Pekin ducks diets to contain 22.5 % CP and about 2800 kcal ME/kg for starter and 18 % CP and approximately 2900 kcal ME/kg for the grower-finisher diet. For optimal early growth, Scott and Dean (1991) reported that typical diets for Pekin ducklings from day 1 to 2 wk of age require 22 % CP and 3080 kcal ME/kg. Although ducklings are characterized by their capacity for compensatory growth, a lower protein percentage of the diet would usually lead to the same finishing growth. Thus, 22 % CP in the starter ration is necessary for feather development, to aid coping with stresses and to minimize heat loss. In the growing and finishing phases of growth, Pekin ducklings require diets containing 16-18 % CP and about 3050 kcal ME/kg for optimal growth (Scott and Dean, 1991). The NRC (1994) recommends for the starting period a 22 % CP level with 2900 kcal ME/kg, and for the growing-finishing period a 16 % CP level with 3000 kcal ME/kg.

1.4- Carcass Quality

Ducks have a greater ability for voluntary energy intake than other poultry species. That intake is associated with a greater deposition of fat, mainly subcutaneous. As human diets are being blamed for various health disorders, consumers are demanding meat products low in fat and high in protein. Researchers and producers are faced with the changing preference of consumers and hence have to work on the factors that influence carcass composition to render it reasonably acceptable.

1.4.1- Dietary Factors

Carcass composition is influenced by many dietary factors, the most important being the energy to protein ratio. Feeding isoenergetic diets (3035 kcal ME/kg) with varying CP levels from 18 to 24 % produced 14-day-old ducklings possessing 18 to 12 % carcass fat having fixed intake, growth rate, and feed efficiency (Siregar *et al.*, 1982a). When dietary CP in the starter diet was below 22 %, carcass fat was higher in the birds on these diets at 56 d of age, and changing the CP level in the finishing period has not shown to be effective. Abdelsamie and Farrell (1986) reported that decreased fat and increased protein in the carcass were observed with dietary protein above 18.5 %. White Pekin ducklings were grown to 56 d of age on various combinations of energy and protein levels (Siregar *et al.*, 1982b). As the ratio of energy:protein (kcal:%) increased from 12 to almost 28, there was a decline in carcass protein and an increase in carcass fat percentage in both sexes.

Feed restriction has been shown to influence carcass characteristics in many species. Campbell *et al.*(1985) investigated the effect of feed intake on carcass weight and fat of ducks grown from 14 to 56 d of age. As intake increased, there was an increase in growth rate and carcass fat, and a decrease in the protein content of the carcass. At 56 d of age, carcass fat showed more response to change in feed intake than did growth rate. Eighty percent of ad libitum intake reduced carcass fat by 23 %, but carcass weight by 12 % only.

The degree of fatness and leanness is greatly influenced by the dietary protein concentration of the diet (Fisher, 1984). Fat deposition in broilers depends on the diet composition and can be reduced by increasing dietary protein (Griffin *et al.*, 1998). Broilers body fatness and the low turnover of adipocyte triglycerides were linked to the decreased levels of plasma GH as a consequence of selection for growth (Griffin and Gobbard, 1994). Reducing dietary protein resulted in depressed plasma IGF-I concentration in chicken (Rosebrough *et al.*, 1998). Bartov and Plavnik (1998) fed male broilers diets with energy to protein ratios lower than the NRC (1994) recommendations, and reported an improvement in feed efficiency and breast meat yield with no effect on body weight gain. The same results were also reported in female broiler chickens (Bartov, 1998). The breast meat yield in the male chickens tended to correlate negatively with abdominal fat (Bartov and Plavnik, 1998), but there was no correlation between the two parameters in the females (Bartov, 1998). Feeding different levels of dietary energy had no effect on growth rate while reducing the energy intake or increasing the protein intake resulted in reduced carcass fat content in broiler chickens (Leeson *et al.*, 1996). Dietary protein was found to have an effect on growth and body composition in chickens selected for high abdominal fat (Touchburn *et al.*, 1981). In these studies, the fat line was less affected by decreasing dietary protein than the lean line when growth rates were compared. The authors suggested that the lean birds might require more protein in their diets because they favored protein synthesis compared to the fat birds. Whitehead et al. (1990) compared lean and fat chickens selected for low or high VLDL and fed diets with varying protein content. They reported that the lean line birds were the leanest when fed the highest protein diets and showed a considerable increase in fatness when fed the diet of the lowest protein content.

1.4.2- Genetic Factors

Cross breeding was used as a means of improving carcass quality. White Pekin and White Muscovy ducks differ in growth rate and carcass composition. The Muscovy breed possesses more lean tissues and less subcutaneous fat than the Pekin (Farhat *et al.*, 1999).Cross breeding of these ducks has been used as a tool to modify carcass composition. Crossing Pekin with Muscovy produced an infertile mule duck (Abdelsamie and Farrell, 1986), with improved carcass yield and quality (Vernam, 1995). The carcass of this hybrid had 17.0 % skin plus fat and 14.6 % muscle compared to pure Pekin with 26.6 % skin plus fat and 12.9 % muscle (Abdelsamie and Farrell, 1986). Selection for 4 generations of ducks for only breast muscle resulted in an increase of 16.2 % in breast muscle thickness, 6.9 % in live weight, and 5.1 % in the proportion of breast in the carcass compared to unselected controls (Pingel and Jung, 1979).The authors observed an increase of 14.9, 9.7, and 5.6 % in breast muscle thickness, body weight, and the amount of breast in carcass, respectively, when selected for both breast muscle and body weight. However, carcass composition of ducks is correlated to body size which in turn is associated with reproduction traits such as the number of eggs laid per laying period (Scott and Dean, 1991). Thus, selection for leaner tissues depending on body size results in an even higher proportion of fat and a reduction in number of eggs (Scott and Dean, 1991). From 25 yr data collection on Pekin ducks, these authors indicated 49 and 31 g increases in skin-fat and total muscle, respectively, for each 100 g increase in eviscerated carcass weight.

Increased carcass fatness has resulted from increasing growth rate as a consequence of improved housing, management, selection, and nutrition. The undesirable fat can be dealt with by relative genetic selection for leaner ducks with the new technologies available such as the use of ultrasound, and the application of the appropriate nutritional principles, mainly the proper energy:protein ratio.

1.4.3- Ultrasound scanning

Evaluation of body composition in live animals is of great importance in selective breeding programs. Over the past few decades, non-invasive approaches have been developed for the selection of livestock and poultry for a certain desirable trait. Magnetic resonance imaging (Scollan *et al.*, 1998) and dual-energy X-ray absorptiometry (Pietrobelli *et al.*, 1998) show a great degree of accuracy, but they are, so far, expensive and unpractical to introduce into selection programs. Ultrasound has been adopted in the selection of animals for greater muscle proportion of their carcass. It has been used in the prediction of carcass composition in cattle (Simm, 1983; Stouffer *et al.*, 1989), pork (Gresham *et al.*, 1992; Schinkel *et al.*, 1994), lambs (Kempster *et al.*, 1982; Fernández *et al.*, 1998), and goats (Stanford *et al.*, 1995). In chicken, ultrasound was used for the prediction of breast muscle yield (Komender and Grashorn, 1990; König *et al.*, 1997). Ultrasound was not recommended and considered inaccurate for selection programs in ducks (Abdelsamie and Farrell, 1986). However, Dean *et al.* (1987) introduced this technique in selective breeding programs for Pekin ducks. The authors used a real-time linear array ultrasound scanner to measure breast muscle thickness on market age White Pekin ducks. A correlation of 0.70-0.80 was found between the measurement of breast muscle thickness and the breast muscle weight. A correlation of 0.62 was found between the ultrasound measurement of breast muscle thickness and breast muscle weight

(Lavallée, 1998). König *et al.* (1998) reported a correlation of 0.73 and 0.71 between breast meat, as a percentage of live weight, and ultrasound measurement in male and female chickens, respectively. The correlations were reduced to 0.69 and 0.68 in males and females, respectively, when breast meat percent was based on carcass weight. After six generations of Pekin ducks selected for greater breast muscle thickness, breast weight increased 20 and 19 percent in males and female (Dean *et al.*, 1996). The breast muscle thickness of Pekin ducklings from the F1 progeny selected for greater breast muscle thickness increased by 9 percent compared to the control ducks (Lavallée, 1998). However, variations in body weight or body composition may alter the efficiency of egg production (Renden *et al.*, 1984).

1.5- Effect of Selection on reproductive performance

Growth rate and egg production correlate negatively in ducks (Pingel, 1990). Selection for growth rate had a negative effect on hatchability where the heavy Pekin ducks laid eggs with lower hatchability than those laid by the light strain (Vagt *et al.*, 1989). Turkeys selected for increase in 16-wk body weight show an increase in egg weight and a decrease in egg production with no effect on egg mass production (Nestor, 1984; Nestor and Bacon, 1986). Selection for body weight did not reflect an increase in breast muscle (including skin and bone) while selection for increased egg production resulted in increased breast meat (including skin and bone) in turkeys (Nestor *et al.*, 1995). Chickens selected for 56-d body weight laid larger eggs than those from chickens selected for low 56-d body weight (Reddy and Siegel 1977). The percentage of normal eggs was lower for the chickens selected for heavy body weight (Anthony *et al.*, 1989). The lean line of chicken selected for low abdominal fat laid less but bigger eggs than the fat line (Leclercq and Simon, 1982). For the 2nd generation, lean and fat chicken lines had similar egg production, but for the third generation, the lean line produced more and heavier eggs with better hatchability than the fat line (Cahaner *et al.*, 1986). In turkeys, carcass protein negatively correlated with carcass lipid and positively with egg production (Lilburn and Nestor, 1993). However, no relationship was found between body composition and age at sexual maturity of White Leghorns selected for 20-wk low or high body weight and control (Renden and Marple, 1986).

1.6- Energy and Nitrogen Metabolism

1.6.1- Energy Metabolism

In addition to the 9 % increase in the breast muscle mass, the line selected for breast muscle thickness had an 11 % increase in body weight over the control line (Lavallée, 1998). As any other mean of selection, ultrasound technique should produce some effects expected to be seen, besides carcass composition, in the metabolic performance. Selection for lean, fat tissues, or parameters used as indicators of carcass composition had little or no effect on the metabolizability of energy in lean or fat chickens (MacLeod *et al.*, 1988; Pym and Farrell., 1977). Obesity in birds results from the intake of excess energy over the requirement for maintenance and normal tissue synthesis. This indicates that at similar metabolizable energy (ME) intake, the difference in body composition between the lean and fat birds can be explained by either a difference in energy expenditure or partitioning of energy retained between fat and protein (MacLeod and Geraert, 1988).

1.6.1.a- Energy Expenditure

Lean and fat lines had similar basal metabolic rate estimated as fasting heat production per unit of metabolic body size ($kJ/kgW^{0.75}$.day) or calculated from linear regression between energy retention and ME (Geraert *et al.*, 1987). However, ME of maintenance was found to be higher in fat chickens selected for high food intake (Pym *et al.*, 1984). Lean and fat chickens had similar diet-induced thermogenesis and cold exposure induced a similar increase in energy expenditure in both lines (Gereart *et al.*, 1988; MacLeod, 1997). No differences in physical activities were observed between lean and fat chickens at 10 wk of age (MacLeod *et al.*, 1988).

1.6.1.b- Partitioning of retained energy

Partitioning of the energy retained from the feed revealed an increase protein accretion and decreased fat deposition in the lean chickens (Leclercq, 1983; Whitehead and Griffin, 1986; Gereart *et al.*, 1988). However, the fat line showed a lower protein deposition due to the increased oxidation of dietary amino acids determined by their greater excretion of uric acid (Gereart *et al.*, 1988).

1.6.2- Protein Metabolism

Lean and fat lines of chickens from the 3rd generation had similar protein degradation estimated by both the methylhistidine excretion and the isotope ^{14}C methods (Saunderson and Whitehead, 1987). Namier *et al.* (1986) observed that the fat chickens incorporated more ^{14}C-Leucine in their fat and protein tissues than the lean birds. When they expressed their data as ^{14}C in protein : ^{14}C in free amino acid, the ratios were similar.

The controversy results on lean and fat tissue deposition among lines of chickens selected for leanness or fatness using different techniques calls for the determination of these differences in lean and fat ducks.

Collectively, the differences in carcass composition of lean and fat chickens seems to depend mainly on the partitioning of the energy retained from the diet between lean or fat tissue deposition. However, the source of energy intake whether from fat or protein also is a strong factor because the degree of leanness or fatness partially depends on dietary protein (Fisher, 1984).

1.7- Plasma Parameters related to leanness or fatness

Selection of birds based on blood parameters associated with body composition is probably considered a simple method to differentiate lean and fat birds to be used in selection programs. Plasma triglyceride concentration was suggested as an indicator of body fatness in chickens (Griffin *et al.*, 1982). Plasma very low density lipoprotein (VLDL) concentration was used as a basis for selecting lines of lean and fat broilers (Whitehead and Griffin, 1984) and turkey (Griffin and Whitehead, 1985). Positive correlation was found between abdominal fat and blood cholesterol concentration in female, but not male Pekin ducks that had lower carcass fat content (Ksiazkiewicz *et al.*, 1993). Leclercq and Guy (1988) reported significantly lower concentrations of triglycerides (TG) in the lean than in the fat line selected for low or high abdominal fat. The authors observed an intra-correlation between TG and abdominal fat in chickens selected for low or high blood glucose level. However, Baeza *et al.* (1997) found no correlation between body fat content and triglyceride or VLDL concentration in Muscovy ducks. In Pekin ducks, Akbar (1996) reported a non-significant correlation between carcass fat and VLDL. Selection based on plasma glucose level in chicken resulted in significant differences in fattening (Leclercq *et al.*, 1987). Plasma glucose were lower in fat line compared to lean line chickens whether in a fasted or fed state and regardless of the dietary protein or energy levels (Touchburn *et al.*,1981). Overnight fasting decreased TG (March, 1984) and glucose (Simon and Rosselin, 1978) concentrations in chickens and TG and glucose concentration in turkeys (Anthony *et al.*, 1990). Fasting was reported to induce an increase in plasma GH, a decrease in TG, and had no effect on plasma glucose concentration in turkey males (Anthony *et al.*, 1990). Plasma uric acid is considered an indication of the protein quality in the feed and its utilization. Plasma uric acid level was higher in the plasma of the fat line compared to the lean line selected for low or high abdominal fat content (Leclercq, 1988). Total plasma protein concentration was suggested as a possible indicator of the physical condition in kestrels (Dawson and Bortolotti, 1997). LeResche *et al.* (1974) suggested that gluconeogenesis may result in a depression in total plasma protein that may be used to assess dietary inadequacies. Plasma protein in growing chickens increased with increasing dietary protein (Leveille and Sauberlich, 1961).

1.7.1- Insulin-Like Growth Factor-I (IGF-I)

Growth hormone (GH) is documented to have metabolic effects represented by nutrient partitioning toward less fat deposition and greater protein accretion (Davis *et al.*, 1995). Many of the anabolic effects of GH are mediated by IGF-I (Guler *et al.*, 1988). Levels of IGF-I are dependent on GH secretion and stimulate body tissue growth (Dodson *et al*, 1996). Growth hormone stimulates muscle growth and lipolysis and inhibits lipogenesis in chicken directly or indirectly through IGF-I (Decuypere and Buyse, 1988). However, pituitary-derived chicken GH had no effect on growth performance of rapidly growing broilers (Cravener *et al.*,, 1989). Plasma IGF-I concentration can be a useful physiological indicator trait because IGF-I is secreted in a non-pulsatile way and is associated with growth rate in swine (Buonomo *et al.*, 1987), cattle (Davis and Bishop., 1991), and chickens (Huybrechts *et al.*, 1985). Hepatically derived endocrine IGF-I could have a role in the regulation of muscle growth in sheep (Pell and Bates, 1993). Selection for greater IGF-I concentration resulted in a significant response of growth rate in mice (Blair et al., 1989). Plasma IGF-I concentrations of pigs selected for fast gain were higher than those selected for slow gain (Clutter *et al.*, 1995). Huybrechts *et al.* (1985) reported higher body weight and higher IGF-I concentrations in control broiler chickens compared to sex-linked dwarf birds studied between one and 21 wk of age. Nevertheless, Ballard *et al.* (1990) observed no difference in IGF-I concentrations between six fast growing and commercial broiler chickens. Concentrations of IGF-I in slow growing egg line of chickens were higher than those in fast growing broilers (Lee *et al.*, 1989).

Overexpression of IGF-I in differentiated muscle fibers of young adult mice induced a 15 % increase in muscle mass, and prevented age-related loss of muscle mass and strength in old adult mice (Barton-Davis *et al.*, 1998). In chickens, abdominal fat was reported to be reduced with the administration of exogenous IGF-I (Huybrechts *et al.*, 1992; Tixier-Boichard *et al.*, 1992). McMurtry (1998) stated that IGF-I and IGF-II in poultry may have more effect on intermediary metabolism than on growth.

Administration of recombinant human IGF-I into incubated eggs resulted in post-hatching improvement of feed efficiency and breast and leg muscle growth (Kocamis *et al.*, 1998). Feeding wide calorie- to-protein ratio diets produced chickens with depressed IGF-I concentration and increased lipogenesis (Lauterio and Scanes 1987; Rosebrough and McMutry, 1992). Chickens fed diets high in protein had higher levels of plasma IGF-I and some of the IGF-I binding proteins, and lower levels of somatotropin than those fed low dietary protein (Caperna *et al.*, 1996)

In chickens, females had the higher concentration of plasma IGF-I at 14 d of age, but males had higher IGF-I at 28 d of age (Newcombe *et al.*, 1992). Male and female chickens had similar IGF-I concentrations from 3 to 5 wk, but females had higher concentrations at earlier age (Johnson *et al.*, 1990). At 1 wk of age, females chickens had higher plasma IGF-I concentrations than males, but at 7 wk of age, males had higher concentrations than females (Ballard *et al.*, 1990). In turkeys, plasma concentrations of IGF-I increased from 1 to 7 wk and were higher in males than females up to 28 wk of age (Bacon *et al.*, 1993).

Huybrechts *et al.* (1985) reported an increase in plasma IGF-I concentration up to 6 wk of age followed by a decrease in this concentration in a light strain of chicken, but the increase in IGF-I levels was maintained up to 12 wk of age in heavy broiler type strains. Plasma IGF-I increases with age up to 28 d of age in broiler chicks (Newcombe *et al.*, 1992; Rosebrough *et al.*, 1998). Goddard *et al.* (1988) detected no difference in plasma IGF-I concentrations between fast and slow growing lines of chicken during early growth.

Growth hormone concentrations increased in overnight feed-deprived chickens (Harvey *et al.*, 1978) and turkeys (Anthony *et al.*, 1990). Morishita *et al.* (1993) reported depressed IGF-I concentration in feed deprived chickens and refeeding restored close to normal levels of IGF-I. Feed restriction in Japanese quail resulted in a decline in plasma IGF-I and refeeding reversed the effect (Schew *et al.*, 1996).

Touchburn *et al.* (1981) observed lower plasma glucose in fat line compared to lean line chickens whether in a fasted or fed state and regardless of the dietary protein or energy levels. Studies with these lines revealed an effect of dietary protein concentration on growth and body composition. Plasma IGF-I increased with increasing dietary protein in broiler chickens (Rosebrough *et al.*, 1999). Feeding broilers decreased levels of dietary protein resulted in decreased lean growth, and increased fat deposition (Stewart and Washburn, 1984). The higher plasma glucose in the lean line reported by Touchburn *et al.* (1981) may be due to the possibility of the lean birds having higher GH activity than the fat birds in addition to the lower insulin level. Foltzer and Mialhe (1976) reported an increase in plasma glucose after GH therapy in hypophysectomized ducks. In broilers, Decuypere *et al.* (1987) reported that chemical hypothyroidism caused by feeding methimazole resulted in reduced plasma IGF-I concentration, increased fatness, and decreased lean growth.

Due to the high fat content of its carcass, the Pekin duck is the poultry species that could benefit the most from the characterization of metabolites involved in leanness. Insulin-like growth factor-I was studied in chickens, turkeys, and Japanese quail but not in ducks.

SECTION II

Reproductive Performance of F1 Pekin Duck Breeders Selected with Ultrasound Scanning for Breast Muscle Thickness and the Effect of Selection on F2 Growth and Muscle Measurement

ANTOINE FARHAT AND EDUARDO R. CHAVEZ

Department of Animal Science
Macdonald Campus of McGill University
21,111 Lakeshore Road, Ste.Anne de Bellevue
Québec, Canada. H9X 3V9

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Reproductive Performance of F1 Pekin Duck Breeders Selected with Ultrasound Scanning for Breast Muscle Thickness and the Effect of Selection on F2 Growth and Muscle Measurement

ABSTRACT

A study was conducted to assess the effect of selection for breast muscle thickness in Pekin ducks on reproduction of F1 and growth performance of the resulting progeny. At 7 and 23 wk of age, the line selected for body weight had higher ($P<0.05$) body weights than the line selected for greater breast muscle thickness which was in turn heavier ($P<0.05$) than the control line. The line selected for breast muscle thickness had greater ($P<0.05$) total breast (skin plus subcutaneous fat and breast muscle) and breast muscle thickness than the lines selected for body weight and control at 7 wk of age. At 23 wk, all the three lines had similar total breast and breast muscle thickness. At 7 and 23 wk, males were heavier ($P<0.05$) and had higher breast measurement than females. The body weight line breeders laid eggs that were heavier ($P<0.05$) than those of breast muscle line and control, while there was no difference in egg weight between breast muscle line and control. The body weight line showed lower ($P<0.05$) % fertility and % hatching of fertile eggs compared to breast muscle line and control, while there was no difference between breast muscle line and control. The F2 ducklings showed similar differences in body weight and breast measurements as those observed in the parents at 7 wk of age. These data demonstrate that selection for body weight, but not for breast muscle thickness, had a negative effect on the reproductive performance and that the selection in the parents is reflected in the progeny.

INTRODUCTION

Reducing fatness in farm animals has been most successful with pigs by selective breeding because the pig fat is mainly subcutaneous and physical measurements on live animals can be assessed. Duck fat distribution follows closely the same pattern as in the pig since the main fat problem in this poultry species is the subcutaneous deposits that cannot be removed during processing. However, reducing body fat content in pigs resulted in poor reproductive performance (Johansson and Kennedy, 1983; Kirkwood and Aherne, 1985). In poultry, selection for maximum weight gain has led to increased body fatness that negatively correlates with body protein, and body protein positively correlates with egg production (Lilburn and Nestor, 1993). Selection for growth rate reduces egg production and hatchability in Pekin ducks (Pingel, 1990; Vagt *et al.*, 1989). Selection for increased egg production in turkeys was associated with decreased egg weight and mature body weight, but the selection had no effect on fertility or hatchability (Nestor and Noble, 1995). Selection for egg production but not for body weight resulted in an increase in breast muscle with skin and bone in turkeys (Nestor *et al.*, 1995). Lean chickens selected for low abdominal fat laid less but bigger eggs than the fat line (Leclercq and Simon, 1982). By the third generation, lean chickens laid more and heavier eggs with better hatchability than fat chickens while there was no difference between the two lines for the second generation (Cahaner *et al.*, 1986).

While improving carcass quality of meat type ducks is an objective and a necessity, the effect of selection for breast muscle thickness using the ultrasound on reproduction of the breeders and the continuity of response of the progeny in term of breast muscle thickness is unknown.

OBJECTIVE

The objective of this study was to assess the effect of selection for breast muscle thickness in Pekin ducks on reproduction and growth performance of the resulting progeny.

MATERIALS AND METHODS

Experimental Animals and diets

The F1 ducklings used as control (C), and those selected for body weight (BW) or breast muscle thickness (MT) were identified by line (C, BW, MT) with wing bands at day of hatching. At 47 d of age, 120 females and 25 males per line were selected for the same criteria and randomly assigned to floor pens with 30 females and 5 males per pen (0.186 m^2/ bird) and 4 pens per line. At 7 and 23 wk of age, the breeders were weighed and their total breast and breast muscle thickness were measured with an ultrasound scanner. The selected breeders were fed a conventional breeder diet up to 23 wk of age. The feeding program was restricted in term of feed quantity to ensure an appropriate breeding weight before reaching laying period. The chemical analysis of the diet is presented in Table 2.1. The eggs were collected, dated, marked by line and pen, individually weighed, and incubated. Four hatches of F2 ducklings were identified with wing bands at hatching and raised on floor. At 47 d of age, the ducklings were weighed and their total breast and breast muscle thickness were measured with an ultrasound scanner.

Ultrasound Measurements

Breast muscle thickness measurements were taken at 6 and 7 wk of age. The birds were positioned on their back on a board and restrained by holding them at the neck and heel using velcro tape. A multipurpose ultrasound gel was used as a contact agent on the full feathered breasts. The ultrasound system used was an ECHO 1000[1] portable real-time ultrasound scanner, equipped with a 7.5 MHz linear array probe. The measurements were taken on a frozen image where the distance between 2 points (mm) was calculated using a built-in caliper.

TABLE 2.1 : Chemical analysis of the breeder diet

Component	DM	EE	CP	ADF	ASH	Ca	P	GE
				(%)				(kcal/g)
Value	89.99	5.64	20.48	9.77	3.20	2.60	0.56	4.219

Statistical analysis

Statistical analysis of the data was performed using the general linear models (GLM) procedures of the SAS (1990) library. The breeders data for body weight and ultrasound measurements were analysed as a factorial design with three lines and two sexes. The data for the reproductive performance were analysed as a completely randomized design. The data for the body weight and ultrasound measurements of the F2 progeny were analysed as a randomized complete block design where each hatch was considered a block.

[1]ECHO 1000, Alliance Medical Inc., Montreal, Canada H4T 1G1.

RESULTS AND DISCUSSION

The effects of line and sex on body weight, total breast and breast muscle thickness of the Pekin breeders at 7 and 23 wk of age are presented in Table 2.2. There was no interaction between line and sex for any of the parameters. There was a significant ($P < 0.05$) difference in body weights among the 3 lines with weights of 3.49, 3.13, and 2.89 kg for BW, MT and C, respectively. That order of difference was not the same for total breast and breast muscle thickness where MT had significantly ($P < 0.05$) higher measurement than C and BW indicating that the heavier ducks do not necessarily possess more breast muscle. This observation agrees with reports in turkeys where the selection for body weight did not result in an increase in breast muscle with skin and bone (Nestor *et al.*, 1995). The same birds were weighed and measured at 23 wk of age, and the data show similar differences in body weights among the lines but no significant ($P > 0.05$) differences in total breast and breast muscle thickness (Table 2.2). This loss of significance between wk 7 and wk 23 can be explained by the MT birds being most affected by the restricted feeding that may have slowed their breast muscle growth. Sex had an effect at both 7 and 23 wk where males were significantly heavier and had higher breast measurement than females (Table 2.2). The lack of a significance interaction indicated that the MT males or females possessed higher breast muscle thickness than BW and C males and females.

The reproductive performance of the F1 breeders from 23 to 31 wk of age is presented in Table 2.3. There was no significant ($P > 0.05$) difference among lines in feed consumption and egg number per duck. The BW breeders laid eggs that were significantly ($P<0.05$) heavier than those of C, while there was no difference between egg weights of

TABLE 2.2 : Effect of line[1] and sex on body weight, total breast (Total) and breast muscle (Muscle) thickness of Pekin breeders at 7 and 23 wk of age (n=435)

		7 wk of age			23 wk of age		
Line	Sex	Body Wt	Total	Muscle	Body Wt	Total	Muscle
		(kg)	(mm)		(kg)	(mm)	
C	M	3.06	11.59	9.21	3.65	17.34	12.75
C	F	2.72	10.90	8.41	3.09	15.54	11.33
BW	M	3.70	12.05	9.41	4.54	18.00	13.68
BW	F	3.29	11.44	8.83	3.85	16.44	12.59
MT	M	3.32	13.43	11.01	3.91	18.33	13.85
MT	F	2.93	12.67	10.27	3.32	16.12	12.22
SEM		0.07	0.21	0.21	0.11	0.34	0.30
		Probabilities					
Line		0.0001	0.0001	0.0001	0.0003	0.4841	0.2189
Sex		0.0001	0.0116	0.0100	0.0003	0.0062	0.0204
Line*Sex		0.8196	0.9709	0.9261	0.9093	0.9036	0.9162
Main Effects							
Line	C	2.89^{c}	11.24^{b}	8.81^{b}	3.37^{c}	16.44	12.04
	BW	3.49^{a}	11.74^{b}	9.12^{b}	4.20^{a}	17.22	13.13
	MT	3.13^{b}	13.05^{a}	10.64^{a}	3.62^{b}	17.23	13.04
Sex	M	3.36^{a}	12.35^{a}	9.87^{a}	4.03^{a}	17.89^{a}	13.43^{a}
	F	2.98^{b}	11.67^{b}	9.17^{b}	3.42^{b}	16.03^{b}	12.05^{b}

[ab] Means within columns with no common superscripts differ significantly ($P < 0.05$)
[1] C: control; BW: line selected for heavy body weight; MT: line selected for greater breast muscle thickness

MT and C. These results agree with reports on eggs laid by chickens (Reddy and Siegel, 1977) and turkeys (Nestor and Bacon, 1986) selected for heavy body weight. The BW eggs included a high percentage of double yolk eggs that were culled before incubation. Chickens selected for heavy body weight laid a higher percentage of abnormal eggs (Anthony *et al.*, 1989). In addition, BW showed significantly (P<0.05) lower percentage fertility and hatching of fertile eggs compared to C and MT, while there was no difference between MT and C. Similarly, previous results have been reported on the reduced hatchability in Pekin ducks selected for body weight (Vagt *et al.*, 1989). These data indicate that the selection for breast muscle thickness had no effect on reproduction, but selection by body weight reduced reproductive performance.

TABLE 2.3 : Effect of line[1] on weight gain, feed consumption (FC), egg number, egg mass, % fertility, and % hatching of fertile eggs of breeder ducks from 23 through 31 wk of age

Line	Weight gain	FC	Egg Number	Egg mass	fertility	hatchability
	(kg)			(g)	(%)	
C	0.213	12.78	38.02	83.67 ^{b}	65 ^{a}	68 ^{a}
BW	0.108	12.63	37.06	93.81 ^{a}	37 ^{b}	52 ^{b}
MT	0.178	12.86	41.66	85.98 ^{b}	61 ^{a}	64 ^{a}
SEM	0.03	0.28	1.03	1.47	2.05	2.19

^{ab} Means within columns with no common superscripts differ significantly ($P < 0.05$).
[1] C: control; BW: line selected for heavy body weight; MT: line selected for greater breast muscle thickness

The F2 ducklings showed similar differences in body weight and breast measurements as those observed in the parents (Table 2.4). Clayton and Powell (1978) reported heritability values of 0.76 and 0.65 for live body weight and breast muscle % in Pekin ducks. The BW birds were heavier ($P<0.05$) than C and MT, while the MT ducklings had higher ($P<0.05$) total breast and breast muscle thickness indicating the response of the progeny to the selection.

TABLE 2.4. Mean body weight and breast measurements at 47 d of age of F2 progeny of control and selected parents

Line [1]	n	Body weight (kg)	Total breast thickness (mm)	Breast muscle thickness (mm)
C	446	3.17 [c]	11.41 [b]	8.04 [b]
BW	99	3.66 [a]	11.46 [b]	8.14 [b]
MT	419	3.31 [b]	12.61 [a]	9.28 [a]
SEM		0.01	0.05	0.05

[ab] Means with different superscripts in the same column differ significantly (*P*<0.05)

[1] C: control; BW: line selected for heavy body weight; MT: line selected for greater breast muscle thickness

The main effect of line is presented in this table because the effects of block or line*block interaction were not significant.

CONCLUSION

These data support the feasibility of applying ultrasound scanning to measure breast muscle thickness of live Pekin ducks at market age. They also demonstrate that selection for body weight only had a negative effect on the reproductive performance and that the selection in the parents based on this trait is reflected in the progeny. The results contribute to the knowledge on improving carcass quality in meat type Pekin ducks.

Connecting Statement : Section II and III

Male and female Pekin ducks were reared mixed in the experiment presented in Section II. Considering the differences in growth rate and feed utilization between males and females, it was important to determine the response of the ducks selected for greater breast muscle thickness to separate-rearing.

In Section II, the use of ultrasound for the selection for greater breast muscle thickness was found feasible and had no affect on the reproductive performance. The selected ducks had greater breast muscle thickness than the control ducks. In Section III, carcass analysis and blood parameters of the two lines were compared to determine whether the selection for greater breast muscle thickness selects also for leaner birds.

SECTION III

Comparative Performance, Blood Chemistry and Carcass composition of two Lines of Pekin Ducks Reared Mixed or Separated by Sex

BY

ANTOINE FARHAT AND EDUARDO R. CHAVEZ

Department of Animal Science
Macdonald Campus of McGill University
21,111 Lakeshore Road, Ste.Anne de Bellevue
Québec, Canada. H9X 3V9

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Comparative Performance, Blood Chemistry and Carcass composition of two Lines of Pekin Ducks Reared Mixed or Separated by Sex

ABSTRACT

Male and female Pekin ducks selected (F2 generation) for greater breast muscle thickness (MT)and an unselected control (C) were used in this study under mixed or separated sex rearing. Ducks in the separated sex program had significantly higher body weights than the birds in the mixed sex program. The ducks selected for greater breast muscle thickness exhibited superior ($P<0.05$) body weight up to 42 d of age. Males from the MT line reached market weight at 6 wk but the breast muscle thickness, measured by ultrasound scanning, improved significantly from 6 to 7 wk of age. Males had greater ($P<0.05$) breast muscle thickness than females. At both ages and for both sexes, the MT line had greater ($P<0.05$) breast muscle thickness than the C line. The MT ducks consumed more ($P<0.05$) feed up to 6 wk but there was no significant difference in the cumulative feed consumption at 7 wk, and the lines did not differ ($P>0.05$) in feed:gain ratio. Males had significantly higher cumulative feed consumption at 6 wk but had a more desirable ($P<0.05$) feed:gain ratio than females at 7 wk. Compared to females from the C line, MT females had significantly higher carcass yield, higher body protein, and lower fat. The MT females had higher plasma glucose and lower uric acid than the C females, but there was no significant difference between MT and C lines in plasma triglycerides and total cholesterol. The results of this study support the utility of ultrasound scanning in duck selection, the separated rearing of ducklings and the possibility of reducing the slaughter age of lean males.

(*Key words:* ducks, mixed and separated rearing, ultrasound, carcass, blood chemistry)

INTRODUCTION

The lack of a pronounced sexual dimorphism in Pekin ducks as well as the cost of sexing ducklings at hatching are reasons that justify rearing males and females together. However, many factors tend to favor separated rearing of ducklings, including the consumer demand for uniformity of carcass and further processed items, the difference in body weight between males and females (Normand *et al.*, 1996a), the low feed efficiency during the 7th wk of growth, and the possibility of reducing the growth period (Farhat *et al.*, 1999). Pekin males possess a faster growth rate than females (Farrell, 1990), better feed efficiency (Leeson and Summers, 1997), and lower fat content in their carcasses (Normand, 1997). Similarly to chickens, ducks can increase their feed consumption to meet their energy requirements (Dean, 1986). However, chickens did not select the appropriate diet to maximize growth when offered free choice of different diets varying in protein and energy levels (Siegel *et al.*, 1997). As the market age of ducklings is being reduced, the birds have less time for compensatory growth (Dean, 1986), and diets have to be tailored to their requirements. Poultry species are influenced by the energy:protein ratio of their diet (Siregar *et al.*, 1982b; Dean, 1986; Farhat *et al.*, 1999). Feeding males and females a single dietary program may not provide the male ducklings with the appropriate dietary protein that enables them to perform to their maximum genetic potential. The market age and weight of most Pekin ducks grown in this region are 49 d and 3.2 kg, respectively. In previous studies (Normand, 1997), it was observed that the growth rate of the two sexes starts to differentiate at 5 wk of age. The same studies revealed a sharp decrease in feed efficiency after 6 wk of age, which is most probably related to the higher energy requirement for maintenance and the deposition of fat. A limiting factor in marketing Pekin ducks at 6 wk of age may be the insufficient breast muscle development. The ultrasound measurement of the breast showed that, in both the selected and control lines, males have higher breast muscle thickness than females at 7 wk of age (Farhat and Chavez, 1999a).

OBJECTIVE

The objectives of this study were to compare the growth performance, ultrasound breast measurements at 6 and 7 wk, blood chemistry, and carcass analysis of male and female Pekin ducks, from the line selected for greater breast muscle thickness (MT) and control birds (C), under mixed sex (MR) and sex separated (SR) rearing programs.

MATERIALS AND METHODS

Experimental Animals and diets

A total of 624 day-old ducklings from the F2 generation of the line selected for greater breast muscle thickness and the unselected control line were used in this study. The birds were sexed at hatching, weighed by groups of 26 and randomly distributed into

24 floor pens (12 per program, 6 per line) of 3.0 m * 1.8 m each which provides 0.21 m^2 per bird. Males and females were identified by toe web notching. All ducklings were individually identified with wing bands at 2 wk of age. Individual body weights and feed consumption on a pen basis were monitored at 2, 4, 5, 6, and 7 wk of age. The ducklings received 24 h of light for the first wk and 16 h of light from 2 to 7 wk. At 14 d of age, the light intensity was reduced to 5 lux to avoid cannibalism. The feeding program was a corn-soybean meal based commercial starter (wk 1-2), grower (wk 3-4), and finisher (wk 5-7). The chemical analysis of the three rations are presented in Table 3.1.

TABLE 3.1. Chemical analysis[1] of the 3 rations fed to the ducks

Ration	DM	EE	CP	ADF	Ash	Ca	P	ME[2]
				(%)				(Kcal/kg)
Starter	88.70	3.54	22.69	5.40	5.38	1.01	0.66	3140
Grower	87.99	4.09	18.83	4.04	4.71	1.10	0.59	3200
Finisher	87.37	6.01	17.43	3.32	4.31	0.82	0.51	3260

[1] Chemical analysis was conducted at the Crampton Nutrition laboratory, Macdonald Campus of McGill University.

[2] Calculated metabolizable energy.

Ultrasound Measurements

Breast muscle thickness measurements were taken at 6 and 7 wk of age. The ultrasound system used was an ECHO 1000[2] portable real-time ultrasound scanner, equipped with a 7.5 MHz linear array probe. The measurements were taken on a frozen image where the distance between 2 points (mm) was calculated using a built-in caliper.

Blood and Carcass analysis

At 7 wk of age, a total of 24 females (12 per line) were randomly selected from the separated rearing program, blood samples were taken from the wing vein, and the carcasses were recovered from the processing plant. The carcasses were cut longitudinally along the back bone and one half was ground and analyzed for dry matter, body fat, protein, and ash. Plasma glucose, triglycerides, total cholesterol, and uric acid were analyzed using a clinical discrete analyzer[3].

Statistical Analysis

Statistical analyses of the data were performed using the general linear models (GLM) procedures and mixed models of the SAS (1990) library. The data were analyzed as a factorial design with two programs and two lines, and the dependent variable was body weight. The data within the segregated program were analyzed as a factorial design with two lines and two sexes, and the dependent variables were body weight, feed consumption and conversion. Data for blood and carcass parameters were subjected to one-way analysis of variance. The ultrasound data at 6 and 7 wk of age were treated as repeated measurements with simple covariance structure and the duck within line was

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[2]ECHO 1000, Alliance Medical Inc., Montreal, Canada H4T 1G1.

[3]Model VP super system, Abbott Laboratories, Mississauga, ON L5N 3R3.

included as a random effect.

RESULTS AND DISCUSSION

The effects of program and line are presented in Table 3.2. There were no significant differences at 2 and 4 wk of age (data not presented). Between 5 and 7 wk of age, when sexual dimorphism starts to show in Pekin ducks, the SR birds had significantly (*P*<0.05) higher body weight than the MR birds. This difference may be explained by the

TABLE 3.2. Effect of program and line on body weight of Pekin ducks at 5, 6 and 7 wk of age (n= 624)

		Body weight (g)		
Program	Line	5 wk	6 wk	7 wk
Mixed	Control	2424	2899	3258
Mixed	Muscle thickness	2569	3027	3265
Separated	Control	2474	2988	3274
Separated	Muscle thickness	2565	3074	3389
SEM		10.59	12.93	15.27
		Probabilities		
Program		0.3422	0.0142	0.0285
Line		0.0001	0.0001	0.0072
Program * Line		0.2126	0.4207	0.0917
Main Effects				
Program				
	Mixed	2496	2963 ^{b}	3316 ^{b}
	Separated	2519	3030 ^{a}	3387 ^{a}
Line				
	Control	2449 ^{b}	2944 ^{b}	3320 ^{b}
	Muscle thickness	2567 ^{a}	3050 ^{a}	3384 ^{a}

^{ab} Means within columns with no common superscripts differ significantly (*P* < 0.05) dominance of the males over the females in MR where the difference in weight exceeded 200 g by 42 d of age. Males have been reported to be heavier by 300 g (Leeson and Summers, 1997) and 100 g (Scott and Dean, 1991) than females at 42 d of age. The line effect showed significant (P<0.05) difference at 5 and 6 wk of age when the MT line had higher body weight than the C line. This difference was reduced during wk 7 when fat deposition most probably occurs. Fat, but not protein content of carcass, increased significantly in male and female Pekin ducks from 6 to 10 wk of age (Abdelsamie and Farrell, 1986). Another possible reason for the lower performance of the MT line may be due to the inadequacy of dietary protein. Touchburn *et al.* (1981) reported a significantly lower body weight in their lean line chickens at 5 wk of age when they received lower dietary protein.

Table 3.3 presents the effects of line and sex on body weight of the ducklings reared sex-separated (SR). The MT line had a significantly (P<0.05) higher body weight than the C line at 6 wk of age with body weights of 3146 and 3023 g, respectively. Male Pekin ducks had significantly higher body weight than females with body weights of 3196 and 2973 g, respectively. The average weight of males in the MT line was the highest (3267 g) at 6 wk of age and exceeded market weight indicating the possibility of reducing the slaughter age of ducklings from 7 to 6 wk. However, the breast muscle thickness presented in Table 3.4 shows a major increase from 42 to 49 d of age. This indicates that the dietary program provided may be insufficient in terms of protein for the MT line of birds, especially the males, to synchronize their breast muscle development with their faster growth revealed by their body weight.

TABLE 3.3. Effect of line and sex on body weight of Pekin ducks under the sex-separated program at 5, 6, and 7 wk of age (n= 312)

		Body weight (g)		
Line	Sex	5 wk	6 wk	7 wk
Control	Male	2587	3126	3462
Control	Female	2446	2921	3188
Muscle thickness	Male	2600	3267	3453
Muscle thickness	Female	2498	3025	3345
SEM		16.34	21.25	23.6
		Probabilities		
Line		0.304	0.0017	0.0792
Sex		0.0002	0.0001	0.0001
Line *Sex		0.5389	0.6311	0.0657
Main Effects				
Line				
	Control	2516	3023 [b]	3325
	Muscle thickness	2549	3146 [a]	3399
Sex	Male	2594 [a]	3196 [a]	3458 [a]
	Female	2471 [b]	2973 [b]	3266 [b]

[ab] Means within columns with no common superscripts differ significantly ($P < 0.05$)

Feeding low protein diets to male broiler chickens resulted in reduced breast meat yield and inferior feed utilization (Leeson *et al.*, 1988), and the lean broilers were more affected in terms of growth than fat birds when fed high energy : protein ratio diet (Whitehead, 1991). The improvement in breast muscle thickness observed during wk 7 is a costly limiting factor in marketing ducklings at 6 wk. The MT line and male birds had significantly (P<0.05) greater total breast and breast muscle thickness than the C line and female birds, respectively (Table 3.4).

The effect of line and sex of ducks on feed consumption (FC) and feed:gain ratio (F:G) are presented in Table 3.5. The MT line consumed significantly (P<0.05) more feed than the C line during wk 5 and consequently that affected the cumulative FC which was

TABLE 3.4. Effect of line, sex, and age on total breast and breast muscle thickness (n=150)

Line	Sex	Age	Total breast[1]	Breast muscle[2]
			(mm)	
Control	Male	42 d	10.4	6.7
Control	Female	42 d	10.2	6.4
Control	Male	49 d	13.9	10.3
Control	Female	49 d	13.4	10.1
Muscle thickness	Male	42 d	11.5	7.6
Muscle thickness	Female	42 d	11	7.3
Muscle thickness	Male	49 d	15.6	11.9
Muscle thickness	Female	49 d	14.5	10.9
SEM			0.12	0.12
			Probabilities	
Line			0.0001	0.0003
Sex			0.0018	0.0147
Age			0.0001	0.0001
Line*sex			0.2392	0.1216
Line*age			0.1717	0.2476
Sex*age			0.1778	0.1086
Line*sex*age			0.4644	0.3182
Main Effects				
Line	Control		12.0[b]	8.4[b]
	Muscle thickness		13.1[a]	9.4[a]
Sex	Male		12.8[a]	9.1[a]
	Female		12.3[b]	8.7[b]
Age	42 d		10.8[b]	7.0[b]
	49 d		14.3[a]	10.8[a]

[ab] Means within columns with no common superscripts differ significantly ($P < 0.05$)

[1] Total breast thickness which includes the skin plus subcutaneous fat and the breast muscle measured by ultrasound.

[2] Breast muscle thickness measured with ultrasound.

TABLE 3.5. Effects of line and sex on weekly feed consumption (FC), cumulative FC (CFC), feed:gain ratio (F:G) and cumulative F:G (CF:G) of Pekin ducks under the sex-segregation program at 5, 6 and 7 wk of age (n=312)

Line	Sex	FC 5	FC 6	FC 7	CFC 6	CFC 7	F:G 6	F:G 7	CF:G 6	CF:G 7
		(g)								
Control	Male	1546	1759	2025	6462	8487	3.39	5.08	2.16	2.5
Control	Female	1571	1721	1861	6427	8288	3.39	7.02	2.23	2.64
Muscle thickness	Male	1719	1826	1907	6781	8688	3.63	5.59	2.19	2.46
Muscle thickness	Female	1618	1733	1872	6561	8433	3.39	5.95	2.25	2.61
SEM		24.62	18.48	49.99	40.77	61.47	0.14	0.39	0.02	0.02
		Probabilities								
Line		0.02	0.2671	0.618	0.0001	0.141	0.704	0.727	0.4681	0.2726
Sex		0.351	0.079	0.3637	0.01	0.06	0.704	0.165	0.059	0.0001
Line*Sex		0.137	0.437	0.5491	0.06	0.806	0.704	0.329	0.9078	0.931
Main Effects										
Line	Control	1558 [b]	1740	1943	6444 [b]	8387	3.39	6.05	2.2	2.57
	Muscle thickness	1668 [a]	1779	1889	6671 [a]	8561	3.51	5.77	2.22	2.53
Sex	Male	1632	1792	1966	6622 [a]	8587	3.51	5.34	2.18	2.48 [b]
	Female	1594	1727	1867	6494 [b]	8361	3.39	6.49	2.24	2.62 [a]

[ab] Means within columns with no common superscripts differ significantly (*P* < 0.05)

also significantly different at 6 wk. However, this difference disappeared at wk 7 because the MT birds consumed less feed during that period. Lean laying hens consumed significantly more feed than fat ones (Leclercq *et al.*, 1985). These authors also reported that the multiple regressions between ME intake and weight gain and egg output were not significantly different between the two lines. The feed:gain ratio of the line selected for breast muscle was similar to that of the control line (Table 3.5). Male ducklings consumed significantly (P<0.05) more feed than females up to 6 wk of age but had a significantly lower F:G ratio at 7 wk of age which is probably due to the tendency of females to deposit more fat during wk 7.

The effect of line on carcass yield, muscle thickness and carcass composition is presented in Table 3.6. Compared to the C line, the MT ducks had significantly (P<0.05) higher carcass yield (75.65 vs 73.10 % of live weight), higher breast muscle thickness (10.6 vs 9.1 mm ultrasound measurement) and body protein (31.27 vs 27.94 % eviscerated carcass weight), and had lower fat (60.74 vs 64.93 % of eviscerated carcass weight). In their studies on chickens selected for low or high plasma glucose, Ricard and Touraille (1988) reported a significant increase in carcass yield and pectoralis muscle (g/kg eviscerated carcass weight) and a reduction in abdominal fat (g/kg live body weight) in lean females of F_3 and F_5 generations. Lilburn and Myers-Miller (1988) observed no difference in eviscerated carcass weight or pectoralis major weight of lean and fat lines of F_1 broilers, but the lean birds had significantly less abdominal fat (g/kg body weight).

There was no significant difference in plasma triglycerides or total cholesterol between MT and C lines (Table 3.7). However, the MT line had higher (P < 0.05) plasma glucose than the C line (Table 3.7). Lean chickens selected for lower abdominal fat exhibited higher plasma glucose than fat birds in the fasted or fed state (Touchburn *et al.*, 1981). Lean lines selected for adiposity or glycemia had higher plasma glucose than the fat lines at 3 and 7 wk of age (Leclercq *et al.*, 1987). The MT ducks also had higher plasma IGF-I than the C ducks (Farhat and Chavez, 1999e) which may partially explain the sparing of glucose in the leaner birds. Foltzer and Mialhe (1976) reported an increase in plasma glucose after GH therapy in hypophysectomized ducks. Administration of porcine somatotropin has been reported to increase plasma IGF-1 and glucose in pigs (Klindt, 1994), and growth hormone was observed to decrease the sensitivity of peripheral tissues to insulin in chicken broilers (Burke and Builder, 1985). This may be further supported by the significantly lower plasma uric acid in the MT ducks (Table 3.7). In chickens, insulin was reported to stimulate uric acid production by isolated hepatocytes (Badenoch-Jones and Buttery, 1975), and increase plasma uric acid by increasing the rate of glutamine conversion into uric acid (Karasawa and Kibe, 1983) or by increasing the activities of liver xanthine dehydrogenase and purine nucleoside phosphorylase involved in uric acid synthesis (Wu *et al.*, 1977).

CONCLUSION

It is concluded from this study that rearing male and female ducklings under sex-separated program may be advantageous in terms of adopting different feeding programs and slaughtering males at an earlier age. The significant improvement in breast muscle thickness from 6 to 7 wk of age is interesting and should be followed more closely with different dietary energy :protein ratios. The high F:G ratio during wk 7 should be considered in an economical study to determine whether it is worth keeping the ducks to 7 wk with such a low efficiency of feed utilization. The selection for greater breast muscle using ultrasound has resulted in a better quality carcass.

TABLE 3.6. Effect of line on carcass yield, total breast thickness, breast muscle thickness and carcass composition of female Pekin ducks at 7 wk of age (n=24)

Line	Body wt	Carc. Wt[1]	Yield[2]	Total[3]	Mt[4]	DM	EE	CP	Ash
	(g)		(%)	(mm)		(%)			
Control	3194	2334	73.10 [b]	12.94	9.1 [b]	52.91	64.93 [a]	27.94 [b]	5.85
Muscle thickness	3176	2403	75.65 [a]	13.94	10.6 [a]	51.67	60.74 [b]	31.27 [a]	6.75
SEM	11.64	20.99	0.62	0.27	0.31	0.68	0.88	0.69	0.27

[ab] Means within columns with no common superscripts differ significantly ($P < 0.05$)
[1] Carcass weight
[2] Carcass yield as % live body weight.
[3] Total breast thickness which includes the breast muscle plus the skin and subcutaneous fat and measured by ultrasound.
[4] Breast muscle thickness measured by ultrasound.

TABLE 3.7. Effect of line on plasma parameters of female Pekin ducks at 7 wk of age (n=24)

Line	Glucose	Triglyceride	Cholesterol	Uric acid
	(mg/dl)			
Control	188.43[b]	264.14	174.14	5.42[a]
Muscle thickness	205.14[a]	226.86	178.71	3.46[b]
SEM	4.26	31.44	5.89	0.5

[ab] Means within columns with no common superscripts differ significantly ($P < 0.05$)

Connecting Statement: Section III and IV

In Section III, both males and females received a feeding program adopted by the industry for mixed-rearing of ducks and tailored for the control ducks used in the experiment presented in Section III. In addition, the lean males reached market weight earlier than females and the breast muscle thickness at 7 wk was significantly greater than that at 6 wk of age most probably because of inadequate dietary protein. In Section IV, males and females were reared separately and received three dietary protein programs. Ultrasound measurement of the breast muscle thickness, carcass dissection and analyses, were conducted between 6 and 7 wk of age to determine the optimum dietary protein program and age at which the ducks can be slaughtered.

SECTION IV

Growth and Carcass Characteristics of Pekin Ducks Selected for Greater Breast Muscle Thickness Using Ultrasound Scanning in Response to Dietary Protein

By

ANTOINE FARHAT AND EDUARDO R. CHAVEZ

Department of Animal Science
Macdonald Campus of McGill University
21,111 Lakeshore Road, Ste.Anne de Bellevue
Québec, Canada. H9X 3V9

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Growth and Carcass Characteristics of Pekin Ducks Selected for Greater Breast Muscle Thickness Using Ultrasound Scanning in Response to Dietary Protein

ABSTRACT

Male and female Pekin ducks selected for greater breast muscle thickness were used in an experiment to determine the effect of dietary protein on growth performance, carcass components yield, and carcass composition. The dietary programs were high protein program (HP) that consisted of 25, 23, and 21 % crude protein (CP) for the starter, grower, and finisher, respectively; medium protein program (MP) that consisted of 23, 21, and 19 % CP for the starter, grower, and finisher rations, respectively; and low protein program that consisted of 21, 19, and 17 % CP for the starter, grower, and finisher, respectively. Males were heavier than females throughout the growth trial for the three dietary programs. Increasing dietary protein improved body weight, breast muscle thickness (MT), and cumulative feed:gain ratio at 6 wk of age. Daily measurements of body weight and MT from 42 to 49 d showed that males receiving HP and MP had similar body weight during wk 7, and were heavier than those receiving LP. Increasing dietary protein improved total breast thickness, and HP had greater MT than MP and LP that had similar MT measurements. Body weight and MT increased with age for both sexes, but MT of males receiving HP at 45 d was comparable to those of MP and LP at 48 and 49 d. Female ducks on HP and MP had similar body weight, but were heavier than the ducks on LP. Similarly to males, increasing dietary protein improved the females MT. Male ducks receiving HP had greater pectoralis muscles yield, longer keel bone, and lower breast skin and total skin plus fat yields than MP and LP males. Males on HP and LP had similar leg plus thigh yield that was greater

than that of MP. Pectoralis yield improved with age up to 48 d, but leg plus thigh yield improved only to 45 d of age. Female dissection data show similar effect of HP and MP on pectoralis yield that was greater than that of LP. Similarly to males, pectoralis yield improved up to 48 d. Carcass yield of both males and females improved with age up to 45 d, and it was not influenced by dietary programs. Analysis of eviscerated carcass showed that increasing dietary protein reduced carcass fat and increased CP content. Age had no effect on male carcass fat and CP content, but carcass CP declined with age in females. Breast muscle thickness measured with ultrasound correlated positively with body weight, pectoralis yield, and keel bone length. Birds with higher pectoralis yield tended to have more CP and less fat in their carcasses. A low correlation was found for the caliper measurement of breast skin plus fat thickness and carcass fat. There was no correlation between IGF-I and carcass composition. These results indicate that males responded more efficiently to increasing dietary protein than females, and males selected for greater MT can be slaughtered at earlier age when fed the high protein program. The correlation ($r = 0.73$, $p = 0.0001$) between the ultrasound breast muscle measurement and pectoralis yield validates this technique for the use in selection of birds for higher carcass merit.

INTRODUCTION

After representing one third of beef production in 1950, poultry production is currently greater than beef, and while pork and beef productions slow down, poultry growth rate is increasing and is the highest among meat animals (Brown, 1997). Poultry meat consumption has also shown a strong increase since the 1950's due to its lower price and the public perception of it as healthier compared to red meat (Woodward and Wheelock, 1990, NRC, 1988). The duck meat is still a small contributor to the poultry industry. However, for the last few decades, there was a remarkable increase in meat type duck production orchestrated by the improvement of growth rate and feed efficiency through selective breeding (Powell, 1986).

Carcass of the Pekin duck contains about 60 % fat on DM basis (Farhat and Chavez, 1999b). The consumption trends in the Western societies are toward less fat, specifically the saturated fat and more ready-to-eat meals (Pollock, 1997). Poultry meat has the highest share in the home meal replacement products that is expected to reach $100 billion of US spending on food (Zeidler, 1998). The breast meat of the duck is the most valuable part of the carcass. Breast and thigh meat yields are considered as important as growth rate and feed conversion in the duck industry (Baeza and Leclercq, 1998). The selection for breast meat yield in high yielding broiler strains resulted in very large profit (Barbato, 1996).

Pingel and Heimpold (1983) selected Pekin ducks for increased body weight and greater breast muscle thickness using a needle probe. The authors reported 0.4 mm increase in breast muscle thickness over seven generations. Selection over two generations resulted in breast muscle thickness improvement by 15 and 14 % in the breast muscle line compared to the control line and the line selected for body weight (Farhat *et al.*, 1999a). From the comparison of broiler stocks of the year 1957 to those of 1991, Havenstein *et al.* (1994) concluded that 80 % of the improvement in broiler performance was due to genetics that can only be effective under the current nutritional and management practices.

The degree of fatness and leanness is greatly influenced by the protein concentration of the diet (Fisher, 1984). Fat deposition in broilers depends on the diet composition and can be reduced by increasing dietary protein (Griffin *et al.*, 1998). Broilers body fatness and the low turnover of adipocyte triglycerides were linked to the decreased levels of plasma GH as a consequence of selection for growth (Griffin and Gobbard, 1994). Increasing dietary protein resulted in increasing plasma IGF-I concentration in Pekin ducks (Farhat and Chavez, 1999e). Bartov and Plavnik (1998) fed male broilers diets with energy to protein ratios lower than the NRC (1994) recommendations, and reported an improvement in feed efficiency and breast meat yield with no effect on body weight gain. The same results were also reported in female broiler chickens (Bartov, 1998). The breast meat yield in the male chickens tended to correlate negatively with abdominal fat (Bartov and Plavnik, 1998), but there was no correlation between the two parameters in the females (Bartov, 1998). Feeding different levels of dietary energy had no effect on growth rate while reducing the energy intake or increasing the protein intake resulted in reduced carcass fat content in broiler chickens (Leeson *et al.*, 1996). Dietary protein was found to have an effect on growth and body composition in chickens selected for high abdominal fat (Touchburn *et al.*, 1981). In these studies, the fat line was less affected by decreasing dietary protein than the lean line when growth rates were compared. The authors suggested that the lean birds might require more protein in their diets because they favored protein synthesis compared to the fat birds. Whitehead *et al.* (1990) compared lean and fat chickens selected for low or high VLDL and fed diets with varying protein content. They reported that the lean line birds were the leanest when fed the highest protein diets and showed a considerable increase in fatness when fed the diet of thelowest protein content.

Similarly to broiler chicken, the growth response of males and females Pekin ducks is different and indicates that they have different nutritional requirements. Male chickens showed a greater response to dietary protein than females (Ajang *et al.*, 1993; Smith *et al.*, 1998). Separate rearing of sexes resulted in better performance than mixed rearing in Pekin ducks, especially the lean males selected for greater breast muscle thickness, were able to reach market weight at 42 d of age (Farhat and Chavez, 1999b). Furthermore, a 36 % increase in the breast muscle development was observed in both sexes from 42 to 49 d of age. Males had greater breast muscle thickness at 42 d but not at 49 d of age indicating that the diet, which was the same for both sexes, may not be suitable to meet the higher potential of males for breast muscle development. Emmerson (1997) suggested that reducing the growing period of broiler chickens by 5 d would allow the producer to raise an extra flock per house per year, and the reduction of 0.17 in feed conversion accounts for a reduction of more than 5 % in production cost. Powell (1986) reported that feed conversion was improved 2 % for a day reduction in reaching market weight in Pekin ducks. The decline in feed efficiency during wk 7 questions the benefit of keeping the ducks to 49 d (Farhat and Chavez, 1999b). These observations represent a good reason to provide the appropriate nutritional program to meet the requirements of ducks selected by ultrasound for breast muscle thickness and explore the possibility of reducing the time of Pekin ducks to reach market weight.

OBJECTIVE

The objectives of this experiment were to determine the appropriate feeding program (starter, grower, and finisher rations) in terms of dietary protein for male and female Pekin ducks selected for greater breast muscle thickness, to examine the possibility of reducing the growth period, to determine the effect of dietary program, age, and sex on the yield of carcass components and carcass composition, and to establish the association between ultrasound measurements and blood parameters with carcass characteristics.

MATERIALS AND METHODS

Day 1 to 42 d

A total of 600 ducklings were sexed at hatching (300 males, 300 females), weighed in groups of 25 and randomly allocated into 24 floor pens at 0.22 m^2 per bird. All birds were individually identified with wing bands at 14 d of age. Individual body weight and pen feed consumption were recorded at 14, 28, and 42 d of age. The ducklings received 24 h of light for the first wk and then 16 hr of light for the rest of their growth period. At 14 d of age, the light intensity was reduced to 5 lux to avoid cannibalism. The ducklings were offered three dietary programs that differed in the percentage of crude protein. The three growth periods were divided as follows: 0-14 d starter, 14-28 d grower, 28-49 d finisher. The high dietary protein program (HP) consisted of 25, 23, and 21 % CP for the starter, grower and finisher diets, respectively. The medium dietary protein program (MP) consisted of 23, 21, and 19 % CP for the starter, grower and finisher diets, respectively. The low dietary protein program (LP) consisted of 21, 19, and 17 % CP for the starter, grower and finisher diets, respectively. The composition and characteristics of the diets are presented in Table 4.1. All diets were served pelleted and *ad libitum*.

TABLE 4.1. Composition (%) and characteristics of the diets containing different amounts of crude protein

Ingredients		Crude Protein %				
		25	23	21	19	17
Corn		22.3	24.15	34.59	35.605	36.62
SBM 48%		24.1	15	14.2	10.85	7.5
Wheat		29.94	29.8	21.6	25.45	29.3
Wheat shorts		9.2	15	14.8	14.9	15
Meat meal		5	6	5	5.4	5.8
feather meal		4	4	4	2	-
Super Premix 20[1]		2	3.15	2	1.85	1.7
Coating (calorie-santé)		1.5	1.7	1.5	2.1	2.7
Brinder (Lignosol)		0.9	0.9	0.9	0.9	0.9
Calcium carbonate		0.35	0.07	0.68	0.47	0.26
Dicalcium phosphate		0.4	-	0.41	0.205	-
Sodium chloride		0.12	0.14	0.12	0.145	0.17
Vit+Min Premix[2]		0.1	0.05	0.1	0.075	0.05
Vit E		0.09	-	0.09	0.045	-
DL-Methionine 98%		-	0.04	0.01	0.005	-
Characteristics	**Units**					
DM	%	88.56	88.52	87.72	87.99	88.08
CP	%	25.13	22.6	21.75	19.23	17.52
Fat	%	5.66	7.53	5.69	6.2	6.36
TME	Kcal/kg	3233	3239	3222	3230	3239
NDF	%	3.23	3.11	3.25	3.16	3.06
ADF	%	4.13	4.34	4.28	4.26	4.25
Na	%	0.15	0.16	0.15	0.15	0.15
Ca	%	0.9	0.78	0.93	0.83	0.8
Total P	%	0.64	0.6	0.64	0.59	0.57
Vit. A	IU/g	11.24	8.77	11.24	10	8.77
Vit. D	IU/g	3.5	2.63	3.5	3.07	2.63
Vit. E	IU/g	48	23.75	48	35.88	23.75

[1] Commercial premix of vitamins, minerals, and amino acids

[2] Commercial vitamins and minerals premix

Day 42 to 49 d

From 42 through 49 d of age, the ducks were daily probed using ultrasound to measure their total breast and breast muscle thickness. At each of 42, 45, 48, and 49d of age, 150 ducks were slaughtered for carcass analyses. Prior to slaughter, the skin and subcutaneous fat of 60 ducklings (10 birds/sex/dietary program) were measured using a digital caliper, and forty-eight ducklings (8 birds/sex/dietary program) were bled to determine total plasma protein, uric acid, and IGF-I. Five milliliters of blood were taken into a heparinized tube from each bird that was randomly selected. The 600 duck carcasses were cut longitudinally along the back bone and one half was ground and analyzed for dry matter, protein, fat, and ash. Before grinding, 192 carcasses were dissected into wing, breast skin, total skin plus fat, pectoralis muscles (minor and major), leg plus thigh, shell, and the length of the keel bone was measured. The yield of each part is reported as a percentage of eviscerated carcass without the neck and giblets. Plasma was analyzed for total protein using Bio-Rad Protein Assay[4], for uric acid using a clinical discrete analyzer[5], and for IGF-I by RIA (Farhat and Chavez, 1999e).

Ultrasound and caliper Measurements

Breast muscle thickness measurements were taken daily from 42 to 49 d on live birds. The birds were held on their back on a restraining board by using velcro tape over their neck and heels. A multipurpose ultrasound gel was used as a contact agent on the full feathered breasts. The ultrasound system used was an ECHO 1000[6] portable real-time

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[4]Cat. No. 500-0006, Bio-Rad Laboratories, Hercules, CA 94547.

[5] Model VP super system, Abbott Laboratories, Mississauga, ON L5N 3R3.

[6]ECHO 1000, Alliance Medical Inc., Montreal, QC H4T 1G1.

ultrasound scanner, equipped with a 7.5 MHz linear array probe. The measurements were taken on a frozen image where the distance between 2 points (mm) was calculated using a built-in caliper. The double breast skin and fat thickness was measured with a digital caliper[7] following the procedure reported by Walters *et al.* (1994).

Statistical Analysis

Statistical analyses of the data were performed using the General Linear Models (GLM) procedures and mixed model of the SAS® (1990) library. The performance data were treated as repeated measures with simple covariance structure, and the duck and pen were included as random effects for body weight and feed consumption, respectively. From day old to 42 d of age, the model included the effects of dietary program, sex, and their interaction. The dependent variables were body weight, feed consumption and conversion, and ultrasound and caliper measurements. From 42 to 49 d of age, the model included the effects of dietary program, age, and interaction for males and females. The dependent variables were body weight and breast measurements, carcass characteristics, and blood parameters. The multi-comparison Scheffe's test was used to separate the differences among the means for statistical significance ($P < 0.05$).

RESULTS AND DISCUSSION

Performance from day 1 to 42 d

Body weight and weight gain from day 1 to 42 d of age are presented in Table 4.2. There was no difference ($P < 0.05$) between the initial average body weights of males and females that were 57.40 and 57.07 g, respectively. Both males and females had higher

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[7]Starrett electronic digital micrometer, No. 734MXFL, Athol, MA 01331

body weights on HP during the starting and the growing periods and both sexes had higher body weights on MP than on LP. From 28 to 42 d of age, males and females on HP maintained a significantly higher body weight than the other programs, but the females on MP had similar body weights as the LP. Analysis of the average daily gain (ADG) within each period shows a significant difference between HP and the MP programs only during the starting period. The ADG during the growing period was similar between the two programs but higher than that of LP. From 28 to 42 d of age, males on the three programs had similar ADG, but the LP females gained significantly more weight than HP and MP females. Although HP ducks lost their superiority in ADG after the starting phase, MP and LP birds were unable to reach similar body weight to that of HP at 42 d of age where the interaction still showed that both males and females had significantly higher body weights than males and females on MP or LP. Japanese quails grown to 70 d had a significant improvement in body weight for only the first 4 wk when fed high dietary CP (Hyánková *et al.*, 1997). Increasing dietary protein with equal feed restriction resulted in similar body weight and improvement of breast muscle yield in breeder pullets at 4 wk of age (Yaissle and Lilburn, 1998). Feeding male and female chickens different energy to protein ratios did not have an effect on body weight gain (Bartov and Plavnick, 1998; Bartov, 1998). Cahaner *et al.* (1995) reported an improved body weight gain from 4 to 8 wk in lean and fat chickens fed high dietary protein. Lean line of chicken showed growth depression when dietary protein decreased (Leclercq, 1983). Our data agrees with the literature suggestion that lean birds require more protein in their diet. Until 42 d of age, the results favor the high protein program for males and the medium protein program for females.

TABLE 4.2. Effect of dietary program (high protein, medium protein, low protein), and sex (M:male, F:female) on body weight and average daily gain (Bwt and Adg) at 2,4, and 6 wk old Pekin ducks (n=600)

Program	Sex	Bwt 14d	Adg at 14d	Bwt 28d	Adg (14-28d)	Bwt 42d	Adg (28-42d)
		(g)					
High protein	M	720	51.01	2109	106.81	3020 ^{a}	70.10 ^{a}
High protein	F	700	49.49	1986	98.9	2763 ^{d}	59.73 ^{c}
Med protein	M	677	47.82	2040	104.82	2955 ^{b}	70.44 ^{a}
Med protein	F	670	47.14	1965	99.58	2650 ^{e}	52.69 ^{d}
Low protein	M	657	46.09	1930	97.88	2875 ^{c}	72.73 ^{a}
Low protein	F	659	46.26	1868	93.02	2691 ^{e}	63.30 ^{b}
SEM		2.54	0.2	6.96	0.43	10.5	0.51
		Probabilities					
Program		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sex		0.0767	0.0705	0.0001	0.0001	0.0001	0.0001
Program*Sex		0.1749	0.1745	0.1110	0.2227	0.0202	0.0001
Main Effects							
Program	HP	710 ^{a}	50.25 ^{a}	2047 ^{a}	102.86 ^{a}	2891	64.91
	MP	673 ^{b}	47.48 ^{b}	2002 ^{b}	102.20 ^{a}	2802	61.47
	LP	658 ^{c}	46.18 ^{c}	1899 ^{c}	95.45 ^{b}	2783	68.02
Sex	M	685	48.31	2026 ^{a}	103.13 ^{a}	2950	71.09
	F	676	47.63	1940 ^{b}	97.14 ^{b}	2701	58.57

^{abcd} Means within columns with no common superscripts differ significantly ($P < 0.05$)

TABLE 4.3. Effect of dietary program, and sex on total breast and breast muscle, and breast skin measurements of 6 wk old Pekin ducks

Program	Sex	Total breast (n=300)	Breast muscle (n=300)	Breast skin[1] (n=60)
			(mm)	
High protein	Male	10.16^{a}	6.78	3.2
High protein	Female	9.64^{b}	6.09	3.28
Med protein	Male	9.10^{c}	5.4	3.66
Med protein	Female	9.31^{bc}	5.33	3.09
Low protein	Male	9.33^{bc}	5.26	4.09
Low protein	Female	9.14^{c}	5.13	3.25
SEM		0.06	0.07	0.09
			Probabilities	
Program		0.0001	0.0001	0.1301
Sex		0.1615	0.0136	0.0992
Program*Sex		0.0409	0.0627	0.0657
Main Effects				
Program	High protein	9.90	6.44^{a}	3.24
	Medium protein	9.20	5.36^{b}	3.38
	Low protein	9.24	5.19^{b}	3.67
Sex	Male	9.53	5.81^{a}	3.65
	Female	9.36	5.52^{b}	3.21

^{abcd} Means within columns with no common superscripts differ significantly ($P < 0.05$)
[1] Double thickness of breast skin determined by a digital caliper.

Ultrasound measurements of the total breast (TOT) and breast muscle (MT) thickness, and caliper measurement of the breast skin double thickness at 6 wk of age are presented in Table 4.3. There was an interaction between program and sex for TOT where the HP males had greater ($P<0.05$) TOT and the HP females had similar ($P>0.05$) TOT to

TABLE 4.4. Effect of program and sex on feed consumption (FC) per bird, and feed:gain (F:G)[1] ratio of Pekin ducks at 2, 4, and 6 wk of age (n=24 pens)

Program	sex	FC2wk	FC2-4wk	FC4-6wk	CFC6wk[2]	F:G2wk	F:G2-4wk	F:G4-6wk	CF:G6wk[3]
		(g)							
High prot	Male	891	2678	2754	6323	1.35	1.93	2.92	2.09
High prot	Female	877	2580	2670	6127	1.36	2.06	3.42	2.23
Med. prot	Male	874	2618	2847	6339	1.41	1.94	3.13	2.15
Med. prot	Female	882	2624	2673	6178	1.44	2.03	3.58	2.28
Low prot.	Male	857	2553	2755	6166	1.43	2.01	2.91	2.14
Low prot.	Female	871	2566	2669	6106	1.45	2.12	3.24	2.27
SEM		6.12	13.88	22.34	33.47	0.01	0.02	0.06	0.01
		Probabilities							
Program		0.4313	0.0657	0.6167	0.2762	0.0001	0.0047	0.0019	0.0032
Sex		0.8537	0.2958	0.0202	0.0388	0.0970	0.0001	0.0001	0.0032
Program*Sex		0.6681	0.1445	0.6578	0.6558	0.8813	0.7204	0.4442	0.9689
Main Effects									
Program									
	HP	884	2629	2712	6225	1.36 [b]	1.99 [b]	3.21[b]	2.16[b]
	MP	878	2621	2760	6258	1.42 [a]	1.98 [b]	3.36 [a]	2.22[a]
	LP	864	2560	2712	6136	1.44 [a]	2.07 [a]	3.08[b]	2.21[a]
Sex									
	Male	874	2616	2786[a]	6276[a]	1.4	1.96[b]	2.99[b]	3.01[b]
	Female	876	2590	2671[b]	6137[b]	1.42	2.07 [a]	3.42 [a]	3.42 [a]

[ab] Means within columns with no common superscripts differ significantly (*P* < 0.05)

[1] Corrected feed to gain ratio for

[2] Cumulative feed consumption up to 6 wk of age.

[3] Cumulative feed to gain ratio at 6 wk of age

MP females and LP males, but greater (P<0.05) than MP males and LP females. For both sexes, the HP had greater (P<0.05) MT than both medium and low protein programs. These last two had similar (P>0.05) MT measurements. Males on all the programs had greater (P<0.05) MT than females. There was no effect (P>0.05) of dietary program or sex on the caliper measurement of breast skin thickness. The superiority of HP ducks in breast muscle thickness indicates that the high protein program is necessary for the improvement of growth rate and development of breast muscle thickness of males at 6 wk of age. While MP was suggested to be enough for the growth rate of females, HP resulted in greater breast muscle thickness at 6 wk of age. However, for both males and females, the body weight and breast muscle thickness are still considered below acceptable market range.

The effects of the dietary program and sex on feed consumption and feed:gain ratio (F:G) from 2 to 6 wk of age are presented in Table 4.4. There was no effect of dietary protein program on feed consumption at 2 wk, from 2 to 4 wk, 4 to 6 wk of age, or on the cumulative feed consumption from day old to 6 wk of age. The HP had a better (P<0.05) F:G than MP and LP during the first 2 wk. HP had a similar F:G to that of MP from 2 to 4 wk, and both had a better (P<0.05) F:G than that of LP. From 4 to 6 wk, the feed conversion of HP and LP were similar and better than that of MP. At 6 wk, the cumulative F:G of the ducks receiving HP was significantly better than those receiving MP or LP that were similar. There was no difference (P>0.05) in feed consumption between males and females up to 4 wk of age, but males on all the programs consumed more (P<0.05) feed than females from 4 to 6 wk and cumulatively up to 6 wk of age. Males had a better F:G than females from 2 to 4 wk, from 4 to 6 wk, and cumulative F:G at 6 wk of age. Similarly to our observation, low energy to protein ratio had no effect on feed intake, but improved feed efficiency from 7 to 42 d of age in male (Bartov and Plavnik, 1998) and female broiler chickens (Bartov, 1998). Feeding four levels of dietary protein to lean and fat chickens, Leclercq (1983) reported that both lines utilized the feed more efficiently as dietary protein was increased.

Performance from 42 to 49 d

The effects of dietary protein program on daily body weight and ultrasound measurements of male ducks from 42 to 49 d of age are presented in Table 4.5. These data include 50 birds per dietary program per age. There was no significant interaction between dietary program and age for any of the three parameters. The difference in body weight between HP and MP males was not significant, but both were heavier ($P<0.05$) than the LP males. For all the dietary program, there was no significant increase in body weight after 47 d with no significant difference between 45,46, and 47 d of age. Plotting the growth curves of males by dietary program (Figure 4.1) show that HP and MP males reached the same body weight during wk 7 after a significant difference at 6 wk. The difference in carcass fat and CP content was significant during wk 7 (Table 4.9) and that agrees with the suggestion of Bass *et al.* (1990) that animals that have a fast early growth followed by a slower finishing growth are leaner than those that have a slower early growth followed by a faster finishing growth when killed at the same body weight. Hyánková *et al.* (1997) reported that the high dietary protein in the starter diet enabled a faster growth rate in quails. The high protein program, in our study, induced a faster early growth followed by a slower growth, while the response to MP was a slower early growth followed by a faster growth. Both programs resulted in a similar body weight at which the HP males were leaner. The difference in growth rate may have had an effect on the carcass composition, but the HP males were leaner even at 6 wk of age when the difference in body weight was still significant. Total breast thickness was the greatest ($P<0.05$) for HP and the lowest ($P<0.05$) for LP males. The breast muscle thickness of HP males was superior ($P<0.05$) to those of the MP and LP that had similar ($P>0.05$) MT. There was a positive association between TOT or MT and age.

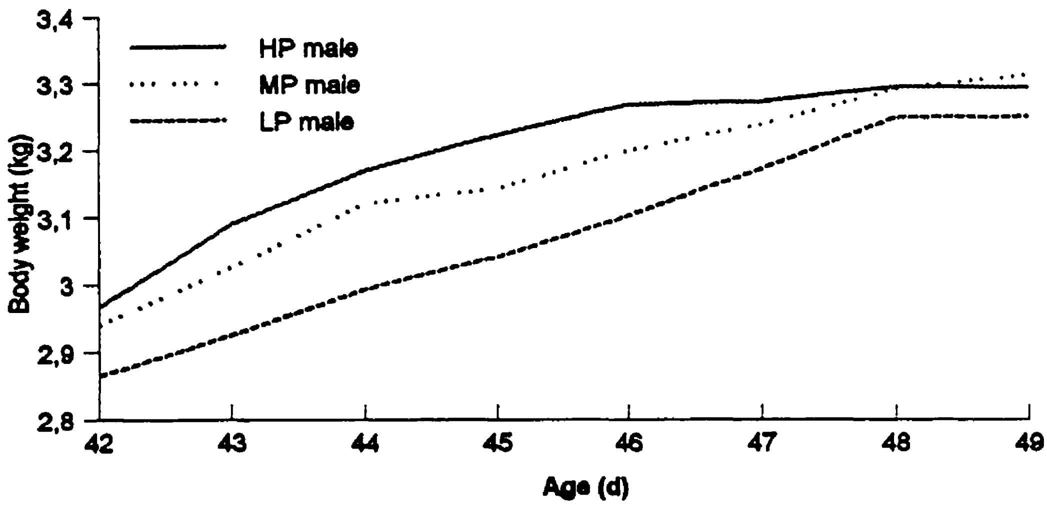

FIGURE 4.1. Effect of dietary protein program on body weight (kg) in male Pekin ducks from 42 to 49 d

Total breast thickness continued to increase ($P<0.05$) up to 49 d of age, but there was no difference ($P>0.05$) between the MT at 48 and 49 d, and between 48 and 47 d of age. In a previous study (Farhat and Chavez, 1999b), there was ≈ 36 % difference between the MT at 42 and 49 d of age. In this study, both MP and LP males showed similar differences (34 %) to the previous report in MT between 42 and 49 d of age. However, the HP reduced this gap to 26 % in the male ducks. At 49 d of age, the HP improved the muscle thickness of males by 11 and 14 % compared to MP and LP, respectively. The muscle thickness of HP malesat 45 d of age was only 4 and 1.5 % less those of MP and LP males at 49 d of

TABLE 4.5. Effects of dietary program and age (42,43,44,45,46,47,48,and 49d) on body weight and ultrasound measurements of male Pekin ducks

Program	age	Bwt	Tot	Mt
		(kg)	(mm)	
High Protein	42 d	2.966	10.16	6.78
High Protein	43 d	3.088	10.29	7.3
High Protein	44 d	3.168	11.15	7.62
High Protein	45 d	3.222	11.4	7.87
High Protein	46 d	3.267	11.74	7.99
High Protein	47 d	3.272	12.55	8.77
High Protein	48 d	3.274	12.63	8.71
High Protein	49 d	3.295	13.05	9.17
Med Protein	42 d	2.939	9.1	5.4
Med Protein	43 d	3.025	9.65	5.66
Med Protein	44 d	3.12	10.18	6.02
Med Protein	45 d	3.142	10.4	6.52
Med Protein	46 d	3.199	10.51	6.85
Med Protein	47 d	3.238	11.58	7.68
Med Protein	48 d	3.292	11.8	7.93
Med Protein	49 d	3.313	12.39	8.24
Low Protein	42 d	2.865	9.33	5.26
Low Protein	43 d	2.925	9.67	5.72
Low Protein	44 d	2.993	10.07	6.13
Low Protein	45 d	3.041	10.19	6.38
Low Protein	46 d	3.102	10.33	6.44
Low Protein	47 d	3.171	11.03	7.35
Low Protein	48 d	3.248	11.53	7.85
Low Protein	49 d	3.25	11.77	7.99
SEM		0.01	0.05	0.05
			Probabilities	
Program		0.0001	0.0001	0.0001
Age		0.0001	0.0001	0.0001
Program*Age		0.8827	0.5646	0.5655
Main Effects				
Program	HP	3.194^{a}	11.62^{a}	8.03^{a}
	MP	3.159^{a}	10.70^{b}	6.78^{b}
	LP	3.074^{b}	10.49^{c}	6.64^{b}
Age	42 d	2.923^{e}	9.53^{f}	5.81^{f}
	43 d	3.012^{d}	9.87^{e}	6.23^{e}
	44 d	3.094^{c}	10.47^{d}	6.59^{d}
	45 d	3.135^{bc}	10.66^{cd}	6.92^{c}
	46 d	3.166^{b}	10.86^{c}	7.10^{c}
	47 d	3.227^{ab}	11.72^{b}	7.93^{b}
	48 d	3.272^{a}	11.99^{b}	8.16^{ab}
	49 d	3.286^{a}	12.41^{a}	8.45^{a}

[abcdef] Means within columns with no common superscripts differ significantly ($P < 0.05$)

age, respectively (Figure 4.2) . So far, duck producers are not paid for the quality of the carcass, but rather for the carcass weight with a relatively acceptable breast muscle development such as the one observed in the MP and LP birds at 49 d of age. This indicates that increasing the dietary protein resulted in early development of the breast muscle enough to send these birds to market, especially because they have reached the

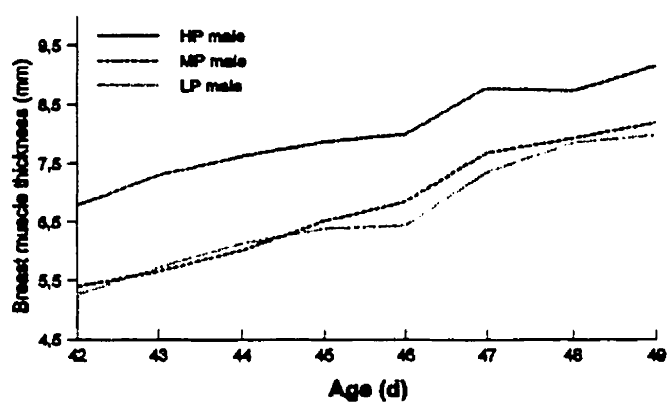

FIGURE 4.2. Effect of dietary protein program on breast muscle thickness (mm) in male Pekin ducks from 42 to 49 d

conventional market weight (> 3.200kg) at 45 d of age. The possibility of reducing the growth period of these birds may represent a considerable profit in terms of flock turnover or feed conversion (Emmerson, 1997; Powell, 1986).

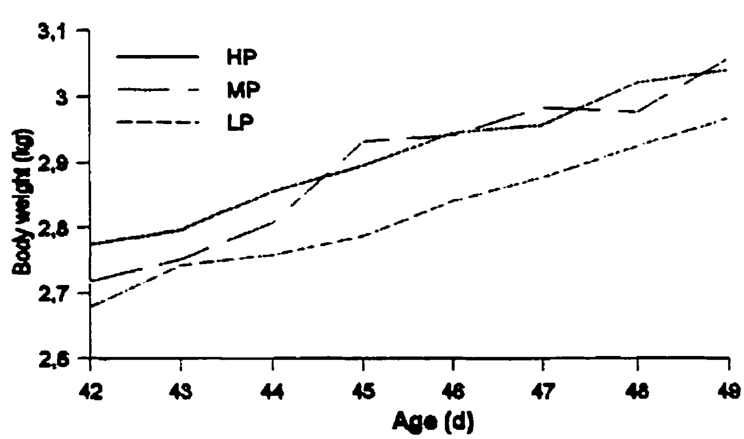

FIGURE 4.3. Effect of dietary protein program on body weight (kg) in female Pekin ducks from 42 to 49 d

TABLE 4.6. Effects of dietary program and age (42,43,44,45,46,47,48,and 49d) on body weight and ultrasound measurements of female Pekin ducks

Program	age	Bwt	Tot	Mt
		(kg)	(mm)	
High protein	42 d	2.773	9.64	6.09^{e}
High protein	43 d	2.795	10.09	6.58^{d}
High protein	44 d	2.854	11.02	7.35^{c}
High protein	45 d	2.894	11.14	7.48^{c}
High protein	46 d	2.944	11.33	7.83^{bc}
High protein	47 d	2.957	12.15	8.33^{ab}
High protein	48 d	3.02	12.43	8.63^{a}
High protein	49 d	3.039	12.51	8.76^{a}
Med protein	42 d	2.718	9.31	5.33^{g}
Med protein	43 d	2.751	9.59	5.94^{ef}
Med protein	44 d	2.807	10.6	6.85^{d}
Med protein	45 d	2.931	10.8	6.82^{d}
Med protein	46 d	2.941	11.17	7.33^{c}
Med protein	47 d	2.984	11.49	7.72^{bc}
Med protein	48 d	2.977	12.23	8.66^{a}
Med protein	49 d	3.057	12.44	8.71^{a}
Low protein	42 d	2.678	9.14	5.13^{g}
Low protein	43 d	2.742	9.19	5.42^{fg}
Low protein	44 d	2.758	9.79	5.78^{ef}
Low protein	45 d	2.786	10.19	6.49^{d}
Low protein	46 d	2.84	10.87	6.58^{d}
Low protein	47 d	2.877	11.38	7.85^{bc}
Low protein	48 d	2.925	11.98	8.01^{b}
Low protein	49 d	2.968	12.23	8.61^{a}
SEM		0.01	0.05	0.05
			Probabilities	
Program		0.0001	0.0001	0.0001
Age		0.0001	0.0001	0.0001
Program*Age		0.8162	0.4176	0.0032
Main Effects				
Program	HP	2.910^{a}	11.29^{a}	7.63
	MP	2.896^{a}	10.95^{b}	7.15
	LP	2.822^{b}	10.60^{c}	6.73
Age	42 d	2.723^{g}	9.36^{g}	5.52
	43 d	2.763^{fg}	9.62^{f}	5.98
	44 d	2.806^{ef}	10.47^{e}	6.59
	45 d	2.870^{d}	10.71^{de}	6.93
	46 d	2.908^{cd}	11.12^{c}	7.25
	47 d	2.939^{bc}	11.67^{b}	7.96
	48 d	2.974^{ab}	12.21^{a}	8.43
	49 d	3.022^{a}	12.39^{a}	8.69

^{abcdefg} Means within columns with no common superscripts differ significantly ($P < 0.05$)

The effects of dietary protein program on daily body weight and ultrasound measurements of female ducks from 42 to 49 d of age are presented in Table 4.6 and Figure 4.3. These data included 50 birds per dietary program per age. There was no significant interaction between dietary program and age for body weight and TOT, but the interaction for MT was significant. Similarly to males, the difference in body weight between HP and MP females was not significant, but both were heavier (*P*<0.05) than the LP females. The TOT of the females increased significantly with increasing dietary protein. Both body weight and TOT of females on all programs improved up to 48 d of age. Within each program, there was a positive association between MT and age. However, the MT of the HP, MP, and LP females stopped increasing at 47, 48, and 49 d of age, respectively. At 42, 43, 44, and 45 d of age, HP females had significantly greater MT than the females on the other programs. There was no significant difference in MT of the females between the three dietary programs at 49 d of age. While the difference in MT between 42 and 49 d of age was 39 and 40 % for MP and LP, respectively, that difference was only 30 % for HP.

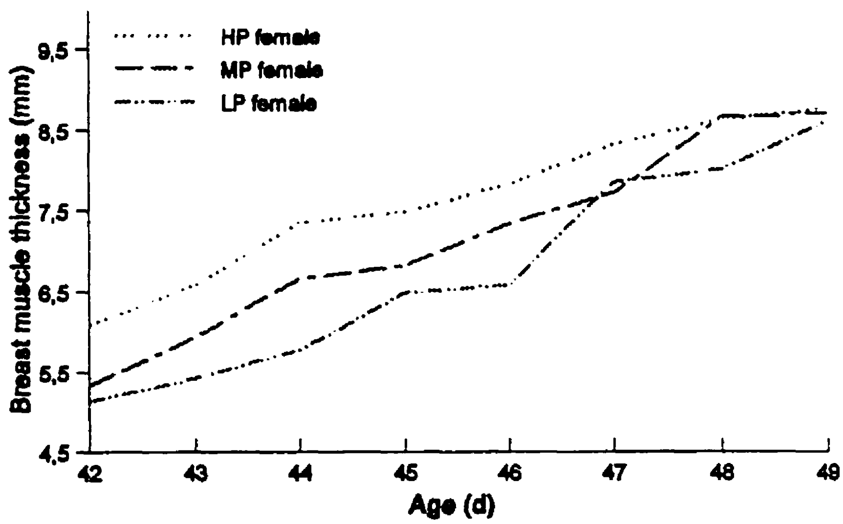

FIGURE 4.4. Effect of dietary protein program on breast muscle thickness (mm) of female Pekin ducks from 42 to 49 d

However, the MT of HP females at 45 d still lagged behind those of MP and LP at 49 d by 14 and 13 %, respectively (Figure 4.4). Females seem to require more time rather than dietary protein for the development of the breast muscle probably because of their slower growth rate than males.

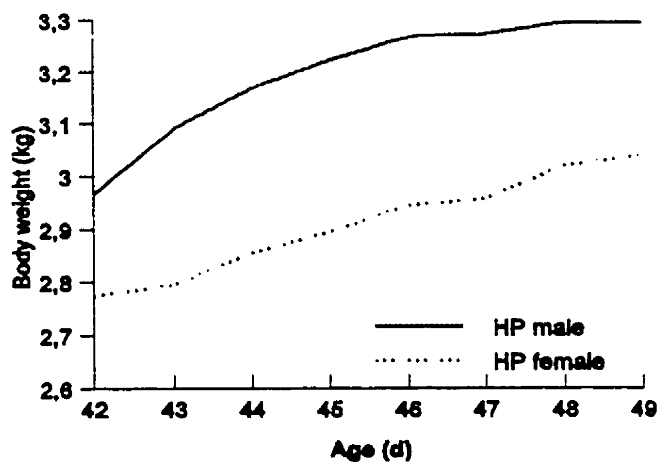

FIGURE 4.5. Effect of high protein program on body weight (kg) of males and females Pekin ducks from 42 to 49

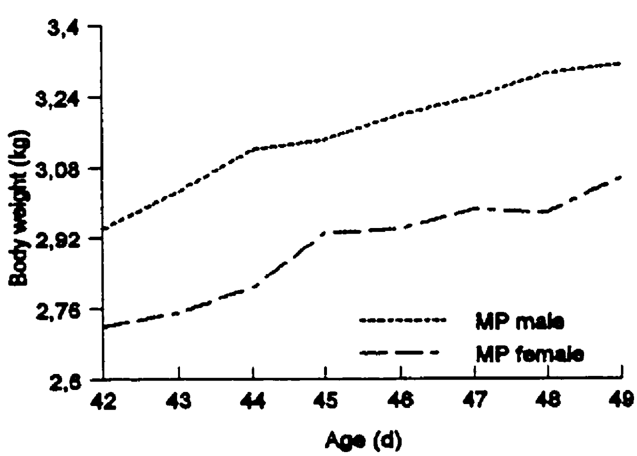

FIGURE 4.6. Effect of medium protein program on body weight (kg) of males and females Pekin ducks from 42 to 49 d

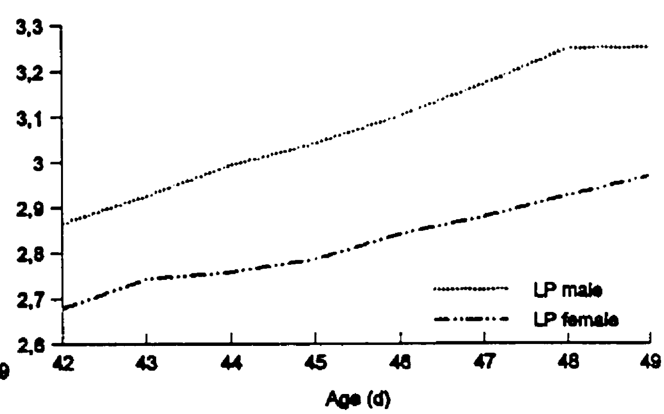

FIGURE 4.7. Effect of low protein program on body weight (kg) of males and females Pekin ducks from 42 to 49 d

Males were significantly heavier than females for HP (Figure 4.5), MP (Figure 4.6) and LP (Figure 4.7) from 42 to 49 d. However, the difference between the males and females receiving high dietary protein was greater than that between the males and females receiving either medium or low protein. This difference was mainly due to the superior performance of males, but not females, on high dietary protein. However, that difference was not associated with a similar difference in breast muscle thickness which was similar in males and females receiving HP (Figure 4.8), MP (Figure 4.9), and LP (Figure 4.10). Female broiler chickens had significantly higher breast muscle yields than males when slaughtered at similar body weights (Gorman and Balnave, 1995).

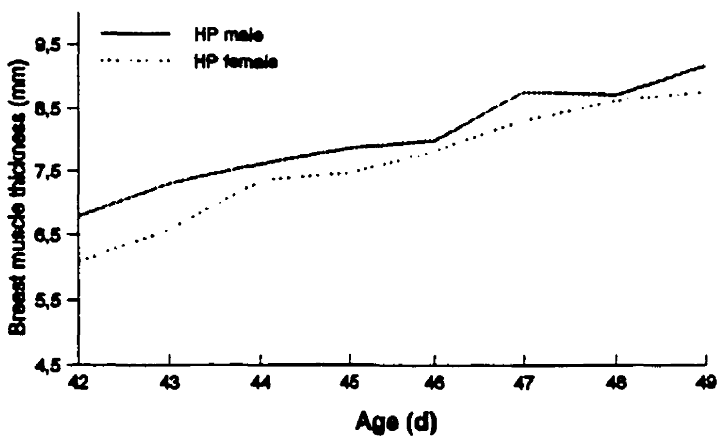

FIGURE 4.8. Effect of high protein program on breast muscle thickness (mm) of males and females Pekin ducks from 42 to 49 d

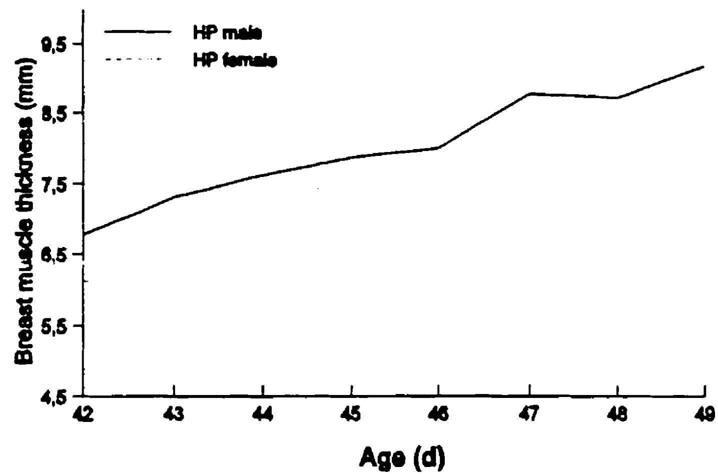

FIGURE 4.9. Effect of medium protein program on breast muscle thickness (mm) of males and females Pekin ducks from 42 to 49 d

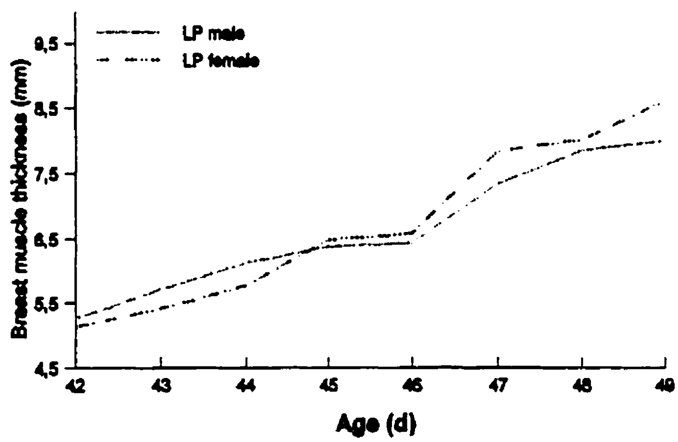

FIGURE 4.10. Effect of low protein program on breast muscle thickness (mm) of males and females Pekin ducks from 42 to 49 d

Carcass characteristics from 42 to 49 d

The effects of dietary program on the carcass components of male ducks at 42, 45, 48, and 49 d of age are presented in Table 4.7. Male ducks on HP had significantly higher yield of wing, pectoralis muscles, and longer keel bone than MP and LP males. The pectoralis muscles yield of the HP males at 45 d was numerically higher than those of the MP and LP at 48 and 49 d of age. This further validates the contribution of the high dietary protein to the earlier development of the breast muscle, the key part of the duck carcass. The HP males also had greater ($P < 0.05$) mass of pectoralis muscles per cm of keel bone than the males on the other programs. The HP males had lower ($P < 0.05$) breast skin and total skin plus fat yields than MP and LP. There was no difference ($P > 0.05$) in leg plus thigh yield of males between HP and LP, but were both higher ($P < 0.05$) than that of MP. The shell yield of HP males was similar ($P > 0.05$) to MP males, but higher ($P < 0.05$) than that of LP while MP and LP had similar ($P > 0.05$) shell yield. Age had no effect on the wing, breast skin, and total skin plus fat yields for the males of the three programs. The pectoralis muscles yield improved from 42 to 45, from 45 to 48, but not from 48 to 49 d. A similar trend was observed for the keel bone length except that there was no difference between 45 and 48d of age. The leg plus thigh and the shell yields were significantly higher ($P<0.05$) at 42 than 45,48,and 49 d of age. Increasing dietary protein improved breast meat yield in male Pekin ducks, and these data agree with those reported on male chickens by Bartov and Plavnik (1998). Considering the yield of the carcass components, the high protein program shows to be more appropriate for males grown to 45 d instead of 49 d of age. Siregar *et al.* (1982b) suggested that low energy to protein ratio was desirable for maximum carcass lean and minimum fat content while a higher ratio was enough for best growth rate of ducklings grown to 8 wk of age.

TABLE 4.7. Effects of dietary program and age on carcass components[1] of male Pekin ducks (n=96)

Program	age	Wing	breast skin	total skin-fat	pecto. muscle	leg+ thigh	shell	pecto/ keel	keel length
		(%)						(g/cm)	(cm)
High protein	42 d	13.63	6.48	23.61	11.8	19.11	25.36	21.31	5.06
High protein	45 d	12.84	7.13	26.25	14.05	17.74	21.98	28.8	5.23
High protein	48 d	12.92	7.09	24.98	15.86	18.06	21.1	30.72	5.22
High protein	49 d	13.23	7.21	23.37	15.79	18.43	21.96	32.58	5.21
Med. protein	42 d	11.82	7.7	28.68	9.84	17.05	24.9	21.1	4.7
Med. protein	45 d	12.13	7.8	28.93	11.72	17.81	21.61	23.71	5.05
Med. protein	48 d	12.18	7.83	28.78	13.62	17.33	20.26	28.04	5.18
Med. protein	49 d	12.95	7.55	28	12.59	16.88	21.04	27.93	5.26
Low protein	42 d	12.44	7.54	29.3	9.6	19.31	21.82	18.09	4.67
Low protein	45 d	11.71	7.77	29.93	11.18	17.47	21.94	23.19	4.96
Low protein	48 d	12.8	7.92	27.43	13.6	18.25	20	25.9	5.05
Low protein	49 d	12.17	8.27	29.28	13.72	17.04	19.53	28.46	5.14
SEM		0.11	0.09	0.33	0.23	0.15	0.29	0.5	0.03
		Probabilities							
Program		0.0005	0.0001	0.0001	0.0001	0.0073	0.0203	0.0001	0.0002
Age		0.2621	0.267	0.1951	0.0001	0.0575	0.0001	0.0001	0.0001
Program*Age		0.1551	0.702	0.4001	0.9742	0.069	0.4373	0.1699	0.1415
Main Effects									
Program	HP	13.15^{a}	6.98^{b}	24.56^{b}	14.38^{a}	18.34^{a}	22.60^{a}	28.35^{a}	5.18^{a}
	MP	12.30^{b}	7.72^{a}	28.60^{a}	12.19^{b}	17.27^{b}	21.95^{ab}	25.20^{b}	5.05^{b}
	LP	12.28^{b}	7.87^{a}	28.99^{a}	12.02^{b}	18.02^{a}	20.82^{b}	23.91^{b}	4.96^{b}
Age	42 d	12.63	7.24	27.2	10.41^{c}	18.49^{a}	24.03^{a}	20.17^{c}	4.81^{c}
	45 d	12.23	7.57	28.37	12.32^{b}	17.67^{b}	21.84^{b}	25.23^{b}	5.08^{b}
	48 d	12.63	7.61	27.07	14.36^{a}	17.88^{b}	20.45^{b}	28.22^{a}	5.14^{ab}
	49 d	12.78	7.68	26.88	14.37^{a}	17.45^{b}	20.84^{b}	29.66^{a}	5.21^{a}

^{abcd} Means within columns with no common superscripts differ significantly ($P < 0.05$)

[1]Wing, breast skin, total skin and fat, pectoralis muscle, leg and tigh, and shell: weight of each part as % of eviscerated carcass weight (without neck and giblets)

Shell: skeleton with remaining meat and fat.

Pecto/keel: grams of pectoralis muscle weight per cm of keel bone length

TABLE 4.8. Effects of dietary program and age on carcass components[1] of female Pekin ducks (n=96)

Program	age	Wing	breast skin	total skin-fat	pecto. muscle	leg + thigh	shell	pecto/keel	keellength
		(%)						(g/cm)	(cm)
High protein	42 d	12.94	6.95	28.17	11.06	17.95	22.93	20.33	4.79
High protein	45 d	12.17	8.13	28.11	12.81	16.84	21.95	25.64	4.89
High protein	48 d	12.6	8.03	27.73	15.15	16.74	19.76	28.46	4.94
High protein	49 d	12.6	8.14	27.98	15.36	17.53	18.39	28.18	5.03
Med protein	42 d	12.33	7.54	28.19	11.05	17.12	23.76	21.94	4.74
Med protein	45 d	12.19	8.04	29.1	12.78	16.22	21.67	24.27	4.88
Med protein	48 d	12.22	8.12	28.51	15.2	16.66	19.29	29.73	4.99
Med protein	49 d	12.21	7.83	28.39	14.55	16.42	20.61	28.8	5.01
Low protein	42 d	12.26	7.72	28.39	10.2	17.15	24.29	19.96	4.75
Low protein	45 d	11.78	7.85	28.24	11.78	16.69	23.67	24.36	4.85
Low protein	48 d	12.36	8.1	29.8	14.24	16.42	19.09	26.4	4.95
Low protein	49 d	11.89	7.92	28.74	14.66	17.2	19.59	28.58	5.13
SEM		0.1	0.08	0.26	0.21	0.14	0.29	0.4	0.02
		Probabilities							
Program		0.1355	0.9256	0.3963	0.0106	0.1692	0.4761	0.1706	0.9418
Age		0.3313	0.0235	0.9241	0.0001	0.1504	0.0001	0.0001	0.0001
Program*Age		0.9423	0.61	0.8966	0.8399	0.9259	0.2961	0.3088	0.9198
Main Effects									
Program	HP	12.58	7.81	28.25	13.60^{a}	17.26	20.76	25.65	4.91
	MP	12.23	7.88	28.55	13.39^{a}	16.6	21.33	26.18	4.9
	LP	12.07	7.89	28.79	12.72^{b}	16.86	21.66	24.83	4.92
Age	42 d	12.51	7.40^{b}	28.25	10.77^{c}	17.4	23.66^{a}	20.74^{c}	4.76^{c}
	45 d	12.04	8.00^{a}	28.48	12.46^{b}	16.58	22.43^{a}	24.76^{b}	4.88^{bc}
	48 d	12.39	8.08^{a}	28.68	14.86^{a}	16.61	19.38^{b}	28.20^{a}	4.96^{ab}
	49 d	12.23	7.96^{a}	28.37	14.86^{a}	17.05	19.53^{b}	28.52^{a}	5.06^{a}

[abcd] Means within columns with no common superscripts differ significantly ($P < 0.05$)

[1]Wing, breast skin, total skin and fat, pectoralis muscle, leg and tigh, and shell: weight of each part as % of eviscerated carcass weight (without neck and giblets)

Shell: skeleton with remaining meat and fat.

Pecto/keel: grams of pectoralis muscle weight per cm of keel bone length

The effects of dietary program on the carcass components of female ducks at 42, 45, 48, and 49 d of age are presented in Table 4.8. Increasing dietary protein had no effect ($P > 0.05$) on any of the carcass components yield except for the pectoralis muscles yield that was similar ($P > 0.05$) for HP and MP, but both had greater ($P < 0.05$) yield than LP. Age from 42 to 49 d had no effect ($P > 0.05$) on the yield of wing, total skin plus fat, and leg plus thigh. The females at 42 d had less ($P < 0.05$) breast skin yield than those at 45, 48, and 49 d that had similar ($P > 0.05$) yields. There was an improvement ($P < 0.05$) in the pectoralis muscles yield and pectoralis mass per keel bone length from 42 to 45 d, and from 45 to 48 d, but there was no difference ($P > 0.05$) between the yields at 48 and 49 d of age. The keel bone length increased ($P < 0.05$) from 42 to 49 d. There was a difference ($P < 0.05$) in the keel length between 42 and 48 or 49 d, but not ($P > 0.05$) between 42 and 45 d; between 45 and 49, but not between 45 and 48 d; and there was no difference between 48 and 49 d of age. Gorman and Balnave (1995) reported that increasing dietary protein resulted in a significant increase in breast muscle yield of female chickens grown to 52 d of age. Breast meat yield in female chickens improved at 57d, but not at 43 d of age, upon feeding low energy to protein ratio (Bartov, 1998). He used a ratio lower than recommended (NRC, 1994); this ratio is relatively comparable to the high protein program used in this study. His results in female chickens at 43 d are in accordance with ours in female Pekin ducks where the breast meat yield did not improve upon feeding high dietary protein up to 49 d of age.

The effects of the dietary protein program on carcass yield and composition of males at 42, 45, 48, and 49 d of age are presented in Table 4.9. Increasing dietary protein did not have an effect on the carcass yield, but the HP male carcasses contained significantly less DM and fat, and contained more CP and ash on DM basis than MP and

TABLE 4.9. Effects of dietary program and age on carcass yield and composition of male Pekin ducks (n=300)

Program	Age	Car. Yield[1]	DM	EE	CP	Ash
		(%)				
High protein	42 d	70.6	36.77	52.98	38.39	8.63
High protein	45 d	72.91	37.52	55.91	36.35	7.73
High protein	48 d	72.88	39.34	54.79	36.46	8.57
High protein	49 d	72.88	39.5	55.75	35.81	8.44
Med protein	42 d	71.97	39.5	60.82	32.22	6.96
Med protein	45 d	72.72	40.12	60.17	33.09	6.74
Med protein	48 d	72.02	42.39	60.5	31.96	7.54
Med protein	49 d	72.56	41.21	60.1	32.64	7.26
Low protein	42 d	71.09	39.15	60.73	32.44	6.83
Low protein	45 d	73.06	39.85	59.57	33.38	7.06
Low protein	48 d	71.36	41.82	60.66	32.49	6.85
Low protein	49 d	72.4	41.67	61.54	31.49	6.97
SEM		0.19	0.17	0.31	0.25	0.08
		Probabilities				
Program		0.707	0.0001	0.0001	0.0001	0.0001
Age		0.0139	0.0001	0.6636	0.2672	0.0931
Program*Age		0.6242	0.9112	0.2984	0.3175	0.1865
Main Effects						
Program	HP	72.32	38.28^{b}	54.91^{b}	36.75^{a}	8.34^{a}
	MP	72.32	40.80^{a}	60.40^{a}	32.48^{b}	7.13^{b}
	LP	71.98	40.62^{a}	60.62^{a}	32.45^{b}	6.92^{b}
Age	42 d	71.22^{b}	38.47^{b}	58.17	34.35	7.47
	45 d	72.90^{a}	39.16^{b}	58.55	34.27	7.17
	48 d	72.09^{a}	41.18^{a}	58.71	33.64	7.65
	49 d	72.61^{a}	40.79^{a}	59.13	33.31	7.56

^{ab} Means within columns with no common superscripts differ significantly ($P < 0.05$)

[1]Carcass yield : eviscerated carcass weight (including neck and giblets) as a % of live weight

LP male carcasses. There was no significant difference between MP and LP carcasses for any of the carcass composition parameters. At 42 d of age, the males had lower ($P < 0.05$) carcass yield compared to 45, 48, or 49 d that had similar ($P > 0.05$) carcass yield. The

DM content of the male carcasses were similar (P >0.05) at 42 and 45 d, and it was less (P < 0.05) than the DM content of the carcasses at 48 or 49 d that had similar (P > 0.05) DM content. There was no effect (P > 0.05) of age from 42 to 49 d on fat, CP and ash content of the male carcasses. This may indicate that the decline in feed efficiency observed previously (Farhat and Chavez, 1999b) during wk 7 of growth is mainly due to the higher maintenance demand of heavier birds and to the service of gain in general and not to the deposition of either fat or protein. In terms of carcass yield and composition, the data do not point out disadvantages in marketing the males as early as 45 d of age.

The effects of dietary protein program on carcass yield and composition of female ducks at 42, 45, 48, and 49 d are presented in Table 4.10. There was no difference (P > 0.05) among dietary programs for carcass yield and DM content of the carcass. Similarly to males, females at 42 d of age had lower (P < 0.05) carcass yield than those at 45, 48, or 49 d that had similar (P > 0.05) yields. The DM content increased (P < 0.05) from 42 to 45 d, and from 45 to 58 d, but was similar (P > 0.05) between 48 and 49 d of age. Similarly to males also, HP female carcasses contained less fat and more ash than MP and LP carcasses. The CP content of the HP carcasses was significantly different from those of LP, but the CP content of MP carcasses was not different (P > 0.05) from either that of HP or LP. There was no age effect on carcass fat or ash content, but the CP content decreased as the birds grew from 42 to 49 d. The CP content at 42 d was similar to that of 45 d, but different from that of 48 d; at 45 d, the CP content was similar to that of 48 d, but different from that of 49 d; and there was no difference between 48 and 49 d of age.

Similarly to the dissection data, increasing dietary protein decreased carcass fat and increased carcass protein. The data on carcass fat and protein of the MP and LP males and females agree with previous reports (Farhat and Chavez, 1999b) where the

TABLE 4.10. Effects of dietary program and age on carcass yield and composition of female Pekin ducks (n=300)

Program	Age	Car. Yield[1]	DM	EE	CP	Ash
		(%)				
High protein	42 d	71.39	39.24	58.98	33.66	7.37
High protein	45 d	73.33	41.09	60.69	32.33	6.78
High protein	48 d	73.77	42.13	59.78	32.87	7.35
High protein	49 d	74.85	41.22	61.18	31.42	7.40
Med protein	42 d	73.56	39.06	59.39	33.35	7.26
Med protein	45 d	73.82	41.2	60.81	32.61	3.38
Med protein	48 d	74.61	43.14	62.98	30.54	6.48
Med protein	49 d	73.81	42.82	62.27	30.86	6.86
Low protein	42 d	72.77	40.21	62.42	30.91	6.67
Low protein	45 d	74.58	40.35	61.1	31.97	6.73
Low protein	48 d	72.76	42.86	62.24	31.02	6.74
Low protein	49 d	73.23	41.84	61.98	31.1	6.92
SEM		0.2	0.17	0.24	0.19	0.07
		Probabilities				
Program		0.3402	0.2624	0.0100	0.0160	0.004
Age		0.0370	0.0001	0.0630	0.0160	0.3338
Program*Age		0.0749	0.2588	0.099	0.1105	0.2969
Main Effects						
Program	HP	73.34	40.92	60.16^{b}	32.57^{a}	7.27^{a}
	MP	73.95	41.55	61.36^{a}	31.84^{ab}	6.80^{b}
	LP	73.36	41.31	61.94^{a}	31.25^{b}	6.82^{b}
Age	42 d	72.57^{b}	39.51^{c}	60.26	32.64^{a}	7.10
	45 d	73.91^{a}	40.88^{b}	60.87	32.30^{ab}	6.83
	48 d	73.72^{a}	42.71^{a}	61.67	31.48^{bc}	6.86
	49 d	73.99^{a}	41.96^{a}	61.81	31.13^{c}	7.06

[abc] Means within columns with no common superscripts differ significantly ($P < 0.05$)

[1]Carcass yield : eviscerated carcass weight (including neck and giblets) as a % of live weight

ducks selected for greater breast muscle thickness had carcasses with 60 and 31 % fat and CP on DM basis, respectively. In the current study, the HP decreased carcass fat by 10 % and increased carcass CP by 13 % compared to MP and LP. However, increasing dietary protein in females decreased carcass fat and increased CP by only 2 %. The data presented herein are in accordance with the literature on the effect of increasing dietary protein on carcass fat and CP in broiler chickens (Leeson *et al.*, 1996; Whitehead *et al.*, 1990).

Plasma uric acid and total protein from 42 to 49 d

Plasma uric acid may be considered an indication of the protein quality in the feed and its utilization because it is the residue of amino acid oxidation in birds. Within each dietary program, the difference in plasma uric acid concentrations may reveal the efficiency of the protein utilization at each of the four days of measurements during wk 7. Plasma uric acid of HP males declined ($P < 0.05$) from 42 to 45 d, and that of MP and LP males increased ($P < 0.05$) to a level similar ($P > 0.05$) to that of HP at 42 d (Figure 4.11). From 45 to 49 d, plasma uric acid concentrations of MP and LP males declined ($P < 0.05$) to a concentration similar ($P > 0.05$) to that of HP males at 45 d. This may indicate that the efficiency of protein utilization in the males receiving HP was seen earlier than in those receiving either MP or LP.

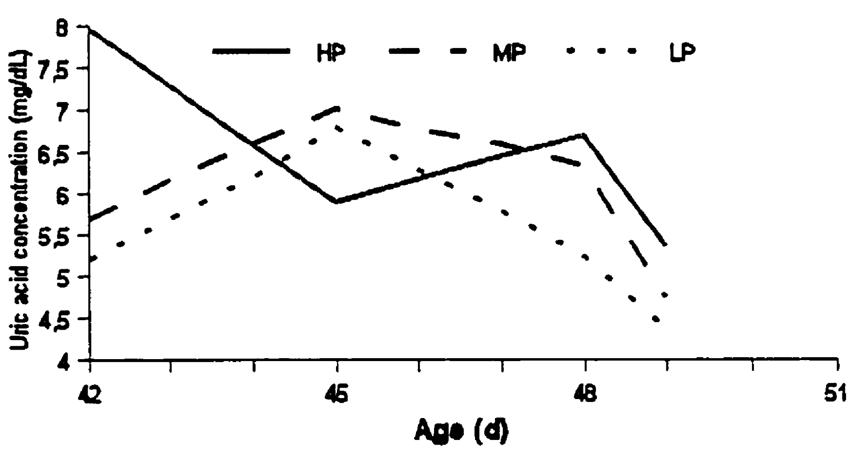

FIGURE 4.11. Plasma uric acid content (mg/dL) in male Pekin ducks from 42 to 49 d for different dietary protein

Plasma uric acid of females declined from 42 to 45 for the three dietary programs (Figure 4.12). While there was no difference (*P* > 0.05) in the uric acid concentrations between 45 and 48 d of HP and MP, the concentration of LP females was significantly higher at 48 than at 45 d, but declined again at 49 d (Figure 4.12).

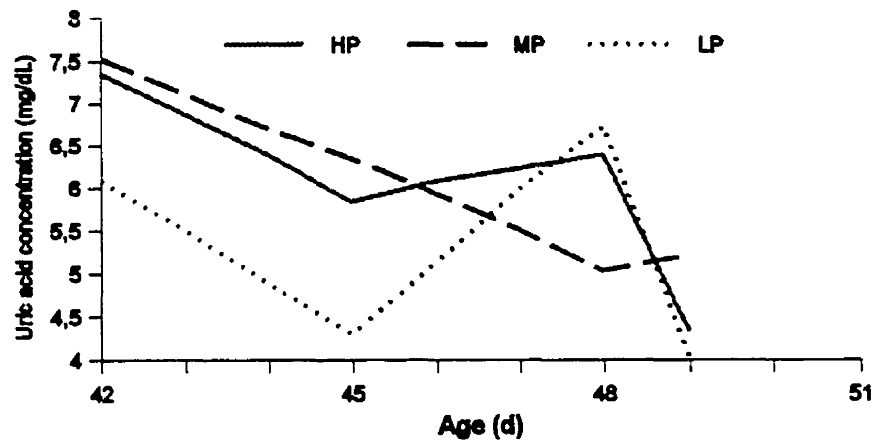

FIGURE 4.12. Plasma uric acid content (mg/dL) in female Pekin ducks from 42 to 49 d for different dietary protein

Dietary protein did not affect total plasma protein in males and females (Figures 4.13 and 4.14). This observation in Pekin ducks does not agree with that reported in growing chickens where increasing dietary protein resulted in an increase in plasma protein (Leveille and Sauberlich, 1961). At 42 d, plasma protein concentration of both males and females were lower than at 45 d, and similar to 48 d concentration; the concentration at 49 d were the highest among the four days of measurements. However, the plasma protein concentration of MP females was an exception where it showed a plateau from 42 to 48 d, and increased significantly at 49 d (Figure 4.14).

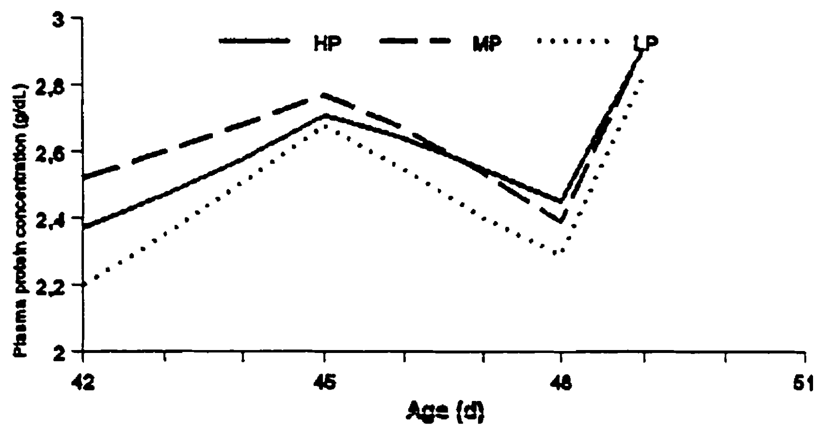

FIGURE 4.13. Plasma protein content (g/dL) in male Pekin ducks from 42 to 49 d for different dietary protein

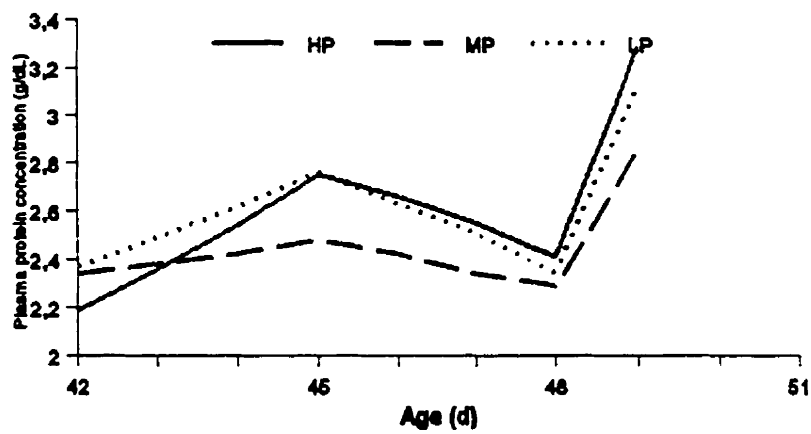

FIGURE 4.14. Plasma protein content (g/dL) in female Pekin ducks from 42 to 49 d for different dietary protein

There was a negative correlation between plasma uric acid and total plasma protein which was higher for the females on HP (r= -0.61, *P*= 0.0004, n= 30) and LP (r= -68, *P*= 0.0001, n= 29) than for the three program together (r= -0.48, *P*= 0.0001, n= 90) because the MP data did not correlate. The correlation in the males was only significant for the HP birds. When the data of males and females for the three dietary programs were combined, the correlation was low (r= -0.18, *P*= 0.0136, n= 184). LeResche *et al.* (1974) suggested that gluconeogenesis may result in a depression in total plasma protein that may be used to assess dietary inadequacies.

Correlations of parameters

Correlations between carcass component and composition, ultrasound and caliper measurements, and plasma parameters of males and females from 42 to 49 d are presented in Table 4.11.

Breast muscle thickness correlated positively ($P < 0.05$) with body weight, total breast thickness (TOT), pectoralis muscles yield, the keel bone length, and total plasma protein concentration (Table 4.11). There was a negative ($P < 0.05$) correlation between the breast muscle thickness and the yields of leg plus thigh and the shell of the carcass. Despite the significant correlation between MT and pectoralis yield ($r= 0.73$, $P= 0.0001$), MT did not correlate ($P > 0.05$) with carcass fat or CP. König et al. (1998) reported correlation of 0.69 and 0.68 for breast muscle thickness measured with ultrasound and breast meat yield as a percent of carcass weight in cocks and hens, respectively. In the Pekin ducks, we found correlations of 0.77 and 0.70 for breast muscle thickness measured with ultrasound and the breast muscle yield as a percentage of carcass weight in males and females, respectively.

Pectoralis muscles yield correlated positively ($P < 0.05$) with body weight, TOT, keel bone length, carcass CP and total plasma protein; and correlated negatively ($P < 0.05$) with pectoralis yield and total skin plus fat, carcass shell, and carcass fat.

The caliper measurement of the breast skin correlated positively ($P < 0.05$) with the total breast minus breast muscle measurement taken with ultrasound, total skin plus fat, breast skin plus fat, and carcass fat; and correlated negatively ($P < 0.05$) with carcass CP. The correlation of breast skin plus fat thickness, taken form processed carcasses, with breast skin yield and whole carcass fat were reported to be 0.72 and 0.68, respectively (Walters *et al.*, 1994). On live ducks, we found correlations of 0.19 for breast muscle thickness and breast skin plus fat yield or eviscerated carcass fat (without neck and giblets). The correlations between carcass fat and breast skin plus fat or total skin plus fat in our study were 0.49 and 0.76, respectively.

TABLE 4.11. Correlations between carcass, and ultrasound and caliper measurements, and blood parameters in male and female Pekin ducks (pooled data from 42 to 49 d of age; n=192)

Parameters	r	*P*	Parameters	r	*P*
MT*body Wt.	0.44	0.0001	Caliper*TOT - MT	0.20	0.0001
MT*TOT	0.89	0.0001	Caliper*tot. skin+fat	0.22	0.0001
MT*pectoralis	0.73	0.0001	Caliper*br.skin+fat[3]	0.19	0.01
MT*keel length	0.43	0.0001	Caliper*FAT	0.19	0.01
MT*pl.Protein[1]	0.30	0.0001	Caliper*CP	-0.20	0.0001
MT*leg+thigh	-0.20	0.02			
MT*shell	-0.40	0.0001	IGF-I*FAT	-0.10	0.09
MT*FAT	-0.01	0.922	IGF-I*CP	0.14	0.06
MT*CP	-0.03	0.694	pl.protein*FAT	0.10	0.505
			pl.protein*CP	-0.22	0.188
Pectoralis*body Wt.	0.27	0.0001			
Pectoralis*TOT	0.68	0.0001	Wing*pectoralis	0.17	0.02
Pectoralis*keel length	0.47	0.0001	Wing*leg+thigh	0.55	0.0001
Pectoralis*CP	0.15	0.04	Wing*keel length	0.20	0.0001
Pectoralis*pl.protein	0.22	0.0001	Wing*CP	0.44	0.0001
Pectoralis*tot.skin+fat[2]	-0.30	0.0001	Wing*tot. skin+fat	-0.60	0.0001
Pectoralis*shell	-0.50	0.0001	Wing*br.skin+fat	-0.30	0.0001
Pectoralis*FAT	-0.20	0.02	Wing*FAT	-0.40	0.0001

Correlations between breast muscle thickness (MT), total breast thickness (TOT), body weight (body Wt.), and carcass fat (FAT) and CP (CP) were taken from 584 male and female ducks.
Correlations between anatomical carcass components, ultrasound and caliper measurements, and blood parameters were taken from 190 male and female ducks.
Correlations between caliper measurements and carcass components and composition were taken from 240 ducks.

[1] Total plasma protein
[2] Total skin plus fat
[3] Breast skin plus fat

There was no significant correlation between plasma parameters and carcass fat or CP. Plasma IGF-I concentration was found to be higher in lean than in fat ducks (Farhat and Chavez, 1999b). Allison (1955) considered total plasma protein as an indication of total protein reserves in an animal. The wing yield had a positive correlation ($P < 0.05$) with pectoralis and leg plus thigh yields, keel bone length, and carcass protein; and correlated negatively ($P < 0.05$) with total skin plus fat, breast skin plus fat, and carcass fat.

CONCLUSION

Current trends in consumer demands have promoted the selection of animals with improved carcass parts that contribute more to edible meat and less fat. The breast meat is the most valuable part of a bird carcass, and selection for this trait employed many techniques including ultrasound scanning. A correlation of 0.73 was found for the ultrasound measurement and the breast meat yield in this study that included males and females receiving three different dietary protein programs. Collectively, male Pekin ducks selected for greater breast muscle thickness responded more efficiently than females to increasing dietary protein. The high dietary protein program contributed to the early development of breast muscle of males at market weight. This observation may be of considerable economical importance for producers in terms of flock turnover and feed conversion efficiency. The correlation coefficients presented herein indicate the relationship of different carcass components and in vivo measurements done by ultrasound. The carcass of ducks raised on HP program contained significantly more protein and less fat than the MP and LP feeding programs. This is a direct benefit for the consumer.

Connecting Statement: Section II,III,IV and Section V

Sections II, III, and IV presented the reproductive performance, carcass characteristics of the ducks selected by ultrasound and their response to dietary protein. The selection resulted in modified carcass composition and some blood parameters. Similar to other means of selection, ultrasound scanning is expected to bring about some effects expected to be seen in the metabolic performance of the ducks. Section V presents the metabolic differences between ducks with high or low breast muscle thickness and determines the effect of fasting and feeding on blood parameters related to leanness or fatness.

SECTION V

Metabolic studies on lean and fat Pekin ducks selected for breast muscle thickness measured by ultrasound scanning

By

ANTOINE FARHAT AND EDUARDO R. CHAVEZ

Department of Animal Science
Macdonald Campus of McGill University
21,111 Lakeshore Road, Ste.Anne de Bellevue
Québec, Canada. H9X 3V9

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ABSTRACT

Thirty male and thirty female Pekin ducks selected for High or Low breast muscle:total breast thickness ratio (MT/TOT) were used in metabolic studies to determine the metabolic differences and assess the effects of fasting and refeeding on plasma parameters. The endogenous energy and nitrogen (N) losses were determined by giving control ducks either dextrose (DS) or starch-oil (SO) solutions. The two groups (High or Low MT/TOT) had similar body weight change throughout the studies. Males from both groups had similar body composition, while the female High MT/TOT had significantly lower fat and higher crude protein (CP) and ash carcass content. High MT/TOT males had similar plasma glucose in the fasting state, but higher ($P < 0.05$) concentration after feeding, and lower ($P < 0.05$) plasma cholesterol than the Low MT/TOT in both states. There was no difference in plasma triglycerides (TG) and uric acid between the 2 groups of males. Fasting resulted in higher ($P < 0.05$) plasma cholesterol and lower ($P < 0.05$) plasma uric acid in males. High MT/TOT females had higher ($P < 0.05$) plasma glucose during fasting, but lower ($P < 0.05$) concentration during feeding. Low MT/TOT females had similar plasma TG after fasting but higher ($P < 0.05$) TG concentration after feeding, and higher ($P < 0.05$) plasma uric acid than the High MT/TOT females after feeding. Similarly to males, fasting in females resulted in higher ($P < 0.05$) plasma cholesterol than feeding. The group had no effect on the dry matter (DM), N, and energy excretion in the males fed the test diet, but the High MT/TOT females fed the test diet retained more ($P < 0.05$) N than the Low MT/TOT females. There was no effect of group on AME and AME_n in both males and females. Feeding SO solution to control birds, for the estimation of the endogenous losses, resulted in less ($P < 0.05$) DM and energy excretion than feeding DS in males and females, and less ($P < 0.05$) N losses in females. High MT/TOT females lost less ($P < 0.05$) N than Low MT/TOT females. Both the group and the method of estimation of endogenous losses had no effect on TME and TME_n.. Plasma cholesterol tended to be negatively correlated ($P = 0.06$) with nitrogen retention (NR), NR negatively correlated ($P < 0.05$) with plasma TG, and TG positively correlated ($P < 0.05$) with total energy excreted in female ducks. There was a positive correlation ($P < 0.05$) between MT/TOT and NR. The MT/TOT correlated ($P < 0.05$) negatively with carcass fat and positively with carcass CP. Estimation of carcass fat or CP content were presented in prediction equations from carcass DM and ash content. The excreta from the ducks fed SO solution contained higher ($P < 0.05$) fat content, but the birds fed either DS or SO solution excreted similar amounts of fat. The amount of individual fatty acid excreted by the birds fed DS was higher ($P < 0.05$) than the SO excreta for all the fatty acids common in both profiles. The results obtained further validate the usefulness of ultrasound scanning in live birds selection for leanness and greater breast muscle thickness, and describe metabolic differences between birds with high or low MT/TOT ratios.

INTRODUCTION

Health conscious consumers are demanding meat products low in fat and high in protein. The consumption of duck meat, in the Western society, remains negligible compared to chicken meat mainly because of culture, custom and price, and partially because of its fat content. At market age, Pekin duck carcasses contain 30 % fat compared to 15 % fat in broiler chickens (Plavnik *et al.*,1982). Improvement of breast meat yield has increased in importance to ameliorate poultry carcass quality and satisfy the consumer choice of ready-to-eat meals (Pollock., 1997).

The use of an ultrasound technique to select for greater breast muscle thickness and leaner ducks has been proven feasible (Farhat and Chavez, 1999b). The selection for greater breast muscle thickness should produce some effects expected to be seen, besides carcass composition, in the metabolic performance.

Leclercq and Saadoun (1982) reported no differences between lean and fat lines of chickens in terms of their ability to metabolize dietary energy, their energetic efficiencies of protein and lipid deposition, and their maintenance requirement. Geraert *et al.* (1988) reported similar TME_n and ME for maintenance between genetically lean and fat chickens, but more protein deposition in the lean line. Similarly, Laurin *et al.*, (1985) found no difference in AME_n and TME_n between lean and fat lines of chickens.

Plasma triglyceride concentration was suggested as an indicator of body fatness in chickens (Griffin *et al.*, 1982). Plasma very low density lipoprotein (VLDL) concentration was used as a basis for selecting lines of lean and fat broilers at 7 wk of age (Whitehead and Griffin, 1984). Positive correlation was found between abdominal fat and blood cholesterol concentration in female Pekin ducks (Ksiazkiewcz *et al.*, 1993). Leclercq and Guy (1988) reported significantly lower concentrations of triglycerides (TG) in the lean than in the fat line selected for low or high abdominal fat. The authors observed an intra-correlation between TG and abdominal fat in chickens selected for low or high blood glucose level. However, Baeza *et al.* (1997) found no correlation between body fat content and triglyceride or VLDL concentration in Muscovy ducks. In Pekin ducks, Akbar (1996) reported a non-significant correlation between carcass fat and VLDL. Selection based on plasma glucose level in chicken resulted in significant differences in fattening (Leclercq *et al.*, 1987). In these birds, plasma glucose concentrations were lower in fat line compared to lean line chickens whether in a fasted or fed state and regardless of the dietary protein or energy levels (Touchburn *et al.*,1981). Plasma uric acid level was higher in the plasma of the fat line compared to the lean line selected for low or high abdominal fat content (Leclercq, 1988). The phenotypic variation between lean and fat ducks should be associated with metabolic differences.

OBJECTIVE

The objectives of these studies were to determine the metabolic differences in terms of metabolizable energy and nitrogen retention between lean and fat male and female ducks, to test the effect of fasting and feeding on blood parameters, to associate metabolic parameters and body composition. In addition, the difference between two feeding solutions for the determination of metabolic endogenous losses were determined.

MATERIALS AND METHODS

General conduct of the studies

Thirty male and thirty female ducklings were selected at 6 wk of age for a high or low breast muscle:total breast measurement ratio (High or Low MT/TOT), and a similar body weight, from the F1 progeny of ducks selected for greater breast muscle thickness. The studies were done with males and females separately. The birds were moved from floor pens into individual metabolic cages for a two-day adaptation period where they were fed the same commercial pelleted feed. Following adaptation, the birds were feed-deprived for 48 h during which they were offered a dextrose solution (DS) (40g/100 ml of water) at 8 and 32 h after feed withdrawal (McNab and Blair, 1988). This solution was offered to partially reduce the effect of energy deprivation on the birds during feed deprivation. There were two groups (High and Low MT/TOT) and seven birds per group that were fed the test diet. Two methods of estimation of fasting energy and nitrogen losses were included, one based on precisely feeding the control ducks a dextrose solution and the other based on precisely feeding a corn starch-oil solution (38.76 g corn starch+1.24 g corn oil per 100ml water) instead of the test diet. Each method included four birds per group (High and Low MT/TOT) for the estimation of fasting energy and nitrogen losses. Each bird represented an experimental unit. At 48 and 54 h, each bird was precisely fed 40 g of the test diet (a corn-SBM finisher diet) except for the control group that received either the dextrose solution or the starch-oil solution. A dextrose solution is commonly used, but this method employs an ingredient that does not trigger the excretion of amylases, lipases, and bile acids. The corn starch and oil solution provides the same energy supplied by the dextrose solution but it also triggers the enzymes secretion and action, which mimics better the normal conditions than the dextrose solution. True metabolizable energy of the test diet and nitrogen retention were calculated using both methods. To validate the starch-oil method, the excreta were analyzed for starch[8], total fat (AOAC, 1990), and fatty acids by

[8]Cat. No 207748 Boehringer Mannheim Quebec, QC H7V.

gas-liquid chromatography[9]. Collection trays were placed under the metabolic cages and excreta were collected for 48 h. Excreta samples were frozen, freeze-dried, allowed to come to equilibrium with the atmospheric moisture, weighed, and ground through a 0.5-mm sieve. Sub-samples were assayed for gross energy in an adiabatic oxygen bomb calorimeter, analysed for DM using a vacuum oven[10], and N using a N analyzer[11]. The metabolic studies followed the protocol described in Table 5.1.

TABLE 5.1. Protocol followed in the metabolic studies

day/hour	Procedure
36181	Feed withdrawal
36196	Each bird received DS
36224	Each bird received DS
36261	Control birds received DS or SO; All other birds 40 g of test diet.
36264	Control birds received DS or SO; All other birds 40 g of test diet
36285	Blood sample from wing vein after overnight fasting (fasting state)
36294	Excreta were collected and frozen
36325	Excreta were collected and frozen
36330	Ad libitum feeding of a finisher diet
36499	Blood samples from wing vein after overnight fasting (fed state)

DS: dextrose solution (40 g / 100 ml water)
SO: starch-oil solution (38.76 g corn starch+1.24 g corn oil per 100ml water)

Blood and Carcass analysis

After 48 h of excreta collection during feed deprivation, all the birds were fed ad libitum a finisher diet for 4 d until they recovered their body weight at the beginning of the studies. Blood samples (3 mL from the wing vein) were taken on d 5 for fasting state and d 12 for fed state after overnight fasting into heparinized tubes and centrifuged at 1500 G for 15

[9]Series II # 5890, Hewlett-Packard, Palo Alto, CA 94304-1181.
[10]National Appliance Co., Portland, OR 97223.
[11]Leco FP-428, Leco Corp., St. Joseph, MI 49085-2396.

min. Plasma was stored at -20C pending analysis. Plasma glucose, triglycerides, total cholesterol, and uric acid were analyzed using a clinical discrete analyzer[12]. Plasma IGF-I was determined by RIA (Farhat and Chavez, 1999e). At 53 d of age, eviscerated carcasses of the ducks were ground, and sub-samples were taken for analyses. Following freeze-drying, sub-samples were analyzed for DM, N, and fat, and ash was determined using a muffle furnace[13]. A factor of 6.25 x N was used for the calculation of CP.

Ultrasound Measurements

Breast muscle thickness was measured at 6 wk of age by an ultrasound system which consisted of an ECHO 1000[14] portable real-time ultrasound scanner, equipped with a 7.5 MHz linear array probe. The measurements were taken on a frozen image where the distance between 2 points (mm) was calculated using a built-in caliper.

Statistical Analysis

Statistical analyses of the data were performed using the General Linear Models (GLM) procedures and mixed model of the SAS® (1990) library. The plasma parameters and body weight data were treated as repeated measures with simple covariance structure and the duck was included as random effect. The multi-comparison Scheffe's test was used to separate the differences among the means for statistical significance ($P < 0.05$).

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[12]Model VP super system, Abbott Laboratories, Mississauga, ON L5N 3R3.
[13] Model F-A1730, Sybron Thermolyne, Dubuque, IA 52001.
[14]ECHO 1000, Alliance Medical Inc., Montreal, Canada H4T 1G1.

RESULTS AND DISCUSSION

Body weight and Carcass data

The male and the female Pekin ducks from both groups (High or Low MT/TOT) maintained similar body weight ($P > 0.05$) from 42 to 53 d of age throughout the feed deprivation and refeeding periods (Table 5.2).

TABLE 5.2. Body weight change of male and female Pekin ducks with different breast muscle thickness[1] during feed deprivation (42-48 days of age) and after feeding (48-53 days of age)

Males n=30										
Group	Breast thickness			Body weight						
	TOT	MT	MT/TOT	42	44	45	46	47	48	53
	— (mm) —			(kg)						
High	9.46[a]	6.9[a]	0.73[a]	3	2.8	2.7	2.7	2.6	2.5	3.1
Low	8.13[b]	4.1[b]	0.51[b]	3	2.7	2.7	2.6	2.6	2.5	3.1
SEM	0.17	0.3	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Prob.	0.0001	0.0001	0.0001	0.1742	0.3594	0.1204	0.087	0.5692	0.102	0.53

Females n=30										
Group	Breast thickness			Body weight						
	TOT	MT	MT/TOT	42	44	45	46	47	48	53
	— (mm) —			(kg)						
High	8.8	5.6[a]	0.63[a]	2.7	2.6	2.5	2.4	2.5	2.4	2.84
Low	9.1	4.1[b]	0.45[b]	2.7	2.6	2.5	2.4	2.4	2.3	2.77
SEM	0.18	0.20	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.06
Prob.	0.4226	0.0001	0.0001	0.9272	0.4052	0.6862	0.3538	0.2301	0.378	0.5773

[1]High or low MT/TOT: breast muscle/total breast thickness measured by ultrasound scanning.

[a,b] Means within columns with different superscripts are statistically different ($P < 0.05$)

Simon and Leclercq (1982) indicated that the selection of broilers for low or high ratios of abdominal fat to body weight resulted in two lines of chicken that considerably differed in carcass lipid content while maintaining similar body weight. The ducks in this experiment were selected based on their MT/TOT, and in both sexes, the High and the Low MT/TOT groups showed differences ($P < 0.05$) in the MT and MT/TOT. However, while High MT/TOT males had greater ($P < 0.05$) TOT than Low MT/TOT males, female ducks from both groups had similar ($P > 0.05$) TOT (Table 5.2).

TABLE 5.3. Carcass composition of male and female Pekin ducks with different breast muscle thickness[1] at 53 d of age

Males n=30				
Group	Dry Matter	Fat	Protein	Ash
	(%)			
High MT/TOT	45.08	58.84	34.01	7.34
Low MT/TOT	44.36	58.35	34.07	7.58
SEM	0.4	0.59	0.48	0.17
Probability	0.3788	0.6835	0.7999	0.4929
Females n=30				
Group	Dry Matter	Fat	Protein	Ash
	(%)			
High MT/TOT	43.11	51.01^{b}	40.46^{a}	8.53^{a}
Low MT/TOT	45.43	61.35^{a}	31.99^{b}	6.67^{b}
SEM	0.84	2.26	1.88	0.46
Probability	0.1796	0.0161	0.0186	0.0392

^{ab}Means within columns with different superscripts are statistically different ($P < 0.05$)

[1]High or low MT/TOT: breast muscle/total breast thickness measured by ultrasound scanning.

The inclusion of the TOT in the ratio was to account for the breast skin and fat thickness that was reported to be significantly correlated with carcass fat in Pekin ducks (Walters *et al.*, 1994). The males from both groups had also similar ($P > 0.05$) carcass composition (DM, fat, CP, and ash) at 53 d of age (Table 5.3). The High MT/TOT female possessed carcasses similar ($P > 0.05$) in DM, lower ($P < 0.05$) in body fat, and higher ($P < 0.05$) in CP and ash than the Low MT/TOT females. In the males, there were no significant

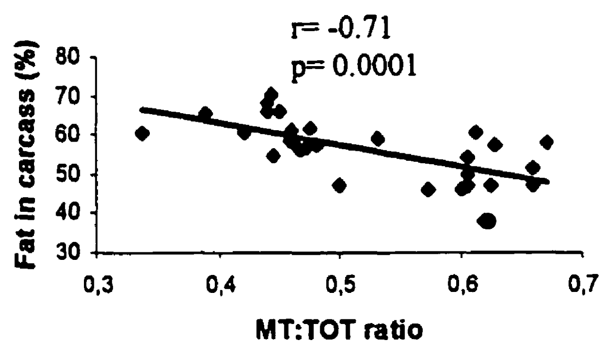

FIGURE 5.1. Relationship between carcass fat and MT/TOT in 30 female Pekin ducks at 53 d of age

correlations between the ultrasound measurements and carcass composition. However, in the females there were significant correlations between MT/TOT and percent fat (Figure 5.1) and percent CP (Figure 5.2) in the carcass. In these studies, plasma was also analysed for IGF-I, and the High MT/TOT females had higher ($P < 0.05$) plasma IGF-I than the Low MT/TOT females (Farhat and Chavez, 1999e)). Furthermore, plasma IGF-I positively correlated ($P < 0.05$) with MT/TOT (Figure 5.3).

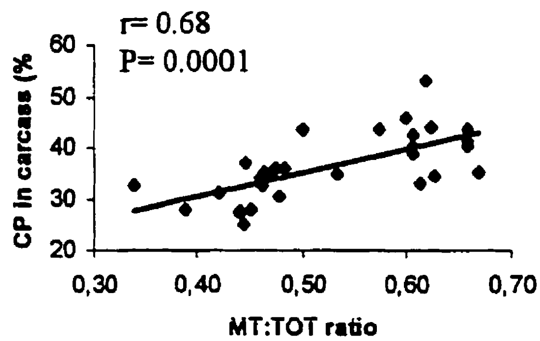

FIGURE 5.2. Relationship between carcass CP and MT/TOT in 30 female Pekin ducks at 53 d of age

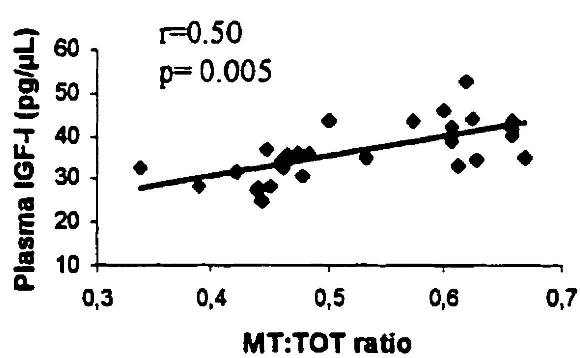

FIGURE 5.3. Relationship between plasma IGF-I and MT/TOT in 30 female Pekin ducks at 53 d of age

Plasma Parameters

The MT/TOT ratio or level of feeding had no effect ($P > 0.05$) on plasma TG of male ducks (Table 5.4).

TABLE 5.4. Effect of state[1] of feeding on blood parameters of male Pekin ducks with different breast muscle thickness[2] (n=30)

Group	State	Glucose	Triglyceride	Cholesterol	Uric Acid
		(mg/dl)			
High MT/TOT	Fasting	188^a	114	222	2.7
High MT/TOT	Fed	178^a	116	186	4.02
Low MT/TOT	Fasting	188^a	109	226	3.39
Low MT/TOT	Fed	159^b	120	213	4.51
SEM		2.24	2.42	3.95	0.17
		Probability			
Group		0.0058	0.9798	0.032	0.0575
State		0.0001	0.1833	0.001	0.0002
Group*State		0.0052	0.3847	0.1057	0.7515
Main Effects					
Group	High MT/TOT	183	115	204^b	3.36
	Low MT/TOT	174	115	220^a	3.95
State	Fasting	188	112	224^a	3.05^b
	Fed	169	118	200^b	4.27^a

[a b] Means within columns with different superscripts are statistically different ($P < 0.05$)

[1] On d 5 (fasting state) and d 12 (fed state) after overnight fasting

[2]High or low MT/TOT: breast muscle/total breast thickness measured by ultrasound scanning

There was a significant interaction for plasma glucose and feeding condition, revealing that during feed deprivation, both groups had similar ($P > 0.05$) plasma glucose, but the High MT/TOT males exhibited higher ($P < 0.05$) plasma glucose than the Low MT/TOT male ducks after feeding. The high MT/TOT male ducks had lower ($P < 0.05$) plasma cholesterol, and similar ($P > 0.05$) plasma uric acid compared to the Low MT/TOT male ducks. Feed deprivation resulted in higher ($P < 0.05$) plasma cholesterol, but lower ($P < 0.05$) plasma uric acid (Table 5.4). When sorted by body fat content (lean <58 % carcass fat, fat >58 % carcass fat), the male Pekin ducks showed no difference ($P > 0.05$) in plasma parameters (Table 5.5). Feeding condition had the same effects as when the males were sorted by MT/TOT except for the lack of interaction for glucose where the overnight fasting following feed deprivation resulted in higher ($P < 0.05$) plasma glucose than the overnight fasting following feeding (Table 5.5). Plasma analyses of the female ducks showed that the High MT/TOT birds had higher ($P < 0.05$) plasma glucose than the Low MT/TOT females during feed deprivation, but had lower ($P < 0.05$) plasma glucose after feeding (Table 5.6). Dimock *et al.* (1988) reported that lean chickens had higher plasma glucose levels than fat birds in the fasted and feeding states. Fasting, in general, results in lower plasma insulin than the fed state in the fowl (Nideau, 1988). Simon and Rosselin (1978) reported that prolonged fasting (65 h) resulted in a significantly higher plasma glucose concentration than early fasting (5 h) in 9-wk-old chickens. After feeding, Low MT/TOT females had higher ($P < 0.05$)plasma TG and uric acid than feed-deprived or fed High MT/TOT females. The latter birds had similar ($P > 0.05$) plasma TG to the feed deprived Low MT/TOT birds. The High MT/TOT female ducks exhibited higher ($P < 0.05$) plasma uric acid after feeding than after feed deprivation. The feed-deprived High MT/TOT females had similar ($P > 0.05$) uric acid level to feed-deprived Low MT/TOT ducks (Table

TABLE 5.5. Effect of state[1] of feeding on blood parameters of male Pekin ducks with different level of fatness[2] (n=30)

Fatness	n	State	Glucose	Triglyceride	Cholesterol	Uric Acid
			(mg/dl)			
Lean	15	Fasting	190	105	231	3.39
Lean	15	Fed	169	115	199	4.45
Fat	15	Fasting	186	118	217	2.75
Fat	15	Fed	169	121	200	4.11
SEM			2.24	2.42	3.95	0.17
			Probability			
Fatness			0.5329	0.0581	0.3905	0.1178
State			0.0001	0.1702	0.0016	0.0002
Fatness*State			0.524	0.4827	0.2904	0.6275
Main Effects						
Fatness		Lean	180	110	215	3.92
		Fat	177	119	209	3.43
State		Fasting	188[a]	111	224[a]	3.07[b]
		Fed	169[b]	118	200[b]	4.28[a]

[a,b] Means within columns with different superscripts are statistically different ($P < 0.05$)

[1] On d 5 (fasting state) and d 12 (fed state) after overnight fasting.

[2] Ducks with carcass fat ≤58 % were considered lean and the ducks with carcass fat >58 % were considered fat.

TABLE 5.6. Effect of state[1] of feeding on blood parameters of female Pekin ducks with different breast muscle thickness[2] (n=30)

Group	State	Glucose	Triglyceride	Cholesterol	Uric Acid
		(mg/dl)			
High MT/TOT	Fasting	202[a]	144[b]	215	2.20[c]
High MT/TOT	Fed	172[c]	147[b]	162	4.54[b]
Low MT/TOT	Fasting	188[b]	122[b]	219	2.17[c]
Low MT/TOT	Fed	184[b]	180[a]	171	5.82[a]
SEM		2.79	5.36	5.81	0.25
		Probability			
Group		0.8985	0.5792	0.5287	0.0206
State		0.0001	0.0012	0.0001	0.0001
Group*State		0.0100	0.0055	0.8013	0.0167
Main Effects					
Group	High MT/TOT	187	146	189	3.37
	Low MT/TOT	186	151	195	4.00
State	Fasting	195	133	217[a]	2.19
	Fed	178	164	166[b]	5.18

[a b c] Means within columns with different superscripts are statistically different ($P < 0.05$).

[1] On d 5 (fasting state) and d 12 (fed state) after overnight fasting

[2]High or low MT/TOT: breast muscle/total breast thickness measured by ultrasound scanning

5.6). Leclercq (1988) reported no difference in plasma TG concentrations in adult male and female chickens from lean and fat lines, while these concentrations were always higher in young birds of the fat line. However, there was no significant difference in plasma

TG concentrations of 5-wk-old chickens of lean and fat lines measured in four hatches of F_2progeny (Lilburn and Myers-Miller, 1988). Leclercq (1988) reported higher uric acid and lower insulin levels in the plasma of the fat line compared to the lean line selected for high low or abdominal fat content. Hazelwood and Langslow (1978) observed an increase in uric acid levels as an effect of insulin in chickens. The ducks with High or Low MT/TOT had similar ($P > 0.05$) plasma cholesterol levels; fasting resulted in higher ($P < 0.05$) plasma cholesterol than feeding (Table 5.6). Previously, plasma cholesterol concentrations were reported to be the same in both lean and fat lines of chickens (Leclercq, 1983). In contrast, Hevia and Visek (1979) observed lower plasma cholesterol concentration as a result of fasting than refeeding in 11-wk-old chickens. The same results were previously observed in young cockerels and suggested to be due to a decreased rate of cholesterol catabolism rather than an increase in synthesis rate (Leveille and Yeh, 1972). In rats, the activity of 3-hydroxy-3-methylglutaryl-CoA reductase (HMG-CoA) decreased as a result of fasting and it was restored to above pre-fasting level after refeeding for 3 d (Ide *et al.*, 1979).

Nitrogen retention and metabolizable energy

The two selected groups of male Pekin ducks fed the test diet had no significant difference in DM excreted, N content of the excreta, NR, and energy excreted (Table 5.7). Similarly to males, female ducks fed the test diet had no significant difference in DM and energy excreted. However, the High MT/TOT females excreted less ($P < 0.05$) N and

TABLE 5.7. Dry matter, nitrogen, and energy excretion of the male and female ducks fed the test diet

Males n= 14					
Group[1]	Dry Matter	Nitrogen	NR[2]	E/g DM[3]	Energy[4]
	(g)	(%)	(mg)	(kcal/g)	(kcal)
High MT/TOT	12.02	5.32	1288	3.91	47.36
Low MT/TOT	13.05	5.48	1217	3.95	51.43
SEM	0.48	0.13	34.31	0.07	1.82
Probability	0.3724	0.571	0.3239	0.7454	0.2795

Females n= 14					
Group[1]	Dry Matter	Nitrogen	NR[2]	E/g DM[3]	Energy[4]
	(g)	(%)	(mg)	(kcal/g)	(kcal)
High MT/TOT	10.32	4.72^{b}	1448^{a}	4.10	42.35
Low MT/TOT	10.49	5.60^{a}	1355^{b}	4.06	42.51
SEM	0.33	0.20	20.84	0.06	1.44
Probability	0.8112	0.0215	0.0205	0.7246	0.9596

[ab] Means within columns with different superscripts are statistically different ($P < 0.05$)

[1]High or low MT/TOT: breast muscle/total breast thickness measured by ultrasound scanning

[2] Nitrogen retention

[3] Energy per g of dry matter excreted

[4] Total energy excreted

All the birds received the same amount of dietary N (13.94g) retained more N than the Low MT/TOT females (Table 5.7). The group effect on AME and AME_n in either sex was not significant (Table 5.8). Similarly, Laurin *et al.*, (1985) found no difference in AME_n and TME_n between lean and fat lines of chickens. Faecal and urinary nitrogen losses of lean broilers were reported to be higher in the fasting state and lower in the fed state than fat broilers at 10 wk of age (MacLeod *et al.*, 1988). However, Geraert *et al.* (1988) found no significant difference in endogenous N losses between lean and fat lines of chickens at 5 and 7 wk of age.

TABLE 5.8. AME and AME_n of the test diet in male and female Pekin ducks with different breast muscle thickness[1]

	Males n= 14		Females n= 14	
Group	AME	AME_n	AME	AME_n
	(kcal/kg)			
High MT/TOT	3808	3676	3871	3722
Low MT/TOT	3757	3632	3869	3729
SEM	22.67	20.07	18.01	17.32
Probability	0.2789	0.294	0.9639	0.8427

[1] High or low MT/TOT: breast muscle/total breast thickness measured by ultrasound scanning

The control male ducks fed DS or SO showed no significant difference between the experimental groups in DM excretion, N excretion as percent of the excreta, and energy excretion (Table 5.9). All the birds were in a similar negative N balance. The male birds precisely fed DS excreted more ($P < 0.05$) DM and total energy, but lower ($P < 0.05$) N (%

TABLE 5.9. Effect of method of estimation of endogenous losses on dry matter, nitrogen, and energy excretion in the control male Pekin ducks with different breast muscle thickness (n=16)

Group[1]	Method[2]	Dry Matter	Nitrogen	NR[3]	E/g DM[4]	Energy[5]
		(g)	(%)	(mg)	(kcal/g)	(kcal)
High MT/TOT	Dextrose	11.77	6.23	-719	3.68	43.14
High MT/TOT	Starch-oil	4.97	9.28	-453	4.25	21.13
Low MT/TOT	Dextrose	15.51	4.33	-643	3.64	56.53
Low MT/TOT	Starch-oil	6.05	9.3	-561	4.08	25.06
SEM		1.27	0.76	52.5	0.08	4.38
		Probability				
Group		0.0624	0.4308	0.883	0.4031	0.1134
Method		0.0001	0.01	0.124	0.0001	0.0001
Group*Method		0.2776	0.4213	0.396	0.5905	0.367
Main effects						
Group	High	8.37	7.76	-586	3.96	32.14
	Low	10.78	6.82	-602	3.86	40.79
Method	Dextrose	13.64^{a}	5.28^{b}	-681	3.66^{b}	49.84^{a}
	Starch-oil	5.51^{b}	9.29^{a}	-507	4.16^{a}	23.09^{b}

^{a,b} Means within columns with different superscripts are statistically different ($P < 0.05$)

[1] High or low MT/TOT: breast muscle/total breast thickness measured by ultrasound scanning

[2] Dextrose solution: 40 g dextrose/100ml of water

Starch-oil solution: 38.76 g corn starch+1.24 g corn oil/100ml water

[3] Nitrogen retention

[4] Energy per g of dry matter excreted

[5] Total energy excreted

TABLE 5.10. Effect of method of estimation of endogenous excretion on dry matter, nitrogen, and energy excretion in the control female Pekin ducks with different breast muscle thickness (n=16)

Group[1]	Method [2]	Dry Matter	Nitrogen	NR[3]	E/g DM[4]	Energy[5]
		(g)	(%)	(mg)	(kcal/g)	(kcal)
High MT/TOT	Dextrose	2.71	7.72	-206	4.53	12.34
High MT/TOT	Starch-oil	1.85	8.51	-156	4.39	8.19
Low MT/TOT	Dextrose	2.81	8.46	-238	4.4	12.31
Low MT/TOT	Starch-oil	2.34	8.63	-198	4.3	9.96
SEM		1.15	0.22	9.93	0.07	0.68
		Probability				
Group		0.4019	0.2996	0.04	0.4104	0.4674
Method		0.0154	0.2675	0.01	0.4341	0.016
Group*Method		0.4523	0.5046	0.749	0.9118	0.4543
Main effects						
Group	High	2.28	8.12	-181[b]	4.46	10.26
	Low	2.57	8.54	-218[a]	4.35	11.13
Method	Dextrose	2.76[a]	8.09	-222[a]	4.47	12.32[a]
	Starch-oil	2.09[b]	8.57	-177[b]	4.34	9.07[b]

[a,b] Means within columns with different superscripts are statistically different ($P < 0.05$)

[1] High or low MT/TOT: breast muscle/total breast thickness measured by ultrasound scanning

[2] Dextrose solution: 40 g dextrose/100ml of water

Starch-oil solution: 38.76 g corn starch+1.24 g corn oil/100ml water

[3] Nitrogen retention

[4] Energy per g of dry matter excreted

[5] Total energy excreted

TABLE 5.11. Effect of method of estimation of endogenous excretion on TME and TME_n in the test male and female Pekin ducks fed the test diet

		Males n=14		Females n=14	
Group[1]	Method[2]	TME	TME_n	TME	TME_n
		(kcal/kg)			
High MT/TOT	Dextrose	3851	3725	3883	3755
High MT/TOT	Starch-oil	3829	3723	3879	3746
Low MT/TOT	Dextrose	3813	3694	3881	3766
Low MT/TOT	Starch-oil	3782	3693	3879	3760
SEM		15.73	13.6	12.48	12.09
		Probability			
Group		0.197	0.2956	0.9772	0.6363
Method		0.4086	0.964	0.9107	0.7647
Group*Method		0.8832	0.976	0.9699	0.9566
Main effects					
Group	High MT/TOT	3840	3724	3881	3751
	Low MT/TOT	3798	3694	3880	3763
Method	Dextrose	3832	3709	3882	3761
	Starch-oil	3805	3707	3879	3753

[1] High or low MT/TOT: breast muscle/total breast thickness measured by ultrasound scanning

[2] Dextrose solution: 40 g dextrose/100ml of water

Starch-oil solution: 38.76 g corn starch+1.24 g corn oil/100ml water

of excreta) and energy content (kcal/g excreta) than the males fed the SO (Table 5.9). The control High and Low MT/TOT female ducks fed DS or SO excreted similar ($P > 0.05$) DM, N (% of excreta), and energy, but High MT/TOT females lost less ($P < 0.05$) N than Low

MT/TOT females (Table 5.10). Precise feeding DS to the control females resulted in higher ($P < 0.05$) excretion of DM and total energy and greater ($P < 0.05$) loss of endogenous N than precise feeding SO (Table 5.10). However, these differences observed in both sexes were not reflected in the TME and TME_n values probably because of the different magnitude and sensitivity of the parameters considered. Neither the group nor the estimation method of endogenous losses had an effect ($P > 0.05$) on the TME and TME_n values of the test diet (Table 5.11). Geraert *et al.* (1988) reported similar TME_n between genetically lean and fat chickens, but more protein deposition in the lean line which are consistent with the results presented herein.

Association of metabolic parameters and ultrasound measurements

Correlations among the metabolic parameters and with MT/TOT in the feed deprived female ducks are presented in Table 5.12. The more the birds retained nitrogen, the lower their plasma cholesterol (r=-0.53, P=0.0615) and TG (r=-0.57, P=0.0440) levels were; the greater their MT/TOT (r=0.58, P=0.03) ratio the lower the % N in the excreta was. The birds that had higher plasma TG concentration excreted more total energy (r= 0.61, P=0.0279). The higher the MT/TOT ratio the higher the NR. Body fat content negatively correlated (r=-0.71, P=0.0001) with MT/TOT (Figure 5.1), but did not correlate with plasma cholesterol and triglyceride concentrations. Ksiazkiewicz *et al.* (1993) obtained a non-significant correlation between plasma cholesterol and body fatness in male Pekin ducks, and a significant correlation in the female ducks. Plasma TG was suggested to be a possible useful indicator for body fatness in chickens (Griffin *et al.*, 1982). However, our results on plasma TG agree

TABLE 5.12. Correlation of metabolic parameters and breast muscle thickness in the feed deprived female Pekin ducks (n=16)

Parameters	Pearson correlation coefficient	Probability
Cholesterol[1] * NR[2]	-0.53	0.0615
Triglycerides[3] * NR	-0.57	0.044
Triglycerides * Energy excreted[4]	0.61	0.0279
% N of excreta[5] * MT/TOT[6]	-0.54	0.0485
NR * MT/TOT	0.58	0.03

[1]Plasma cholesterol of the control birds after overnight fasting

[2] Nitrogen retention (N loss) by the control birds during 48 h of feed deprivation

[3] Plasma triglycerides of the control birds after overnight fasting

[4] Total energy excreted (kcal) by the control birds during 48 h of feed deprivation

[5] N % of the excreta of the control ducks collected during 48 h of feed deprivation

[6] MT/TOT: breast muscle/total breast thickness measured by ultrasound scanning

with the conclusion of Baeza *et al.* (1997) who found no significant correlation between plasma TG and carcass fatness in Muscovy ducks.

Estimation of carcass CP and fat

The regression equations of the carcass composition parameters show that the estimation of carcass CP % can be determined from carcass fat %, DM %, or carcass ash % with different reliability. The regression line representing the relationship between carcass CP % and fat % (Figure 5.4) was described by the following equation:

$$CP\ \% = -0.8241\ Fat\ \% + 82.395 \qquad R^2 = 0.9804$$

The estimation of carcass fat and CP from either DM or Ash content of the carcass are given in the following equations:

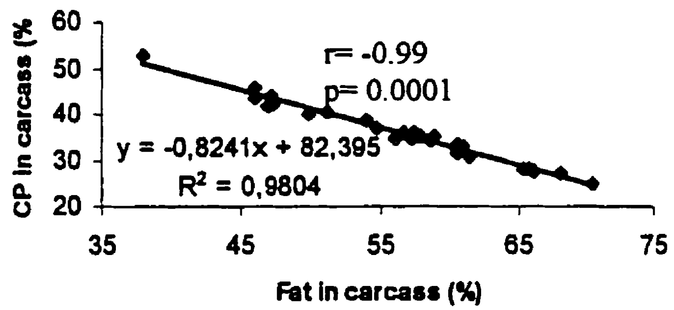

FIGURE 5.4. Relationship between carcass CP and fat in 30 female Pekin ducks at 53 d of age

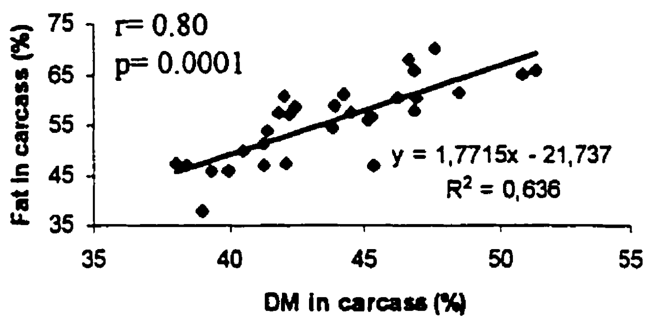

FIGURE 5.5. Relationship between carcass fat and DM in 30 female Pekin ducks at 53 d of age

Fat % = 1.7715 DM % - 21.737	R^2 = 0.6360 (Figure 5.5)
CP % = -1.5079 DM % + 102.41	R^2 = 0.6653 (Figure 5.6)
Fat % = -3.9512 Ash % + 86.595	R^2 = 0.6950 (Figure 5.7)
CP % = 2.9512 Ash % + 13.405	R^2 = 0.5600 (Figure 5.8)

where fat , CP and ash % are on DM basis.

Although the correlations between DM or ash, and fat or CP are high ($P < 0.01$), the data from this study show that carcass fat can only be predicted with certain precision (99 %) from carcass CP.

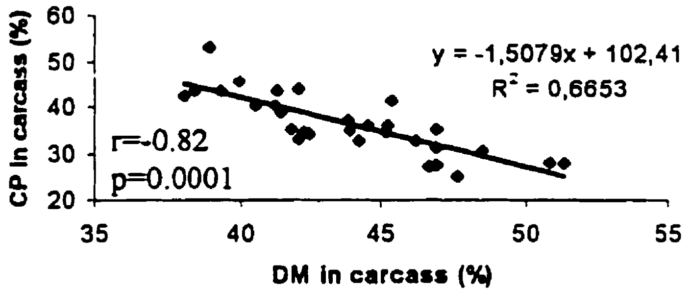

FIGURE 5.6. Relationship between carcass CP and DM in 30 female Pekin ducks at 53 d of age

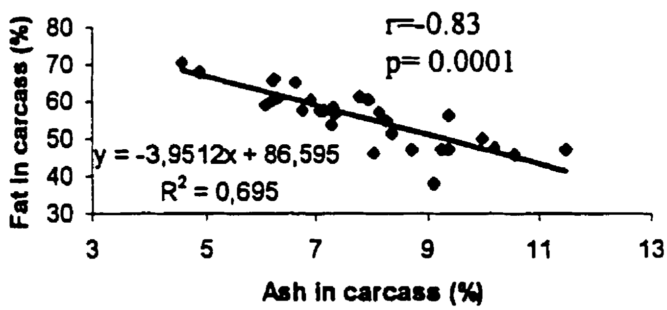

FIGURE 5.7. Relationship between carcass fat and ash in 30 female Pekin ducks at 53 d of age

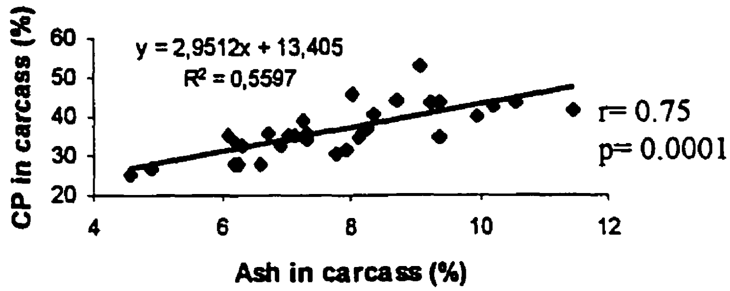

FIGURE 5.8. Relationship between carcass CP and ash in 30 female Pekin ducks at 53 d of age

Dextrose vs starch-oil solutions

The precise feeding of SO instead of DS to estimate the endogenous N and energy losses did not have an effect on the ME values. The SO solution contained ingredients that may not be 100 % digestible as is the case with the DS solution. Therefore, we analysed the SO excreta (from males only due to too small collection of female excreta for the analyses) for starch, fat and fatty acids. There was no starch detected in the excreta. The effects of group and method of endogenous losses estimation, on fat percent of the excreta and total fat excreted during the 48 h of collection, are presented in Table 5.13. There was no group effect ($P > 0.05$), but the control males fed SO had higher ($P < 0.05$) fat content in the excreta than the control birds fed DS. However, because of the greater ($P < 0.05$) DM excretion of the DS birds, the total fat excreted for the 48 h of collection was similar ($P > 0.05$) for the DS and SO methods (Table 5.13). The comparison of the fatty acid profiles of corn oil used in SO, and the excreta of males fed either DS or SO reveals great differences (Table 5.14). The SO excreta profile showed the widest profile from saturated fatty acids (SFA) to polyunsaturated fatty acids (PUFA). Although the profile of DS excreta included fewer FA, the percent of SFA was higher ($P < 0.05$) than the SO excreta. Corn oil, included as base was significantly lower in SFA compared to the excreta of both DS and SO, but was much higher ($P < 0.05$) in Oleic acid (C18:1n9), Linoleic acid (C18:2), and γ-Linolenic acid

TABLE 5.13. Effect of method of endogenous losses estimation on the ether extract % of the excreta and total fat excreted per 48 h in control male Pekin ducks fed either dextrose or starch-oil solutions (n=16)

Group[1]	Method[2]	EE % of excreta	DM of excreta	Fat excreted/48 h
		(%)	(mg)	
High MT/TOT	Dextrose	2.55	11776	310
High MT/TOT	Starch-oil	5.10	4973	254
Low MT/TOT	Dextrose	2.97	15507	475
Low MT/TOT	Starch-oil	5.13	6045	306
SEM		0.38	1225	40.82
		Probability		
Group		0.6542	0.0624	0.188
Method		0.0004	0.0001	0.1725
Group*Method		0.6939	0.2776	0.4797
Main effects				
Group	High MT/TOT	3.83	8374	282
	Low MT/TOT	4.05	10776	390
Method	Dextrose	2.76[b]	13641[a]	393
	Starch-oil	5.12[a]	5509[b]	280

[a,b] Means within columns with different superscripts are statistically different ($P < 0.05$)
[1] High or low MT/TOT: breast muscle/total breast thickness measured by ultrasound scanning
[2] Dextrose solution: 40 g dextrose/100ml of water
Starch-oil solution: 38.76 g corn starch+1.24 g corn oil/100ml water

(C18:3n6) than both excreta. Elongated FA were higher ($P < 0.05$) in the SO profile although the FA % of Arachidic acid (C20:0) and Arachidonic acid (C20:4) were higher ($P < 0.05$) in

TABLE 5.14. Comparison of fatty acid profiles of corn oil and excreta of control male ducks fed dextrose[1] or starch-oil[2] solutions

Fatty Acid	Corn oil	DS excreta	SO excreta	SEM	Probability
	% by weight				
C6:0	-	-	0.51	0.22	
C8:0	-	-	0.48	0.1	
C10:0	-	14.19^a	5.59^b	1.65	0.0025
C11:0	-	-	0.67	0.04	
C12:0	-	1.81	1.6	0.08	0.1885
C13:0	-	12.18^a	0.47^b	1.89	0.0001
C14:0	0.1^c	2.03^a	1.44^b	0.18	0.0001
C14:1	-	1.49^a	0.92^b	0.11	0.0013
C15:0	-	2.16	1.77	0.19	0.3243
C15:1	-	-	0.79	0.08	
C16:0	10.5^c	16.99^b	21.91^a	1.11	0.0001
C16:1	0.12^c	8.62^a	4.44^b	0.86	0.0001
C18:0	3.63^b	14.62^a	16.26^a	1.28	0.0001
C18:1n9	23.9^a	10.45^b	11.92^b	1.27	0.0001
C18:1n7	1.4^c	6.57^a	4.99^b	0.51	0.0001
C18:2	52.1^a	3.14	10.92^b	4.5	0.0001
C18:3n6	7.66^a	5.02^b	5.48^b	0.35	0.0138
C18:3n3	0.35^b	-	3.00^a	0.44	0.0001
C20:0	-	4.47^a	1.15^b	0.1	0.0089
C20:1	0.37^b	-	1.58^a	0.24	0.012
C20:2	-	-	1.58	0.22	
C20:4	-	3.52^a	1.26^b	0.4	0.001
C22:0	-	-	1.64	0.03	
C22:2	-	-	1.88	0.03	

^{abc}Means within rows with different superscript are statistically different ($P < 0.05$)

[1] Excreta of ducks fed a dextrose solution (40 g dextrose/100ml of water)

[2] Excreta of ducks fed a starch-oil solution (38.76 g corn starch+1.24 g corn oil/100ml water)

TABLE 5.15. Comparison of fatty acid consumption/48 h (mg of each corn oil FA in the starch-oil solution) and excreted/48 h (mg FA) of control male Pekin ducks fed dextrose[1] or starch-oil[2] solutions

Fatty Acid	Corn oil	DS excreta	SO excreta	SEM	Probability
	(mg)				
C6:0	-	-	1.42	0.61	
C8:0	-	-	1.36	0.33	
C10:0	-	55.76^{a}	15.65^{b}	7.23	0.001
C11:0	-	-	1.88	0.1	
C12:0	-	7.11^{a}	4.48^{b}	0.46	0.0001
C13:0	-	47.86^{a}	1.31^{b}	7.51	0.0001
C14:0	2.48	7.98^{a}	4.02^{b}	0.62	0.0001
C14:1	-	5.85^{a}	2.58^{b}	0.55	0.0001
C15:0	-	8.51^{a}	4.96^{b}	0.83	0.025
C15:1	-	-	2.22	0.21	
C16:0	260	66.78^{a}	61.36^{b}	1.51	0.0001
C16:1	2.98	33.87^{a}	12.43^{b}	3.44	0.0348
C18:0	90	57.47^{a}	45.53^{b}	2.95	0.0044
C18:1n9	592	41.05^{a}	33.37^{b}	1.53	0.0001
C18:1n7	34	25.80^{a}	13.98^{b}	1.97	0.0001
C18:2	1292	12.33^{b}	30.58^{a}	3.08	0.0304
C18:3n6	189	19.55^{a}	15.33^{b}	1.06	0.0001
C18:3n3	8.68	-	8.4	0.25	
C20:0	-	17.55^{a}	3.22^{b}	4.14	0.0069
C20:1	9.18	-	4.41	0.52	
C20:2	-	-	4.44	0.61	
C20:4	-	13.83^{a}	3.52^{b}	1.77	0.0001
C22:0	-	-	4.59	0.09	
C22:2	-	-	5.5	0.25	

[ab] Means within rows (excreta) with different superscript are statistically different ($P < 0.05$)

[1] Excreta of ducks fed a dextrose solution (40 g dextrose/100ml of water)

[2] Excreta of ducks fed a starch-oil solution (38.76 g corn starch+1.24 g corn oil/100ml water

the DS profile and absent in the corn oil (Table 5.14). The comparison of the amount of each FA consumed (corn oil consumption by the SO ducks) and excreted (DS and SO ducks) per 48 h is presented in Table 5.15. The statistical analysis pertains only to the DS and SO excreta. For all the common FA of the three profiles, the DS birds excreted more ($P < 0.05$) mg of each FA except for the Linoleic acid (C18:2) indicating that the contribution of the corn oil to the excreta of the birds fed SO was negligible. However, 8.68 and 9.18 mg of Linolenic acid (C18:3n3) and Eicosenoic acid (C20:1), respectively, were consumed and 8.40 and 4.41 mg, respectively, were detected in the excreta of the birds fed SO (Table 5.15). This observation does not confirm that the FA in the excreta are of dietary origin, and if they were, they are of negligible impact.

CONCLUSION

The fat content of ducks is in general undesirable for the western consumer and can be associated with higher cost of production. Fat is of high energy density and requires considerable feed energy input to be deposited as body fat. The birds selected with ultrasound show comparable metabolic and blood differences to the literature presented on fat and lean birds. These differences between the High and Low MT/TOT groups are indicative of the possible use of the ultrasound scanning for the selection of live ducks. The blood parameters determined in this study can not be used as indicators of leanness or fatness in Pekin ducks. However, the significant correlations between carcass fat or CP and the MT/TOT further validate the feasibility of ultrasound use in the selection for greater breast muscle thickness and leanness in Pekin duck.

Connecting Statement: Sections III, IV, V, and Section VI

Insulin-like growth factor-I has been suggested to mediate growth hormone effects and play a role in muscle growth in ruminant and monogastric species. In ducks, IGF-I was not characterized. Plasma harvested in the experiments presented in Sections III, IV, and V were also analysed for IGF-I after adaptation of an RIA for this growth factor in duck plasma. This Section presents the response of plasma IGF-I to the selection for greater breast muscle thickness, dietary protein, sex, age, and the state of feed-deprivation or feeding in Pekin ducks.

SECTION VI

Effects of Line, Dietary Protein, Sex, Age, and Feed Withdrawal on Insulin-Like Growth Factor-I (IGF-I) in White Pekin Ducks

By

ANTOINE FARHAT AND EDUARDO R. CHAVEZ

Department of Animal Science
Macdonald Campus of McGill University
21,111 Lakeshore Road, Ste.Anne de Bellevue
Québec,Canada. H9X 3V9

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Effects of Line, Dietary Protein, Sex, Age, and Feed Withdrawal on Insulin-Like Growth Factor-I (IGF-I) in White Pekin Ducks

ABSTRACT

Three experiments were conducted to determine and characterize plasma IGF-I concentrations in Pekin ducks. Plasma IGF-I in Pekin ducks was assayed in a heterologous radioimmunoassay for human IGF-I. When treated with acid, the response dose of duck IGF-I was parallel to that of human rIGF-I. The effect of line, greater breast muscle thickness vs control, was determined in Experiment 1 in female ducks. The ducks with greater breast muscle thickness had higher ($P < 0.05$) plasma IGF-I concentration than the control ducks. In Experiment 2, the effects of dietary protein, sex, and age were examined from 42 to 49 d of age. Three dietary programs that differ in dietary crude protein were used in this experiment. Ducks on the high protein program had ($P < 0.05$) higher plasma IGF-I concentrations than ducks on either medium or low protein programs. Males exhibited higher ($P < 0.05$) IGF-I than females. Plasma IGF-I concentrations decreased with age from 42 to 49 d. In Experiment 3, the effects of selection criterion (high or low breast muscle thickness to total breast thickness ratio) and the fasted or fed state were studied in female Pekin ducks. The high ratio ducks were more affected by feed deprivation. These ducks had similar plasma IGF-I concentrations to low ratio ducks during fasting, but had higher ($P < 0.05$) concentrations when fed. These data contribute to an understanding of the influence of IGF-I on metabolism and will be of value to the improvement of lean Pekin duck production.

(Key words: Pekin ducks, insulin-like growth factor-I, line, dietary protein, fasting)

INTRODUCTION

Growth hormone (GH) is documented to have metabolic effects represented by nutrient partitioning toward less fat deposition and greater protein accretion (Davis *et al.*, 1995). Many of the anabolic effects of GH are mediated by IGF-I (Guler *et al.*, 1988). Levels of IGF-I are dependent on GH secretion and stimulate body tissue growth (Dodson *et al.*, 1996). Hepatically derived endocrine IGF-I could have a role in the regulation of muscle growth in sheep (Pell and Bates, 1993). Huybrechts *et al.* (1985) reported higher body weight and higher IGF-I concentrations in control broiler chickens compared to sex-linked dwarf birds studied between one and 21 wk of age.

Touchburn *et al.* (1981) observed lower plasma glucose in fat line compared to lean line chickens whether in a fasted or fed state and regardless of the dietary protein or energy levels. Studies with these lines revealed an effect of dietary protein concentration on growth and body composition. Feeding broilers decreased levels of dietary protein resulted in decreased lean growth, and increased fat deposition (Stewart and Washburn, 1984). The higher plasma glucose in the lean line reported by Touchburn *et al.* (1981) may be due to the possibility of the lean birds having higher GH activity than the fat birds in addition to the lower insulin level. Foltzer and Mialhe (1976) reported an increase in plasma glucose after GH therapy in hypophysectomized ducks. In broilers, Decuypere *et al.* (1987) reported that chemical hypothyroidism caused by feeding methimazole resulted in reduction of IGF-I plasma concentration, increased fatness, and decreased lean growth.

Due to the high fat content of its carcass, the Pekin duck is the poultry species that could benefit the most from the characterization of metabolites involved in leanness. Insulin-like growth factor-I was studied in chickens, turkeys, and Japanese quail but not in ducks.

In recent studies on carcass quality improvement of Pekin ducks, we used ultrasound measurements to select ducks for greater breast muscle thickness. The selected ducks had similar reproductive performance to control ducks (Farhat and Chavez, 1999a), but yielded carcasses lower in fat and higher in protein content than the controls (Farhat and Chavez, 1999b). Three experiments were conducted to characterize the biochemical differences between lean and fat Pekin ducks, to assess the effects of dietary protein, sex, and age during the last week of growth on selected parameters, and to measure metabolic differences. The objective of the present study was to examine the effects of genetic line, dietary protein, sex, age, and the feed-deprived or fed state on plasma IGF-I in White Pekin ducks.

MATERIALS AND METHODS

Experiment 1

The description of this experiment has been presented elsewhere (Farhat and Chavez, 1999b). In short, 624 ducklings of two lines (control and greater breast muscle thickness lines) were weighed by groups of 26, randomly distributed into 24 floor pen, and raised from day-old on a commercial feeding program based on corn and soybean meal. The diets had 22.69, 18.83, and 17.43 % CP for the starter (wk 1-2), grower (wk 3-4), and finisher (wk 5-7), respectively. At 7 wk of age, blood samples (5 mL from the wing vein) were taken from 12 female ducks per line. The carcasses were ground, and sub-samples were taken for analyses. Following freeze-drying, dry matter values were obtained using a vacuum oven[15]. Total fat was determined after ether extraction, and crude protein was measured using a N analyzer[16]. The ash content was determined using a muffle furnace[17]. The plasma was harvested in heparinized tubes and stored at –20 C until assayed for IGF-I.

Experiment 2

A total of 600 ducklings were sexed at day-old and randomly allocated to three dietary programs that differed only in protein level (high protein, medium protein, and low protein). The high protein program had 25, 23, and 21 % CP for the starter, grower, and finisher, respectively. The medium protein program had 23, 21, and 19 % CP for the starter, grower, and finisher, respectively. The low protein program had 21, 19, and 17 % CP for the starter, grower, and finisher, respectively. The diets were based on corn, wheat, wheat shorts, and soybean meal. At each of 42, 45, 48, and 49 d of age, blood samples (5 mL from the wing vein) were taken from 48 birds (24 per sex, 16 per dietary program). The breast muscle thickness of these ducks was measured with an ECHO 1000[18] ultrasound system equipped with a 7.5 MHz linear array probe. The measurements were taken on a frozen image where the distance between two points (mm) was calculated using a built-in caliper. The carcasses were dissected into breast skin, total skin, wing, pectoralis muscle, leg and thigh, and shell, and analyzed for dry matter, fat, protein, and ash. The plasma was harvested in heparinized

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[15] National Appliance Co., Portland, OR 97223.
[16] Leco FP-428, Leco Corp., St. Joseph, MI 49085-2396.
[17] Model F-A1730, Sybron Thermolyne, Dubuque, IA 52001.
[18] ECHO 1000, Alliance Medical Inc., Montreal, Canada H4T 1G1

tubes and stored at –20 C until assayed for IGF-I.

Experiment 3

Thirty female ducks were selected for high or low ratios of breast muscle thickness (MT) to total breast (TOT) thickness using ultrasound measurement at 6 wk of age. The ducks were placed in metabolic cages and were fed a commercial finisher diet for two days of adaptation. The study was designed to examine TME and nitrogen retention differences between the high and the low ratio ducks (Farhat and Chavez, 1999d). The birds went through 48 h of feed deprivation, except for a dextrose solution (40g/100ml per 24 h) administered by tube into the lower esophagus, to empty their alimentary canal. The ducks were then tube-fed 80 g of a test diet and were deprived of feed for 15 h. Blood was then collected and the plasma samples were stored at –20 C. The ducks were fed the same test diet for ad libitum consumption for 5 d, blood was collected at 0700 h (same hour as first collection), and the plasma samples were stored at –20 C until assayed for IGF-I.

IGF-I Radioimmunoassay

Plasma concentration of IGF-I in Pekin ducks was evaluated by heterologous radioimmunoassay employing an anti-human IGF-I antibody (UB2-495; NIDDK), with human recombinant IGF-I[19] as tracer and standard (Copeland *et al.*, 1980). Prior to the assay, plasma samples were acid treated to prevent the effects of plasma binding protein. Glycine-Glycine HCL (0.1 M) was added to plasma samples at a ratio of 6 to 5 (v:v), respectively, and incubated at 37 C in a water bath for 40 h. The samples were then neutralized with 1 M NaOH (4 % of incubation volume) and diluted in assay buffer (0.03 M phosphate buffer containing 0.01 M EDTA and 0.05 % Tween 20, pH 7.5). Acid treatment resulted in a parallel dose-response curve to that of human r-IGF-I (Figure1). All samples from each experiment were assayed at the same time to eliminate inter-assay variation. The intra-assay coefficients of variation averaged 4.38, 3.94, and 3.86 % for Experiments 1, 2, and 3, respectively. The sensitivity of the assay, at the plasma dilutions used, was equivalent to 5 pg/µL plasma.

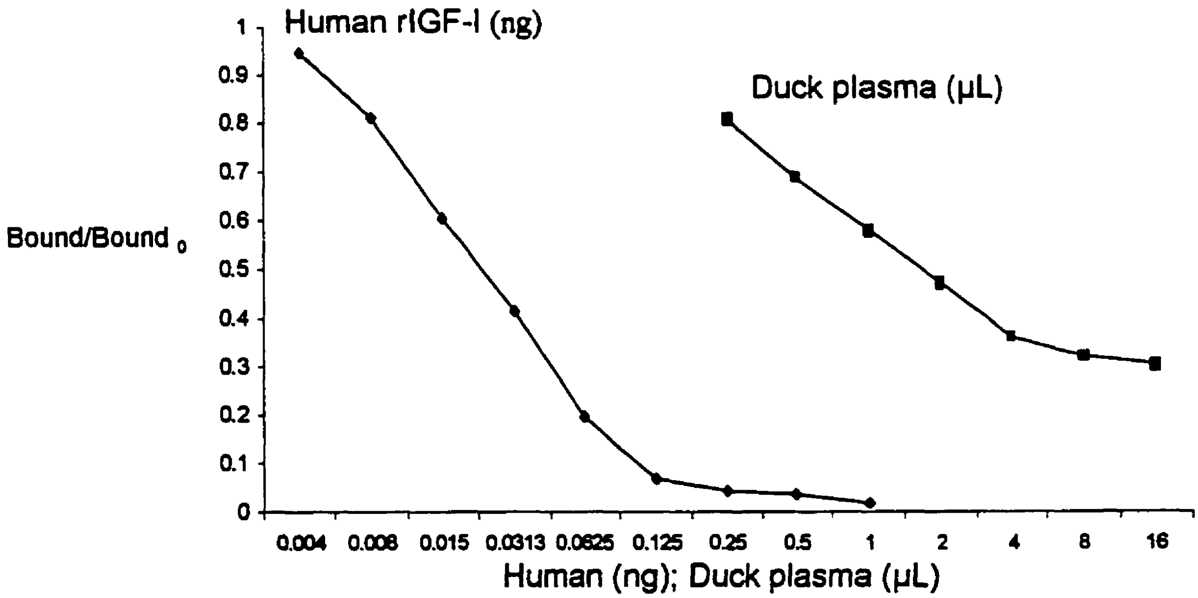

FIGURE 6.1. Dose-response curve in the RIA of acid treated Pekin duck plasma. The radioligand was ^{125}I-labeled human recombinant insulin-like growth factor-I. Values are means of three determinations at each concentration. Bound: binding at observation point in standard curve or with unknown; Bound $_0$: binding of ^{125}I-labeled human recombinant insulin-like growth factor-I in absence of standard or unknown.

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1 [19] Bioresource International, Camarillo, CA 93012.

Statistical Analysis

Statistical analyses of the data were performed using the General Linear Models (GLM) procedures and mixed models of the SAS® (1990) library. In Experiment 1, the model included the effect of line. In Experiment 2, the data were analyzed as a factorial design with three dietary programs, two sexes, and four ages. In Experiment 3, the data were analyzed as a factorial design with two selection criteria and state of feed deprived or fed. These data were treated as repeated measures with simple covariance structure and the duck was included as random effect. The multi-comparison Scheffe's test was used to separate the differences among the means for statistical significance ($P < 0.05$).

RESULTS AND DISCUSSION

Experiment 1

The selection for greater breast muscle thickness using ultrasound measurement resulted in ducks with higher ($P < 0.05$) plasma IGF-I concentration (27.32 vs 19.32 pg/μL) than the control ducks (Figure 6.2). The selected ducks were found to be leaner with higher protein (31.27 vs 27.94 % crude protein) and lower fat (60.74 vs 64.93 % fat) in their carcasses (Farhat and Chavez, 1999b). Overexpression of IGF-I in differentiated muscle fibers of young adult mice induced a 15 % increase in muscle mass, and prevented age-

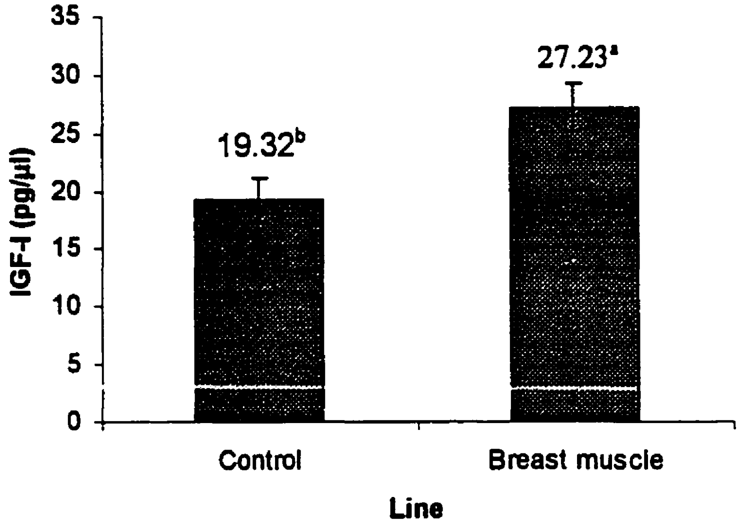

FIGURE 6.2. Effect of line on plasma IGF-I of female Pekin ducks at 7 wk of age (SEM=1.72, P=0.01). Values are means for 12 control and 12 breast muscle ducks

related loss of muscle mass and strength in old adult mice (Barton-Davis *et al.*, 1998). In chickens, abdominal fat was reported to be reduced with the administration of exogenous IGF-I (Huybrechts *et al.*, 1992; Tixier-Boichard *et al.*, 1992). Although the birds selected for greater breast muscle thickness had improved carcass composition, their body weights were similar (Farhat and Chavez, 1999b) indicating that the higher IGF-I concentration was not associated with higher growth rate. This observation agrees with a statement by McMurtry (1998) that IGF-I and IGF-II in poultry may have more effect on intermediary metabolism than on growth.

Experiment 2

In Experiment 1, all the ducks from the line selected for greater breast muscle and the control line were 7 wk-old females and had received the same feeding program. In this experiment, all the ducks were selected for breast muscle, but received three dietary programs that differed in protein level. Both males and females were studied between 42 and 49 d of age. The dependent variables studied were the dietary program, sex, age, and their interactions.

There were no two-way or three-way interactions among program, sex, and age (Table 6.1). The main effects on plasma IGF-I concentrations are presented in Figures 6.3, 6.4, and 6.5, respectively.

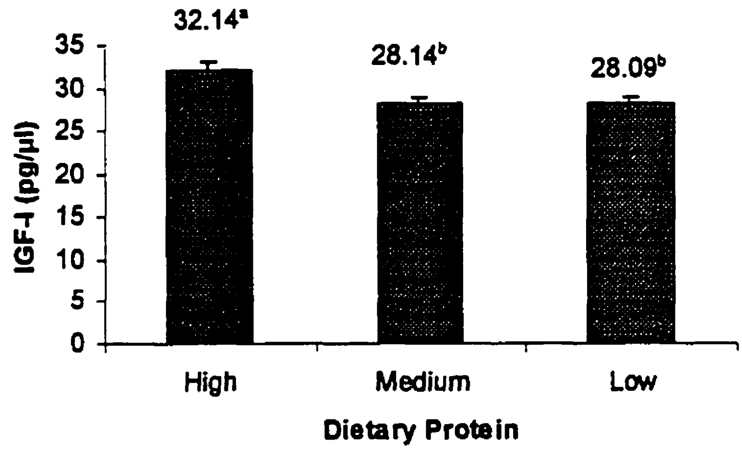

FIGURE 6.3. Effect of dietary protein on plasma IGF-I of Pekin ducks (P<0.0009). High protein was significantly different from the medium and low protein programs. Values are for 16 ducks per dietary protein program

Birds on the high dietary protein program had higher ($P < 0.05$) plasma IGF-I than those on the programs with medium or low dietary protein which both had similar effects (Figure 6.3). Similar differences ($P < 0.05$) were observed for the ultrasound measurements of breast muscle thickness, 8.42 vs 7.26 and 6.93 mm for high protein vs medium and low protein programs, respectively; as well as for the pectoralis muscle (weight as percent of carcass weight), 14.38 vs 12.19 and 12.02 % for high protein vs medium and low protein programs, respectively (Farhat and Chavez, 1999c).

TABLE 6.1. Effects of dietary program, sex, and age on plasma IGF-I of Pekin ducks (n=192)

Program	Sex	Age	IGF-I (pg/mL)
High protein	Male	42 d	40.69
High protein	Male	45 d	33.11
High protein	Male	48 d	30.42
High protein	Male	49 d	28.30
High protein	Female	42 d	37.27
High protein	Female	45 d	29.1
High protein	Female	48 d	28.58
High protein	Female	49 d	29.69
Medium protein	Male	42 d	34.84
Medium protein	Male	45 d	29.07
Medium protein	Male	48 d	27.18
Medium protein	Male	49 d	24.36
Medium protein	Female	42 d	32.91
Medium protein	Female	45 d	26.88
Medium protein	Female	48 d	25.70
Medium protein	Female	49 d	24.19
Low protein	Male	42 d	35.10
Low protein	Male	45 d	28.98
Low protein	Male	48 d	28.33
Low protein	Male	49 d	23.20
Low protein	Female	42 d	33.15
Low protein	Female	45 d	27.15
Low protein	Female	48 d	24.18
Low protein	Female	49 d	24.64
SEM			0.58
			Probabilities
Program			0.0009
Sex			0.0249
Age			0.0001
Program * Sex			0.9632
Program * Age			0.9934
Sex * Age			0.5748
Program * Sex * Age			0.9928

Means are for 8 ducks per program per sex per age.

There were no significant two-way or three-way interactions among programs, sexes and ages. The main effects are presented in Figures 3, 4, and 5.

Kocamis *et al.* (1998) reported that administration of recombinant human IGF-I into incubated eggs resulted in post-hatching improvement of feed efficiency and breast and leg muscle growth. Feeding wide calorie- to-protein ratio diets produced chickens with depressed IGF-I concentration and increased lipogenesis (Lauterio and Scanes 1987; Rosebrough and McMutry, 1992). Ducks fed the high protein diet had higher plasma IGF-I and a higher growth rate than those fed the medium or low protein diets. At 45 d of age, the ducks fed the high protein diet had higher body weights (3.438 kg) than those fed the medium (3.310 kg) and low protein diets (3.274 kg) at 49 d of age (Farhat and Chavez, 1999c). Although an effect of IGF-I on growth rate was not observed in Experiment 1, it is still not clear whether the growth rate difference observed in this experiment is a direct effect of dietary protein or through increasing IGF-I concentration.

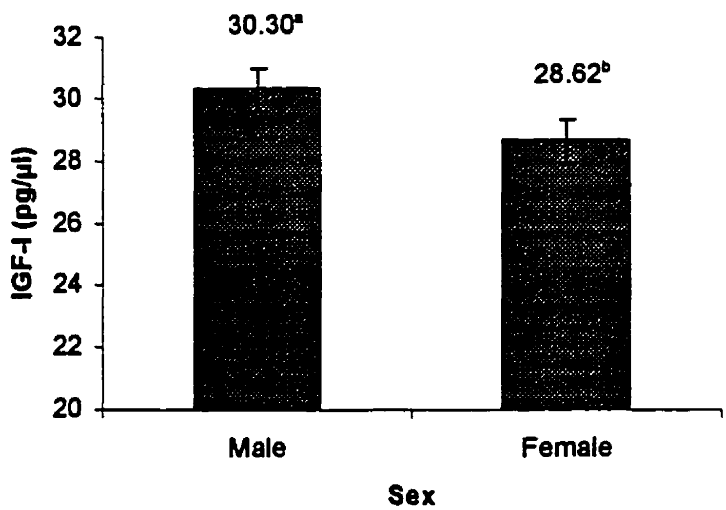

FIGURE 6.4. Effect of sex on plasma IGF-I of Pekin ducks ($P<0.025$). Values are means for 24 ducks per sex

The effect of sex on IGF-I (Figure 6.4) was significant ($P < 0.05$) and males had higher plasma IGF-I than females (30.30 vs 28.62 pg/µL). This difference may be explained by the higher growth rate and the higher lean tissue deposition in males. In chickens, females had the higher concentration of plasma IGF-I at 14 d of age, but males had higher IGF-I at 28 d of age (Newcombe *et al.*, 1992). The values reported by these authors for chickens at 28 d of age were 31.78 vs 29.09 pg/µL, indicating very similar plasma IGF-I concentrations between chickens and Pekin ducks.

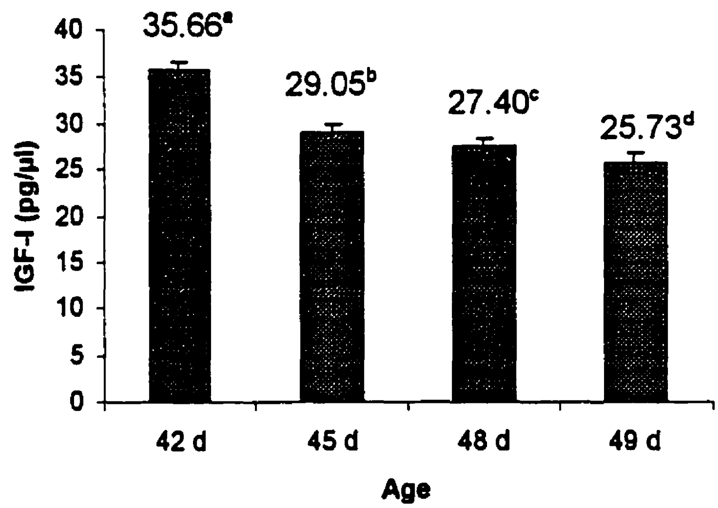

FIGURE 6.5. Effect of age on plasma IGF-I of Pekin ducks from 42 to 49 d of age ($P<0.0001$). Values are means for 48 ducks per age

There was a consistent and significant decline in plasma IGF-I from 42 to 49 d of age (Figure 6.5). Huybrechts *et al.* (1985) reported an increase in plasma IGF-I concentration up to 6 wk of age followed by a decrease in this concentration in a light strain of chicken, but the increase in IGF-I levels was maintained up to 12 wk of age in heavy broiler type strains. Newcombe et al. (1992) reported an increase in plasma IGF-I with age only up to 28 d of age in broiler chicks. The decrease in plasma IGF-I observed in this study may be important in terms of its association with the sharp decline of feed efficiency in Pekin ducks observed after 6 wk of age (Farhat and Chavez, 1999b) when most of the metabolizable energy acquired from the feed is dedicated to body maintenance and fat deposition rather than lean tissue growth.

Experiment 3

The effects of selection for breast muscle thickness and the state of feed deprivation or feeding on plasma IGF-I are presented in Table 6.2. There was a significant ($P < 0.05$) interaction between the selection criteria (high or low breast muscle to total breast thickness ratio, MT:TOT) and the state of feed deprivation or feeding. The ducks with higher MT:TOT ratio were more affected by fasting than those with a low ratio, but both had similar plasma IGF-I concentrations. When fed, the high MT:TOT ratio ducks had significantly higher IGF-I than the low MT:TOT ratio ducks. These data agree with those seen in chickens and Japanese quail. Morishita *et al.* (1993) reported depressed IGF-I concentration in feed deprived chickens and refeeding restored close to normal levels of IGF-I. Feed restriction in Japanese quail resulted in a decline in plasma IGF-I and refeeding reversed the effect (Schew *et al.*, 1996).

TABLE 6.2. Effects of selection for high or low breast muscle thickness to total breast thickness and state of fasting or feeding on plasma IGF-I of female Pekin ducks (n=30)

Selection criterion	State	IGF-I (pg/ml)
High breast muscle : total breast	Fasted	11.81 [c]
High breast muscle : total breast	Fed	21.20 [a]
Low breast muscle : total breast	Fasted	11.43 [c]
Low breast muscle : total breast	Fed	16.97 [b]
SEM		0.65
		Probabilities
Selection criterion		0.0060
State		0.0001
Selection criterion * state		0.0207
Main effects		
Selection criterion		
High breast muscle : total breast		16.5
Low breast muscle : total breast		14.32
State		
Fasted		11.62
Fed		19.09

[abc] Means within column with no common superscript differ significantly (*P*<0.05)

CONCLUSION

Pekin ducks have a fast growth rate compared to other poultry species, but possess a less desirable carcass because of its high proportion of fat. To meet current and future consumer demands, the duck industry must consider alternative dietary and management systems as well as genetic selection programs. An understanding of the characteristics of important factors influencing the metabolism involved in lean growth such as IGF-I should contribute toward improving the efficiency of lean duck production.

SECTION VII

OVERALL SUMMARY AND CONCLUSIONS

With the continuous change in the trends of animal products consumption, livestock and poultry productions have to adapt to meet the consumer demands. Recently two important issues in meet consumption have become of considerable importance, the health-wise undesirable fat content and the booming business of home replacement meals. Consequently, selection for more meat and less fat in animal meat have been very active during the last two decades. In poultry, breast muscle yield is the main target in research efforts because it is considered the most important meat mass in the bird. Previously, our team have selected Pekin ducks for greater breast muscle thickness (MT) at market age. The objectives of this thesis were to study the effect of selection for breast muscle thickness on the reproductive and metabolic performance of the selected line, to determine the response of growth and carcass component and composition to the selection and to dietary protein programs, and to examine the effects of line, dietary protein, sex, age, and the feed-deprived or fed state on plasma IGF-I and other metabolites in White Pekin ducks.

The selection for MT produced similar reproductive response as that of the control line (C). However, the selection of heavy body weight (BW) resulted in reduced fertility and hatchability partly explained by the larger eggs laid by the BW line. It was concluded from this study that the selection for MT had no negative effect on the reproductive performance of Pekin ducks.

When fed a single conventional diet, males from MT line reached market weight at 6 wk, but the breast muscle thickness improved significantly from 6 to 7 wk. This indicates that the dietary program provided may be insufficient in terms of protein for the MT line of birds, especially the males, to synchronize their breast muscle development with their faster growth revealed by their body weight. Compared to the C line, the MT ducks had higher carcass yield, breast muscle thickness, and body protein, and had lower fat that confirms the desirable effect of selection on the improvement of carcass quality.

Increasing dietary protein improved body weight, MT, and cumulative ratio at 6 wk of age. Daily measurements of MT in vivo and through dissection from 42 to 49 d demonstrated that increasing dietary protein improved breast meat yield. Males receiving high protein program were ready to market with improved carcass quality at 45 d instead of 49 d. This reduction in processing time is of important economical importance because 2/3 of an extra flock can be reared per year and represent about 8 % improvement in feed efficiency. Medium protein program was observed to be optimal for the female Pekin ducks. Analysis of eviscerated carcass showed that increasing dietary protein reduced carcass fat and increased CP content. Age had no effect on male carcass fat and CP content, but carcass CP declined with age in females. Breast muscle thickness measured with ultrasound correlated positively with body weight and pectoralis yield, and birds with higher pectoralis yield tended to have more CP and less fat in their carcasses. A low correlation was found for the caliper measurement of breast skin plus fat thickness and carcass fat. It was concluded from this study that males responded more efficiently to increasing dietary protein than females, and males selected for greater MT can be slaughtered at earlier age when fed the high protein program. In addition, the correlation ($r=0.73$, P=0.0001) between the ultrasound breast muscle measurement and pectoralis yield validates this technique for the use in selection of birds for higher carcass merit.

Female ducks with greater breast muscle:total breast thickness ratio (MT/TOT) had lower carcass fat and higher CP content than the low MT/TOT ducks. Apparent and true metabolizable energy of the precisely-fed test diet were similar between the two groups of ducks, but the high ratio ducks retained more nitrogen from the diet and lost less nitrogen when deprived of feed. The effect of feed-deprivation and refeeding, in lean and fat ducks, on blood parameters related to fatness were discussed comparatively with other poultry species selected for fatness and leanness. Although plasma parameters determined in this study can not be used as indicators of leanness or fatness in Pekin ducks, significant correlations of these parameters with the breast thickness measurement, nitrogen retention, and energy excretion were reasonable. Precisely-feeding starch-oil solution for the estimation of metabolic endogenous losses resulted in less dry matter, energy, and individual fatty acid excretion than feeding dextrose solution. This study described the metabolic differences between lean and fat ducks comparatively to lean and fat birds from other species. The positive or negative correlations between MT/TOT and carcass CP or fat, respectively, support the use of MT measurement by ultrasound technique for the selection of superior quality carcass.

Plasma IGF-I in Pekin ducks was assayed in a heterologous radioimmunoassay for human IGF-I. When treated with acid, the response dose of duck IGF-I was parallel to that of human rIGF-I. The ducks with greater MT had higher plasma IGF-I concentration than the control ducks. There was no significant difference in plasma triglycerides or total cholesterol between MT and C lines. However, the MT line had higher ($P < 0.05$) plasma glucose than the C line. Lean chickens selected for lower abdominal fat or glycemia exhibited higher plasma glucose than fat birds. The higher plasma IGF-I in MT ducks may partially explain the sparing of glucose in the leaner birds, an effect of growth hormone that might be mediated by IGF-I. The lower plasma uric acid in the MT ducks may be in support of this speculation because, in chickens, growth hormone was observed to decrease the sensitivity of peripheral tissues to insulin that was reported to stimulate uric acid production by isolated hepatocytes and increase plasma uric acid. Although the birds selected for greater breast muscle thickness had improved carcass composition, their body weights were similar to control ducks indicating that the higher IGF-I concentration may not be associated with higher growth rate. These observations may refer to a more possible involvement of IGF-I in intermediary metabolism and lean tissue development than in growth in Pekin ducks. However, similarly to the effect on breast muscle yield and carcass protein content, increasing dietary protein induced an increase in plasma IGF-I level. The increase in breast meat growth may be either a direct effect of increasing dietary protein, indirectly through increasing plasma IGF-I, or a synergistic effect of both. The higher IGF-I in males plasma may explain the higher growth rate or degree of leanness in males than in females. The gradual decrease in plasma IGF-I concentrations with age from 42 to 49 d could be associated with the significant and economically important decline in feed efficiency observed in the ducks from 6 to 7 wk of age.

Feed deprivation was more detrimental on the plasma IGF-I level of lean ducks than of fat ones. Ducks with higher MT/TOT had higher plasma IGF-I after refeeding, and there was a positive correlation between MT/TOT and plasma IGF-I concentrations.

The outcome of this research project supports the implementation of breast muscle ultrasonography in the selection of ducks to improve growth and carcass characteristics. The nutritional support of the selection for higher breast muscle yield presented in these experiments may result in invaluable economical gain by reducing the growth period of Pekin ducks to market age. The analysis and characterization of plasma IGF-I in Pekin ducks is an original contribution to poultry science in general, and specifically to the research in Pekin ducks. Insulin-like growth factor-I seems to be involved in the regulation of lean tissue development in Pekin ducks.

SECTION VIII

REFERENCES

Abdelsamie, R.E., and J.D. Farrell, 1986. Carcass composition and carcass characteristics of ducks. Pages 83-101 in: Duck Production Science and World Practice (Farrell and Stapleton, Eds.).University of New England, Armidale, Australia.

Ajang, O. A., S. Prijono, and W. K. Smith, 1993. Effect of dietary protein content on growth and body composition of fast and slow feathering broiler chickens. Br. Poult. Sci. 34:73-91.

Akbar, M. K., 1996. Application of very low density lipoprotein and other parameters as indicators of carcass fat in ducks. Poultry Sci. 75 (Suppl. 1):64.

Allison, J. B., 1955. Biological evaluation of proteins. Physiol. Rev. 35:664-700.

American Poultry Association, 1989. American Standard of Perfection. American Poultry Association, Inc., Estacada, Oregon.

Anthony, N. B., R. Vasilatos-Younken, W. L. Bacon, and M. S. Lilburn, 1990. Secretory pattern of growth hormone, insulin, and related metabolites in growing male turkeys. Effects of overnight fasting and refeeding. Poultry Sci. 69:801-811.

Anthony, N. B., E. A. Dunnington, and P. B. Siegel, 1989. Composition of eggs from dwarf and normal chickens in lines selected for 56-day body weight. Poultry Sci. 68:591-595.

AOAC, 1990. Official Methods of Analysis 15th ed. Association of Official Analytical Chemists. Washington, DC.

Bacon, W. L., K. E. Nestor, D. A. Emmerson, and R. Vasilatos-Younken, 1993. Circulating IGF-I in plasma of growing male and female turkeys of medium and heavy weight lines. Domest. Anim. Endocrinol. 10:267-277.

Badenoch-Jones, P., and P.J. Buttery, 1975. Ureate synthesis by isolated chick liver cells. International J. Biochem. 6:387-392.

Baeza, E., and B. Leclercq, 1998. Use of industrial amino acids to allow low protein concentrations in finishing diets for growing Muscovy ducks. Br. Poult. Sci. 39:90-96.

Baeza, E., H. DE Carville, M. R. Salichon, G. Marche, and B. Leclercq, 1997. Effects of selection, over three and four generations, and meat yield and fatness in Muscovy ducks. Br. Poult. Sci. 38:359-365.

Ballard, F. J., R. J. Johnson, P. C. Owens, G. L. Francis, F. M. Upton, J. P. McMurtry, and J. C. Wallace, 1990. Chicken insulin-like growth factor-I: amino acid sequence, radioimmunoassay, and plasma levels between strains during growth. Gen. Comp. Endocrinol. 79:459-468.

Barbato, G. F., cited in Thornton, G., 1996. High-yielding broiler production: the big trade-off. Broiler Industry Aug.:18-22.

Barton-Davis, E. R., D. I. Shoturma, A. Musro, N. Rosental, and H. L. Sweeney, 1998. Viral mediated expression of insulin-like growth factor I blocks the aging-related loss of skeletal muscle function. Proc. Natl. Acad. Sci. 95:15603-15607.

Bartov, I., 1998. Effect of diets with adequate or low energy to protein ratio on carcass and breast meat yields of Ross female broiler chicks at 43 and 57 days of age. Page 647-650 in: Proceedings of the Tenth European Poultry Conference, WPSA .

Bartov, I, and I. Plavnik, 1998. Moderate excess of dietary protein increases breast meat yield of broiler chicks. Poultry Sci. 77:680-688.

Bass, J. J., B. W. Butler-Hogg, and A. H. Kirton, 1990, Practical methods of controling fatness in farm animals. Pages 145-200 in: Reducing Fat in Meat Animals (Wood and Fisher Eds.). Elsevier Applied Science, UK.

Blair, H. T., S. N. McCutcheon, D. D. S. Mackenzie, P. D. Gluckman, J. E. Ormsby, and B. H. Breier, 1989. Responses to divergent selection for plasma concentrations of insulin-like growth factor-I in mice. Genet. Res. 53:187-191.

Brown, L. R., 1997. Meat production growth slows. Pages 300-31 in: Vital Signs. Worldwatch Institute, Norton, NY.

Buonomo, F. C., T. J. Lauterio, C. A. Baile, and D. R. Campion, 1987. Determination of insulin-like growth factor 1 (IGF1) and IGF binding protein levels in swine. Domest. Anim. Endocrinol. 4:23-31.

Burke, W.H., and S.E. Builder, 1985. The effect of recombinant chicken growth hormone on circulating growth hormone levels, growth, feed efficiency, plasma hormones and carcass composition of broilers. Poultry Sci. 64 (suppl. 1):8.

Cahaner, A., Y. Pinchasov, and I. Nir, 1995. Effects of dietary protein under high ambient temperature on body weight, breast meat yield, and abdominal fat deposition of broiler stocks differing in growth rate and fatness. Poultry Sci. 76:968-975.

Cahaner, A., Z. Nitsan, and I. Nir, 1986. Reproductive performance of broiler lines divergently selected on abdominal fat. Poultry Sci. 65:1236-1243.

Campbell, R. G., H. Karunageevra, and I. Bagot, 1985. Influence of food intake and sex on the growth and carcass composition of Pekin ducks. Br. Poult. Sci., 26:43-50.

Caperna, T. J., R. W. Rosebrough, J. P. McMurtry, and R. Vasilatos-younken, 1996. Influence of dietary protein on insulin-like growth factor (IGF) binding proteins in the chicken. FASEB 10:A727.

Chu, F, C. Kies, and E. T. Clemens, 1995. Studies of human diets with pork, beef, fish, soybean, and poultry: nitrogen and fat utilization, and blood serum chemistry. J. Appl. Nutr. 47:51-66.

Clayton, G. A., and J. C. Powell, 1979. Growth, food conversion, carcass yields and their heritability in ducks (Anas platyrhynchos). Br. Poult. Sci. 20:121-127.

Clutter, A. C., L. J. Spicer, M. D. Woltmann, R. W. Grimes, J. M. Hammond, and D. S. Buchanan, 1995. Plasma growth hormone, insulin-like growth factor-I, and insulin-like growth factor binding proteins in pigs with divergent genetic merit for postweaning average daily gain. J. Anim. Sci. 73:1776-1783.

Copeland, K.C., L. E. Underwood, and J. J. Van Wyk, 1980. Induction of immunoreactive Somatomedin C in human serum by growth hormone: dose response relationships and effect on chromatographic profiles. J. Clin. Endocrinol. Met. 50: 690-697.

Cravener, T. L., R. H. Wellenreiter, and R. Vasilatos-Younken, 1989. Effect of subcutaneous infusion of pituitary-derived chicken growth hormone on growth performance of broiler pullets. Poultry Sci. 68:1133-1140.

Davis, M. E., M. D. Bishop, N. H. Park, and R. C. M. Simmen, 1995. Divergent selection for blood serum insulin-like growth factor I concentration in beef cattle. 1. Nongenetic effects. J. Anim. Sci. 73:1927-1932.

Davis, M. E., M. D. Bishop, 1991. Preliminary results on between and within twin set variation in insulin-like growth factor I (IGF-I) and some relationship with performance traits in identical twin heifers. Livest. Prod. Sci. 27:255-262.

Dawson, R. D., and G. R. Bortolotti, 1997. Total plasma protein level as an indicator of condition in wild American Kestrel (Falco sparverius). Can. J. Zool. 75:680-686.

Dean, W. F., 1996. Personal communication.

Dean, W. F., J. R. Stouffer, and D. L. Cunningham, 1987. Estimation of breast muscle mass in ducks with ultrasound. Poultry Sci. 66 (suppl. 1):90.

Dean, W.F., 1986. Nutrient requirements of meat-type ducks. Pages 31-57 in: Duck Production Science and World Practice (Farrell and Stapleton, Eds.).University of New England, Armidale, Australia.

Dean, W. F., 1972. Recent findings in duck nutrition. Proc. Cornell Nutr. Conf., Ithaca, NY.

De Buisonjé, F., 1999. Three phase feeding ducks. World Poultry 15(4):23-24.

Decuypere, E., and J. Buyse, 1988. Thyroid hormones, corticosterone, growth hormone and somatomedins in avian species: general effects and possible implications in fattening. Pages 295-312 in: Leanness in Domestic Birds. (Leclercq, B., and C.C.Whitehead, Eds.). INRA, Butterworths.

Decuypere, E., J.Buyse, C. G. Scanes, L. M. Huybrechts, and E. R. Káhn, 1987. Effects of hyper- or hypothyroid status on growth, adiposity and levels of growth hormone, somatomedin C and thyroid metabolism in broiler chickens. Reprod., Nutr. Dev. 27:71-81.

Dimock, H. D., E. B. Marliss, and S. P. Touchburn, 1988. Plasma pancreatic hormones in genetically fat and lean chickens. Pages 323-325 in: Leanness in Domestic Birds. (Leclercq, B., and C.C.Whitehead, Eds.). INRA, Butterworths.

Dodson, M.V., K.L.Hossner, J.L.Vierck, B.Mathison, and E. Krabbenhoft, 1996. Correlation of serum GH and IGF-1 with satellite cell responsiveness in Targhee rams. Anim. Sci. 62:89-96.

Douglas, C. R., and R. H. Harms, 1959. Peanut oil meal as a source of protein in broiler diets. Poultry Sci. 38:786-790.

Dunn, N., 1998. Integrated duck production for 80 countries. World Poultry 14(12):41-43.

Elkin, R. G., 1987. A review of duck nutrition research. World Poultry Sci. 43:84 -106.

Emmerson, D. A., 1997. Commercial approaches to genetic selection for growth and feed conversion in domestic poultry. Poultry Sci. 76:1121-1125.

Farhat, A., L.Normand, E.R.Chavez, and S.P.Touchburn, 1999. Comparison of growth performance, carcass yield and composition, and fatty acid profiles of Pekin and Muscovy ducklings fed diets based on food wastes. Can.J.Anim.Sci. (Submitted MS # 9052).

Farhat A., and E. R. Chavez, 1999a. Reproductive performance of F1 Pekin duck breeders selected with ultrasound scanning for breast muscle thickness and the effect of selection on F2 growth and muscle measurement. Poultry Sci. (In preparation).

Farhat A., and E. R. Chavez, 1999b. Comparative performance, blood chemistry and carcass composition of two lines of Pekin ducks reared mixed or separated by sex. Poultry Sci. (Submitted).

Farhat A., and E. R. Chavez, 1999c. Growth and carcass characteristics of Pekin ducks selected for greater breast muscle thickness using ultrasound scanning in response to dietary protein. Poultry Sci. (In preparation).

Farhat A., and E. R. Chavez, 1999d. Metabolic studies on lean and fat Pekin ducks selected for breast muscle thickness measured by ultrasound scanning. Poultry Sci. (Submitted).

Farhat A., and E. R. Chavez, 1999e. Effects of line, dietary protein, sex, age, and feed withdrawal on insulin-like growth factor-I (IGF-I) in White Pekin ducks. Poultry Sci. (In Press).

Farrell, D.J., 1990. Nutrition and carcass quality in ducks. Pages 177-197 in: Recent Advances in Animal Nutrition ((Haresign and Cole Eds.). Butterworths, UK.

Fernández, C., A. Garciá, H. Vergara, and L. Gallego, 1998. Using ultrasound to determine fat thickness and longissimus dorsi area on Manchego lambs of different live weight. Small Ruminant Research 27:159-165.

Fisher, C., 1984. Fat deposition in broilers. Pages 437-470 in: Fats in Animal Nutrition (J. Wiseman Ed.). Butterworths, London.

Foltzer, C., and P. Mialhe, 1976. Pituitary and adrenal control of pancreatic endocrine function in the duck. II. Plasma free fatty acids and insulin variations following hypophysectomy and replacement therapy with growth hormone and corticosterone. Diabète et Métabolisme 2:101-105.

Geraert, P. A., M. G. Macleod, and B. Leclercq, 1988. Energy metabolism in genetically fat and lean chickens: Diet -and cold-induced thermogenesis. J. Nutr. 118:1232-1239.

Geraert, P. A., M. G. Macleod, T. R. Jewitt, and J. Anderson, 1987. Energy and nitrogen metabolism in genetically fat and lean chickens. Proceedings of the Nutrition Society 46:34A.

Gille, U, and F-V. Salomon, 1998. Muscle growth in wild and domestic ducks. Br. Poult. Sci.

39:500-505.

Goddard, C., R. S. Wilkie, and I. C Dunn, 1988. The relationship between insulin-like growth factor-I, growth hormone, thyroid hormones and insulin in chickens selected for growth. Domest. Anim. Endocrinol. 5:165-176.

Gorman, I, and D. Balnave, 1995. The effect of dietary lysine and methionine concentrations on the growth characteristics and breast meat yields of Australian broiler chickens. Aust. J. Agric. Res. 46:1569-1577.

Greshman, J. D., S. R. McPeake, J. K. Bernard, and H. H. Henderson, 1992. Commercial adaptation of ultrasonography to predict pork carcass composition from live animal and carcass measurements. J. Anim. Sci. 70:631-639.

Griffin, H., D. Windsor, D. Burt, A. Law, and P. Hocking, 1998. Manipulation of lipid metabolism in poultry. Pages 12-15 in: Proceedings of the Tenth European Poultry Conference, WPSA .

Griffin, H. D., and C. Gobbard, 1994. Rapidly growing broiler (meat-type chickens): their origin and use for comparative studies of the regulation of growth. International J. Biochem. 26:19-28.

Griffin, H. D., C. C. Whitehead, 1985. Identification of lean or fat turkeys by measurement of plasma very low density lipoprotein concentration. Br. Poult. Sci. 26:51-56.

Griffin, H. D., C. C. Whitehead, and L. A. Broadbent, 1982. The relationship between plasma triglyceride concentrations and body fat content in male and female broilers-a basis for selection? Br. Poult. Sci. 23:15-23.

Guler, H. P., J. Zapf, E. Scheiwiller, and E.R.Froesch, 1988. Recombinant human insulin-like growth factor I stimulates growth and has distinct effects on organ size in hypophysectomized rats. Proc. Natl. Acad. Sci. USA 85:4889-4893.

Harvey, S., C. G. Scanes, A. Chadwick, and N. J. Bolton, 1978. Influence of fasting, glucose and insulin on the level of growth hormone and prolactin in the plasma of the domestic fowl (Gallus domesticus). J. Endocrinol. 76:501-506.

Havenstein, G. B., P. R. Ferket, S. E. Scheideler, and D. V. Rives, 1994. Carcass composition and yield of 1991 vs 1957 broilers when fed "typical" 1957 and 1991 broiler diets. Poultry Sci. 73:1795-1804.

Hazelwood, R.L., and D.R.Langslow, 1978. Intrapancreatic regulation of hormone secretion in the domestic fowl, Gallus domesticus. J. Endocrinol. 76:449-459.

Heath, J. J., 1981. Sex-separate rearing, feeding and fat pads. Poultry Digest 40 (475):450,454.

Hetzel, D. J. S., 1986. Domestic ducks: an historical perspective. Pages 1-5 in: Leanness in Domestic Birds. (Leclercq, B., and C.C.Whitehead, Eds.). INRA, Butterworths.

Hevia, P., and W. J. Visek, 1979. Dietary protein and plasma cholesterol in chickens. J. Nutr.

109:32-38.

Huybrechts, L.M., E. Decuypere, J. Buyse, E. R. Kühn, and M. Tixier-Boichard, 1992. Effect of recombinant human insulin-like growth factor-I on weight gain, fat content, and hormonal parameters in broiler chickens. Poultry Sci. 71:181-187.

Huybrechts, L.M., D.B.King, T.J.Lauterio, J.Marsh, and C.G.Scanes, 1985. Plasma concentrations of somatomedin-C in hypophysectomized, dwarf and intact growing domestic fowl as determined by heterologous radioimmunoassay. J.Endocrinol. 104:233-239.

Hyánková, L., L. Dědková, H. Knížetová, and D. Klecker, 1997. Response in growth, food intake and food conversion efficiency to different dietary protein concentrations in meat-type lines of Japanese quail. Br. Poult. Sci. 38:564-570.

Ide, T., T. Tanaka, and M. Sugano, 1979. Dietary fat-dependent changes in hepatic cholesterogenesis and the activity of 3-hydroxy-3methylglutaryl-CoA reductase in fasted-refed rats. J. Nutr. 109:807-818.

Johansson, K., and B. W. Kennedy, 1983. Genetic and phenotypic relationships of performance test measurements with fertility in Swedish Landrace and Yorkshire sows. Acta. Agric. Scand. 33:195-199.

Johnson, R. J., J. P. McMurtry, and F. J. Ballard, 1990. Ontogeny and secretory patterns of plasma insulin-like growth factor-I concentrations in meat-type chickens. J. Endocrinol. 124:81-87.

Karasawa, Y., and K. Kibe, 1983. Stimulation of uric acid production and depression of increase in plasma glutamine concentration by insulin in chickens infused with ammonia. Comp. Biochem. Physiol. 74A:95-99.

Kempster, A. J., D. Arnall, J. C. Alliston, J. D. Blarker, 1982. An evaluation of two ultrasonic machines (Scanogram Danscaner) for predicting the body composiiton of live sheep. Anim. Prod. 34:249-255.

Kirkwood, R. N., and F. X. Aherne, 1985. Energy intake, body composition and reproductive performance of the gilt. J. Anim. Sci. 60:1518-1529.

Klindt, J., 1994. Influence of porcine somatotropin administration and sex on glucose and endocrine response of obese pigs. Proceedings of the Society for Experimental Biology and Medicine 207:48-56.

Knížetová, H., J. Hyánek, L. Hyánková, and P. Bělíček, 1995. Comparative study of growth curves in poultry. Genet. Sel. Evol. 27:365-375.

Kocamis, H., D. C. Kirkpatrick-Keller, H. Klandorf, and J. Killefer, 1998. In ovo administration of recombinant human insulin-like growth factor-I alters postnatal growth and development of the broiler chicken. Poultry Sci. 77: 1913-1919.

Komender, P., and M. Grashorn, 1990. Ultrasound measurement of breast meat. Poult. Int. 29:36-40.

König, T., M. A. Grashorn, and W. Bessei, 1998. Estimation of breast meat yield in living broilers using B-scan sonography. Second Report: accuracy of the method. Arch. Geflügelk. 62:121-125.

König, T., M. A. Grashorn, and W. Bessei, 1997. Estimation of breast meat yield in living broilers using B-scan sonography. First Report: Defining sites of measurement. Arch. Geflügelk. 61:227-231.

Ksiazkiewicz, J., H. Kontecka, and L. Nogowski, 1993. A note on blood cholesterol as an indicator of body fatness in ducks. J. Anim. Feed Sci. 1:289-294.

Lavallée, S., 1998. Application of ultrasound technology for selection and production of lean Pekin ducks. M.Sc. thesis, McGill University, Montréal, QC, Canada.

Lavallée, S., E. R. Chavez, S. P. Touchburn, and P. C. Laguë, 1998. Assessment of feeding program during thr rearing period of Pekin ducks selected as breeders for lean meat production. Pages 117-120 in: Research Reports, Department of Animal Science, McGill University, Montreal, QC, Canada. http://animsci.agrenv.mcgill.ca/

Laurin, D. E., S. P. Touchburn, E. R. Chavez, and C. W. Chan, 1985: Methods of measuring energy utilization in broilers: effect of genetic line and presence of supplemental dietary fat. Poultry Sci. 64:969-978.

Lauterio, T. J., and C. G. Scanes, 1987. Hormonal responses to protein restriction in two strains of chickens with different growth characteristics. J. Nutr. 117:758-763.

Leclercq, B., 1988. Genetic selection of meat-type chickens for high or low abdominal fat content. Pages 25-40 in: Leanness in Domestic Birds. (Leclercq, B., and C.C.Whitehead, Eds.). INRA, Butterworths.

Leclercq, B., and G.Guy, 1988. Plasma phospholipids and triglycerides in four experimental lines genetically different in their fattening. Pages 235-237 in: Leanness in Domestic Birds. (Leclercq, B., and C.C.Whitehead, Eds.). INRA, Butterworths.

Leclercq, B., J.Simon, and F.H.Ricard, 1987. Genetic selection of chickens for high or low plasma glucose concentration and its effects on adiposity and feed efficiency. Br. Poult. Sci. 28:557-565.

Leclercq, B., J. Kouassi-Kouakou, and J. Simon, 1985. Laying performance, egg composition and glucose tolerance of genetically lean and fat meat-type breeders. Poultry Sci. 64:1609-1616.

Leclercq, B, 1984. Adipose tissue metabolism and its control in birds. Poultry Sci. 63:2044-2054.

Leclercq, B., 1983. The influence of dietary protein content on the performance of genetically lean or fat growing chickens. Br. Poult. Sci. 24:581-587.

Leclercq, B., and A.Saadoun, 1982. Selecting broilers for low or high abdominal fat : comparison of energy metabolism of the lean and fat lines. Poultry Sci. 61:1799-1803.

Leclercq, B., and J. Simon, 1982. Selecting broilers for low or high abdominal fat: observations on the hens during the breeding period. Ann. Zootech. 31:161-170.

Lee, P. D. K., A. Peacock, M. K. Roessler, J. Hester, and J. T. Reeves, 1989. Insulin-like growth factor (IGF)-I and IGF-binding activity in normal and fast-growing chickens. Life Sci. 45:2465-2470.

Leeson, S., 1997. Poultry feeding 2010. Pages 186-193 in: Eastern Nutrition Conference. University of Guelph, ON, Canada.

Leeson, S. and J.D. Summers, 1997. Pages 248-259 in: Commercial Poultry Nutrition. 2nd ed. University Books, Guelph, Ontario, Canada.

Leeson, S., L. Caston, and J. D. Summers, 1996. Broiler response to diet energy. Poultry Sci. 75:529-535.

Leeson, S., L.J. Caston, and J.D. Summers, 1988. Response of male and female broilers to diet protein. Can. J. Anim. Sci. 68:881-889.

Leeson, S., and J. D. Summers, 1980. Production and carcass characteristics of the broiler chicken. Poultry Sci. 59:786-798.

LeResche, R. E., U. S. Seal, P. D. Karns, and A. W. Franzmann, 1974. A review of blood chemistry of moose and other Cervidae with emphasis on nutritional assessment. Nat. Can. (Que.) 101:263-290.

Leveille, G. A. and Y. Yeh, 1972. Influence of intermittent fasting or protein-free feeding on lipid metabolism in young cockerels. J. Nutr. 102:733-740.

Leveille, G. A., and H. E. Sauberlich, 1961. Influence of dietary protein level on serum protein components and cholesterol in the growing chick. J. Nutr. 74: 500-504.

Lilburn, M. S., and K. E. Nestor, 1993. The relationship between various indices of carcass growth and development and reproduction in turkey hens. Poultry Sci. 72:2030-2037.

Lilburn, M. S., and D. J. Myers-Miller, 1988. Development of lean and fat lines of chickens by sire family selection procedures. Pages 87-93 in: Leanness in Domestic Birds. (Leclercq, B., and C.C.Whitehead, Eds.). INRA, Butterworths.

Lühmann, M., and H.Vogt, 1975. Slaughter losses and breast muscle weights of 7-9 weeks old Pekin ducks. Arch. Geflugelk. 4:126-134.

MacLeod, M. G., 1997. Effects of amino acid balance and energy:protein ratio on energy and nitrogen metabolism in male broiler chickens. Br. Poult. Sci. 38:405-411.

MacLeod, M. G., C. C. Whitehead, H. D. Griffin, and T. R. Jewitt, 1988. Energy and nitrogen retention and losses in broiler chickens genetically selected for leanness and fatness. Br. Poult. Sci. 29:285-292.

MacLeod, M. G., and P. A. Geraert, 1988. Energy metabolism in genetically fat and lean birds and mammals. Pages 109-120 in: Leanness in Domestic Birds. (Leclercq, B., and C.C.Whitehead, Eds.). INRA, Butterworths.

March, B. E., 1984. Plasma triglyceride and glucose clearance in broiler-type and White Leghorn chickens with different degrees of adiposity. Poultry Sci. 63:1586-1593.

May, G. C., and D. Hawksworth, 1982. British Poultry Standards, fourth ed. London, Butterworths.

McMurtry, J. P., 1998. Nutritional and developmental roles of insulin-like growth factors in poultry. J.Nutr. 128: 302S-305S.

McNab, J. M., and J. C. Blair, 1988. Modified assay for true and apparent metabolizable energy based on tube feeding. Br.Poult.Sci. 29:697-707.

Metzler, M. J., W. M. Britton, and L. R. McDougald, 1987. Effects of monensin feeding and withdrawal time on growth and carcass composition in broiler chickens. Poultry Sci. 66:1451-1458.

Morishita, D., M. Wakita, and S. Hoshino, 1993. Effect of hypophysectomy on insulin-like growth factor (IGF)-I binding activity of serum in chickens. Comp. Biochem. Physiol. 104A:261-265.

Namier, B., P. A. Geraert, and M. Larbier, 1986. Metabolic utilization of leucine in fat and lean line of chicken. Comp. Biochem. Physiol. 83A:735-737.

National Research Council (NRC), 1988. Designing Foods: Animal porduct options in the marketplace. Committee on technological options to improve the nutritional attributes of animal products. Board on Agriculture, National Research Council. Washington, DC., National Academy Press.

Nestor, K. E., and D. O. Noble, 1995. Influence of selection for increased egg production, body weight and shank width of turkeys on egg composition and the relationship of the egg traits to hatchability. Poultry Sci. 74:427-433.

Nestor, K. E., Y. M. Saif, D. A. Emmerson, and N. B. Anthony, 1995. The influence of genetic changes in body weight, egg production, and body conformation on organ growth of turkeys. Poultry Sci. 74:601-611.

Nestor, K. E., and W. L. Bacon, 1986. The influence of genetic increases in egg production and body weight on egg mass production and biological efficiency of turkey hens. Poultry Sci. 65:1410-1412.

Nestor, K. E., 1984. Genetics of growth and reproduction in the turkey. 9. Long-term selection for increased 16-week body weight. Poultry Sci. 63:2114-2122.

Newcombe, M., A. L. Cartwright, J. M. Harter-Dennis, and J. P. McMurtry, 1992. The effect of increasing photoperiod and food restriction in sexed, broiler-type birds. II. Plasma thyroxine, triiodothyronine, insulin-like growth factor-I and insulin. Br. Poult. Sci. 33:427-436.

Nideau, N., 1988. Insulin secretion in birds. Pages 269-294 in: Leanness in Domestic Birds. (Leclercq, B., and C. C. Whitehead, Eds.). INRA, Butterworths.

Normand, L., 1997. Recycling of agro-industrial food wastes into feed for Pekin duck meat production towards a sustainable agriculture in the province of Québec. M.Sc. thesis, McGill University, Montréal, QC, Canada.

Normand, L., A. Farhat, E. R. Chavez, S. P. Touchburn, and P. C. Laguë, 1996a. Duck meat production based on the recycling of agro-industrial food waste in the province of Québec. Pages 75-78 in: Research Reports, Department of Animal Science, McGill University, Montréal, QC, Canada.

Normand, L., S. Lavallée, A. Farhat, E. R. Chavez, S. P. Touchburn, and P. C. Laguë, 1996b. Comparison of carcass composition of ducks receiving diets based on industrial food wastes and commercial feed. Pages 82-85 in: Research Reports, Department of Animal Science, McGill University, Montréal, QC, Canada.

N.R.C., 1994. Nutrient Requirements of Poultry. 9th Ed. National Academic Press, Washington, DC.

Payne, C. G., and D. Lewis, 1963. Fats and amino acids in broiler rations. 4. Energy-protein balance in finisher rations. Br. Poult. Sci. 4:179-190.

Pell J. M., and P. C. Bates, 1993. Differential action of growth hormone and insulin-like growth factor I on tissue protein metabolism in dwarf mice. Endocrinology 130:1942-1950.

Pietrobelli, A., Z. Wang, C. Formica, and S. B. Heymsfield, 1998. Dual-energy X-ray absorptiometry: fat estimation errors due to variation in soft tissue hydration. Am. J. Physiol.-Endocrinol. Met. 37:E808-E816.

Pingel, H., 1990. Genetics of egg production and reproduction in waterfowl. Pages 771-780 in: Poultry Breeding and Genetics (Crawford, R. D., Ed.). Elsevier, Amsterdam.

Pingel, H., and M. Heimpold, 1983. Efficiency of selection for live weight and breast meat proportion in ducks. Archiv Tierzucht 26:435-444.

Pingel, H., and S. Jung, 1979. Untersuchungen uber die selektion auf brustmuskeldicke bei enten. Arch. Fur. Tierzucht 22:281-286.

Plavnik, I., S.Hurwitz, and H.Barash, 1982. The effect of feed restriction on the growth, feed conversion and fattening of Pekin ducks. Nutrition Reports Internat. 25:907-911.

Pollock, D., 1997. Maximizing yield. Poultry Sci. 76:1131-1133.

Powell, J. C., 1986. The possibilities for genetic improvement of commercial production characteristics and carcass quality in the meat duck. Pages 184-192 in: Duck Production Science and World Practice (Farrell and Stapleton, Eds.).University of New England, Armidale, Australia.

Pym, R. A. E., P. J. Nicholls, E. Thomson, A. Choice, and D. J. Farrell, 1984. Energy and nitrogen metabolism of broilers selected over ten generations for increased growth rate, food consumption and conversion of food to gain. Br. Poult. Sci. 25: 529-539.

Pym, R. A. E., and D. J. Farrell, 1977. A comparison of the energy and nitrogen metabolism in broilers selected for increased growth rates, food consumption and food conversion ratio. Br. Poult. Sci. 19:411-426.

Reddy, P. R. K., and P. B. Siegel, 1977. Selection for body weight at eight weeks of age. 12. Egg production in selected and relaxed lines. Poultry Sci. 56:673-686.

Renden, J. A., and D. N. Marple, 1986. Body composition and other physical parameters as determinants of age at sexual maturity and performance efficiency in dwarf hens divergently selected for body weight. Poultry Sci. 65: 1429-1436.

Renden, J. A., G. R. McDaniel, and J. A. McGuire, 1984. Egg characteristics and production efficiency of dwarf (dw) White Leghorn hens divergently selected for body weight. Poultry Sci. 63:214-221.

Ricard, F.H., and C. Touraille, 1988. Selection for leanness and carcass quality. Pages 377-386 in: Leanness in Domestic Birds. (Leclercq and Whitehead, Eds.). INRA, Butterworths.

Roenigk, W., 1999. World poultry consumption. Poultry Sci. 78:722-728.

Rosebrough, R. W., J. P. McMurtry, and R. Vasilatos-Younken, 1999. Dietary fat and protein interactions in the broiler. Poultry Sci. 78:992-998.

Rosebrough, R. W., J. P. McMurtry, and R. Vasilatos-Younken, 1998. Further studies on carry-over effects of dietary crude protein and triiodothyronine (T_3) in broiler chickens. Br. J. Nutr. 79:89-95.

Rosebrough, R. W., and J. P. McMurtry, 1992. Metabolic and hormonal effects of feeding chickens thyroxine and diets containing varied calorie to protein ratios. Nutr. Research 12:77-87.

SAS Institute, 1990. SAS / STAT® User's Guide : Statistics. Version 6, 4th Edition. SAS Institute Inc., Cary, NC.

Saunderson, C. L., and C. C. Whitehead, 1987. N-methylhistidine excretion and (U-^{14}C)amino acid oxidation in fully fed chickens from two lines selected for high and low body fat contents. Comp. Biochem. Physiol. 86B:419-422.

Schew, W. A., F. M. A. McNabb, and C. G. Scanes, 1996. Comparison of the ontogenesis of thyroid hormones, growth hormone, and insulin-like growth factor-I in ad libitum and food-restricted (altricial) European starlings and (precocial) Japanese quail. Gen. Comp. Endocrinol. 101:304-316.

Schinckel, A. P., J. C. Forrest, J. R. Wagner, and W. Chen, 1994. Evaluation of B-mode (real-time) and A-mode ultrasound. Swine day. Anim. Sci. Dept. Purdue University.

Scollan, N. D., L. J. Caston. Z. Liu, A. K. Zubair, S. Leeson, and B. W. McBride, 1998. Nuclear magnetic resonance imaging as a tool to estimate the mass of the Pectoralis muscle of chickens in vivo. Br. Poult. Sci. 39:221-224.

Scott M.L., and W.F. Dean, 1991. Nutrition and Management of Ducks. M.L. Scott of Ithaca, Publisher, NY.

Siegel, P.B., M. Picard, I. Nir, E.A. Dunnington, M.H.A. Willemsen, and P.E.. Williams, 1997. Responses of meat-type chickens to choice feeding of diets differing in protein and energy from hatching to market weight. Poultry Sci. 76:1183-1192.

Simm, G., 1983. The use of ultrasound to predict the carcass composition of live cattle - A review. Anim. Breeding Abstr. 51:853-875.

Simon, J., and B.Leclercq, 1982. Longitudinal study of adiposity in chickens selected for high or low abdominal fat content : further evidence of a glucose-insulin imbalance in the fat line. J. Nutr. 112:1961-1973.

Simon, J., and G. Rosselin, 1978. Effect of fasting, glucose, amino acids and food intake on in vivo insulin release in the chicken. Horm. Metab. Res. 10:93-98.

Siregar, A. P., R. B. Cumming, and D. J. Farrell, 1982a. The nutrition of meat-type ducks. I. The effects of dietary protein in isoenergetic diets on biological performance. Aust. J. Agric. Res. 33:857-864.

Siregar, A. P., R. B. Cumming, and D. J. Farrell, 1982b. The nutrition of meat-type ducks. II. The effects of variation in energy and protein contents of diets on biological performance and carcass characteristics. Aust. J. Agric. Res. 33:865-875.

Smith, E. R., G. M. Pesti, R. I. Bakalli, G. O. Ware, and J. F. M. Menten, 1998. Further studies on the influence of genotype and dietary protein on the performance of broilers. Poultry Sci. 77:1678-1687.

Stanford, K., T. A. McAllister, M. MacDougall, and D. R. C. Bailey, 1995. Use of ultrasound for the prediction of carcass characteristics in Alpine goats. Small Ruminant Research 15:195-201.

Stevens, P., and B. Sauveur, 1986. Duck production and management in France. Pages 248-257 in: Leanness in Domestic Birds. (Leclercq, B., and C.C.Whitehead, Eds.). INRA, Butterworths.

Stewart, P.A., and K. W. Washburn, 1984. Hormone and lipogenic enzyme response of the heterozygous dw chick to dietary protein level. J.Nutr. 114:132-143.

Stimpson, M. J., 1998. Future developments of the duck industry in Asia Pacific. World Poultry 14(12):38-40.

Stouffer, J. R., T. C. Perry, and D. G. Fox, 1989. New techniques for real time ultrasonic evaluation of beef cattle. J. Anim. Sci. 67 (suppl 1):121.

Tixier-Boichard, M., L. M. Huybrechts, E. Decuypere, E. R. Kühn, J. L. Monvoisin, G. Coquerelle, J. Charrier, and J. Simon, 1992. Effects of insulin-like growth factor-I (IGF-I) infusion and dietary tri-iodothyronine (T_3) supplementation on growth, body composition and plasma hormone levels in sex-linked dwarf mutant and normal chickens. J. Endocrinol. 133:101-110.

Torges, H.G., 1986. Slaughter-performance of Muscovy ducks due to their age and sex. Arch. Geflügelk. 50:31-41.

Touchburn, S.P., J. Simon, and B. Leclercq, 1981. Evidence of a glucose-insulin imbalance and effect of dietary protein and energy level in chickens selected for high abdominal fat content. J. Nutr. 111:325-335.

Turcotte, R., 1995. Le canard dans le monde et chez nous. Ministère de l'Agriculture, des Pêheries et de l'alimentation du Québec.

Vagt et al., 1989. Cited in Pingel, H., 1990. Genetics of egg production and reproduction in waterfowl. Pages 771-780 in: Poultry Breeding and Genetics (Crawford, R. D., Ed.). Elsevier, Amsterdam.

Vernam, J. P., 1998. The relationship of costs in Pekin duck production. World Poultry 14(10):34-35.

Vernam, J. P., 1995. Assessing the mule duck as a meat producer. World Poultry-Misset 11(5):44-45.

Waldroup, P. W., N. M. Tidwell, and A. L. Izat, 1990. The effects of energy and amino acid levels on performance and carcass quality of male and female broilers grown separately. Poultry Sci. 69:1513-1521.

Walters, B. S., J. Maurer, G. E. Rodgers, A. J. Kohl, 1994. Duckling breast skin and fat measurement as an indicator of whole carcass fat. Poultry sci. 73:322-325.

Whitehead, C.C., 1991. Nutrition and growth of fat and lean broiler genotypes. Pages 83-94 in: Recent Advances in Animal Nutrition (Haresign and Cole Eds.). Butterworths, UK.

Whitehead, C. C., J. Armstrong, and K. M. Herron, 1990. The growth to maturity of lean and fat lines of broiler chickens give diets of different protein content: body composition, plasma lipoprotein concentration and initial egg production. Anim. Prod. 50:183-190.

Whitehead, C.C., 1988. Selection for leanness in broilers using plasma lipoprotein concentration as selection criterion. Pages 41-57 in: Leanness in Domestic Birds. (Leclercq, B., and C.C.Whitehead, Eds.). INRA, Butterworths.

Whitehead, C. C., and H. D. Griffin, 1986. Development of divergent lines of lean and fat broilers using plasma very low density lipoprotein concentration as selection criterion; results over the fourth generation and lack of effect of dietary fat on performance and carcass fat content. Br. Poult. Sci. 27: 317-324.

Whitehead, C. C., and H. D. Griffin, 1984. Development of divergent lines of lean and fat broilers using plasma very low density lipoprotein concentrations as selection criteria: the first three generations. Br. Poult. Sci. 25:573-582.

Woodward, J. and V. Wheelock, 1990. Consumer attitudes to fat in meat. Pages 66-100 in: Reducing Fat in Meat Animals (J.D. Wood, and A.V. Fisher Eds.), University of Bristol, Langford, Bristol, UK.

Wu, J. M., J. S. Nickels, and J. R. Fisher, 1977. Regulation of nitrogen catabolic enzymes in chick liver - effects of insulin. Enzyme 22:60-69.

Yaissle, J., and M. S. Lilburn, 1998. Effects of dietary protein and strain on the growth of broiler breeder pullets from zero to five weeks of age. Poultry Sci. 77:1613-1619.

Zeidler, G., 1998. Poultry products in the 21st century. Pages 132-141 in: Proceedings of the Tenth European Poultry Conference, WPSA .

CLAIMS OF ORIGINALITY AND CONTRIBUTION TO KNOWLEDGE

To the best of the author's knowledge, the following findings have not been previously reported elsewhere and constitute original contributions to knowledge.

1. We determined for the first time the effect of ultrasound selection for greater breast muscle yield on the reproductive performance of meat-type White Pekin ducks from the second generation.

2. This thesis contains the first determination of the apparent and true metabolizable energy, nitrogen retention, plasma glucose, triglycerides, cholesterol, and uric acid in lean and fat Pekin ducks.

3. We determined for the first time the effect of feed-deprivation and refeeding on plasma glucose, triglycerides, cholesterol, and uric acid in lean and fat Pekin ducks.

4. This thesis contains the first determination of fatty acid profile of endogenous excretion of Pekin ducks.

5. This is the first report on the precise-feeding of starch-oil solution for the determination of metabolic endogenous losses.

6. This thesis contains the first report on the change in daily breast muscle development from 42 to 49 d of age in male and female Pekin ducks.

7. We determined for the first time the growth and carcass characteristics response of male and female Pekin ducks selected for greater breast muscle thickness to dietary protein programs.

8. Our studies permitted for the first time to adapt a radioimmunoassay for the analysis of plasma IGF-I in Pekin ducks.

9. This thesis provides the first report on the response of plasma IGF-I to the selection for breast muscle yield.

10. This thesis contains the first report on the response of plasma IGF-I to dietary protein in Pekin ducks.

11. We determined for the first time the differences in plasma IGF-I between male and female Pekin ducks.

12. We determined for the first time the change in plasma IGF-I with age from 42 to 49 d in Pekin ducks.

13. This thesis provides the first report on the effect of feed-deprivation and refeeding on plasma IGF-I in lean and fat Pekin ducks.

APPENDIX

I. Protocol for the RIA of White Pekin duck plasma IGF-I

A volume of 25 µl of each plasma sample were transferred into a new 1.5 ml tube containing 30 µl of glycine-glycine HCl (0.1M). The tubes were incubated at 37 °C in a water bath for 40 h. Following incubation with glycine-glycine HCl to prevent the effects of plasma binding protein, 2 µl of 1 M NaOH were added to each tube and the mixture was then diluted to 1.2 ml with RIA buffer. A volume of 100 µl of each sample was transferred in duplicate into 5 ml test tubes for the assay. To each tube, 50 µl of primary antiserum (rabbit anti-human IGF-I)[1], and 250 µl of RIA buffer were added, and the tubes incubated at 4 °C for 72 h. Following incubation, 100 µl of ^{125}I-labeled human IGF-I were added as a tracer and the tubes were incubated at 4 °C for 20 h. Following incubation, 100 µl of goat-rabbit antibodies[2] were added to each tube and the tubes were incubated at room temperature for 1 h followed by the addition of 1ml of 10 % polyethylene glycol solution. The tubes were then centrifuged[3] at 2000 G for 25 min at 4 °C. The supernatant was immediately decanted and the precipitated pellet was counted on a gamma-counter[4].

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[1] Dr. C.A. Price, Université de Montréal.
[2] Dr. C.A. Price, Université de Montréal.
[3] Beckman Instruments Inc., Irvine, CA 92713.
[4] ICN Biomedical Inc., Costa Mesa, CA 92626.