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

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Abstract: Male and female Pekin ducks selected for greater breast muscle thickness (MT) were used in an experiment to determine the effect of dietary protein on carcass components yield, and carcass composition. The dietary programs were high protein program (HP) that consisted of 25, 23, and 21 % 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, respectively; and low protein program that consisted of 21, 19, and 17 % CP for the starter, grower, and finisher, respectively. 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 yields 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.

Key words: Breast muscle thickness, ultrasound scanning, carcass characteristics, dietary protein

INTRODUCTION

Carcass composition of the Pekin duck contains about 60 % fat on DM basis [1]. The consumption trends in the western societies are toward less fat, specifically the saturated fat [2], and more ready-to-eat meals [3]. Poultry meat has the highest share in the home meal replacement products that is expected to reach $100 billion of US spending on food [4]. The breast meat yield 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 [5]. The selection for breast meat yield in broiler high yielding strains result in very large profit [6] and had no negative impact on the reproductive performance of Pekin ducks [7].

The degree of fatness and leanness is greatly influenced by the dietary protein concentration of the diet [8]. Fat deposition in broilers depends on the diet composition and can be reduced by increasing dietary protein [9]. 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 [10]. Increasing dietary protein resulted in increasing plasma IGF-I concentration in Pekin ducks [11]. Improvement in feed efficiency and breast meat yield with no effect on body weight gain were reported [12] in male broilers fed diets with energy to protein ratios lower than the NRC recommendations [13]. The same results were also reported in female broiler chickens [14]. The breast meat yield in the male chickens tended to correlate negatively with abdominal fat [12], but there was no correlation between the two parameters in the females [14]. Feeding different levels

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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 [15]. Dietary protein was found to have an effect on growth and body composition in chickens selected for high abdominal fat [16]. In the latter study, 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. The lean line chickens, selected for low or high VLDL, 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 compared to the fat line [17].

Objective: The objectives of this experiment were 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

Experimental Animals and Diets: A total of 600 ducklings were fed three dietary protein programs. 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 1.

From 42 to 49 d of age, the 600 ducks were divided into 4 groups of 150 birds each (group A, B, C, and D). At 42 d of age, 300 ducklings (group A and C) (25 birds/sex/dietary program) were probed using ultrasound to measure their total breast and breast muscle thickness. The skin and subcutaneous fat of 60 birds (10 birds/sex/dietary program) were measured using a digital caliper. Forty-eight ducklings were bled to determine total plasma protein, uric acid, and IGF-I. Group A (150 birds) was slaughtered at 42 d of age, and the other 150 birds (group C) were followed with the ultrasound measurement on day 44, 46, and 48 when ultrasound, caliper and bleeding were performed before slaughtering. At 43 d of age, another group of 300 birds (group B and D) were weighed, and total breast and breast muscle thickness measured using ultrasound. At 45 d of age, both groups were probed, group B was slaughtered after ultrasound and caliper measurements, and bleeding, while group D was followed with the ultrasound on day 47 and 49 when it was slaughtered after ultrasound, caliper and bleeding were performed.

Blood Parameters and Carcass Characteristics: Five mL of blood were taken into a heparinized tube from each bird that was randomly selected. The 600 ducks 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 % of eviscerated carcass without the neck and giblets. Plasma was analyzed for uric acid using a clinical discrete analyzer (Model VP super system, Abbott Laboratories, Mississauga, ON), and for total plasma protein using Bio-Rad Protein Assay (Car. No. 500-0006, Bio-Rad Laboratories, Hercules, CA), and for IGF-I determined by RIA [11].

Ultrasound and Caliper Measurements: Breast muscle thickness measurements were taken daily from 42 to 49 d of 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 (Alliance Medical Inc., Montreal, QC) 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. A digital caliper (Starrett electronic digital micrometer, No. 734MXFL, Athol, MA) was used to measure the double breast skin and fat thickness [18].

Statistical Analysis: Statistical analyses of the data were performed using the General Linear Models (GLM) procedures and mixed model of the SAS® library [19]. The model included the effects of dietary program, age, and interaction for males and females. The dependent variables were carcass characteristics. The multi-comparison Scheffe's test was used to separate the differences among the means for statistical significance ($P < 0.05$). Pearson correlation coefficients of carcass characteristics with breast measurements and blood parameters were determined.

RESULTS AND DISCUSSION

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 2. 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 [11]. Considering the yield of the carcass components, the high protein program shows to be more appropriate for males grown to 45 d instead for 49 d of age. 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 [20].

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 3. 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 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 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. Increasing dietary protein resulted in a significant increase in breast muscle yield of female chickens grown to 52 d of age [21]. Breast meat yield in female chickens improved at 57d, but not at 43 d of age, upon feeding low energy to protein ratio [14]. He used a ratio lower than recommended [12] and is relatively comparable to our high protein program. 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. 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 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 49d on fat, CP and ash content of the male carcasses. This may indicate that the decline in feed efficiency observed previously [1] 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 and agrees with reported studies in Pekin ducks [22].

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 5. 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 [1] where the 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 [15, 17].

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 6. Breast muscle thickness correlated positively ($P < 0.05$) with body weight, TOT, pectoralis muscles yield, the keel bone length, and total plasma protein concentration (Table 6). 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. 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, were reported [23]. 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 percent of carcass weight in males and females, respectively.

Table 1: Characteristics of the experimental diets

Characteristics	Units	% CP				
		25	23	21	19	17
DM	%	88.56	88.52	87.72	87.99	88.08
CP	%	25.13	22.60	21.75	19.23	17.52
Fat	%	5.66	7.53	5.69	6.20	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	%	0.90	0.78	0.93	0.83	0.80
Total P	%	0.64	0.60	0.64	0.59	0.57
Vit. A	IU/g	11.24	8.77	11.24	10.00	8.77
Vit. D	IU/g	3.50	2.63	3.50	3.07	2.63
Vit. E	IU/g	48.00	23.75	48.00	35.88	23.75

Table 2: Effects of dietary program and age on carcass components[1] of male Pekin ducks (n=96)

Program	Age	Wing (%)	breast skin (%)	skin-fat (%)	Pectoralis (%)	leg+thigh (%)	Shell (%)	pecto/ keel (g/cm)	keel length (cm)
HP	42 d	13.63	6.48	23.61	11.8	19.11	25.36	21.31	5.06
	45 d	12.84	7.13	26.25	14.05	17.74	21.98	28.8	5.23
	48 d	12.92	7.09	24.98	15.86	18.06	21.1	30.72	5.22
	49 d	13.23	7.21	23.37	15.79	18.43	21.96	32.58	5.21
MP	42 d	11.82	7.7	28.68	9.84	17.05	24.9	21.1	4.7
	45 d	12.13	7.8	28.93	11.72	17.81	21.61	23.71	5.05
	48 d	12.18	7.83	28.78	13.62	17.33	20.26	28.04	5.18
	49 d	12.95	7.55	28.00	12.59	16.88	21.04	27.93	5.26

Table 2: Continue

LP	42 d	12.44	7.54	29.3	9.6	19.31	21.82	18.09	4.67
	45 d	11.71	7.77	29.93	11.18	17.47	21.94	23.19	4.96
	48 d	12.8	7.92	27.43	13.6	18.25	20	25.9	5.05
	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 thigh, 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 3: Effects of dietary program and age on carcass components[1] of female Pekin ducks (n=96)

Program	Age	Wing (%)	breast skin(%)	skin-fat (%)	Pectoralis (%)	leg+thigh (%)	Shell (%)	pecto/ keel (g/cm)	keel length (cm)
HP	42 d	12.94	6.95	28.17	11.06	17.95	22.93	20.33	4.79
	45 d	12.17	8.13	28.11	12.81	16.84	21.95	25.64	4.89
	48 d	12.6	8.03	27.73	15.15	16.74	19.76	28.46	4.94
	49 d	12.6	8.14	27.98	15.36	17.53	18.39	28.18	5.03
MP	42 d	12.33	7.54	28.19	11.05	17.12	23.76	21.94	4.74
	45 d	12.19	8.04	29.1	12.78	16.22	21.67	24.27	4.88
	48 d	12.22	8.12	28.51	15.2	16.66	19.29	29.73	4.99
	49 d	12.21	7.83	28.39	14.55	16.42	20.61	28.8	5.01
LP	42 d	12.26	7.72	28.39	10.2	17.15	24.29	19.96	4.75
	45 d	11.78	7.85	28.24	11.78	16.69	23.67	24.36	4.85
	48 d	12.36	8.1	29.8	14.24	16.42	19.09	26.4	4.95
	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	0.0108	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

Table 3: Continue

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 thigh, 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: 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 (%)
HP	42 d	70.6	36.77	52.98	38.39	8.63
	45 d	72.91	37.52	55.91	36.35	7.73
	48 d	72.88	39.34	54.79	36.46	8.57
	49 d	72.88	39.5	55.75	35.81	8.44
MP	42 d	71.97	39.5	60.82	32.22	6.96
	45 d	72.72	40.12	60.17	33.09	6.74
	48 d	72.02	42.39	60.5	31.96	7.54
	49 d	72.56	41.21	60.1	32.64	7.26
LP	42 d	71.09	39.15	60.73	32.44	6.83
	45 d	73.06	39.85	59.57	33.38	7.06
	48 d	71.36	41.82	60.66	32.49	6.85
	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		0.7070	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	38.28b	54.91b	36.75a	8.34a
	MP	72.32	40.80a	60.40a	32.48b	7.13b
	LP	71.98	40.62a	60.62a	32.45b	6.92b
Age	42 d	71.22b	38.47b	58.17	34.35	7.47
	45 d	72.90a	39.16b	58.55	34.27	7.17
	48 d	72.09a	41.18a	58.71	33.64	7.65
	49 d	72.61a	40.79a	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

Table 5: 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 (%)
HP	42 d	71.39	39.24	58.98	33.66	7.37
	45 d	73.33	41.09	60.69	32.33	6.78
	48 d	73.77	42.13	59.78	32.87	7.35
	49 d	74.85	41.22	61.18	31.42	7.4
MP	42 d	73.56	39.06	59.39	33.35	7.26
	45 d	73.82	41.2	60.81	32.61	3.38
	48 d	74.61	43.14	62.98	30.54	6.48
	49 d	73.81	42.82	62.27	30.86	6.86
LP	42 d	72.77	40.21	62.42	30.91	6.67
	45 d	74.58	40.35	61.1	31.97	6.73
	48 d	72.76	42.86	62.24	31.02	6.74
	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	0.01	0.016	0.004
Age		0.037	0.0001	0.063	0.016	0.3338
Program*Age		0.0749	0.2588	0.099	0.1105	0.2969
Main Effects						
Program	HP	73.34	40.92	60.16b	32.57a	7.27a
	MP	73.95	41.55	61.36a	31.84ab	6.80b
	LP	73.36	41.31	61.94a	31.25b	6.82b
Age	42 d	72.57b	39.51c	60.26	32.64a	7.1
	45 d	73.91a	40.88b	60.87	32.30ab	6.83
	48 d	73.72a	42.71a	61.67	31.48bc	6.86
	49 d	73.99a	41.96a	61.81	31.13c	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

Table 6: 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)

Parameters	r	P	Parameters	r	P
MT*Pectoralis	0.73	0.0001	Caliper*Skin+fat	0.22	0.0036
MT*Keel length	0.43	0.0001	Caliper*Breast skin+fat[3]	0.19	0.0132
MT* Plasma protein[1]	0.30	0.0001	Caliper*FAT	0.19	0.0116
MT*Leg+thigh	-0.17	0.0228	Caliper*CP	-0.22	0.0043
MT*Shell	-0.44	0.0001			
MT*FAT	-0.01	0.9220	IGF-I*FAT	-0.13	0.0899
MT*CP	-0.03	0.6943	IGF-I*CP	0.14	0.0642
			Plasma protein*FAT	0.05	0.5054

Table 6: Continue

Pectoralis*Body Weight	0.27	0.0001	Plasma protein*CP	-0.09	0.1881
Pectoralis*TOT	0.68	0.0001			
Pectoralis*Keel length	0.47	0.0001	Wing*Pectoralis	0.17	0.0162
Pectoralis*CP	0.15	0.0391	Wing*Leg+thigh	0.55	0.0001
Pectoralis* Plasma protein	0.22	0.0024	Wing*Keel length	0.20	.0055
Pectoralis*Skin+fat[2]	-0.33	0.0001	Wing*CP	0.44	0.0001
Pectoralis*Shell	-0.49	0.0001	Wing*Skin+fat	-0.59	0.0001
Pectoralis*FAT	-0.17	0.0181	Wing*Breast skin+fat	-0.33	0.0001
			Wing*FAT	-0.43	0.0001

Correlations between breast muscle thickness (MT), total breast thickness (TOT), body weight, 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

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 (Table 6).

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 [18]. 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 6).

Plasma IGF-I concentration was found to be higher in lean than in fat ducks [11], and total plasma protein was considered an indication of total protein reserves in an animal [24]. However, in the current study, there was no significant correlation between plasma parameters and carcass fat or CP content.

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 (Table 6).

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 important 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.

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