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Effects of breed, sex and diet and their interactions on carcass composition and tissue weight distribution of broiler chickens

Abstract

The effects of breed (Hubbard and Anak), sex and diet (two levels of protein (high or low) with two levels of crude fiber (low or high) at each level of protein) on carcass composition and distribution of tissues over the carcass were studied.

Carcass composition and ratios of muscle: bone, muscle: fat and meat: bone in the carcass did not differ significantly between breed groups. Male carcasses had more muscle, more bone, more fat-free carcass, higher ratios of muscle: bone, muscle: fat but less fat, less meat and lower meat: bone ratio than female carcasses. Carcasses of chicks fed high protein (with either low or high fiber) diet had more muscle than carcasses of chicks fed low protein (with either low or high fiber) diet. Carcasses of chicks fed high fiber (with either low or high protein) diet had more bone but less meat than carcasses of chicks fed low fiber (with either low or high protein) diet. Increasing both protein and fiber in the diet resulted in lowering carcass fat, consequently raising muscle: fat ratio. Breed and sex did not influence the distribution of muscle and meat throughout the carcass parts. Breed differences in fat weight distribution were not significant. Anak had significantly higher proportions of bone in wing and neck than Hubbard did. The proportion of total carcass muscle in breast, drumstick, wing were not significantly affected by diet. Carcasses of chicks fed high fiber (with either low or high protein) diet had higher proportion of total meat in thigh and neck than carcasses from chicks fed low fiber (with either low or high protein) diet. Diet had no significant effect on bone weight distribution. Increasing crude fiber in diets resulted in lowering proportion of total fat in breast, thigh but increasing proportion of total fat in drumstick and wing. Breed x sex, breed x diet and sex x diet interactions did not significantly influence most of carcass traits indicating that the factors under consideration act independently of each other's. Significant sex x diet interactions was found for carcass fat and boneless carcass relative to live body weight: the sexual dimorphism in low protein diet is more pronounced than in high protein diets.

Key Words: chicken, breed, sex, diet, carcass composition, tissues distribution, genotype x nutrition interactions

Zusammenfassung

Titel der Arbeit: **Der Einfluss der Rasse, des Geschlechtes und der Fütterung auf die Schlachtkörperzusammensetzung bei Broilern**

An 147 Broilern der in Ägypten gehaltenen Rassen Hubbard und Anak wurde der Einfluss der Rassse, des Geschlechtes sowie von vier Fütterungsvarianten auf unterschiedliche Schlachtkörpermerkmale untersucht. Die Fütterungsvarianten unterschieden sich hinsichtlich des Eiweiß- und Rohfaseranteils in der Ration (hoch-niedrig). Bei den Schlachtkörpermerkmalen ergaben sich keine signifkanten Unterschiede zwischen den Rassen. Höhere Fleischanteile erreichten die männlichen Tiere sowie die mit der eiweißreichen Ration gefütterten Tiere. Unabhängig vom Eiweißanteil führte ein höherer Rohfaseranteil zu erhöhtem Knochen- und geringerem Fettanteil, vor allem im Brustfleisch und damit zu verändertem Fleisch:Fettverhältnis im Schlachtkörper. Ein signifkanter Einfluss hinsichtlich Geschlecht und Fütterung konnte für den Fett- und Knochenanteil in Beziehung zum Lebendgewicht nachgewiesen werden. Der Geschlechtsdimorphismus war bei niedrigerem Eiweißniveau ausgeprägter als bei höherer Eiweißversorgung.

Schlüsselwörter: Broiler, Rasse, Geschlecht, Fütterung, Schlachtkörperzusammensetzung, Gewebeanteile, Genotyp : Fütterungsinteraktion

Introduction

A superior carcass is characterized by a desirable composition: maximum proportion of muscle, minimum proportion of bone and optimum proportion of fat dictated by specific trade preference. Also, superior carcass must contain high proportion of most valuable muscles (i.e. breast and thigh muscles). Carcass composition in broilers can be manipulated through genetic and nutritional routes. Increasing protein: energy ratio resulted in increasing carcass leanness and decreasing body fatness with the opposite effect was elicited by a low protein: energy ratio (JONES and WISEMAN, 1985; LEENSTRA, 1986; BARTOV and PLAVNIK, 1998). Also, carcass leanness can be achieved by feeding animals and birds low energy, low-cost high fibrous diets and by restricted feeding (GODFREY et al., 1991; LEESON et al., 1992; LEESON et al., 1996; KHANTAPRAB et al., 1997).
Separate effects of breed, sex and nutrition on carcass composition of chickens were reported by BROADBENT et al. (1981); ORR et al. (1984); MARKS (1990); BARTOV (1998); SMITH and PESTI (1998) and WISEMAN and LEWIS (1998). Variation in lean, bone and fat distribution due to breed have been investigated by ABDALLAH et al. (1990), SHAHIN et al. (1990) and SHAHIN et al. (1996). The combined effects of breed, sex, and diet and their interactions on carcass characteristics have received little attention and partitioning of bird response due to these effects have not been widely reported. To test the hypothesis that the similarity of breeds and sexes in their response to diets, this study was designed to consider simultaneously the effects of breed-type, sex and diet and their respective interactions on compositional relationships and tissue weight distribution of broiler chickens.

Materials and methods

The study contained dissection data from 147 broiler chickens, 74 males and 73 females; from 72 (36male, 36 female) Hubbard and 75 (38, 37) Anak broilers. These birds were from the Poultry Nutrition Research Station, Department of Poultry Production, Ain Shams University. Chicks of each breed were divided equally into four groups, and randomly assigned to one of four diets (37 birds/treatment) in four replicates. The diets were formulated to contain two levels of protein (high or low) with two levels of crude fiber (low or high) at each level of protein. The ingredients and chemical composition of the four diets are given in Table 1.
Diet I 'commercial, high protein- low fiber', comprised of approximately 21% protein and a metabolizable energy of 3000 Kcal/kg during starter phase (1 to 4 weeks) and contained approximately 18% protein and a metabolizable energy of 3120 Kcal/kg during finisher phase (5 to 8 weeks). The percent of fiber in both phases was 4%. **Diet II 'high protein- high fiber'**, was similar to diet I in protein but different in metabolizable energy (2750 Kcal/kg in starter phase and 2862 in finisher phase) and in fiber (8%). **Diet III 'low protein- low fiber'**, was similar to diet I in metabolizable energy and fiber but lower in protein (19 % protein during starter phase and 16 % protein during finisher phase). **Diet IV 'low protein- high fiber'**, contained similar levels of protein **to** diet III and higher fiber (8%) but the metabolizable energy was similar to that in diet II. All the diets were provided *ad. libitum* and conventional brooding and rearing practices were followed.

Table 1
Ingredients and composition of the experimental diets (Inhaltstoffe und Zusammensetzung der Fütterungsvarianten)

	Starter diets (1 – 4 weeks)				Finisher diets (5 – 8 weeks)			
	High protein		Low protein		High protein		Low protein	
Item	Low fiber	High fiber	Low fiber	High fiber	Low fiber	High fiber	Low fiber	High fiber
Ingredients, %								
Yellow corn	53.13	43.13	57.10	46.30	55.15	45.20	59.50	48.00
Soy-bean meal (44% CP)	33.30	32.50	30.00	28.50	28.25	25.00	21.50	19.00
Fish meal (72% CP)	1.50	1.00	0.25	0.25	-	-	-	-
Clover hay	0.50	15.40	0.75	16.15	2.50	16.50	2.50	16.50
Wheat bran	4.50	1.00	4.30	1.60	4.40	5.00	7.45	8.10
Plant oil	4.00	4.00	4.00	4.00	6.00	6.00	6.00	6.00
Bone meal	2.15	2.20	2.55	2.35	2.35	1.50	1.50	1.50
Limestone	0.20	0.05	0.30	0.05	0.70	0.15	0.80	0.15
Premix+	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.17	0.17	0.20	0.18	0.10	0.10	0.15	0.15
Lysine	-	-	-	0.07	-	-	0.05	0.05
Total	100	100	100	100	100	100	100	100
Composition Analyzed++								
Dry matter, %	91.30	91.43	90.75	90.78	93.13	93.08	93.15	93.07
Organic matter, %	84.29	83.22	83.66	82.80	87.02	87.08	87.13	86.54
Crude protein, %	21.04	21.00	19.05	19.01	18.08	18.03	16.04	16.02
Crude fiber, %	4.06	8.01	4.04	8.00	4.15	8.05	4.20	8.01
Ether extract, %	6.61	6.53	6.69	6.46	8.52	8.45	8.70	8.62
N- free extract, %	52.58	47.68	53.88	49.33	56.27	52.55	58.19	53.89
Crude ash, %	7.01	8.21	7.09	7.98	6.11	6.00	6.02	6.53
Calculated +++								
Metabolizable energy, Kcal/kg	3008	2751	3007	2761	3120	2862	3128	2862
Calcium, %	1.06	1.07	1.01	1.03	0.82	0.81	0.86	0.87
Available phosphorous, %	0.45	0.45	0.46	0.45	0.31	0.33	0.32	0.33
Methionine, %	0.50	0.51	0.50	0.50	0.39	0.39	0.39	0.39
Lysine, %	1.13	1.17	1.10	1.11	0.85	0.95	0.89	0.87

+Each 3 Kg of vit-mineral mixture contains: vit A 12000000 IU, vit D_3 2200000 IU, vit E 10 g, vit K_3 2 g, vit B_1 1 g, vit B_2 5 g, vit B_6 1.5 g. vit B_{12} 0.01 g, Niacin 30 g, Biotin 0.05 g, folic acid 1 g, pantothenic acid 10 g, zinc 50 g, Manganese 60 g, Iron 30 g, Copper 4 g, Iodine 1 g, Selenium 0.1 g and Cobalt 0.1 g.
++According to the methods of AOCA (1994); +++Calculated according to NRC (1994)

At the time of slaughter (8 weeks of age) the birds were individually weighed and killed by severing the carotid artery and jugular veins. The head was removed at the atlanto-occipital articulation. After dressing the carcass was stored in closed bags at -20 °C. Prior to dissection, carcasses were thawed for approximately 20 hr. at 5 °C while being in their bags. The breast was removed from the carcass. It composed of the sternum and its associated muscles. The hind leg was removed from the carcass at the acetabulum so that the pelvic muscles and bones were left attached to the leg. The proximal part 'thigh' of the hindleg was separated from the distal part 'drumstick' at the tibio-femoral joint. The thigh included proximal hindleg muscles and bones. The glutes 'oyster' muscles were removed and included with the thigh muscles. The foreleg ‘wing’ was separated from the carcass. The neck was removed from the carcass as close to the clavicle as possible. Thus the right side was divided into the following commercial cuts: drumstick, thigh, breast, wing, neck, rib plus abdominal wall. The breast and thigh were considered as highly desired cuts. The skin, subcutaneous fat, muscle, bone and intermuscular fat in each cut were dissected and weighed. For each cut, the total weight of muscle, bone and fat was referred to as the 'entire' cut and the total weight of muscle and fat was referred to as 'boneless' cut. The sum of muscle, intermuscular fat and subcutaneous fat forms the edible meat. The sum of these parts over all cuts gives total side muscle, total side edible meat, total side bone and total side fat. The sum of the dissected muscle, fat and bone was used as dissected side weight.

Statistical analyses:

To assess breed-type, sex and diet influences on carcass composition, the data were analyzed by the General Linear Models procedures of SAS (SAS Institute, 1995) according to the following model

$$\mathbf{Y_{ijkl} = \mu + B_i + S_j + D_k + (BS)_{ij} + (BD)_{ik} + (SD)_{jk} + E_{ijkl}}$$

Where,

Y_{ijkl} = weight (g) or percentage of the component Y of the $_{ijkl}$ bird;

μ = grand mean;

B_i = fixed effect of the breed group (i= 1,2);

S_j = fixed effect of the sex (j= 1,2);

D_k = fixed effect of the diet (k=1… 4);

$(BS)_{ij}$ = the interactions between breed and sex;

$(BD)_{ik}$ = the interactions between breed and diet;

$(SD)_{jk}$ = the interactions between sex and diet;

E_{ijkl} = the random error assumed N.I.D. (0, s^2 e).

DUNCAN'S multiple range test was used to test for significant differences between pairs of means.

Results

Table 2 presents the means, standard deviations, and coefficient of variability and ranges for live weight and muscle, fat and bone traits. Live body weight averaged 2350 g and ranged from 1400 to 3500 g. Total carcass muscle ranged from 468 to 1492 g with a mean of 951 g, total carcass fat ranged from 182 to 586 g with a mean of 364 g and total carcass bone ranged from 146 to 424 g with a mean of 266 g.

Among the major carcass tissues, fat was the most variable tissue (CV= 12.7%) followed by bone (CV= 9.1%) and then muscle (CV= 4.8%).

Table 2
Means, standard deviations (SD), coefficient of variability (CV%) and minimum and maximum values for live body weight and carcass traits in broiler chickens. (Durchschnitt, Standardabweichung (SD) Variationskoeffizient (CV%) sowie Minimum- und Maximumwerte für Lebendgewicht- und Schlachtkörpermerkmale von Broilern)

	Means	SD	CV%	Range
Live weight (g)	2350.29	426.41	18.14	1400 – 3505
Carcass weight (g)	1621.72	316.06	17.49	869 – 2552
Carcass muscle (g)	951.12	203.91	21.44	468 - 1492
Carcass fat (g)	364.04	86.52	23.77	182 – 586
Carcass bone (g)	266.31	52.02	19.54	146 – 424
Boneless carcass (g)	1315.16	275.73	20.97	714 – 2074
Fatless carcass (g)	1217.43	251.45	20.65	626 – 1916
Muscle: bone ratio	3.57	0.35	9.92	2.77 – 4.85
Muscle: fat ratio	2.66	0.44	16.38	1.69 – 3.06
% of live weight				
Muscle	40.41	4.10	10.16	26.43 – 51.08
Fat	15.48	2.43	15.72	9.98 - 25.47
Bone	11.37	1.29	11.37	8.34 - 15.79
% of carcass weight				
Muscle	60.04	2.41	4.82	52.25 – 66.67
Fat	23.02	2.92	12.71	16.41 – 30.84
Bone	16.94	1.55	9.13	12.13 – 21.16
% of total muscle				
Breast	40.11	3.06	7.63	27.80 – 48.68
Thigh	24.42	1.66	6.79	19.64 – 31.05
Drumstick	15.66	1.17	7.47	13.05 – 18.85
Wing	9.65	0.86	8.93	7.82 – 12.06
Neck	4.10	0.68	16.53	2.44 – 8.55
% of total bone				
Breast	19.55	1.98	10.27	10.27 – 24.55
Thigh	28.81	1.59	5.51	25.23 – 34.93
Drumstick	18.58	1.30	7.00	15.93 – 22.38
Wing	15.41	1.28	8.33	12.41 – 19.61
Neck	7.34	1.05	14.27	4.82 – 10.38
% of total fat				
Breast	19.09	3.09	16.21	10.29 – 29.63
Thigh	29.79	3.72	12.48	21.17 – 40.00
Drumstick	12.21	2.13	17.44	7.25 – 16.91
Wing	16.11	2.04	12.65	11.65 – 22.31
Neck	13.60	2.10	15.41	8.28 – 18.71

Live body weight

Differences in live body between breeds were found to be significant. The live body weight of the Hubbard was significantly heavier than that of the Anak (Table 3).

Sexual dimorphism for live body weight favored males, where they weighed 14% heavier than females (Table 3).

Chicks fed diet 1 (high protein- low fiber) had significantly heavier live body weight than those fed other diets (Table 3). On the other hand chicks fed diet II (high protein- high fiber) did not differ significantly from those fed diet 4 (low protein – high fiber) in their live body weight.

Carcass composition

Expressed either as a percentage of live body weight or carcass weight, the proportional composition of muscle, fat, bone, fat-free carcass, boneless carcass, muscle: bone ratio, muscle: fat ratio and meat: bone ratio did not differ significantly between breed groups (Table 3).

Table 3
Live body weight, carcass weight and major carcass tissues mean weights (Lebendgewicht, Schlachtkörpergewicht und –zusammensetzung)

	Breed (B)		Sex (S)		Diet (D)[+]				Significance of difference[++]		
	Hubbard	Anak	Male	Female	HP-LF	HP-HF	LP-LF	LP-HF	B	S	D
Live weight (g)	2417.08a	2285.67b	2502.21a	2195.49b	2664.57a	2181.39c	2405.05b	2138.36c	*	**	**
Carcass weight (g)	1675.61a	1569.99b	1727.22a	1514.75b	1870.05a	1498.25c	1668.50b	1440.58c	*	**	**
Dissected side weight (g)	817.97a	764.59b	836.65a	744.19b	901.27a	722.61c	815.16b	719.47c	**	**	**
Total side muscle (g)	493.00a	458.81b	508.77a	444.93b	542.86a	445.28bc	482.37b	429.47c	**	**	**
Total side fat (g)	187.51a	176.75b	187.41a	176.56b	212.51a	150.00b	198.03a	165.81b	*	*	**
Total side bone (g)	137.46a	129.03b	143.47a	122.70b	145.89a	27.33b	134.76b	124.19b	*	**	**
% of live weight											
Muscle	40.74	40.10	40.40	40.42	40.51	40.95	40.12	40.09	NS	NS	NS
Fat	15.51	15.46	14.88a	16.10b	15.97a	13.78b	16.45a	15.67a	NS	*	*
Bone	11.41	11.34	11,51	11.23	10.96b	11.71a	11.23ab	11.64a	NS	NS	*
Fatless	52.15	51.44	51.91	51.65	51.45	52.65	51.35	51.72	NS	NS	NS
Boneless	56.24	55.56	55.28a	56.52b	56.48	54.73	56.57	55.76	NS	NS	NS
% of carcass											
Muscle	60.20	59.89	60.45a	59.63b	60.01a	61.54a	59.14b	59.53b	NS	*	**
Fat	22.98	23.13	22.29a	23.75b	23.70a	20.80b	24.27a	23.20a	NS	**	**
Bone	16.98	16.90	17.25a	16.62b	16.28b	17.66a	16.59b	17.26a	NS	**	**
Fatless	77.10	76.87	77.71a	76.25b	76.30b	79.20a	75.73b	76.80b	NS	**	**
Boneless	83.10	83.02	82.75a	83.38b	83.72a	82.34b	83.41a	82.74b	NS	**	**
Ratios											
Muscle :bone	3.59	3.56	3.62a	3.53b	3.71a	3.51b	3.61ab	3.47b	NS	*	**
Muscle: fat	2.68	2.65	2.76a	2.56b	2.57a	3.00b	2.46a	2.62a	NS	**	**
Meat :bone	4.96	4.95	4.84a	5.07b	5.18a	4.70b	5.10a	4.83b	NS	**	**

a, b, c means in raw bearing different superscripts differs significantly at $P < 0.05$.
*, ** $P < 0.05$ and $P < 0.01$, respectively. NS, not significant ($P > 0.05$). [+]The abbreviations are defined in the text;
[++]BS, BD, SD interactions almost all not significant

Expressed as a percentage of live body weight, males and females did not differ significantly from each other in carcass muscle, carcass bone and fat-free carcass, but they differed significantly in carcass fat and carcass meat which were higher in females than in males. Expressed as a percentage of carcass weight, male carcasses had more muscle, more bone and more fat-free carcass but less fat, less boneless carcass than female carcasses (Table 3). Males had higher muscle: bone ratios and higher muscle: fat ratios but they had lower meat: bone ratios than females.

Expressed as a percentage of live body weight, broilers fed high level of protein (with either low or high fiber) and those fed low level of protein (with either low or high fiber) did not differ significantly from each other in carcass muscle, fat-free carcass and boneless carcass. Carcasses of chicks fed high level of protein- high level of fiber had significantly lower carcass fat than those of chicks fed other diets which were not significantly different from each other (Table 3). Carcasses of chicks fed high level of protein with high level of fiber (diet 2) were significantly higher in carcass bone than those of chicks fed high protein with low level of fiber.

Expressed as a percentage of carcass weight, carcasses of chicks fed high protein (with either low or high fiber) diet had more muscle than carcasses of chicks fed low protein (with either low or high fiber) diet (Table 3). Carcasses of chicks fed high fiber (with either low or high protein) diet had more bone but less boneless than carcasses of chicks fed low fiber (with either low or high protein) diet. Diets with a constant level of protein but with increasing levels of fiber decreased fat-free carcass. The relative decrease in fat-free carcass was greater with high protein level than with low protein level (-12.2% *vs.* – 4.4).

Significant ($P < 0.05$) sex x diet interactions were revealed by analysis of variance for carcass fat and boneless carcass (meat) relative to live body weight (Table 3). Interaction analysis of major carcass tissues relative to carcass weight (Table 3) indicated that the effect of breed was essentially the same regardless of sex and that differences between sex tended to be similar for different breeds. Also, the effect of diet on carcass composition was independent of the breed of bird.

Distribution of carcass parts 'entire cuts'

The yield of the various cuts expressed as a percentage of carcass weight. There were no significant differences between Hubbard and Anak in proportion of total carcass weight occurring in all cuts other than wing which constituted a significantly higher proportion of the Anak carcasses than the Hubbard carcasses. Sex did not significantly affect carcass weight distribution.

The only significant differences due to diet were found in breast plus thigh. Chicks fed low protein- high fiber diet had significantly lower breast plus thigh than those fed high protein – low fiber diet (57.5 vs. 58.7).

There were no significant breed x sex, breed x diet and sex x diet interactions for any proportions of total carcass weight found in various cuts. The absence of these interactions indicated that, breeds and sexes were similar in their response to various levels of dietary protein and fibers.

Muscle weight distribution

Muscle weight distribution as used here refers to the proportions of anatomically distinct muscle in various cuts in relation to the total musculature. There were no significant differences between breeds and between sexes in muscle weight distribution (Table 4).

The effect of diet upon total muscle in the different parts of the carcass is shown in Table 4. The percentages of breast muscle, drumstick muscle, wing muscle were not significantly different between diets. On the other hand the percentage of thigh muscle was significantly higher in carcasses of chicks fed high protein and high fiber diet than that from chicks fed low protein and low fiber diet. The percentage of neck muscle was significantly higher in birds fed low protein-high fiber diet than that in birds fed low protein- low fiber diets.

There were no significant interaction effects between the effects of breed and sex, breed and diet and sex and diet on proportions of total muscle weight found in various cuts (Table 4).

Table 4
The effect of breed, sex and diet on muscle, bone, fat and meat weight distribution in broiler chickens (Einfluss von Rasse, Geschlecht und Fütterung auf Muskel, Knochen, Fett und Fleischverteilung im Schlachtkörper)

	Breed (B)		Sex (S)		Diet (D)+				Significance of difference++		
	Hubbard	**Anak**	**Male**	**Female**	**HP-LF**	**HP-HF**	**LP-LF**	**LP-HF**	**B**	**S**	**D**
Percentage of total muscle											
Breast muscle	40.33	39.91	39.90	40.31	40.49	39.94	40.58	39.40	NS	NS	NS
Thigh muscle	24.53	24.31	24.56	24.28	24.30ab	24.90a	23.95b	24.55b	NS	NS	*
Drumstick muscle	15.72	15.59	15.80	15.51	15.61	15.43	15.83	15.75	NS	NS	NS
Wing muscle	9.68	9.62	9.69	9.62	9.78	9.58	9.73	9.51	NS	NS	NS
Neck muscle	4.19	4.01	4.03	4.16	3.99b	4.15ab	3.86b	4.41a	NS	NS	*
Remaining part muscle	6.15	5.98	6.00	6.12	5.83b	5.99ab	6.05ab	6.37a	NS	NS	*
Leg muscle	39.90	40.25	40.36	39.79	39.91	40.33	39.70	40.31	NS	NS	NS
Breast and thigh muscle	64.64	64.43	64.48	64.59	64.79	64.84	64.54	63.96	NS	NS	NS
Percentage of total bone											
Breast bone	19.76	19.35	19.42	19.69	19.52	19.05	19.79	19.83	NS	NS	NS
Thigh bone	28.80	28.82	29.00	28.62	28.57	29.04	28.97	28.67	NS	NS	NS
Drumstick bone	18.74	18.43	18.74	18.41	18.31	18.64	18.67	18.71	NS	NS	NS
Wing bone	15.19a	15.63b	15.20a	15.63b	15.58	15.44	15.13	15.51	*	*	NS
Neck bone	7.10a	7.58b	7.36	7.32	7.53	7.51	7.15	7.18	**	NS	NS
Remaining part bone	10.42	10.19	10.27	10.33	10.48	10.32	10.29	10.10	NS	NS	NS
Leg bone	47.54	47.25	47.74	47.03	46.88	47.67	47.63	47.37	NS	NS	NS
Breast and thigh bone	48.56	48.18	48.42	48.31	48.10	48.09	48.76	48.50	NS	NS	NS
Percentage of total fat											
Breast fat	19.25	18.93	19.06	19.11	19.75a	18.96ab	19.56a	18..04b	NS	NS	*
Thigh fat	30.03	29.55	29.21a	30.37b	30.56a	28.56b	30.45a	29.52ab	NS	*	*
Drumstick fat	12.21	12.20	12.40	12.01	11.94ab	12.90a	11.70b	12.33ab	NS	NS	*
Wing fat	16.25	15.97	15.97	16.25	15.21b	16.77a	15.83ab	16.67a	NS	NS	*
Neck fat	13.92	13.26	14.05a	13.15b	13.68	13.70	13.27	13.77	NS	**	NS
Remaining part fat	9.37	7.14	9.30	9.11	8.86	9.12	9.18	9.67	NS	NS	NS
Leg fat	42.24	41.76	41.61	42.38	42.49	41.46	42.16	41.85	NS	NS	NS
Breast and thigh fat	49.29	48.48	48.28	49.49	50.31a	47.52b	50.02a	47.57b	NS	NS	**
Percentage of total meat											
Breast meat	34,54	34.06	34.31	34.25	34.66	34.63	34.46	33.41	NS	NS	NS
Thigh meat	25.94	25.98	25.86	26.07	26.10	25.87	25.88	26.00	NS	NS	NS
Drumstick meat	14.63	14.72	14.86	14.49	14.54	14.78	14.62	14.77	NS	NS	NS
Wing meat	11.35	11.48	11.36	11.47	11.30	11.39	11.49	11.49	NS	NS	NS
Neck meat	6.53	6.89	6.71	6.73	6.71ab	6.55b	6.59b	7.02a	NS	NS	*
Remaining part meat	7.02	6.86	6.90	6.97	6.69	6.78	6.97	7.31	NS	NS	NS
Leg meat	40.57	40.71	40.71	40.72	40.64	40.65	40.50	40.77	NS	NS	NS
Breast and thigh meat	60.48	60.05	60.17	60.35	60.77a	60.50a	60.33ab	59.41b	NS	NS	*

a, b, c means in raw bearing different superscripts differ significantly at $P < 0.05$.
*, ** $P < 0.05$ and $P < 0.01$, respectively
NS, not significant ($P > 0.05$). +The abbreviation are defined in the text; ++BS, BD, SD interactions almost all not significant

Meat weight distribution

The distribution of meat weight was not significantly different between breeds and between sexes (Table 4).

Diet had no significant effect on proportion of total carcass meat in breast, thigh, drumstick, leg and neck. The proportion of total meat in wing was significantly higher in birds fed on diet 4 than in those fed diets 2 and 3 but was similar to that fed diet 1. The proportion of total meat in breast plus thigh (desirable and expensive meat) was significantly higher in birds fed high protein – low fiber diet than that in birds fed low protein – high fiber diet.

There were no significant breed x sex, breed x diet and sex x diet interactions for any proportions of total meat weight found in various cuts.

Bone weight distribution

There were no significant differences between breeds in proportion of total bone found in all cuts studied other than wing (forelimb) and neck (cervical vertebrae) (Table 4). Anak had significantly higher proportions of bone in wing and neck than Hubbard did.

The proportions of bone in breast, neck, thigh and drumstick were similar in males and females, but the proportion of bone in wing was higher in females than in males.

There were no significant differences between diets in proportion of total bone found in all cuts studied.

There were no significant breed x sex and sex x diet interactions for any proportions of total bone weight found in various cuts (Table 4). The significant breed x diet interaction for proportion of total bone in neck indicated that the effect of diet was dependent on the breed of bird (genetic differences in their response to diets). In that Hubbard birds receiving diets 1, 2 and 4 had lower proportion of total bone in neck than Anak birds, but those receiving diet 3 had higher proportion of total bone in neck than Anak (Table 6). The differences between breeds were greater in high fiber diets than in low fiber diets.

Fat weight distribution

Hubbard and Anak tended to have similar proportion of fat in all cuts (Table 4).

Compared with males, females tended to have higher proportion of their total fat posteriorly in thigh, lower proportion in neck and similar proportion of fat in breast, drumstick and wing (Table 4).

The effect of diet on fat weight distribution is presented in Table 4. Birds fed diet 4 had significantly lower proportion of total fat in breast than those fed diet 1 and diet 3. Birds fed diets 1, 2 and 3 had similar proportion of breast fat. The proportion of thigh fat in birds fed diet 2 was significantly lower than that in birds fed diet 1 and diet 3 but not significantly different from that in birds fed diet 4. The proportion of drumstick fat in birds fed diet 2 was significantly higher than those in birds fed diet 3. It is of interest to note that within high level of protein, increasing crude fiber % resulted in decreased breast fat by 4%, thigh fat by 6.5% but increased drumstick fat by 8% and wing fat by 10.3% (Table 4). It is also worth noting that increasing crude fiber and lowering protein level in the diet resulted in decreased breast fat by 8.7%, thigh fat by 3.4% increased drumstick fat by 3.3% and wing fat by 9.6%.

There were no significant breed x sex, breed x diet and sex x diet interactions for any proportions of total fat weight found in various cuts (Table 4). The non-significant breed x diet interactions for the above mentioned traits indicated that genetic differences did not exist between growing-finishing broilers in their response to diets.

Muscle: bone ratio 'fleshiness'

There were no significant differences between breeds and between sexes in muscle: bone ratios in various carcass parts (Table 5).

Muscle: bone ratios in breast, drumstick and wing were significantly affected by diet . Chicks fed low protein-high fiber diet had lower muscle: bone ratio in breast than those fed other diets, Muscle: bone ratios in drumstick in chicks fed high protein-low fiber diet was significantly higher than corresponding values in chicks fed diet 2 and diet 4. Within each protein level, increasing crude fiber % resulted in lowering muscle: bone ratio in wing.

Table 5
Mean ratios of muscle to bone, meat to bone and muscle to fat components of various parts of broiler chickens by breed, sex and diet (Muskel:Knochen, Fleisch:Knochen und Muskel:Fettverteilung in verschiedenen Schlachtkörperteilstücken in Abhängigkeit von Rasse, Geschlecht und Fütterung)

	Breed (B)		Sex (S)		Diet (D) [+]				Significance of difference[++]		
	Hubbard	Anak	Male	Female	HP-LF	HP-HF	LP-LF	LP-HF	**B**	**S**	**D**
Muscle : bone ratio in:											
Breast	7.37	7.43	7.34	7.47	7.73a	7.45a	7,48a	6.93b	NS	NS	*
Thigh	3.03	3.03	2.99	3.07	3.15	3.03	2.99	2.97	NS	NS	NS
Drumstick	2.99	3.05	2.98	3.06	3.17a	2.91b	3.06ab	2.93b	NS	NS	**
Wing	2.28	2.22	2.26	2.24	2.35a	2.18b	2.33a	2.13b	NS	NS	**
Neck	2.06	1.99	1.07	2.08	1.99	1.98	1.97	2.16	NS	NS	NS
Meat : bone ratio in:											
Breast	8.72	8.80	8.64	8.88	9.24a	8.64ab	8.96a	8.18b	NS	NS	**
Thigh	4.48	4.47	4.32a	4.63b	4.74a	4.20c	4.57ab	4.38bc	NS	**	**
Drumstick	3.87	3.96	3.84	4.00	4.11a	3.74c	3.99ab	3.81bc	NS	NS	**
Wing	3.72	3.64	3.62	3.74	3.78ab	3.47c	3.88a	3.58bc	NS	NS	**
Neck	4.68	4.59	4.51	4.76	4.72	4.20	4.77	4.83	NS	NS	*
Muscle : fat ratio in:											
Breast	5.72	5.70	5.91a	5.51b	5.38bc	6.42a	5.24c	5.83b	NS	**	**
Thigh	2.23	2.25	2.37a	2.10b	2.00bc	2.67a	1.97c	2.23b	NS	**	**
Drumstick	3.50	3.45	3.58a	3.37b	3.43	3.68	3.40	3.38	NS	*	NS
Wing	1.63	1.59	1.69a	1.52b	1.67a	1.73a	1.53b	1.51b	NS	**	**
Neck	0.83	0.81	0.81	0.83	0.77bc	0.93a	0.73c	0.85ab	NS	NS	* *

a, b, c means in raw bearing different superscripts differ significantly at $P < 0.05$.
*, ** $P < 0.05$ and $P < 0.01$, respectively; NS, not significant ($P > 0.05$).
[+]The abbreviations are defined in the text; [++]BS, BD, SD interactions not significant

Meat: bone ratio

Breed had no significant effect on meat: bone ratios in various cuts.

There were no significant differences between males and females in meat: bone ratios in breast, drumstick, wing and neck, but thigh meat: fat ratio was significantly higher in females than in males.

Irrespective of protein level, increasing fiber level resulted in lowering meat: bone ratios in breast and wing (Table 5). Also, within high level of protein, increasing fiber level led to decreasing meat: bone ratio in thigh and drumstick cuts. Meat: bone ratio in neck was significantly lower in chicks on high protein - high fiber diet than corresponding values in chicks on other diets.

Muscle: fat ratio

There were no significant differences between Hubbard and Anak in muscle: fat ratios in various parts of the carcass (Table 5).

Muscle: fat ratios in various parts of the carcass differed with sex. Compared with females, males had higher muscle: fat ratios in breast, thigh, drumstick, wing and neck.

Chicks fed diet 2 had significantly higher muscle: fat ratio in breast and thigh than those fed other diets (Table 5). Moreover, within each protein level, chicks fed high fiber diets (2 and 4) had significantly higher muscle: fat ratio in breast than chicks fed low fiber diets (1 and 3). Muscle: fat ratio in wing of chicks fed high protein with either low or high fibers was significantly higher than corresponding values of chicks fed low protein with either low or high fibers.

There were no significant breed x sex, breed x diet and sex x diet interactions for any of muscle: bone ratio 'fleshiness', meat: bone ratio and muscle: fat ratio traits.

Discussion

General trends

Carcass composition refers the proportions of muscle, fat and bone in the carcass. Muscle, bone and fat relative to live body weight were estimated at 40.4%, 11.4% and 15.5% for broiler chickens, 27.9%, 11.8% and 15.9% for Pekin ducklings (SHAHIN et al., 2000a) and 39.7%, 9.6% and 5.6% for the Japanese quail (SHAHIN et al., 2000b). The carcass muscle: bone ratio in the present study ranged from 2.77 to 4.85 with a mean of 3.57, corresponding value in Pekin ducklings was 2.4 (SHAHIN et al., 2000a) and in Japanese quail was 4.23 (SHAHIN et al., 2000b).

In the present study breast muscle accounted for 40% of the total carcass muscle weight and the thigh muscle accounted for 24% of the total carcass muscle weight. Corresponding values for in Pekin ducklings were 28 and 20%, respectively (SHAHIN et al., 2000a) and for Japanese quail were 47 and 23% (SHAHIN et al., 2000b).

Fat tended to accumulate differentially in different carcass parts and the patterns of accumulation varies with species. In chickens fat accumulates in great quantity in thigh followed by breast, while in Pekin ducklings the patterns of accumulation were reversed. In chickens, thigh fat comprised approximately 29% of total and breast fat accounted for approximately 19% of total carcass fat, while corresponding values in Pekin ducklings were 16 and 24%, respectively.

Live body weight

The present study showed significant differences between breeds and sexes for live body weight. Hubbard was significantly heavier than Anak and males were heavier than females. Similar results have been reported by MALONE et al. (1979) who found that at 8 weeks of age live body weight of Hubbard males exceeded that of females by 24%.

In the present study diet significantly affected live body weight in that increasing fiber level of grower-finisher diets above norm resulted in a decreased of this trait. Similar findings have been reported by ABBAS (1992) who found that increasing crude fiber in diets from 3 to 9% depressed live body weight by 10%, but he found that live body weight was not significantly affected by increasing fiber level from 3 to 5 to 7%. LEESON et al. (1996) found that reducing the energy level in the diet from 3300 to 2700 Kcal ME/ kg resulted in reduced live body weight at 7 weeks by 11 %. The reduction of live weight could be due to reduced energy content of the fiber diets. Fibrous diets may prove to be practicable in terms of economy of broiler production (decreases feed costs) especially when high-energy diets are expensive and their prices increase substantially.

Carcass composition and distribution of carcass parts, muscle, meat, fat and bone

Proportions of major carcass tissues and distribution of these tissues throughout the carcass is important to carcass value. Manipulation of these traits depends on the combined genetic and nutrition. In the present study Hubbard and Anak did not differ significantly in carcass composition and in distribution of carcass parts, total muscle, total fat, total meat and total bone weight throughout the carcass parts. The absence of breed effect on these traits is probably due to the two breeds did not differ very much genetically and the breeds are compared at the same stage of physiological development (i.e. they are equally mature). These results were at variance with the results obtained by MERKLEY et al. (1980) who reported significant differences among broiler strains in percentage of yield of carcass parts. They found that the Ross crosses had significantly higher proportion of breast and lower proportion of legs than Hubbard crosses. Also, ORR et al. (1984) found economically important differences between eight Canadian broilers strains in carcass yield characteristics. They found the ratio of the highest to the lowest strains was 1.07 for breast weight and 1.02 for legs. Ross strain had the highest breast and the lowest legs, while in the Cobb strain the situation was reversed.

Significant differences between dual-purpose type breed and broiler type breed in muscle weight distribution and in fat weight distribution. have been reported by ABDALLAH et al. (1990) and SHAHIN et al. (1990). Also, significant differences between breeds in bone weight distribution have been reported by SHAHIN et al. (1996). The differences between breeds in distribution of tissues throughout the bird's body reported by those workers were small and probably reflected differences in stage of maturity and may be related to carcass shape. Breed had no significant effect on meat: bone ratios in various cuts. Similar findings have been reported by PANDEY et al. (1985).

Sex significantly affected carcass composition, proportion of total carcass bone in wing, proportion of total carcass fat in thigh and neck. These differences between sexes are in line with the results in the literature. These differences probably arise from metabolic differences and from differences in the onset of fattening.

Males and females did not differ significantly from each other in muscle and meat weight distributions and in yield of all carcass parts. MERKLEY et al. (1980) found significant differences between sexes in the yield of all carcass parts. They found that compared with male broilers, females had greater breast and back but smaller legs. Also, other workers (BROADBENT et al., 1981; GREY et al., 1982; SHAHIN et al. 1996) found that compared with males, females had higher proportion of total muscle in breast and lower of their total muscle in leg (thigh plus drumstick).

In the present study carcass composition was manipulated by diet in that carcass fat was greatly depressed and carcass muscle was increased consequently muscle: fat ratio was increased *via* feeding birds high protein accompanied with high fiber diet. The relatively lower proportion of fat in carcasses from chicks fed high fiber diets could be related to their lighter carcass weights and probably to their younger physiological age.

The proportion of total carcass muscle in breast did not altered by diet but those of thigh and neck did altered by diet. Similar findings have been reported by LEESON et al. (1996) and PETER et al. (1997) who found that the proportion of meat in valuable parts of the carcass was influenced less by diet and more by slaughter weight. It seems that the distribution of muscle is influenced by total carcass muscle not by nutritional treatments.

Carcasses of chicks fed high fiber (with either low or high protein) diets had higher proportion of bone, higher proportion of total meat in thigh and neck, but less proportion of boneless carcass than carcasses of chicks fed low fiber (with either low or high protein) diets. Increasing crude fiber in diets resulted in lowering proportion of total fat in breast, thigh but increasing proportion of total fat in drumstick and wing. Diet did not influence bone weight distribution. It seemed that bone weight distribution is independent of diet.

In the present study, diet significantly affected nearly all muscle: bone, meat: bone and muscle: fat ratios in various carcass parts. These ratios can be used as a measures of carcass desirability; a higher ratio being better than a low one. It is of interest to note that muscle: bone ratios in breast of chicks fed high fiber diets were lower than corresponding ratios of chicks fed low fiber diets, while the opposite trend was observed for muscle: bone ratios in drumstick. No comparable data were found in the literature.

Genetic and nutritional Interactions

Breed x sex, breed x diet and sex x diet interactions did not significantly influence most of carcass traits indicating that the factors under consideration act independently of each other's. The absence of significant interactions on these traits indicated that the effect of diet was essentially the same regardless of breed and sex and indicated that differences between diets tended to be similar for different breeds and sexes. SHAHIN et al. (1996) found significant breed x sex interactions for proportion of total lean in breast and thigh and for proportions of bone in all cuts whereas the differences between males and females were greater in some breeds than in others.

Table 6
Means for major carcass tissues and bone weight distribution with significant sex x diet and breed x diet interactions (Durchschnittswerte der wichtigsten Gewebe- und Knochengewichtsanteile mit signifikanten Geschlecht:Fütterung und Rasse:Fütterung Interaktionen)

	High Protein		Low Protein	
	Low fiber	High fiber	Low fiber	High fiber
	Fat as a percentage of live body weight			
Males	15.85	13.47	15.92	14.18
Females	16.10	14.09	16.98	17.17
Males/Females %	98.45	95.60	93.76	82.59
	Boneless as a percentage of live body weight			
Males	56.67	54.67	55.78	53.90
Females	56.28	54.78	57.36	57.62
Males/Females %	100.69	99.80	97.25	93.35
	Neck bone as a percentage of total carcass bone			
Hubbard	7.42	7.08	7.23	6.65
Anak	7.64	7.95	7.08	7.70
Hubbard/Anak %	97.12	89.06	102.12	86.36

Significant sex x diet interactions was found for carcass fat and boneless carcass relative to live body weight: the sexual dimorphism in low protein diet is more pronounced than in high protein diets (Table 6). These indicated that the effect of diet on the above mentioned traits was dependent on the sex of bird and the differential responses in these traits may be more important than the main effects. Such information is sparse in the literature.

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