Carcass Composition and Yield of 1957 Versus 2001 Broilers When Fed Representative 1957 and 2001 Broiler Diets[1]

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ABSTRACT The yield of carcass parts as well as levels of carcass fat, moisture, and ash were measured in the 1957 Athens-Canadian Randombred Control (ACRBC) and in the Ross 308 commercial broiler, when fed diets that were representative of those being fed during 1957 and 2001. The Ross 308 was used to represent 2001 commercial broilers. Comparisons of carcass weights of the Ross 308 on the 2001 diet versus the ACRBC on the 1957 diet showed they were 6.0, 5.9, 5.2, and 4.6 times heavier than the ACRBC at 43, 57, 71, and 85 d of age, respectively. Yields of hot carcass without giblets (fat pad included) were 12.3, 13.6, 12.2, and 11.1 percentage points higher for the Ross 308 than for the ACRBC at those ages. The yields of total breast meat for the Ross 308 were 20.0, 21.3, 21.9, and 22.2% and were 8.4, 9.9, 10.3, and 9.8 percentage points higher than for the ACRBC at those ages. Yields of saddle and legs for the Ross 308 broiler were approximately 31 to 32% over the four ages and were about 1.5 to 2% higher than for the ACRBC at the different ages. The Ross 308 averaged 13.7, 15.0, 18.6, and 18.5% whole carcass fat versus 8.5, 10.6, 12.7, and 14.0% for the ACRBC at the four ages. In conjunction with previous studies, the current data show that yield of broiler carcass parts has continued to increase over time and that genetics has been the major contributor to changes in yield.

(*Key words*: broiler, carcass composition, diet, genetic change, yield)

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INTRODUCTION

The growth rate of commercial broilers has changed tremendously over the past 45 yr, and previous investigations (Sherwood, 1977; Havenstein et al., 1994a,b) have shown that the majority of that change (85 to 90%) has been brought about by the quantitative selection practiced by commercial breeding organizations. It has been 10 yr since a 1991 study was reported in a series of papers by Havenstein et al. (1994 a,b) and Qureshi and Havenstein (1994), in which an attempt was made to assess the relative contributions of genetics and nutrition to changes that occurred between 1957 and 1991 in broiler growth, livability, feed conversion, carcass characteristics, and immune function. The data reported herein are part of a study that attempted to assess changes in broiler carcass characteristics and yield that occurred between 1957 and 2001. Data on growth, livability, feed conversion, and immune function from the birds used in the current study are reported in two companion papers (Havenstein et al., 2003; Cheema et al., 2003). The Ross 308, one of the most popular commercial strains in 2001, was chosen to represent 2001 commercial broilers. It was compared with the performance of the Athens-Canadian Randombred (ACRBC) strain of broilers that has been maintained for many years at the Southern Regional Poultry Breeding Laboratory, the University of Georgia. Genetic change is, of course, a function of both within- and between-strain selection over time. As in the studies by Havenstein et al. (1994a,b), both sexes of each strain were placed on a modern state-of-the-art 2001 commercial-type diet and on a 1957-type diet in an attempt to separate the genetic and nutritional contributions to the changes in observed performance.

The history of the ACRBC and attempts to assess genetic change in broilers were reviewed by Havenstein et al. (1994a,b; 2003), and that information will not be repeated herein. Havenstein et al. (1994a) also provided a graphic presentation of the historical 56-d BW for the ACRBC from data that was kindly provided by Henry Marks, University of Georgia, Athens, GA, showing that the regression of BW on years from 1957 to 1991was not significantly different from zero. So, the ACRBC strain, which was started from several of the first commercial

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Abbreviation Key: ACRBC = Athens Canadian Randombred Control.

white-feathered strains of broilers (Hess, 1962; Gowe and Fairfull, 1990), grew at the same rate in 1991 as it did when it was founded in 1957. Although the authors have not seen data on the performance of ACRBC in the years since 1991, the data on growth rate that are provided in the companion paper (Havenstein et al., 2003) show that ACRBC grew very similarly in 2001 to how it grew in 1991 and the years before. Because growth rate changes are also accompanied by changes in body composition and yield, as in the previous study, all of the birds in the current study were slaughtered and processed. The objective of this part of the study was to provide an assessment of the changes that have taken place over the past 44 yr (i.e., 1957 to 2001) in terms of broiler body composition and yield as well as to estimate the relative contribution that genetics and nutrition have made to those changes.

MATERIALS AND METHODS

Strains and Strain Management

The current study (Havenstein et al., 2003) was designed using the ACRBC, along with one of the most popular broiler stocks in the United States during 2001, the Ross 308 feather-sexable strain. Rations representative of those used in 1957 and 2001 (Havenstein et al., 2003) were used to assess the relative influence that dietary changes have had on the traits measured. The 1957 diets were a minor modification of diets published by Titus (1961). The 2001 diets were based on personal observations of diets being used by the United States broiler industry and those recommended by the Ross Breeding organization in 2001. All diets were corn and soybean meal based; details of those diets are provided by Havenstein et al. (2003). The 1957 diets contained meat and bone meal, alfalfa meal, distiller's grains, and fishmeal, which provided some of the vitamins that are supplemented in synthetic form in modern diets. The 2001 diet used poultry meal and poultry fat, which were not used in the 1957 diets. The 1957 starter and grower diets were fed as mash, whereas the 2001 starter diet was fed as crumbles, and the two growers and the finisher were fed as pellets. A change from the 1991 study (Havenstein et al., 1994a) was made in that the starter for the 1957 diet was fed from 1 to 42 d of age, and the grower was fed thereafter. This is probably more typical of what was actually done in 1957 rather than providing the starter diet for the first 3 wk only, as was done in the 1991 study. The 2001 dietary regimen consisted of a starter (d 0 to 21), grower 1 (2 kg/bird), grower 2 (2 kg/bird), and a finisher, which is different than the 0-to-21-d starter and single grower regimen used for the 1991 diet in the 1991 study. This change in dietary regimen might have had some effects on the outcome of the current study in comparison to what was observed for the 1991 study but is reflective of nutritional management changes that have taken place in the industry and will be included in the diet effects from the current study.

Details of the design and conduct of the growout portion of the current study were provided by Havenstein et al. (2003). In brief, 21 birds per pen were placed into a 32-pen curtain-sided house [same house used in the Havenstein et al. (1994a) study] in a randomized block design with a $2 \times 2 \times 2$ factorial arrangement [i.e., two strains (ACRBC and the 2001 Ross 308), two dietary regimens, and two sexes]. The eight treatment groups were randomly assigned within each of four replicate blocks (i.e., eight pens per block).

All living birds were individually weighed and their uneaten feed was weighed back at 21, 42, 56, 70, and 84 d of age for the calculation of feed conversion (Havenstein et al., 2003). One replicate block of pens was electrically stunned and exanguinated for the collection of processing data at 43, 57, 71, and 85 d of age. These ages were chosen to span the ages at which the two strains reached market weight (i.e., about 12 wk of age for the ACRBC and about 6 wk for the modern broiler in 2001). It should be noted that the marketing age for the modern broiler has decreased only a few days since 1991, because broilers are now being marketed at about 15% higher weights in 2001 (i.e., about 2,300 g live weight) than in 1991 (i.e., about 2,000 g live weight), the time of the previous study (USDA, 2003). The data for growth rate, feed conversion, and mortality are reported by Havenstein et al. (2003), and information on immune function are reported by Cheema et al. (2003).

Processing Procedures

All birds in the eight pens of replicate block 1 were deprived of feed approximately 10 h before being slaughtered during the morning of d 43 for carcass yield measurements. The birds in replicate blocks 2, 3, and 4 were treated similarly and were slaughtered at 57, 71, and 85 d of age, respectively.

At the time of slaughter, the fasted BW of each bird was measured immediately prior to stunning and exsanguination. The bird was then bled for 180 s, scalded at 63°C for approximately 120 s, and was then placed into a rotary drum mechanical picker for 30 s. After the head, shanks and feet, and feathers were removed, the carcass was eviscerated by cutting around the vent to remove all of the viscera except the kidneys. As much as possible, the abdominal fat pad was left intact and attached to the carcass. Once eviscerated, the carcass without giblets was weighed to determine hot dressed yield. The weights of the heart and lungs were also measured at each processing age.

The hot carcasses were then submerged in an ice-water bath without agitation for 60 min. They were then drained and reweighed to calculate water uptake. Each carcass was then cut into its component parts. Further processing was completed for all birds within approximately 1 h from the time the birds were removed from the ice bath.

After reweighing of the drained carcass, each was placed on a cone and cut into its component parts: wings, saddle and legs (i.e., the combination of drumsticks, thighs, and back posterior to the thoracic vertebrae), breast skin, pectoralis major, pectoralis minor, fat pad, and rack (i.e., the thoracic vertebrae and ribs with overlying skin and muscle, the clavicle, and the sternum). All weights were recorded to the nearest gram, except for the heart and lung weights, which were measured to the nearest 0.01 g. All carcasses from each pen were randomly assigned to four bags (i.e., four to five complete carcasses without giblets including the abdominal fat pads, per bag). The contents of each bag were then finely ground using a large meat grinder with a 0.95 cm mesh plate. Two composite 10-g samples were then taken from the contents of each bag for the whole carcass analysis of moisture, fat, and ash, using Association of Official Analytical Chemists (1984) approved methods. Because experience has shown that the individual doing the cutup of the carcass makes some difference in the cuts received, the cutter was identified so that those effects could be removed from the analyses.

Statistical Analysis

Yield of the whole hot carcass (including the abdominal fat pad), heart and lungs, and the carcass parts [i.e., wings, saddle and legs, pectoralis major, pectoralis minor, total breast (i.e., pectoralis major plus pectoralis minor), breast skin, abdominal fat pad, and rack] were calculated for each bird as a percentage of the live BW after feed deprivation. Water uptake was calculated as the percentage of hot carcass weight. All data from each age (eight pens involving a $2 \times 2 \times 2$ factorial arrangement with two sexes, two strains and two diets) were analyzed using the general linear means procedure of SAS software (SAS Institute, 1996). Strain, diet, sex, and the two and three-way interactions were included in all analyses. Identification of the individual cutting up the carcasses was included as a block or fixed effect in the statistical model for analysis of the carcass parts to remove the variation from that source from the main and interaction effects.

RESULTS AND DISCUSSION

Carcass Yield

The hot carcass weight and percentage hot carcass yield data are summarized across all ages and strain diet groups in Table 1. Hot carcass weight, as one would expect, showed the same basic relationships discussed for live weight (Havenstein et al., 2003). The current result is in good agreement with the results of Havenstein et al. (1994b). Using the average of both sexes, the carcass weights of the 2001 Ross 308 strain on the 2001 diet were 6.0, 5.9, 5.2, and 4.6 times heavier than those of the 1957 ACRBC on the 1957 diets at 43, 57, 71, and 85 d of age. The Ross 308 birds fed the 2001 diets had significantly (25 to 33%) heavier carcass weights than those fed the 1957 diets. In contrast, the difference between carcass weights of the ACRBC on the two diets was only 12 to 13%, resulting in strain × diet effects ($P < 0.0001$) at all processing ages. The difference between the two diets was also larger in males than in females, resulting in significant to highly significant sex × diet and strain × sex × diet interactions at the different ages.

The yield of the hot carcass without giblets (sexes combined) for the Ross 308 on the 2001 diet was 12.3, 13.6, 12.2, and 11.1 percentage points higher than those for the ACRBC on the 1957 diet at 43, 57, 71, and 85 d, respectively (Table 1). The average Ross 308 yields on the 2001 diet ranged from 72.3 to 76.1% at those ages. In contrast, yields for the Arbor Acre feather-sexable strain on the 1991 diet were only 6 to 7% higher than those of the ACRBC on the 1957 diet in the 1991 study (Havenstein et al., 1994b). The strain and diet differences for yield of the hot carcasses were present ($P < 0.0001$) at all processing ages. Strain × diet interactions were highly significant at 43, 57, and 71 d, but not at 85 d of age. Strain × sex interactions increased with slaughter age, becoming significant at 71 d of age ($P = 0.0207$) and highly significant at 85 d of age ($P < 0.0001$). Although leg problems and the incidence of tibial dyschondroplasia were not measured in the current study (Havenstein et al., 2003), visual observations led the authors to suspect that the strain × sex interactions were the result of increasing leg and mortality problems during the latter two ages in the modern strain male.

Water Uptake

The percentages of water uptake by the carcass, including the abdominal fat pad, following 1 h of immersion in ice water for all strain, sex, diet, and slaughter age groups are provided in Table 2. Many different factors affect water absorption, the most important of which were summarized by Brandt (1963) as reported by Katz and Dawson (1964): water temperature, time of chilling, ice to water ratio, agitation, size of the bird, fat, skin thickness, and application of polyphosphates to the chilling water. Bailey et al. (1948) and Katz and Dawson (1964) reported that parts of broilers absorb water differently and are listed from most to least as follows: neck, back, thigh, wing, breast and drumstick. Lentz and Rooke (1958) reported that skin absorbs the greatest amount of water and bone and muscle the least. Essary and Dawson (1965) found that percentage moisture uptake was greater in small than in large carcasses and greater in females than in males. Water uptake in the current study was 3 to 4 percentage points higher in the ACRBC on the 1957 diet than for the Ross 308 on the 2001 diet (Table 2). This is a 1.0 to 1.5 percentage point greater difference in water uptake than was seen in the 1991 study (Havenstein et al., 1994b). Water uptake is negatively influenced by the percentage of carcass fat (Brandt, 1963) because of the hydrophobic property of fat. It appears, therefore, in agreement with previous studies, that as growth rate and fat level have increased, water uptake by the carcass has decreased. Water uptake

TABLE 1. Hot dressed carcass weight and percentage hot dressed carcass yield by strain, diet, sex, and age

Strain[1]	Diet[2]	Sex	Hot carcass weight (g)				Hot carcass yield (% BW)			
			43 d	57 d	71 d	85 d	43 d	57 d	71 d	85 d
2001	2001	Male	2,078	3,145	3,938	4,591	72.3	74.1	76.0	74.3
2001	1957	Male	1,536	2,207	2,874	3,494	68.7	70.1	74.1	73.8
1957	2001	Male	391	632	882	1,216	61.5	62.8	64.4	66.1
1957	1957	Male	340	535	790	1,101	60.4	60.9	64.7	65.2
2001	2001	Female	1,774	2,484	3,165	3,839	72.3	74.7	76.0	77.8
2001	1957	Female	1,383	2,022	2,676	3,216	67.9	71.3	74.1	75.5
1957	2001	Female	329	437	652	847	60.5	61.9	64.1	66.0
1957	1957	Female	303	425	579	721	59.7	60.6	62.9	64.6
Strain averages within diet										
2001	2001		1,926	2,814	3,552	4,215	72.3	74.4	76.0	76.0
2001	1957		1,460	2,114	2,775	3,355	68.3	70.7	74.1	75.8
1957	2001		360	534	767	1,031	61.0	62.4	64.2	66.0
1957	1957		322	480	684	911	60.0	60.8	63.8	64.9
Pooled SEM			24.3	35.0	46.4	57.0	0.80	0.56	0.34	
Source of variation			Probability							
Strain			0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Diet			0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001
Sex			0.0001	0.0001	0.0001	0.0001	0.2894	0.7979	0.9747	0.0001
Strain × diet			0.0001	0.0001	0.0001	0.0001	0.0073	0.0113	0.0061	0.5205
Strain × sex			0.0001	0.0001	0.0001	0.0833	0.6877	0.0575	0.0207	0.0001
Sex × diet			0.0112	0.0001	0.0001	0.0048	0.8112	0.4344	0.7745	0.0185
Strain × sex × diet			0.0692	0.0001	0.0001	0.0032	0.6544	0.9413	0.0484	0.1870

[1]2001 = Ross 308 feather-sexable; 1957 = Athens-Canadian Randombred Control.

[2]2001 = broiler diet typical of those being fed in calendar year 2001; 1957 = broiler diet typical of those being fed in 1957 (adapted from Titus, 1961). The 1957 starter and grower diets were fed as mash, and the 2001 starter was fed as crumbles and the grower and finisher were fed as pellets. The 1957 starter was fed through 42 d of age, and the 2001 starter was fed through 21 d of age.

also decreased with increasing age and BW in the present study and in the studies by Brake et al. (1993) and Havenstein et al. (1994b). In agreement with the reports by Essary and Dawson (1965) and Havenstein et al. (1994b), in all but one comparison at 43 d of age, females had consistently higher levels of water uptake than males at all ages and across both diets in the current study. Water uptake also decreased with increasing age and carcass

TABLE 2. Percentage water uptake and percent rack by strain, diet, sex, and age

Strain[1]	Diet[2]	Sex	Water uptake (% BW)				Rack (% BW)			
			43 d	57 d	71 d	85 d	43 d	57 d	71 d	85 d
2001	2001	Male	3.1	3.1	2.3	2.2	10.9	11.1	11.1	11.4
2001	1957	Male	4.1	3.6	3.2	2.4	11.6	11.3	11.0	11.3
1957	2001	Male	6.8	5.9	5.3	5.2	11.3	11.3	11.1	11.8
1957	1957	Male	7.6	5.7	5.6	6.1	11.6	11.3	12.1	11.6
2001	2001	Female	3.5	3.4	3.2	2.5	11.1	11.3	11.2	11.7
2001	1957	Female	4.2	4.0	4.0	2.7	11.2	11.0	11.2	10.7
1957	2001	Female	7.8	7.4	6.0	5.6	11.3	11.7	11.6	12.4
1957	1957	Female	7.2	6.9	6.2	6.4	11.5	11.5	12.1	12.2
Strain averages within diet										
2001	2001		3.3	3.2	2.8	2.3	11.0	11.2	11.2	11.6
2001	1957		4.1	3.8	3.6	2.6	11.4	11.2	11.1	11.4
1957	2001		7.3	6.6	5.7	5.4	11.3	11.5	11.4	11.9
1957	1957		7.4	6.3	5.9	6.3	11.6	11.4	12.1	11.9
Pooled SEM			0.25	0.28	0.27	0.26	0.27	0.20	0.32	0.24
Source of variation			Probability							
Cutter[3]			—	—	—	—	0.0001	0.0001	0.0001	0.0001
Strain			0.0001	0.0001	0.0001	0.0001	0.2111	0.0624	0.0134	0.0005
Diet			0.0020	0.5318	0.0076	0.0027	0.5866	0.4866	0.1498	0.0465
Sex			0.2095	0.0001	0.0001	0.1042	0.2801	0.4017	0.1328	0.1328
Strain × diet			0.0150	0.0245	0.1378	0.0546	0.6570	0.8438	0.1054	0.3626
Strain × sex			0.6860	0.0116	0.6367	0.8371	0.9991	0.2186	0.7683	0.0208
Sex × diet			0.0035	0.8205	0.9381	0.8352	0.4401	0.1792	0.6134	0.1930
Strain × sex × diet			0.2222	0.7428	0.9143	0.8986	0.6164	0.5703	0.4958	0.1555

[1]2001 = Ross 308 feather-sexable; 1957 = Athens-Canadian Randombred Control.

[2]2001 = broiler diet typical of those being fed in calendar year 2001; 1957 = broiler diet typical of those being fed in 1957 (adapted from Titus, 1961). The 1957 starter and grower diets were fed as mash, and the 2001 starter was fed as crumbles and the grower and finisher were fed as pellets. The 1957 starter was fed through 42 d of age, and the 2001 starter was fed through 21 d of age.

[3]Individuals conducting carcass cut-up.

TABLE 3. Percentage saddle and legs and wings by strain, diet, sex, and age

			Saddle and legs (% BW)				Wings (% BW)			
Strain[1]	Diet[2]	Sex	43 d	57 d	71 d	85 d	43 d	57 d	71 d	85 d
2001	2001	Male	30.8	31.9	32.9	31.7	7.8	7.6	7.9	7.7
2001	1957	Male	30.8	31.5	32.5	32.9	7.9	8.1	8.4	8.3
1957	2001	Male	29.1	30.2	30.4	31.6	10.1	9.8	9.7	9.3
1957	1957	Male	28.8	29.5	30.8	31.4	9.7	9.8	9.8	9.5
2001	2001	Female	30.5	30.6	29.6	29.8	7.9	7.9	7.5	7.6
2001	1957	Female	29.4	30.4	31.2	30.3	7.9	7.8	8.0	7.7
1957	2001	Female	28.1	28.1	29.0	29.7	9.8	9.9	9.5	9.2
1957	1957	Female	27.9	28.5	29.0	29.4	9.5	10.0	9.6	9.3
Strain averages within diet										
2001	2001		30.6	31.2	31.2	31.2	7.8	7.8	7.7	7.6
2001	1957		30.1	31.0	31.8	31.6	7.9	8.0	8.2	8.0
1957	2001		28.6	29.2	29.7	30.6	10.0	9.8	9.6	9.2
1957	1957		28.4	29.0	29.9	30.4	9.6	9.9	9.7	9.4
Pooled SEM			0.42	0.23	0.38	0.28	0.16	0.13	0.15	0.13
Source of variation			Probability							
Cutter[3]			0.6718	0.0001	0.0068	0.1604	0.3551	0.0002	0.0001	0.0004
Strain			0.0001	0.0001	0.0001	0.0068	0.0001	0.0001	0.0001	0.0001
Diet			0.1471	0.1476	0.1257	0.1154	0.4515	0.1886	0.0094	0.0012
Sex			0.0024	0.0001	0.0001	0.0001	0.1501	0.5656	0.0044	0.0059
Strain × diet			0.5606	0.7358	0.4408	0.0037	0.0270	0.3329	0.0596	0.2596
Strain × sex			0.8410	0.3146	0.1934	0.2645	0.3137	0.4015	0.4747	0.1278
Sex × diet			0.4735	0.0484	0.1169	0.2327	0.5377	0.0642	0.8542	0.1226
Strain × sex × diet			0.2223	0.2498	0.0248	0.5100	0.4760	0.0748	0.8960	0.2667

[1]2001 = Ross 308 feather-sexable; 1957 = Athens-Canadian Randombred Control.

[2]2001 = broiler diet typical of those being fed in calendar year 2001; 1957 = broiler diet typical of those being fed in 1957 (adapted from Titus, 1961). The 1957 starter and grower diets were fed as mash, and the 2001 starter was fed as crumbles and the grower and finisher were fed as pellets. The 1957 starter was fed through 42 d of age, and the 2001 starter was fed through 21 d of age.

[3]Individuals conducting carcass cut-up.

size in these same studies. Most of the strain, diet, and sex differences for carcass water uptake in the current study were highly significant at all processing ages, whereas most of the interaction effects were not significant.

Carcass Parts

The yield of rack (i.e., the weight of the rib cage, sternum, thoracic vertebrae, and associated muscles and back skin with the pectoralis major and pectoralis minor and breast skin removed divided by the live BW following feed deprivation × 100) is summarized in Table 2. In agreement with observations made by Havenstein et al. (1994b), the differences in percentage rack were small and for the most part not significant for strain, diet, sex, and their interactions. The primary exception was for strain at 71 and 85 d at which the ACRBC had higher percentage of rack than did the Ross 308 broiler ($P < 0.01$).

The yield of saddle and legs was approximately 31% at all ages for the Ross 308 on both diets and ranged from 28.5 to 30.6% for the ACRBC (Table 3) across the two diets. The strain difference was evident at all ages ($P < 0.0007$), and the Ross 308 percentages were approximately 1 percentage point less at all four processing ages than were the saddle and leg percentages for the Arbor Acre in the 1991 study (Havenstein et al., 1994b). The ACRBC percentages were similar in the two studies. Females had consistently lower ($P < 0.003$) percentages of saddle and legs than males at all ages. None of the diet or interaction effects for saddle and legs were significant at any age.

The yield of wings averaged approximately 7.9% for the ROSS and 9.7% for the ACRBC over both diets, and all of the strain differences were highly significant (Table 3). The effects of diet were significant ($P < 0.01$) only at 71 and 85 d, with slightly higher percentages of wings for birds grown on the 1957 diets. The Arbor Acre in the 1991 study averaged 8.6% wings (Havenstein et al., 1994b).

The percentage yields of the two major breast muscles (pectoralis major and pectoralis minor) are presented by strain, sex, diet, and age group in Table 4. Total breast yield is presented in Table 5. The Ross 308 broiler on the 2001 diet (average of both sexes) had 16.2, 16.9, 17.7, and 17.9% pectoralis major and 3.8, 4.2, 4.2, and 4.4% pectoralis minor at 43, 57, 71, and 85 d of age, respectively. Thus, total breast meat averaged 20.0, 21.3, 21.9, and 22.2% at these ages. The yield of total breast for the ACRBC on the 1957 diet averaged 11.6, 11.4, 11.6, and 12.4% for the same ages. Therefore, the Ross 308 broiler on the 2001 diet averaged almost 10 percentage points more total breast meat than the ACRBC in the current study. In contrast, the Arbor Acres on the 1991 diet averaged only 4.4 percentage points more total breast meat than the ACRBC on the 1957 diet in the 1991 study (Havenstein et al., 1994b). Thus, the change from the "normal" broiler strains that were being used in the late 1980's and early 1990's to the so-called meat-type or high-yield broiler that is in current use has resulted in a doubling in the percentage yield of breast meat. This change has primarily taken place during the past 10 yr. Based on the current data and that of Havenstein et al. (1994b), most

TABLE 4. Percentage Pectoralis major and Pectoralis minor by strain, diet, sex, and age

Strain[1]	Diet[2]	Sex	Pectoralis major (% BW) 43 d	57 d	71 d	85 d	Pectoralis minor (% BW) 43 d	57 d	71 d	85 d
2001	2001	Male	15.8	16.8	16.9	17.0	3.7	4.1	3.9	4.3
2001	1957	Male	13.5	14.0	14.4	16.8	3.4	4.4	4.0	4.3
1957	2001	Male	8.5	8.6	8.6	8.6	2.8	2.9	3.4	3.2
1957	1957	Male	8.8	8.4	8.3	8.9	2.8	3.0	3.0	3.2
2001	2001	Female	16.5	17.4	18.5	18.8	4.0	4.3	4.5	4.6
2001	1957	Female	14.1	15.7	16.3	16.8	3.8	4.4	4.5	4.9
1957	2001	Female	8.8	9.0	8.9	9.3	3.1	3.1	3.4	3.3
1957	1957	Female	9.1	8.4	8.9	9.5	2.7	2.9	3.1	3.4
Strain averages within diet										
2001	2001		16.2	16.9	17.7	17.9	3.8	4.2	4.2	4.4
2001	1957		13.8	14.8	15.4	16.8	3.6	4.4	4.2	4.6
1957	2001		8.6	8.8	8.8	9.0	2.9	3.0	3.4	3.2
1957	1957		9.0	8.4	8.6	9.2	2.7	3.0	3.0	3.3
Pooled SEM			0.36	0.26	0.26	0.29	0.20	0.10	0.22	0.09
Source of variation			Probability							
Cutter[3]			0.0001	0.0001	0.0001	0.0001	0.2516	0.2508	0.1668	0.0001
Strain			0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Diet			0.0001	0.0001	0.0001	0.0002	0.0950	0.3371	0.3049	0.0605
Sex			0.0485	0.0003	0.0001	0.0001	0.1281	0.0001	0.0388	0.0001
Strain × diet			0.0001	0.0001	0.0001	0.0001	0.8555	0.4851	0.1969	0.3311
Strain × sex			0.5429	0.0089	0.0003	0.0171	0.6326	0.0052	0.1182	0.0201
Sex × diet			0.9172	0.3032	0.5110	0.5361	0.5678	0.8318	0.9838	0.0670
Strain × sex × diet			0.9397	0.0342	0.9372	0.5519	0.4144	0.0217	0.7428	0.3023

[1]2001 = Ross 308 feather-sexable; 1957 = Athens-Canadian Randombred Control.

[2]2001 = broiler diet typical of those being fed in calendar year 2001; 1957 = broiler diet typical of those being fed in 1957 (adapted from Titus, 1961). The 1957 starter and grower diets were fed as mash, and the 2001 starter was fed as crumbles and the grower and finisher were fed as pellets. The 1957 starter was fed through 42 d of age, and the 2001 starter was fed through 21 d of age.

[3]Individuals conducting carcass cut-up.

of this change appears to have come about through increases in the growth of the pectoralis major muscle.

Most strain, diet, sex, and strain × diet effects were highly significant for pectoralis major and total breast meat at all processing ages studied (Tables 4 and 5). Strain was the only significant effect for pectoralis minor. In agreement with the data of Brake et al. (1993) and Havenstein et al. (1994b), females had slightly greater average breast yields than males, and breast yield increased with age.

The percentage yields of breast skin are summarized by strain, diet, sex and age in Table 5. Breast skin measurements were slightly but consistently higher in the current study than in the previous study (Havenstein et al., 1994b). It is thought that this is more a reflection of differences in the way individuals who were involved in the removal of the head and necks of the birds for the two studies (and, therefore, the amount of remaining breast skin) than for an actual change in breast skin levels. Although the Ross 308 broiler tended to have slightly more breast skin on a percentage basis than the ACRBC, as did the Arbor Acres compared to the ACRBC in the 1991 study (Havenstein et al., 1994b), the differences appeared to be minor and from visual observation appeared to be primarily due to the amount of fat in the skin. Significant ($P < 0.05$) differences due to diet and sex for percentage breast skin were observed in the current study, with higher skin levels for the 2001 diet than for the 1957 diet, and higher skin levels in the females than in the males. Again in both cases, from visual observations, this appeared to be related to the amount of fat in the skin.

Heart and Lungs

Increasing levels of mortality and incidences of leg problems and flip-overs in modern broiler strains over the past 20 yr prompted Havenstein et al. (1994a,b) to look at the percentage of heart and lungs in the modern broiler in comparison to the ACRBC strain. This was done at the latter two ages in that study but was done at all four processing ages in the current study. The heart and lung data are summarized by strain, diet, sex, and age in Table 6. In agreement with the 1991 study (Havenstein et al., 1994b), both heart and lung percentages tended to be significantly lower in the modern strain at most of the slaughter ages than in the ACRBC strain. Also in agreement with the 1991 study, the modern diet reduced the percentage of BW found in the lungs in comparison to the 1957 diet (significant at 57 and 71 d), and males tended to have significantly higher heart and lung percentages than did the females at the latter three processing ages.

Again, in agreement with the data of Havenstein et al. (1994b), the data suggest that both heart and lung size as a percentage of live BW have decreased with genetic selection for increased growth rate and other growth related traits. This, along with the rapid increase in body fat at the later ages (discussed later) on the modern diet may be contributing factors to the increased incidence of late mortality in the modern strain (Havenstein et al., 2003), i.e., relative size of the heart and lungs may be contributing factors to the ability of modern broilers to service the respiratory demands of their bodies. Although

TABLE 5. Percentage total breast meat and breast skin by strain, diet, sex, and age

Strain[1]	Diet[2]	Sex	Total breast meat (% BW)				Breast skin (% BW)			
			43 d	57 d	71 d	85 d	43 d	57 d	71 d	85 d
2001	2001	Male	19.5	20.9	20.8	21.2	3.2	2.5	2.4	1.8
2001	1957	Male	17.0	17.8	18.4	19.7	2.7	2.0	2.0	1.6
1957	2001	Male	11.2	11.5	12.0	11.8	2.4	2.3	2.2	2.6
1957	1957	Male	11.5	11.4	11.3	12.0	2.6	2.0	2.2	2.4
2001	2001	Female	20.5	21.7	23.0	23.3	2.8	2.8	3.2	3.3
2001	1957	Female	17.9	20.1	20.8	21.7	2.9	2.4	2.9	3.0
1957	2001	Female	11.9	12.1	12.3	12.6	2.6	2.6	2.8	2.8
1957	1957	Female	11.8	11.3	12.0	12.9	2.4	2.3	2.3	2.7
Strain averages within diet										
2001	2001		20.0	21.3	21.9	22.2	3.0	2.6	2.8	2.6
2001	1957		17.4	19.0	19.6	20.7	2.8	2.2	2.4	2.8
1957	2001		11.6	11.8	12.2	12.2	2.5	2.7	2.5	2.7
1957	1957		11.6	11.4	11.6	12.4	2.5	2.4	2.2	2.6
Pooled SEM			0.44	0.30	0.38	0.33	0.28	0.11	0.12	0.17
Source of variation			Probability							
Cutter[3]			0.0009	0.0001	0.0001	0.0001	0.0242	0.0001	0.0001	0.0067
Strain			0.0001	0.0001	0.0001	0.0001	0.0086	0.0721	0.0077	0.1219
Diet			0.0001	0.0001	0.0001	0.0001	0.2837	0.0001	0.0006	0.0590
Sex			0.0207	0.0001	0.0001	0.0001	0.8987	0.0001	0.0001	0.0001
Strain × diet			0.0001	0.0001	0.0009	0.0001	0.8074	0.2166	0.4814	0.6597
Strain × sex			0.4736	0.0017	0.0009	0.0056	0.4517	0.7076	0.0017	0.0001
Sex × diet			0.7300	0.3383	0.6476	0.9515	0.5810	0.6708	0.2816	0.7664
Strain × sex × diet			0.7570	0.0106	0.8952	0.7985	0.3508	0.8140	0.0990	0.8460

[1]2001 = Ross 308 feather-sexable; 1957 = Athens-Canadian Randombred Control.

[2]2001 = broiler diet typical of those being fed in calendar year 2001; 1957 = broiler diet typical of those being fed in 1957 (adapted from Titus, 1961). The 1957 starter and grower diets were fed as mash, and the 2001 starter was fed as crumbles and the grower and finisher were fed as pellets. The 1957 starter was fed through 42 d of age, and the 2001 starter was fed through 21 d of age.

[3]Individuals conducting carcass cut-up.

few, if any other broiler studies have looked at heart and lung size relative to body size, many experiments have studied the development and causes of ascites-related mortality in modern fast-growing broiler strains, e.g., see the review by Wideman (2001).

Increased levels of total body fat and fat around the heart may be other factors that contribute to the higher death rates of modern broilers (Havenstein et al., 1994a, 2003) than in the randombred control strain. The data from the current study show a concomitant increase, especially in males, in mortality (see mortality levels in the companion paper by Havenstein et al., 2003) and the level of abdominal fat and total body fat (Table 7). Mortality and fat levels were also higher in birds on the higher energy modern diets than on the old diets in the current and Havenstein et al. (1994a,b) studies. Although not measured, birds with high abdominal fat levels were observed to also have a lot of fat throughout the visceral mesentery and around the heart.

Fatness

The degree of fatness for the different treatment groups was measured in two different ways, and those data are reported in Table 7 for each strain, sex, and diet group. The abdominal fat pad data after feed deprivation showed that the Ross 308 broiler on the 2001 diet had a consistently higher percentage ($P < 0.001$) of abdominal fat pad as a percentage of live BW than did the ACRBC strain on the 1957 diet at all ages. In agreement with the data reported by Havenstein et al. (1994b), females had higher percentages of abdominal fat ($P < 0.0001$) than males at 71 and 85 d but not at 43 and 57 d of age. None of the interactions for percentage abdominal fat pad were significant except for strain × sex where the difference between males and females was larger ($P < 0.0001$) on the 1957 diet than on the 2001 diet at 85 d of age. These results are in good agreement with those from the 1991 study reported by Havenstein et al. (1994b).

The results from the analyses of the percentage of carcass fat (Table 7) are quite consistent with those from the abdominal fat pad. That is, the strain diet groups have the same ranking, and the percentage of carcass fat increased with age in all groups, although at somewhat different rates. The data on carcass fat from the current study, due to a much larger sample size per treatment group, should be more accurate than the data reported by Havenstein et al. (1994b). All strain, diet, and sex effects were highly significant ($P < 0.01$) at all ages for carcass fat. Strain-by-diet effects were significant ($P < 0.02$) at 57, 71, and 85 d, due to larger differences between the Ross 308 groups than for the ACRBC groups on the two diets. The strain × diet × sex interactions were also significant ($P < 0.05$) at 42, 56, and 71 d, but not at 85 d of age.

The Ross 308 broiler on the 2001 diet averaged 13.7, 15.0, 18.6, and 18.5% whole carcass fat at 43, 57, 71, and 85 d of age versus 8.5, 10.6, 12.7, and 14.0% for the ACRBC on the 1957 diet at the same ages (Table 7). In agreement with the 1991 study reported by Havenstein et al. (1994b), in which data showed that the carcass fat levels of the 1991 Arbor Acres at 43 d was not much different from the carcass fat level of the ACRBC at 85 d (approximate

TABLE 6. Percentage heart and lung by strain, diet, sex, and age

			Heart (% BW)				Lungs (% BW)			
Strain[1]	Diet[2]	Sex	43 d	57 d	71 d	85 d	43 d	57 d	71 d	85 d
2001	2001	Male	0.535	0.465	0.462	0.434	0.540	0.478	0.514	0.505
2001	1957	Male	0.487	0.455	0.438	0.424	0.589	0.692	0.667	0.708
1957	2001	Male	0.591	0.520	0.539	0.497	0.586	0.636	0.731	0.590
1957	1957	Male	0.547	0.530	0.540	0.474	0.590	0.675	0.766	0.600
2001	2001	Female	0.458	0.408	0.436	0.418	0.515	0.509	0.454	0.528
2001	1957	Female	0.526	0.450	0.382	0.418	0.546	0.589	0.522	0.534
1957	2001	Female	0.556	0.470	0.434	0.447	0.592	0.595	0.678	0.442
1957	1957	Female	0.559	0.472	0.468	0.416	0.568	0.551	0.596	0.482
Strain averages within diet										
2001	2001		0.496	0.436	0.449	0.426	0.527	0.494	0.484	0.516
2001	1957		0.506	0.452	0.410	0.421	0.568	0.640	0.595	0.621
1957	2001		0.574	0.495	0.486	0.472	0.589	0.616	0.704	0.516
1957	1957		0.553	0.501	0.504	0.447	0.579	0.613	0.681	0.541
Pooled SEM			0.030	0.123	0.015	0.016	0.024	0.025	0.031	0.026
Source of variation			Probability							
Strain			0.0049	0.0001	0.0001	0.0020	0.0349	0.0094	0.0001	0.3191
Diet			0.8073	0.2124	0.3005	0.1446	0.3820	0.0001	0.0506	0.1584
Sex			0.4861	0.0001	0.0001	0.0037	0.2199	0.0013	0.0001	0.1128
Strain × diet			0.4738	0.5656	0.0084	0.3117	0.1486	0.0001	0.0026	0.1695
Strain × sex			0.8673	0.1967	0.0234	0.0587	0.4577	0.2010	0.8439	0.1932
Sex × diet			0.0620	0.2124	0.9599	0.9699	0.5192	0.0030	0.0232	0.1909
Strain × sex × diet			0.4247	0.0884	0.1401	0.6981	0.8788	0.4797	0.7122	0.1934

[1]2001 = Ross 308 feather-sexable; 1957 = Athens-Canadian Randombred Control.

[2]2001 = broiler diet typical of those being fed in calendar year 2001; 1957 = broiler diet typical of those being fed in 1957 (adapted from Titus, 1961). The 1957 starter and grower diets were fed as mash, and the 2001 starter was fed as crumbles and the grower and finisher were fed as pellets. The 1957 starter was fed through 42 d of age, and the 2001 starter was fed through 21 d of age.

market weights for the two different strains), the current data indicates that the Ross 308 broiler on the 2001 diet had a slightly lower percentage of carcass fat at 43 d (13.7%) than the ACRBC strain on the 1957 diet had at 85 d (14.0%). The modern diets produced consistently better growth rates in both studies (Havenstein et al., 1994a; 2003) but also produced considerably higher fat levels than the 1957 diets (Havenstein et al., 1994b). As

TABLE 7. Percentage abdominal fat and carcass fat by strain, diet, sex, and age

			Abdominal fat (% BW)				Carcass fat (%)[4]			
Strain[1]	Diet[2]	Sex	43 d	57 d	71 d	85 d	43 d	57 d	71 d	85 d
2001	2001	Male	1.29	1.52	2.07	1.63	12.9	14.4	17.2	14.7
2001	1957	Male	1.08	1.34	1.31	1.17	12.1	11.9	15.5	10.8
1957	2001	Male	0.75	0.90	1.36	1.78	10.8	12.3	13.6	16.8
1957	1957	Male	0.24	0.39	1.03	1.21	7.8	10.0	12.0	13.2
2001	2001	Female	1.50	1.98	2.84	3.32	14.5	17.4	20.0	22.3
2001	1957	Female	1.12	1.57	2.27	2.75	12.3	13.8	15.5	18.7
1957	2001	Female	0.50	0.88	1.81	2.13	11.0	12.9	17.0	18.7
1957	1957	Female	0.30	0.39	1.09	1.21	9.2	11.3	13.4	14.8
Strain averages within diet										
2001	2001		1.40	1.75	2.46	2.48	13.7	15.9	18.6	18.5
2001	1957		1.10	1.46	1.73	1.96	12.2	12.4	15.5	14.8
1957	2001		0.62	0.89	1.58	1.96	10.9	12.6	15.3	17.9
1957	1957		0.27	0.39	1.06	1.21	8.5	10.6	12.7	14.0
Pooled SEM			0.10	0.16	0.16	0.21	0.37	0.31	0.32	0.42
Source of variation			Probability							
Cutter[3]			0.0972	0.0633	0.0494	0.4293	—	—	—	—
Strain			0.0001	0.0001	0.0001	0.0008	0.0001	0.0001	0.0001	0.0163
Diet			0.0001	0.0003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sex			0.8362	0.1237	0.0001	0.0001	0.0033	0.0001	0.0001	0.0001
Strain × diet			0.6622	0.3532	0.5313	0.4207	0.1023	0.0186	0.0001	0.0001
Strain × sex			0.1180	0.1006	0.0077	0.0001	0.7809	0.0022	0.0270	0.8821
Sex × diet			0.6537	0.6457	0.6593	0.4306	0.8289	0.5497	0.5192	0.9271
Strain × sex × diet			0.0828	0.5990	0.1997	0.6837	0.0282	0.0436	0.0015	0.5509

[1]2001 = Ross 308 feather-sexable; 1957 = Athens-Canadian Randombred Control.

[2]2001 = broiler diet representative of those being fed in calendar year 2001; 1957 = broiler diet representative of those being fed in 1957 (adapted from Titus, 1961). The 1957 starter and grower diets were fed as mash, and the 2001 starter was fed as crumbles and the grower and finisher were fed as pellets. The 1957 starter was fed through 42 d of age, and the 2001 starter was fed through 21 d of age.

[3]Individuals conducting carcass cut-up.

[4]Percentage of ground carcass including abdominal fat pad.

TABLE 8. Percentage carcass moisture and carcass ash by strain, diet, sex, and age

			Moisture (%[3])				Ash (%[3])			
Strain[1]	Diet[2]	Sex	43 d	57 d	71 d	85 d	43 d	57 d	71 d	85 d
2001	2001	Male	66.2	65.6	63.2	63.5	1.81	2.10	2.23	2.34
2001	1957	Male	67.6	68.0	67.7	67.2	1.90	2.48	2.46	2.52
1957	2001	Male	68.8	67.5	65.0	62.2	2.70	1.90	3.01	2.93
1957	1957	Male	71.2	68.4	66.9	63.9	1.89	3.22	3.04	3.08
2001	2001	Female	65.4	63.2	60.9	57.8	2.91	1.92	2.06	1.80
2001	1957	Female	66.9	66.6	64.7	60.3	2.82	2.03	2.20	2.14
1957	2001	Female	69.2	67.6	63.6	59.5	2.44	2.42	2.51	2.72
1957	1957	Female	69.3	68.3	65.7	63.6	3.06	2.72	2.69	2.86
Strain averages within diet										
2001	2001		65.8	64.4	62.0	60.6	2.36	2.01	2.14	2.07
2001	1957		67.0	67.3	66.2	63.8	2.35	2.26	2.33	2.33
1957	2001		69.0	67.6	64.3	60.8	2.57	2.16	2.76	2.82
1957	1957		70.2	68.4	66.1	63.8	2.48	2.97	2.86	3.02
Pooled SEM			0.37	0.27	0.28	0.34	0.26	0.14	0.14	0.13
Source of variation			Probability							
Strain			0.0001	0.0001	0.0001	0.6550	0.4027	0.0001	0.0001	0.0001
Diet			0.0001	0.0001	0.0001	0.0001	0.7891	0.0001	0.1706	0.0421
Sex			0.0085	0.0001	0.0001	0.0001	0.0006	0.1290	0.0048	0.0013
Strain × diet			0.7457	0.0001	0.0001	0.7056	0.8098	0.0069	0.7006	0.5513
Strain × sex			0.9384	0.0001	0.0028	0.0001	0.1508	0.1105	0.3121	0.2063
Sex × diet			0.0440	0.1934	0.6417	0.2423	0.1020	0.0028	0.8963	0.7142
Strain × sex × diet			0.0317	0.1279	0.1893	0.0012	0.0398	0.0663	0.5478	0.6515

[1]2001 = Ross 308 feather-sexable; 1957 = Athens-Canadian Randombred Control.

[2]2001 = broiler diet representative of those being fed in calendar year 2001; 1957 = broiler diet representative of those being fed in 1957 (adapted from Titus, 1961). The 1957 starter and grower diets were fed as mash, and the 2001 starter was fed as crumbles and the grower and finisher were fed as pellets. The 1957 starter was fed through 42 d of age, and the 2001 starter was fed through 21 d of age.

[3]Percentage of ground carcass including abdominal fat pad.

mentioned by Havenstein et al. (1994b), commercial breeders have reduced fat levels in broilers considerably from what they were in the mid to the late 1970s. Abdominal fat pad weights were 2.5 to 3% of live weight for approximately 1,800 g broilers at that time (e.g., Griffiths et al., 1978).

Carcass Moisture and Ash

The percentage carcass moisture and ash by strain, diet, sex, and age are summarized in Table 8. In contrast to the 1991 study (Havenstein et al., 1994b), carcass moisture was lower ($P < 0.0001$) in the modern strain than in the ACRBC strain except at 85 d. Carcass moisture was also affected ($P < 0.0001$) by diet and sex, with higher moisture levels for the 1957 diet and the males, than for the 2001 diet and the females. Several of the strain × diet and strain × sex interactions were also significant, indicating that the differences between diets and sexes were different for the two strains. In agreement with the observations of Chambers et al. (1981) and Havenstein et al. (1994b), carcass ash tended to be significantly lower in the modern bird and from the modern diet than in the ACRBC strain on the 1957 diet at the later processing ages.

In conclusion, carcass yield and the percentage of carcass parts for the 1957 ACRBC strain of broilers and for the 2001 Ross 308 commercial broiler were compared when fed representative 1957 and state-of-the-art 2001 dietary regimens. The results showed that carcass weights (average of both sexes) of the 2001 Ross 308 strain on the 2001 diet were 6.0, 5.9, 5.2, and 4.6 times heavier than those of the 1957 ACRBC strain on the 1957 diet at 43, 57, 71, and 85 d of age. Ross 308 birds fed the 2001 diets had significantly (25 to 33%) heavier carcass weights than those fed the 1957 diets. The difference between carcass weights of the ACRBC strain on the two diets was only 12 to 13 percentage points.

The percentage yield of hot carcass weight without giblets (sexes combined) for the Ross 308 broiler on the 2001 diet was 12.3, 13.6, 12.2, and 11.1 percentage points higher than those for the ACRBC strain on the 1957 diet at 43, 57, 71, and 85 d, respectively. The Ross 308 yields ranged from 72.3 to 76.1% at those ages. In contrast, yields for the Arbor Acre feather-sexable strain were only 6 to 7 percentage points higher than those of the ACRBC in a similar 1991 study. Water uptake was 3 to 4 percentage points higher in the ACRBC strain on the 1957 diet than it was for the Ross 308 on the 2001 diet. This is a 1.0 to 1.5 percentage point greater difference in water uptake than was seen in the 1991 study. The yield of saddle and legs was approximately 31 to 32% at all ages for the Ross 308 broiler on both diets, and approximately 28.5 to 30% for the ACRBC strain. The Ross 308 percentages were approximately 1 percentage point less at all four processing ages than were the saddle and leg percentages for the Arbor Acre strain in the 1991 study. The yield of wings averaged approximately 7.9% for the Ross 308 and 9.7% for the ACRBC over both diets. The Ross 308 on the 2001 diet (sexes combined) averaged 20.0, 21.3, 21.9, and 22.2% total breast meat at 43, 57, 71, and 85 d of age, respectively, whereas the ACRBC strain on the 1957 diet averaged 11.6, 11.4, 11.6, and 12.4% total breast meat at the same ages. Thus, the Ross 308 broiler on the 2001 diet averaged almost 10 percentage points more total breast meat than the ACRBC strain. In contrast, the Arbor Acres broiler on the 1991 diet averaged only 4.4 percentage points more total breast meat than the ACRBC strain. The Ross 308 broiler on the 2001 diet averaged 13.7, 15.0, 18.6, and 18.5% whole carcass fat at 43, 57, 71, and 84 d of age, versus 8.5, 10.6, 12.7, and 14.0% for the ACRBC strain at the same ages. Thus, the modern strain on the modern diet at its near market age actually had a slightly lower percentage of carcass fat at 43 d (13.7%) than the ACRBC strain on the 1957 diet had at 85 d (14.0%), at its near market age.

In agreement with results of the previous 1991 study by the authors, and with the data of Sherwood (1977) genetics contributed about 85 to 90% of the differences observed in carcass and parts yield. Nutritional changes account for 10 to 15% of these differences.

REFERENCES

Association of Official Analytical Chemists. 1984. Methods of Analysis. 14th ed. Association of Official Analytical Chemists, Washington, DC.

Bailey, R. L., G. L. Stewart, and B. Long. 1948. Ice slush cooling of poultry. Refrig. Eng. 55:368–371.

Brake, J., G. B. Havenstein, S. E. Scheideler, P. R. Ferket. and D. V. Rives. 1993. Relationship of sex, age and body weight to broiler carcass yield and offal production. Poult. Sci. 72:1137–1145.

Brandt, A. W. 1963. Chilling poultry (a review). Poultry Process. Mark. 69(May):14–22.

Chambers, J. R., J. S. Gavora, and A. Fortin. 1981. Genetic changes in meat-type chickens in the past twenty years. Can. J. Anim. Sci. 61:555–563.

Cheema, M. A., M. A. Qureshi, and G. B. Havenstein. 2003. A comparison of the immune response of a 2001 commercial broiler with a 1957 randombred broiler strain when fed representative 1957 and 2001 broiler diets. Poult. Sci. 82:1519–1529.

Essary, E. O. and L. E. Dawson, 1965. Quality of fryer carcasses as related to protein and fat levels in the diet. Poult. Sci. 44:7–15.

Gowe, R. S., and R. W. Fairfull. 1990. Genetic controls in selection. Pages 935–954 in Poultry Breeding and Genetics. R. D. Crawford, ed. Animal and Veterinary Sciences 22. Elsevier Science Publishers, New York.

Griffiths, L., S. Leeson, and J. D. Summers. 1978. Studies on abdominal fat with four commercial strains of male broiler chickens. Poult. Sci. 57:1198–1203.

Havenstein, G. B., P. R. Ferket, and M. A. Qureshi. 2003. Growth, livability and feed conversion of 1957 versus 2001 broilers when fed representative 1957 and 2001 broiler diets. Poult. Sci. 92:1500–1508.

Havenstein, G. B., P. R. Ferket, S. E. Scheideler, and B. T. Larson. 1994a. Growth, livability and feed conversion of 1991 vs 1957 broilers when fed "typical" 1957 and 1991 broiler diets. Poult. Sci. 73:1785–1794.

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

Hess, C. W. 1962. Randombred populations of the Southern Regional Poultry Breeding Project. World's Poult. Sci. J. 18:147–152.

Katz, M., and L. E. Dawson. 1964 Water absorption and retention by cut up broiler parts chilled in polyphosphate solutions. Poult. Sci. 43:1541–1546.

Lentz, C. P., and E. A. Rooke. 1958. What changes occur in eviscerating poultry during immersion cooling and drainage. Food Canada 18:24–27.

Qureshi, M. A., and G. B. Havenstein. 1994. A comparison of the immune performance of a 1991 commercial broiler with a 1957 randombred broiler strain when fed "typical" 1957 and 1991 broiler diets. Poult. Sci. 73:1805–1812.

SAS Institute. 1996. SAS User's Guide: Statistics SAS Institute Inc., Cary, NC.

Sherwood, D. H. 1977. Modern broiler feeds and strains: What two decades of improvement have done. Feedstuffs 49:70.

Titus, H. W. 1961. Pages 20–22 in The Scientific Feeding of Chickens. 4th ed. The Interstate Printers and Publishers, Danville, IL.

USDA. 2003. Agricultural Marketing Service, Washington, DC. http://www.ams.usda.gov/poultry/mncs/BroilerReport/. Accessed Aug. 2002.

Wideman, R. F. 2001. Pathophysiology of heart/lung disorders: pulmonary hypertension syndrome in broiler chickens. World's Poult. Sci. J. 57:289–307.