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Evaluation of the potential growth and body composition of the Cobb 700 genotype

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ABSTRACT

1. The potential growth of the chemical and physical components of males and females of the Cobb 700 strain was measured from hatch to 15 weeks of age.
2. A four-phase ad libitum feeding programme was used to feed 200 chicks of each sex. All birds were weighed weekly. Ten birds per sex were sampled at 0, 7, 14, 28, 42, 56, 70, 84 and 105 d of age. They were weighed before and after plucking to determine the weight of feathers. Physical parts were measured on defeathered birds, whereafter these components were combined, minced, freeze dried to measure water content, and then analysed for protein, lipid and ash content.
3. Mature body weights of males and females averaged 8.38 and 6.94 kg, respectively, mature body protein weights averaged 1.48 and 1.19 kg and mature body lipid contents averaged 1.08 and 1.54 kg, respectively.
4. Rates of maturing of the empty feather-free body weights of males and females averaged 0.0417 and 0.0402/d, respectively. All chemical and physical components within a sex, other than feathers, had the same rate of maturing. The rate of maturing of feathers, calculated by iteration, in males was lower than in females (0.0324 vs. 0.0357/d) and the mature weight was higher (435 vs. 372 g).
5. The ratios of the chemical components to feather-free body protein at maturity for males and females were, for water, 3.80 and 3.34; for lipid, 0.73 and 1.29; and for ash, 0.13 and 0.19, respectively. Separate equations were required for males and females to describe the allometric relationship between lipid and protein in the feather-free body.
6. Mature body weights of broilers in this trial were considerably higher than those measured using the same protocol 28 years ago, whereas rates of maturing have remained the same.

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Chemical composition; feathering; Gompertz equation; protein; physical composition

Introduction

Food intake and growth of monogastric animals may be predicted using the theoretical framework described by Emmans (1987, 1997). This framework has been used in the development of growth models for broilers (Gous 1998) and pigs (Ferguson 2014; Ferguson, Gous, and Emmans 1994). A pre-requisite of this approach is knowledge of the potential growth of the animal in question.

Non-limiting conditions are required for predicting the potential growth of an animal, which is assumed to reflect the genotype of the animal. This does not mean that the conditions need to be perfect, but only non-limiting. These conditions cannot be precisely defined, but experience with broilers (Gous et al. 1996, 1999; Hancock et al. 1995; Hruby, Hamra, and Coon 1996), turkeys (Gous et al., 2019a, 2019b) and pigs (Ferguson and Gous 1993) has demonstrated that suitable experiments can be designed which give realistic estimates of the parameters of potential growth. Even where no special attempt is made the conditions may still allow the potential to be attained (Emmans 2022). The distinction between potential growth and observed growth under 'typical' conditions in growth studies is a critical one and needs to be considered in experiments concerned with the estimation of growth curve parameters (Fisher 2014).

Following the relevant arguments by Wellock et al. (2004) and by Emmans (2022), the Gompertz equation (Gompertz 1825) was used in this study to describe potential growth, the objective being to determine the potential growth rate and body composition of male and female Cobb 700 broilers. This information was necessary for predicting feed intake (Emmans 1987) and, thereby, maximising nutritional feeding strategies using a simulation model. The Cobb 700 has been genetically selected for use in rearing programs primarily focused on meat yield and the production of deboned meat products The following paper is concerned with updating the potential growth of a modern broiler strain.

Materials and methods

One-d-old male and female broilers chicks were housed in floor pens in an environmentally controlled room, with fresh pine shavings on used litter as bedding. Each pen was provided with an appropriate number of nipple drinkers and hanging feeders with a commercial-style feed pan. Broilers had free access to water and feed.

Upon arrival, the entire population of 1,000 chicks was group weighed and counted to obtain a mean weight for each sex. Twenty chicks of each sex were randomly selected and group weighed to confirm that their this fell within 2% calculated weight based on the population mean. A total of 400 chicks was selected in this way for each sex (800 birds in

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total), and these chicks were assigned randomly to 20 replications of each sex. Each replicate pen measured 1.22 × 1.52 m, providing 0.093 m^2 per bird. The trial continued for 15 weeks.

Light was continuous for the first 24 h after placement, and a 16 h daylength was used for the remainder of the trial (16 L:8D) as this has been shown to reduce mortality, produce stronger bones, improve feed conversion, whilst enabling broilers to grow as rapidly as those on longer photoperiods (Lewis et al., 2009a, 2009b).

A four-phase feeding programme was used (1 to 14, 15 to 28, 29 to 35 and 36 to 112 d of age). The experimental feeds were formulated to contain a constant amount of energy (13.0 MJ AMEn/kg) and meet or exceed the nutritional requirements suggested by the EFG broiler growth model (EFG Software 2019) for males with a potential mature body protein weight of 1.6 kg and a rate of maturing of 0.038/d. The composition of the experimental feeds is given in Table 1.

After weekly weighing, 10 birds per sex were selected from randomly predetermined pens to be individually weighed and used for processing and body composition analysis on all weeks, except 9, 11, 13, and 14. The selection process included five pens from each sex, with two birds being randomly selected from each pen for a total of 10 birds per sex for each sampling period. The group of five pens per sex used for sampling was alternated throughout the trial to minimise effects on stocking density. Selected birds were moved into separate pens and feed was withdrawn approximately 8 h before processing on the following day. Sampled birds, at 1, 7, 14, 21, 28, 35, 42, 56, 70, 84 and 105 d of age, were weighed just prior to slaughter and again after bleeding. All feathers were removed, after which each bird was weighed again to determine the feather-free body weight and the total weight of feathers. Each bird was then dissected, with the thighs, drums, wings, breast, breast tender, rack and skin, head and feet, viscera and offal being weighed separately.

After all the separate parts were weighed, all the parts from each bird, other than feathers, were gathered together in a plastic bag, sealed and frozen at a temperature of −4°C in a cold chamber. The frozen samples were then passed three times through a mincer to ensure adequate mixing, after which a 100 g sample was kept for chemical analysis. The composite sample from each bird was analysed for water (freeze-dried), protein (as N using the Dumas method on a LECO N analyser, AOAC 2003), ash (AOAC 2003) and lipid (Soxhlet extraction, AOAC 2003.

Weekly body weights from each pen were averaged for each sex. The plucked empty body weights of sampled birds were calculated by subtracting the feather weight from the empty body weight. Gompertz growth equations were fitted to the mean empty body weights for each sex using pen means. The plucked empty body weights, as well as to the weights of the chemical and physical components of the body of individuals sampled, using Genstat (VSN International 2017). The form of the equation used was:

$$W = W_m \exp - (-\exp(G_0 + B.t))$$

where W_m was the mature empty body weight, G_0 = -ln (-ln (W_0/W_m)) the initial condition, or current place, and B a measure of the rate of maturing (per d).

In addition to the use of Genstat to determine the value of the Gompertz parameters (Method 1), an alternative approach was used (Method 2). Weekly mean data were

Table 1. Composition (g/kg) of feeds used in the trial.

Ingredient	Phase 1	Phase 2	Phase 3	Phase 4
Yellow maize	566	631	680	747
Soybean oilcake	348	299	260	213
Fat, poultry	41.7	29.5	21.0	7.50
Dicalcium Phosphate	12.0	11.2	11.4	10.6
Limestone	9.84	9.67	9.85	9.67
L-Lysine HCl 98.5%	5.08	4.14	3.48	1.78
Sodium Bicarbonate	3.02	2.69	2.46	1.60
Salt	2.78	3.04	3.22	3.89
L-Arginine 98%	2.66	1.91	1.39	0.00
DL-Methionine 99%	2.25	1.75	1.50	0.67
L-Threonine 98%	2.10	1.82	1.61	0.67
Choline Chloride	1.50	1.67	1.79	1.00
L-Valine 98.5%	0.91	0.88	0.64	0.00
OptiPhos (2000)	0.50	0.50	0.50	0.50
Vitamin & mineral premix[1]	0.30	0.30	0.30	0.30
Danisco Xylanase	0.08	0.08	0.08	0.08
Nutrient content calculated				
AMEn (MJ/kg)	13.0	13.0	13.0	13.0
Crude Protein	221	201	185	165
Calcium	9.6	9.2	9.2	8.8
Available Phosphorus	4.8	4.6	4.6	4.4
Sodium	2.0	2.0	2.0	2.0
Chloride	3.0	3.0	3.0	3.0
Arginine[2]	15.8	13.7	12.1	9.5
Lysine	15.0	13.0	11.5	9.0
Methionine	5.3	4.6	4.2	3.2
Met + Cys	8.2	7.3	6.8	5.7
Tryptophan	2.5	2.2	2.0	1.8
Threonine	8.9	8.0	7.3	5.8
Isoleucine	8.8	7.9	7.2	6.4
Valine	10.4	9.5	8.6	7.2

[1] Provide/kg of diet: Mn = 150.000 mg. Fe = 100.000 mg. Zn = 100.000 mg. Cu = 16.000 mg. I = 1.500 mg. Content/kg of product: Folic acid = 1000 mg. Pantothenic acid = 15.000 mg. Niacin = 40.000 mg. Biotin = 60 mg. vit B1 = 1.800 mg. vit B12 = 12.000 mg. vit B2 = 6.000 mg. vit B6 = 2.800 mg. vit D3 = 2.000.000 UI. vit E = 15.000 mg. vit K3 = 1.800 mg. Se = 300 mg.

[2] Standardised ileal digestible amino acid contents given.

split into early (0–42 d) and late (42–105 d) and the Gompertz variable:

$$Gt = -\ln(-\ln(W_t/A))$$

was calculated in Excel for each weekly weight (W_t), and the value of A, the mature weight, was adjusted by iteration such that the estimates of the rate of maturing, B, for the two periods were the same. This was accomplished by plotting G_t against age and minimising the difference in linear regression between the two periods, the slope representing B. The complete dataset (7 to 105 d) was then used, with the common value of A to estimate B.

The hypothesis that the rates of maturing of each of the four chemical components, and of the whole plucked body were the same was tested. The test was to find mature values that were consistent with each other *i.e.*, the mature component weights summed to the mature weight of the whole (Ym) while forcing a common B value for all components. The mature values for the four chemical components (protein, water, lipid and ash) that resulted in the same B value as for Ym were estimated in Excel by iteration. The tests of the fit of the model were that the sum of the four values was very close to the value of Ym, adjusted for the small residual, and that the R^2 values for the regressions were close to unity. A similar procedure was used for the physical components measured, using Excel.

Results

Weekly mean body weights are presented in Table 2 for male and female Cobb 700 broilers to 105 d of age. The mean cumulative feed conversion efficiencies (FCE, g gain/kg feed) of males and females over the same period are shown. Body weight and FCE were all higher in males than in females throughout the growing period.

The resultant coefficients, when the Gompertz growth equation was fitted to weekly mean empty body weights of males and females using Methods 1 and 2, are given in Table 3.

Mature empty body weight (EBW_m) was the same in males and higher in females when estimated by Method 2, whereas B was lower for females and higher for males. Empty feather-free body weight at maturity (EFFBWm) was higher than EBWm in females when Method 1 was used, with B being considerably lower. However, for males, using both methods, EFFBWm was reduced by the weight of feathers at maturity when compared with EBWm. The value of B on EFFBW, when using Method 2, increased for females and males compared with Method 1 values, but remained the same for EBWm.

The relevant Gompertz coefficients describing the rate of growth of feathers in females using Method 1 were 333 ± 28.9 g for A and 0.0344 ± 0.005/d for B. The equivalent coefficients for male feathering were 283 ± 12.9 g and 0.0540 ± 0.007/d. The value of A was higher in both females (372 g) and males (435 g) when the Method 2 procedure was used, whilst the value of B was similar for females (0.0357 ± 0.004/d) but considerably lower for males (0.0324 ± 0.002/d).

Changes in chemical composition of broilers over the growing period, and the differences between males and females, are presented in Table 4.

The biggest differences over time and between sexes were for the water and lipid components. The water content at 105 d was 94 g/kg higher in males than in females, whereas the lipid content in females was almost twice the content in males (223 *vs.* 127 g/kg). The protein content increased marginally during the growing period, whereas the ash content remained relatively constant, with each of these components remaining similar in both males and females.

The chemical compositions were multiplied by the respective weekly weights to obtain the mean weights of each component each week, and the Gompertz equation was fitted to these weights using Methods 1 and 2. The resultant coefficients are presented in Table 5. When using Method 1, the values for B over the four components varied from 0.0345 to 0.0457/d in females, and from 0.0352 to 0.0429/d in males. With Method 2, all components within each sex had the same value for B, namely, 0.0402 and 0.0417/d for females and males, respectively.

Allometric coefficients describing the water, lipid and ash contents in terms of body protein in Cobb 700 females and males are presented in Table 6.

The mean weights of the physical parts of the body of female and male Cobb 700 broilers are given in Table 7.

Table 2. Mean body weight (g) (± standard deviation) and cumulative feed conversion efficiency (FCE, g gain/kg feed) at weekly intervals during the growth of female and male Cobb 700 broilers to 104 d of age.

	Females			Males		
Day	Mean body weight, g		FCE Cumulative	Mean body weight, g		FCE Cumulative
0	39	±0.25		39	±0.34	
6	132	±4.59	736	133	±3.22	743
13	379	±11.6	781	385	±11.3	782
20	844	±20.6	739	886	±24.6	745
27	1470	±32.8	709	1585	±40.8	723
34	2148	±42.0	657	2424	±64.9	684
41	2820	±59.5	600	3273	±80.9	635
48	3509	±78.9	539	4211	±107	567
55	4076	±98.6	509	5024	±156	544
62	4535	±107	478	5585	±205	508
69	5093	±181	457	6549	±185	505
76	5397	±226	427	7012	±255	475
83	5723	±267	407	7316	±298	448
90	5917	±265	385	7608	±386	427
97	6123	±159	359	7838	±491	404
104	6266	±183	344	8029	±605	387

Table 3. Gompertz parameters[1], with coefficients of determination (R^2), describing the growth of female and male Cobb 700 broilers as derived using Methods 1 and 2, as described in the text.

Parameter	Females			Males		
	Mean	SE[6]	R^2	Mean	SE	R^2
Empty body						
Method 1						
B^2,/d	0.0413	0.0006	99.6	0.0410	0.0007	99.5
$W_0{}^3$, g	39.0	3.45		39.0	2.32	
$W_m{}^4$, g	6630	44.4		8710	72.3	
Method 2						
B,/d	0.0402			0.0416		
W_0, g	39.0		99.9	39.0		99.9
W_m, g	7230			8710		
Empty feather-free body[5]						
Method 1						
B,/d	0.0368	0.0188	97.6	0.0407	0.0022	94.4
W_0, g	34.0	3.45		39.0	2.32	
W_m, g	7056	44.4		8477	210	
Method 2						
B,/d	0.0402			0.0417		
W_0, g	34.0		99.7	39.0		99.8
W_m, g	6940			8380		

[1] Using the form of the equation $W = W_m. \exp - (-\exp (G_0 + B.t))$ where W_m is the mature empty body weight, $G_0 = -\ln (-\ln (W_0/W_m))$ is the initial condition, or current place, and B is a measure of the rate of maturing (/d). [2] Rate of maturing, per d. [3] Initial empty body weight, g. [4] Mature empty body weight, g. [5] Estimated from the birds sampled for further analysis. [6] Standard error.

Table 4. Mean weekly feather-free contents of the chemical components of female (F) and male (M) Cobb 700 broilers, with standard errors of the means (SEM).

	Protein, g/kg		Water, g/kg		Lipid, g/kg		Ash, g/kg	
Age, d	F	M	F	M	F	M	F	M
0	135	131	787	792	45.7	49.1	32.5	27.9
7	138	144	755	769	69.1	59.4	38	27.4
14	179	179	680	702	105	92.3	35.6	26.9
21	164	164	685	699	115	114	36.4	23.0
28	167	170	680	685	119	123	33.6	22.1
35	163	164	678	693	123	119	35.9	24.1
42	169	171	656	674	142	131	32.7	24.3
49	166	169	629	667	172	140	32.9	25.3
56	168	169	616	675	181	130	35.1	25.7
70	163	174	619	672	184	128	33.8	25.7
84	165	180	607	668	194	126	34.1	25.7
105	175	175	572	675	222	128	31.4	21.8
SEM								
Age		1.794**[1]	3.99**		4.04**		1.06**	
Sex		0.732	1.63**		1.65**		0.432**	
Age x sex		2.537	5.64**		5.72**		1.495**	

[1] Due to either an analytical or sampling error, these values have been calculated as the mean of the values for days 56 and 84. ** denotes significance at $p < 0.01$.

Relative increases in the proportion of breast and tender in the body as the bird grows are shown in Table 8.

In the same way as the chemical components of the body were described by the two methods, so too were the physical components (Table 9).

Table 5. Gompertz parameters (± standard error), with coefficients of determination (R^2), describing chemical component growth in the feather-free body of male (M) and female (F) Cobb 700 broilers calculated using Methods 1 and 2.

	Protein		Water		Lipid		Ash	
Coefficient	M	F	M	F	M	F	M	F
Method 1								
B^1,/d	0.0369	0.0345	0.0429	0.0366	0.0352	0.0430	0.0404	0.0457
	±0.0038	±0.0038	±0.0025	±0.0022	±0.0048	±0.0026	±0.0058	±0.0049
$W_0{}^2$, g	5.06	4.59	30.6	26.7	1.90	1.55	0.69	0.64
	0.322	0.467	1.95	2.72	0.121	0.158	0.044	0.065
Wm^3, g	1645	1213	5073	4481	1529	1126	227	221
	±88.1	±71.7	±129	±133	±115	±65.0	±13.6	±5.80
R^2	92.1	90.4	96.7	96.7	88.6	88.0	88.0	89.4
Method 2								
B,/d	0.0417	0.0402	0.0417	0.0402	0.0417	0.0402	0.0417	0.0402
Wm, g	1480	1194	5619	3984	1083	1541	198	221
R^2	98.9	98.4	99.9	99.7	99.6	97.7	95.0	99.2

[1] Rate of maturing,/d. [2] Initial component weight, g. [3] Mature component weight, g.

Table 6. Allometric coefficients[1] with standard errors (SE) and coefficients of determination (R^2) describing body water, lipid and ash contents in terms of body protein weight in Cobb 700 females and males.

	Females					Males				
	Constant term (a)	SE	b	SE	R^2	Constant term (a)	SE	b	SE	R^2
Water	1.881	0.025	0.9115	0.004	99.7	1.840	0.029	0.9266	0.005	99.7
Lipid	−1.478	0.046	1.2303	0.008	99.5	−1.194	0.069	1.1386	0.012	98.8
Ash	−1.876	0.041	0.9827	0.007	99.4	−1.911	0.051	0.9927	0.009	99.1

[1] Using equation ln (Y) = a + b*ln (X).

Table 7. Mean weights of the physical parts of the body of female and male Cobb 700 broilers, with standard errors of means (SEM).

Week	FFBW[1]	Feather weight	Breast	Tender	Wing	Thigh	Drum	Rack + Skin	Viscera	Head + feet	Offal
Females											
1	132	5									
2	382	13	46.3	11.8	30.6	41.3	34.7	90	*	*	109
3	827	30	122	28.1	72.4	96.0	78.6	190	116	61.7	178
4	1336	75	265	55.7	103	157	122	303	160	96.6	257
5	2036	136	420	96.2	162	244	203	463	221	197	418
6	2754	116	662	136	203	337	241	587	249	199	449
7	3317	123	807	171	238	416	286	759	276	213	489
8	3853	160	995	203	271	504	328	836	324	244	568
10	4956	189	1374	267	343	632	413	1069	362	283	645
12	5659	314	1620	318	381	728	481	1259	378	312	690
15	6498	269	1851	329	415	853	515	1489	505	293	798
Males											
1	134	6									
2	378	12	47.5	11.3	29.5	40.4	34.6	84.1	*	*	116
3	885	31	140	28.3	68.8	104	85.9	208	132	68.9	201
4	1534	69	276	57.5	119	184	155	363	184	116	300
5	2396	32	495	95.4	193	268	230	567	290	213	503
6	3173	122	742	138	235	393	300	682	292	237	529
7	3976	145	978	195	294	530	374	875	313	281	594
8	4945	193	1256	231	359	656	463	1036	361	349	710
10	6180	237	1637	300	433	838	556	1342	414	388	802
12	7203	306	1943	358	528	1069	685	1460	406	468	874
15	7841	239	1972	356	583	1229	812	1601	423	514	937
SEM											
Age	90.3^{**2}	7.82**	29.5**	6.09**	7.12**	18.4**	9.56**	29.8**	12.7**	6.26**	15.9**
Sex	36.9**	3.19	12.1**	2.49**	2.91**	7.53**	3.90**	12.2**	5.19**	2.56**	6.47**
Age x sex	128**	11.1*	41.8**	8.61	10.1**	26.1$^{((}$	13.5**	42.2*	18.0**	8.86**	22.4**

1Feather-free body weight. 2* denotes significance at $p < 0.05$ and ** denotes significance at $p < 0.001$.

Table 8. Breast and tender weights as a proportion of feather-free body weight (g/kg) in female and male Cobb 700 broilers with age.

	Females			Males		
Age, d	Breast	Tender	Breast + tender	Breast	Tender	Breast + tender
14	117	30	147	122	29	151
21	143	33	175	153	31	184
28	188	39	227	173	36	209
35	194	44	238	204	39	243
42	230	47	278	225	42	267
49	235	50	284	238	47	285
56	248	51	299	245	45	290
70	267	52	319	255	47	302
84	271	53	325	259	48	306
105	274	49	322	244	44	288

Variation in the value of B between physical components within a sex varied from 0.0229 to 0.0624 and from 0.0324 to 0.0495/d in females and males, respectively. Using Method 2, these values were the same as for the chemical components of the body. The weights of the physical components of the body may be predicted from the weight of body protein using the allometric coefficients given in Table 10.

Discussion

A prerequisite for predicting the food intake and growth of a broiler genotype is an accurate description of its potential growth rate (Emmans 1987). With such information it is possible to determine the amount of each essential nutrient required by the bird for maintenance and growth of body and feathers, and hence calculate the daily intake of a given feed required to enable the bird to grow at its potential. Because genetic selection has been so successful in improving growth rate and feed efficiency of broiler chickens, genotype evaluations need to be conducted relatively frequently to determine the effect on potential growth of the selection processes that have taken place in the interim. Vargas et al. (2020a) compared the Gompertz parameters measured on broiler strains 25 years apart and calculated that, at 35 d of age, older strains of males would have had the potential to weigh 1.53 kg at that age, whilst the equivalent weight for

Table 9. Gompertz parameters (± standard error), with coefficients of determination (R^2), describing the growth of the physical parts of female and male Cobb 700 broilers calculated using Methods 1 and 2.

	Females					Males				
Physical part	Mature weight, g		Rate of maturing,/d		R^2	Mature weight, g		Rate of maturing,/d		R^2
Method 1										
Breast	2055	±69.6	0.0387	±0.0026	96.4	2126	±58.4	0.0490	±0.0033	95.9
Tender	355	±8.32	0.0446	±0.0026	99.1	384	±12.9	0.0495	±0.0042	93.3
Thigh	934	±40.5	0.0365	±0.0031	93.8	1428	±69.3	0.0342	±0.0029	94.8
Drum	555	±16.6	0.0391	±0.0026	95.4	929	±37.8	0.0324	±0.0023	96.1
Wing	441	±10.5	0.0402	±0.0022	96.7	642	±21.7	0.0368	±0.0025	95.7
Rack & skin	1680	±76.0	0.0326	±0.0027	94.5	1710	±67.3	0.0419	±0.0038	91.9
Head & feet	302	±7.44	0.0624	±0.0059	88.1	545	±17.2	0.039	±0.0030	94.5
Offal	802	±30.4	0.0408	±0.0040	88.9	956	±24.7	0.0453	±0.0032	93.5
Viscera	599	±83.4	0.0229	±0.0356	75.9	426	±14.2	0.0561	±0.0079	76.5
Sum	7723					9146				
Method 2										
Breast	1869		0.0402		98.5	2027		0.0417		95.3
Tender	337		0.0402		96.0	363		0.0417		94.6
Thigh	840		0.0402		98.3	1309		0.0417		99.0
Drum	509		0.0402		96.3	779		0.0417		99.1
Wing	408		0.0402		95.7	564		0.0417		97.8
Rack & skin	1441		0.0402		98.8	1561		0.0417		95.8
Head & feet	293		0.0402		78.5	482		0.0417		95.0
Offal	476		0.0402		92.9	396		0.0417		91.2
Viscera	766		0.0402		96.2	898		0.0417		80.0
Sum	6940					8380				

Table 10. Allometric coefficients[1] with standard errors (SE) describing the weights of the physical parts in terms of body protein in Cobb 700 females and males.

	Females				Males			
	Constant term (a)	SE	b	SE	Constant term (a)	SE	b	SE
Breast	−1731	0.078	1.332	0.013	−1.263	0.081	1.243	0.013
Tender	−2.669	0.084	1.228	0.014	−2.404	0.093	1.162	0.015
Thigh	−0.838	0.057	1.088	0.009	−0.838	0.057	1.088	0.009
Drum	−0.401	0.074	0.958	0.012	−0.543	0.068	0.995	0.071
Wing	−0.336	0.076	0.918	0.013	−0.553	0.051	0.958	0.008
Head and feet	0.607	0.185	0.749	0.030	0.098	0.112	0.852	0.017
Rack and skin	0.327	0.074	0.992	0.012	0.576	0.082	0.948	0.013

[1] Using equation ln (Y) = a + b*ln (X).

males in the trial was 2.23 kg. Using the parameter estimates for the Cobb 700 measured in the present trial, males would now have the potential to achieve a weight of 2.30 kg at 35 d. This improvement has been achieved predominantly by means of an increase in the mature weight, as the rate of maturing at 0.0382/d, is marginally faster than the mean for males at 0.0366/d reported by Hancock et al. (1995). This is similar (0.0381/d) to that reported for the male Cobb 500 by Vargas et al. (2020a). The mature weight of males, representing the mean of the population, of 8.66 kg, was higher than that reported previously (Vargas, Sakomura, Leme, Antayhua, Reis, et al. 2020a) who reported a mature weight of 8.42 kg for Ross 308 males.

When the Gompertz parameters were estimated using a non-linear program, such as Genstat, to minimise the residual sum of squares, it was assumed that errors in measuring the weight of the birds and environmental factors, including feed, that influenced growth, remained the same over the 200-fold increase in body weight from hatching to maturity, and that the weights remained normally distributed over this range. It was thus assumed that, say, 20 g was as important at one-d-old as it was at 15 weeks, which cannot be correct. To illustrate this point, the coefficient of variation (SD/mean) of male body weights increased from 0.87% at one-d-old to 7.5% at 105 d (Table 2). An alternative approach, designed to avoid this error, would be to split the data into early and late and find the value of A, the mature weight, such that the two estimates of the rate of maturing, B, were the same. This approach (Method 2) resulted in lower EBWm in males and higher weights in females, while B was lower for females and higher for males compared with the values generated by Method 1. More sensible values were obtained for FFEBWm in females using Method 2 than Method 1, this value being lower than that for EBWm.

The rate of maturing of feathers has, in the past, been shown to be faster than for the rest of the body. Hancock et al. (1995) reported mean feathering rates in female and male broilers over six strains as being 1.27 and 1.29 times faster than the rates for feather-free body weight. The equivalent rates for two strains in the trial by Vargas et al. (2020a) were 1.57/d for females and 1.04/d for males. In the present trial, these rates were both below 1.0/d (0.89/d for females *vs.* 0.78/d for males, using Method 2 results), which suggested that this genotype was slow-feathering compared with others. In a subsequent paper by Vargas et al. (2020b), where the rate of maturing of feathers in female broilers was reported to be faster than that in males (0.0483 *vs.* 0.0335/d). Feather weight measurements at discrete ages failed to predict some moults which were detected by the measurement of feather losses. The authors cautioned that such loss needs to be considered when growth is determined from feather weight measured at different ages. Moulting may well account for much of the variation observed when using the method applied here to measure feather growth. By not accounting for feather losses, their potential growth would be underestimated. Differences in the rate of growth of feathers in relation to plucked body have implications when determining the optimum amino acid composition of feeds for growing broilers. Because the amino acid composition of feathered and non-feathered tissue differs, and as these components grow at different rates, the amino acid balance required by the bird will not remain constant during the growing period. The ideal amino acid composition within each phase of a given feeding programme must be adjusted accordingly.

The protein content of the feather-free carcasses (Table 5) increased with time to the same extent in both males and females ($154 \pm 1.49 + 0.234 \pm 0.028 \times$ age, g/kg), whereas ash content decreased to the same extent in both sexes over time ($35.9 \pm 0.562 – 0.0226 \pm 0.0106 \times$ age, g/kg). The goodness of fit was low in both cases (R^2 for protein content being 0.023 and for ash, 0.015). Water content in the feather-free body was highly negatively correlated with lipid content over both sexes (lipid content = $697 \pm 10.6 – 0.840 \pm 0.0156 \times$ water content, g/kg; $R^2 = 0.93$), but the changes in both components differed significantly between sexes: water content was described as $742 \pm 4.76 – 1.766 \pm 0.0907 \times$ age. g/kg for females, and $728 – 0.9095 \times$ age for males; $R^2 = 0.69$; lipid content = $71.59 \pm 3.98 + 1.5956 \pm 0.0758 \times$ age, g/kg for females and $85.9 + 0.6546 \times$ age for males; $R^2 = 0.71$. The rates of change over time in water and lipid contents were considerably less in males than in females.

The water:protein ratio at maturity ($WAPR_m$) in the feather-free body was 3.69 in females and 3.29 in males. The ratio for females is higher, on average, than that reported by Hancock et al. (1995) of 2.82 but similar to that of Vargas et al. (2020a), of 3.62. Both previous authors reported ratios similar to those for males (from 3.20 to 3.60). The lipid: protein ratio at maturity (LPR_m) in the Cobb 700 male (0.96) was similar to that reported by Hancock et al. (1995) being between 0.92 and 1.15 but was higher than that reported by Vargas et al. (2020a) at 0.58. The LPR_m for females in this trial (0.97) was lower than those reported previously (between 1.12 and 1.43). Of interest was the similarity in the LPR_m between males and females.

Within each sex, the weight of any chemical or physical component, other than feathers, may be predicted from the weight of body protein. This was possible because the rate of maturing of each component was the same within each sex. Components whose allometric regression coefficients are greater than 1.0 will grow faster than body protein, and *vice versa*. The allometric regression coefficient for ash content was close to 1.0, which suggested an isometric relationship, whereas water content increased at a slower rate, and body lipid content increased at a faster rate than body protein weight. Hence, breast and tender meat grew increasingly faster as the bird developed, whereas the rates of growth of the drum and wing were slower in relation to that of body protein (Table 10).

Because the rates of maturing of each component were successfully forced to be the same, these components were allometrically related, which means that the weight of any component could be predicted from the weight of body protein using the respective allometric coefficients. These allometric coefficients are presented in Table 7 for each of the chemical components for males and females separately. The excellent fit of the allometric relationships supported the view that there is a single value for B for a given genotype.

In previous trials, in which broiler and turkey genotypes have been described (Hancock et al. 1995, Gous et al., 2019a, 2019b; Vargas et al. 2020a, 2020b), the rates of maturing of all chemical and physical components were reported as predicted using the Gompertz equation (Method 1) without considering sample variation or if these components mature at the same rate. As a result, a range of rates of maturing for the different components has been presented in these publications. However, theoretically, all components should mature at the same rate within a genotype (Emmans 1988) and as a result, the mature weights of the components should be calculated using the same rate of maturing. Such a correction was applied in this paper, with the result that the allometric coefficients describing the weight of each component in terms of body protein weight are more accurately estimated than in previous papers.

Conclusions

Poultry geneticists continue to increase the rate of growth of commercial broilers, this improvement apparently being the result of increasing the mature body protein weight of the bird to a greater extent than by increasing the rate of maturing. Because all chemical and physical components of the body, other than feathers, grow at the same rate, the mature weight of each component should be adjusted to ensure that the reported rates of maturing are the same.

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