Ann. Anim. Sci., Vol. 15, No. 1 (2015) 51–66 *DOI: 10.2478/aoas-2014-0058*

DE GRUYTER
OPEN

VARIATION IN GROWTH PERFORMANCE AND CARCASS YIELD OF PURE AND RECIPROCAL CROSSBRED TURKEYS*

Krzysztof Damaziak[1], Monika Michalczuk[1♦], Żaneta Zdanowska-Sąsiadek[1], Jan Niemiec[1], Dariusz Gozdowski[2]

[1]Department of Animal Science, Warsaw University of Life Sciences, Ciszewskiego 8, 02-786 Warzawa, Poland
[2]Department of Experimental Design and Bioinformatics, Warsaw University of Life Sciences, Nowoursynowska 159, 02-786 Warszawa, Poland
♦Corresponding author: monika_michalczuk@sggw.pl

Abstract

This study compared growth, feed conversion ratio (FCR), mortality rate and results of slaughter analysis of slow-growing Bronze turkeys (SG), fast-growing Big 6 turkeys (FG), and their reciprocal crosses (SF and FS). Until 6 weeks of age the birds were kept indoors and afterwards they were allowed to use free ranges. Toms were reared until 21 and hens until 15 weeks of age. The FS turkeys were characterized by higher (P≤0.05) BW and dressing percentage and by lower FCR compared to the SF crosses of both sexes. The analysis of orthogonal contrasts demonstrated that values of most of the slaughter analysis parameters were due to the additive effect of genes. Only weight of skin with fat and of gizzard could result from heterosis. Study results demonstrate that FS crosses constitute better material for the alternative production of turkeys compared to the other analysed groups (SG, SF, FG).

Key words: turkeys, reciprocal crosses, growth, carcass yield

Intensive poultry selection has resulted in significantly lowered age of birds at slaughter and feed conversion ratio (FCR) on the one hand, and in increased final body weight of birds due to a fast growth rate and in increased weight of edible elements in the carcass on the other hand. The effectiveness of rearing is known to depend on genetic predispositions of birds, housing conditions and feeding. Commercial poultry production has, therefore, developed based on the fast-growing genetic material reared exclusively in strictly-controlled conditions of the intensive system. Negative effects of these practices are being observed these days and include reduced immunity to diseases (Cheema et al., 2007), problems with the osseous sys-

*This report is a part of Krzysztof Damaziak's PhD thesis.

Source of financing: The case of turkey twins occured during the experiment no. 50510070300-K0022699 under 92 the internal project of University of Life Scienced in Warsaw.

tem (Zhong et al., 2012), insufficiency of the cardiovascular system (Julian, 2005), as well as deterioration of meat quality (Berri et al., 2005) and welfare of animals (Fanatico et al., 2008). All these factors combined with growing awareness of consumers contribute to the raising global interest in alternative systems of poultry meat production. The alternative production system includes less intensive production, access to the outdoor areas or pastures. However, this production does not have a detailed definition, thus the type of outdoor access provided in both organic and free-range production systems varies. At the same time, increased farmer interest in converting to alternative production methods is stimulated by governmental support or subsidies. Ample studies have proved, however, that the commercial fast-growing genetic material of poultry is unsuitable for rearing in any other than intensive system (Fanatico et al., 2008; Zhong et al., 2012). For this reason, a search has begun for birds that effectively use free ranges, are characterized by natural immunity to diseases and, simultaneously, ensure cost-effective production.

Attention of scientists and producers is focused most of all on chickens, as this species has predominated the market of poultry meat worldwide. Fanatico et al. (2005) analysed the usability of slow-, medium- and fast-growing chickens, whereas Sola-Ojo and Ayorinde (2011) and Zhao et al. (2012) the usability of local breeds and their reciprocal crosses for free range rearing. The most useful, however, turned out to be hybrids of slow-growing local breeds and commercial meat lines investigated by, among others, Mikulski et al. (2011) and Sheng et al. (2013). Relatively less attention has been devoted to these issues regarding turkeys in spite of the fact that the consumption of their meat is successively increasing and that their meat is perceived as a dietetic product with a high nutritive value. Damaziak et al. (2012, 2013) described production results of slow-growing turkeys reared in the free range system, but the low rate of their growth, high feed intake and low dressing percentage showed this type of rearing to be completely non-profitable. Nevertheless the turkeys were characterized by high quality of meat, high survivability rate and easiness of feeding, which was perceived by these authors as desirable in the production with alternative methods. Attempts have been undertaken therefore to produce turkeys by crossing the slow- and fast-growing birds. Owing to the fact that the phenotype of the progeny may differ depending on the value of a given trait transferred by each of the parent, and that the reciprocal crossing of these genetic groups of turkeys has not been investigated so far, we decided to conduct reciprocal crossbreeding.

This study was aimed at comparing differences in the growth rate, feed conversion ratio and dressing percentage between reciprocal crosses of slow- and fast-growing turkeys with their parental forms. Another goal of this study was to determine which of the crosses is more suitable for alternative production.

Material and methods

Experiments were conducted with slow-growing Bronze turkeys (SG) (APA, 2001; Damaziak et al., 2012, 2013), fast-growing Big 6 turkeys (FG) (B.U.T., 2013) and their reciprocal crosses (SF and FS). Genetic distance between pure lines of turkey (SG and FG) has been previously reported (ca. 0.40) (Kamara et al., 2007). One thousand three hundred and fifty eight turkeys were studied. The factorial cross-breeding was set up in order to produce four genotypes:

SG males × SG females = F_1: SG males (n = 180) and SG females (n = 180),
SG males × FG females = F_1: SF males (n = 136) and SF females (n = 142),
FG males × SG females = F_1: FS males (n = 180) and FS females (n = 180),
FG males × FG females = F_1: FG males (n = 180) and FG females (n = 180).

The number of SF males and females was lower than expected due to hatching problems (high mortality of embryos). All poults were hatched simultaneously under identical conditions of incubation. After hatching, the poults were subjected to sexing and were tagged with poult tags. The birds were not subjected to debeaking, declawing nor to wattle dubbing. Until the 6th week, turkeys were reared on litter at stocking density of 5 birds/3.50 m^2, according to standards adopted for medium-heavy turkey rearing (B.U.T., 2013). Afterwards, the birds were allowed to use free ranges, at which stocking density reached 1 bird/12.5 m^2. Free ranges were available to birds in the period of May-August (Wilanów Obory near Warszawa; 52.259ºN, 21.020ºE). Weather conditions during the experiment were as follows: the average daily mean temperature and humidity was respectively 17.9°C, 87.3% in May, 19.9°C, 81.5% in June, 22.1°C, 79.2% in July and 23.8°C, 74.0% in August; there were also 13 days of rain and total precipitation was at 258.7 mm. The birds were fed *ad libitum* with a feed mixture for free range turkeys: 0 to 21 d, starter: 7.94 ME_N of energy, 26.6% protein; 22 to 42 d, grower 1: 7.96 ME_N of energy, 20.9% protein; 43 to 105 d, grower 2: 8.03 ME_N of energy, 16.4% protein; 106 to 147 d (only males), and finisher 1: 8.17 ME_N of energy, 15.1% protein (AOAC, 2005). Throughout the experiment, body weight of the birds was controlled individually at 7-day intervals (accuracy of measurement: ±1.0 g until the 6th week; ±10.0 g since the 6th week of life) and feed intake was controlled in groups (±1.0 g). Clinical examinations and autopsies enabled determining the causes of birds' mortality and culling. Turkey hens were reared until the 15th, whereas turkey toms until the 21st week of life. At the end of rearing, after 12-h fasting, 15 males and 15 females with body weight similar to the mean body weight for particular sex in a group were selected from each genetic group for slaughter. Turkeys were fasted for approximately 12 h before slaughter. They were killed using an electrical waterbath stunner supplied with 380 volts, 50 Hz sine wave alternating current for 4 s, followed by cutting the jugular vein as practiced normally in a processing plant. Next, the birds were bled out for 5 min and scalded in water with a temp. of 63°C. After manual plucking and evisceration following the removal of head (between the occipital condyle and the atlas) and feet (at the carpal joint), carcasses were eviscerated. Carcasses were placed in a cold store at a temp. of 4°C. After 24 h of cooling, the carcasses were weighed (±1.0 g), and dissected according to the method described for turkeys by Murawska (2013). Experimental procedures were reported to the Ethical Commission (Warsaw, 30 March 2012).

Collected data served to characterize the growth and mortality of turkeys and feed conversion ratio (FCR, kg/kg) throughout the study period. After slaughter, weight and percentage of particular tissues in BW were determined, and the tissues were divided into edible components (breast muscle, leg muscle, wings, neck, giblets) and non-edible components (fat and skin, bones, head, feet, feather, blood, loss during dissection and other loss during post-slaughter processing). Owing to high sexual dimorphism in BW of turkeys and their various age at slaughter, all calculations were made separately for males and females.

The statistical analysis included the characteristics of the analysed traits: arithmetic means and SD and the determination of the significance of differences in averages between genetic groups, by Duncan's D test. Normality of variable distribution was verified with the Kolmogorov-Smirnov test. All analysed traits were characterized by normal distribution. Computations were performed using STASTISTICA 10.0 software (Statistica, 2011). The one-way analysis of variance was applied according to the following model:

$$y_{ij} = \mu + S_i + e_{ij}$$

where:

y_{ij} – trait value of j-th individual from i-th group,
μ – overall mean,
S_i – fixed effect of i-th genotype,
e_{ij} – random error connected with ij-th observation.

Birds' growth was characterized using a Richards (Richards, 1959), Gompertz-Laird (Laird et al., 1965) and Logistic (Mignon-Grasteau and Beaumont, 2000) model.

The Richards model is as follows:

$$W_t = W_A[1 - (1 - m)exp[- K(t - t_i)/m^{m/(1 - m)}]]^{1/(1 - m)}$$

where:

W_t – weight of bird at time t,
W_A – asymptotic (mature) BW,
K – maximum relative growth (per wk),
t_i – age at maximum rate of growth (wk),
m – shape parameter, with the property that $m^{m/(1 - m)}$ is relative weight at t_i.

The Gompertz-Laird model is as follows:

$$W_t = W_0 \, exp[(L/K)(1 - exp - Kt)]$$

where:

W_t – weight of bird at time t,
$W_0 = BW_0$,
L – instantaneous growth rate (per wk),
K – rate of exponential decay of the initial specific growth rate, L, which measures the rate of decline in the growth rate. The parameters derived for the inflection point, t_i, the body weight at the inflection point and the asymptotic body, W_A are:

$$ti = (1/K)log(L/K);\ Wi = W_0\ exp((L/K)^{-1});\ W_A = W_0\ exp(L/K)$$

The Logistic model is as follows:

$$W_t = W_A[1 + exp - K(t - ti)]$$

where:

W_t – weight of bird at time t,
W_A – asymptotic (mature) BW,
K – exponential growth rate,
ti – age at the inflection point.

Dickerson's model (Dickerson, 1969) was used to estimate the crossbreeding parameters (orthogonal contrast): direct additive effects (g^I), maternal additive effects (g^M) and individual heterosis (h^I). They were estimated from linear contrasts between the genetic groups means according to coefficients given in Table 1. Due to generally low mortality, 100% survivability in some groups and different causes of deaths and culling, no statistical analysis was carried out for this trait.

Table 1. Crossbreeding parameters as linear combinations of breed type means

	Breed types (sire breed given first)			
	SG × SG	SG × FG	FG × SG	FG × FG
Direct additive effect (g^I_{SG})	0.5	0.5	–0.5	–0.5
Maternal additive effect (g^M_{SG})	0	–0.5	0.5	0
Individual heterosis ($h^I_{SG\times FG}$)	–0.5	0.5	0.5	–0.5

$g^I_{FG} = g^I_{SG}$; $g^M_{FG} = -\ g^M_{SG}$.

Results

The poults that hatched from eggs of SG hens (SG and FS) weighed from 49 to 52 g regardless of sex and sire genotype, whereas those that hatched from eggs of FG hens (SF and FG) weighed from 55 to 69 g, however a statistically significant ($P\leq0.05$) $BW_{0\ d}$ was demonstrated for the FG poults. In the case of crosses, although $BW_{0\ d}$ was higher in the SF group the $BW_{1\ wk}$ did not differ and $BW_{2\ wk}$ was significantly ($P\leq0.05$) higher in both males and females from the FS group. This tendency persisted and differences were increasing along with birds' age. The $BW_{0–21\ wk}$ of parental forms was attaining extreme values: the lowest in the SG group and the highest in the FG group (Figures 1 and 2). Out of the analysed models, the Gompertz model showed the best fit to turkeys growth, which was indicated by the highest values of the R^2 coefficient (Tables 3 and 4). Also, the average values investigated by Gompertz model represent very smooth curves without error spans (Figures 1 and 2).

The growth of the turkeys as predicted by the Richard model deviates slightly from the Gompertz, especially in the case of FG turkeys where it displayed significantly lower values of R^2 coefficients for both toms and hens. Whereas the Logistic model could either grossly over- or under-predict the model parameters compared with the Gompertz model. Soonest, the maximum growth rate (Tables 3 and 4), however at the lowest body weight gains (males – 378.64 g/wk; females – 255.03 g/wk) was reported for both sexes of the SG turkeys and for SF hens (412.01 g/wk). For FG toms, the peak of growth was also observed early (Table 3) and additionally they showed the highest body weight gains (1158.93 g/wk) of all groups examined. The FG turkey hens reached maximum body weight gains in ca. 14 wk (1047.00 g/wk). The latest, the maximum growth was observed for SF and FS turkey toms (Table 3) at: SF – 585.13 g/wk and FS – 971.80 g/wk, as well as for FS hens – 971.80 g/wk (Table 4).

The most beneficial FCR was determined in the FG group, and the highest in the SG group in both males and females (Table 2). The crosses (SF and FS) showed intermediate FCR values, but still a lower ($P \leq 0.05$) FCR value was noted in FS turkeys of both sexes (Table 2). The highest mortality rate was reported in the FS group (3 males and 4 females), followed by FG group (4 males and 1 female). In the group of SF crosses and in the SG group the mortality was negligible (only 1 male). The causes of birds' mortality included: aortic rupture and locomotor problems with symptoms of perosis, and in the case of FG males – aggressive pecking.

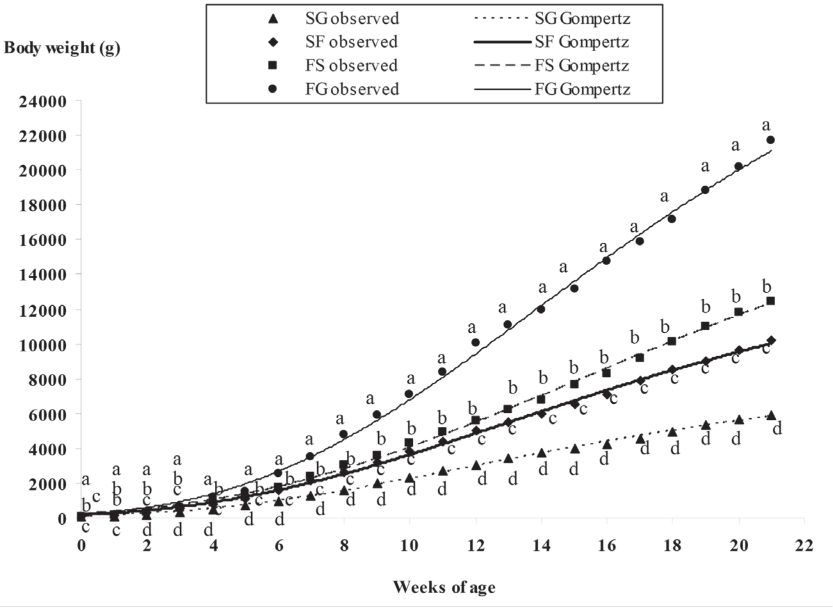

Figure 1. Growth curves of slow- (SG) and fast-growing (FG) turkey males and their reciprocal crosses (SF, FS); a, b, c, d means within a week with no common superscript are significantly different ($P \leq 0.05$)

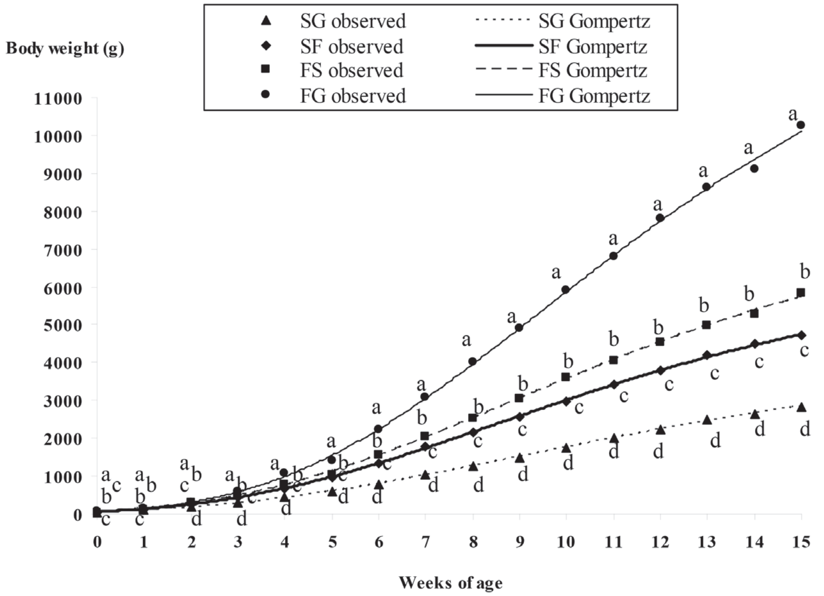

Figure 2. Growth curves of slow- (SG) and fast-growing (FG) turkey females and their reciprocal crosses (SF, FS); a, b, c, d means within a week with no common superscript are significantly different (P≤0.05)

The highest dressing percentage was noted in the FG group and the lowest in the SG group. The crosses showed intermediate values, but a significantly higher (P≤0.05) dressing percentage was demonstrated for FS turkeys (Table 5). Similar dependency was determined in the total weight of edible (Table 5) and non-edible components (Table 6), and their contribution to BW (Figures 3 and 4). The weight of all analysed edible components differed significantly (P≤0.05) between the four groups of birds, except for edible giblets (Table 5). No difference was found in the weight of gizzard in both sexes from groups SG, SF and FS, and in the weight of liver of SG, SF and FS toms and of hens from both groups of crosses (Table 5). The FS and FG males had also similar weight of heart. The percentage content of particular giblets in BW was in turn always the lowest in the FG group, the highest in the SG group and intermediate in both groups of crosses but similar to that noted in the SG group (Figures 3 and 4). The highest percentage of large muscles in BW was determined in FG group and the lowest one in SG group. Compared to the SF group, the FS group was characterized by higher percentage of breast muscles in both sexes (in toms by 1.6%, in hens by 0.6%), and of leg muscles in toms (by 1.0%), whereas in the case of hens the content of leg muscles was lower (by 0.2%). Of all groups examined, the SG males had the lowest fat content and the highest bone content. In the case of males, the highest percentage of skin with fat was noted in the crosses, however, the difference between SF and FS toms was very small and reached 0.2% (Figure 3). Female crosses had less fat compared to FG females, with a higher percentage of skin with fat noted in the FS group (Figure 4).

Table 3. Estimated coefficient (±SE) for Richards, Gompertz-Laird and Logistic model growth parameters in slow- (SG) and fast-growing (FG) turkeys and their reciprocal crosses (SF, FS) – males

Model	Statistical measure							
	SG		SF		FS		FG	
Richards								
asymptotic weight (W_A)	5519.02	149.1	10000.12	458.0	12188.32	593.0	21169.00	497.2
relative growth (K)	0.07	0.01	0.07	0.02	0.02	0.01	0.05	0.02
age of maximum growth (ti)	12.33	2.17	17.46	0.22	17.62	1.02	13.15	0.33
shape parametr (m)	0.93	0.08	0.90	0.12	1.00	0.01	1.00	0.06
coefficient of determination (R^2)	99.82%		99.80%		99.72%		96.00%	
Gompertz-Laird								
hatching weight (W_0)	50.00	3.74	56.62	5.45	49.98	4.82	66.03	6.04
initial growth rate (L)	0.63	0.03	0.81	0.08	0.95	0.11	0.79	0.03
rate of decay (K)	0.12	0.00	0.11	0.00	0.10	0.00	0.12	0.01
age of maximum growth (ti)	12.07	0.05	16.97	0.19	17.07	0.73	12.78	0.26
asymptotic weight (W_A)	5786.67	70.8	10324.11	172.4	12569.40	540.2	21535.16	801.6
coefficient of determination (R^2)	99.86%		99.84%		99.78%		99.80%	
Logistic								
asymptotic weight (W_A)	4346.05	91.2	9372.08	74.9	11878.76	88.3	19110.19	139.2
exponential growth rate (K)	0.26	0.02	0.24	0.02	0.23	0.02	0.26	0.02
age of maximum growth (ti)	13.40	0.99	20.32	0.22	20.43	2.31	16.06	4.16
coefficient of determination (R^2)	98.40%		97.37%		96.35%		95.31%	

Table 4. Estimated coefficient (±SE) for Richards, Gompertz-Laird and Logistic model growth parameters in slow- (SG) and fast-growing (FG) turkeys and their reciprocal crosses (SF, FS) – females

Model	Statistical measure							
	SG		SF		FS		FG	
Richards								
asymptotic weight (W_A)	3417.02	38.88	5363.12	49.03	6359.54	58.40	11186.00	90.11
relative growth (K)	0.14	0.00	0.19	0.00	0.21	0.02	0.18	0.03
age of maximum growth (ti)	10.12	0.12	10.01	0.05	13.02	0.20	14.89	0.20
shape parametr (m)	0.35	0.11	0.18	0.06	0.85	0.53	0.74	0.00
coefficient of determination (R^2)	99.98%		99.95%		99.93%		88.97%	
Gompertz-Laird								
hatching weight (W_0)	51.95	3.49	54.73	5.12	51.84	4.61	69.19	4.82
initial growth rate (L)	0.42	0.33	0.55	0.12	0.78	0.15	0.79	0.99
rate of decay (K)	0.16	0.00	0.18	0.00	0.18	0.00	0.18	0.00
age of maximum growth (ti)	10.20	0.07	10.09	0.03	13.14	0.06	14.00	0.15
asymptotic weight (W_A)	3026.11	29.60	5005.01	38.78	6199.47	42.02	11586.39	65.94
coefficient of determination (R^2)	99.98%		99.98%		99.95%		99.93%	
Logistic								
asymptotic weight (W_A)	2978.37	37.07	4857.12	49.31	5244.84	49.23	10029.09	78.93
exponential growth rate (K)	0.35	0.01	0.37	0.02	0.37	0.02	0.39	0.02
age of maximum growth (ti)	12.78	0.03	12.66	0.05	14.07	0.09	14.17	0.09
coefficient of determination (R^2)	97.84%		95.76%		95.71%		99.62%	

Table 2. Feed conversion ratio (FCR) of slow- (SG) and fast-growing (FG) turkeys and their reciprocal crosses (SF, FS)

Parameter		Statistical measure							
		SG		SF		FS		FG	
		mean	SD	mean	SD	mean	SD	mean	SD
Males									
FCR	starter	1.91 c	0.1	1.60 b	0.1	1.48 b	0.1	1.29 a	0.0
FCR	grower 1	2.06 c	0.1	1.89 b	0.1	1.63 a	0.1	1.53 a	0.1
FCR	grower 2	2.46 d	0.1	2.23 c	0.1	2.06 b	0.1	1.92 a	0.1
FCR	finisher	3.21 d	0.2	2.99 c	0.2	2.68 b	0.2	2.49 a	0.1
FCR	total	2.62 d	0.1	2.37 c	0.1	2.19 b	0.1	2.03 a	0.1
Females									
FCR	starter	1.88 d	0.0	1.57 c	0.1	1.44 b	0.1	1.26 a	0.1
FCR	grower 1	2.16 c	0.1	1.98 b	0.1	1.68 a	0.1	1.58 a	0.1
FCR	grower 2	2.72 c	0.1	2.46 b	0.1	2.22 a	0.2	2.07 a	0.1
FCR	total	2.47 c	0.1	2.23 b	0.1	1.96 a	0.1	1.81 a	0.1

a, b, c, d – means within a row with no common superscript are significantly different (P≤0.05).

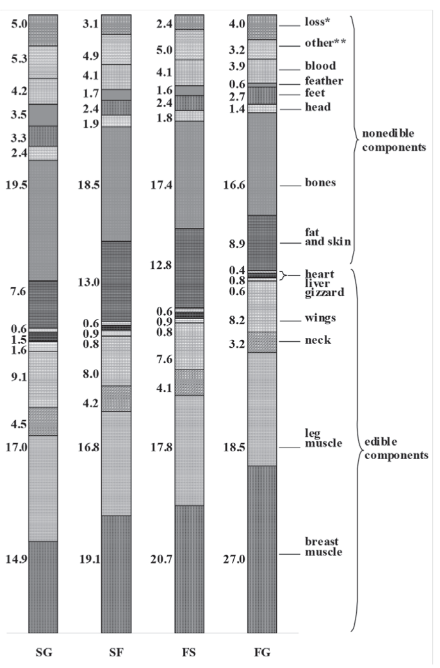

Figure 3. Percentage content of particular components in the BW of turkey males; * loss = BW loss during dissection; ** other = BW loss during post-slaughter processing

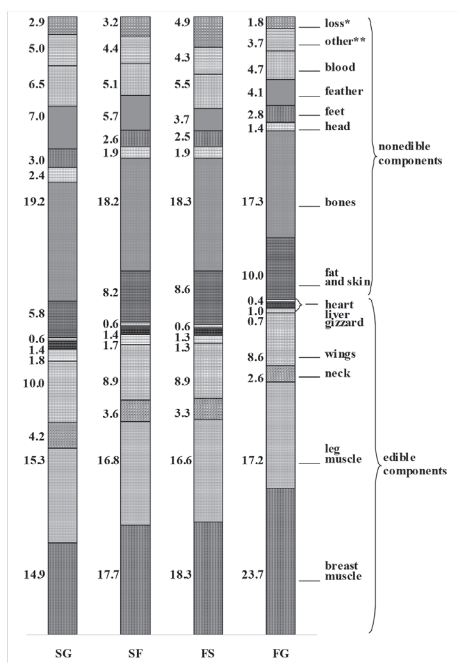

Figure 4. Percentage content of particular components in the BW of turkey females; * loss = BW loss during dissection; ** other = BW loss during post-slaughter processing

Table 5. Arithmetic means and SD for carcass and edible components, and genetic effects of slow- (SG) and fast-growing (FG) turkeys and their reciprocal crosses (SF, FS)[1]

Item		Statistical measure								Orthogonal contrasts		
		SG		SF		FS		FG		additive	heterosis	maternal
		mean	SD	mean	SD	mean	SD	mean	SD	(g^I_{SG})	($h^I_{SG\times FG}$)	(g^M_{SG})
Male carcass	(g)	4354.51 d	154.2	8858.32 c	187.7	10723.31 b	100.6	18183.30 a	293.4	7846.9 z	–1478.1 z	–932.5 z
	ratio[2]	73.31 c	0.3	79.81 b	0.6	81.13 b	0.6	83.28 a	0.5	5.6 z	2.2 z	–0.6
Female carcass	(g)	2315.02 d	56.1	3935.10 c	38.0	4937.03 b	74.2	9375.24 a	42.2	4030.8 z	–1486.5 z	–639.9 z
	ratio[2]	72.42 c	0.9	76.03 b	0.7	76.49 b	0.7	82.19 a	0.3	5.1 z	–1.0	–0.2
Weight of edible components (g)												
Males												
breast muscle		881.50 d	27.6	2114.51 c	82.4	2736.00 b	66.4	5895.17 a	154.5	2817.6 z	–963.1 z	–310.8 z
leg muscle		1008.53 d	29.9	1860.14 c	43.3	2360.83 b	81.1	4031.49 a	136.8	1761.8 z	–963.1 z	–310.8 z
wings		540.77 d	21.2	884.67 c	21.8	1010.07 b	30.4	1796.70 a	48.2	690.7 z	–221.3 z	–62.8 z
neck		269.00 d	13.9	448.15 c	23.1	538.72 b	23.4	704.03 a	13.1	262.8 z	6.9	–45.3 z
gizzard		93.66 b	5.4	96.83 b	6.8	103.22 b	5.2	126.47 a	4.3	19.7 z	–10.0	–3.3
liver		90.04 c	6.1	104.50 c	7.3	131.10 b	7.1	165.48 a	10.9	51.1 z	–9.9	–13.3 z
heart		37.33 c	2.6	56.33 b	1.0	78.00 a	8.1	79.67 a	1.9	32.0 z	8.7	–10.8 z
total edible comp.		2920.83 d	75.6	5565.12 c	110.9	6958.17 b	130.7	12799.00 a	264.3	5635.6 z	–1598.3 z	–696.5 z
Females												
breast muscle		475.01 d	15.2	914.82 c	22.9	1177.80 b	33.9	2703.23 a	64.0	1245.6 z	–542.8 z	–131.5 z
leg muscle		489.07 d	17.8	867.70 c	18.4	1072.33 b	21.2	1963.26 a	36.4	839.4 z	–256.1 z	–102.3 z
wings		320.23 d	7.2	461.75 c	9.4	577.21 b	17.2	979.84 a	8.0	387.6 z	–130.6 z	–57.8 z
neck		133.33 d	3.6	185.00 c	5.6	213.86 b	6.8	299.71 a	12.7	97.6 z	–17.1 z	–14.4 z
gizzard		56.83 b	3.3	85.50 b	10.7	83.17 b	5.4	83.16 a	3.4	12.0	14.3 z	1.2
liver		44.71 c	1.9	72.48 b	4.4	81.11 b	3.2	116.01 a	2.6	40.3 z	–3.5	–4.3
heart		19.42 d	0.9	29.66 c	1.2	34.12 b	1.8	41.79 a	1.8	13.5 z	1.3	–2.3
total edible comp.		1538.14 d	46.0	2617.11 c	35.1	3240.02 b	58.0	6187.24 a	79.3	2636.0 z	–934.3 z	–311.3 z

a, b, c, d – means within a row with no common superscript are significantly different ($P \leq 0.05$); z – significantly different ($P \leq 0.05$) for the orthogonal contrasts;
[1] values are means for 4 genetic groups (SG, SF, FS, FG) of 15 males and 15 females in each group,
[2]The ratio (%) to body weight before slaughter.

Table 6. Arithmetic means and SD for non-edible components, and genetic effects of slow- (SG) and fast-growing (FG) turkeys and their reciprocal crosses (SF, FS)[1]

Item	Statistical measure								Orthogonal contrasts		
	SG		SF		FS		FG				
	mean	SD	mean	SD	mean	SD	mean	SD	additive (g^{I}_{SG})	heterosis ($h^{I}_{SG\times FG}$)	maternal (g^{M}_{SG})
Weight of non-edible components (g)											
Males											
fat and skin	455.85 d	42.6	1443.00 c	94.4	1687.17 b	75.4	1944.50 a	94.6	866.4 z	364.9 z	–127.0 z
bones	1161.33 d	69.6	2050.67 c	61.6	2304.85 b	49.1	3622.33 a	129.0	1357.5 z	-214.2 z	–127.0 z
head	139.83 c	5.6	213.17 b	5.0	232.21 b	9.0	313.67 a	26.9	96.4 z	-4.1	–9.5
feet	193.39 d	6.7	265.00 c	6.3	317.17 b	6.8	594.83 a	19.8	226.8 z	-103.0 z	–26.1 z
feather	207.00 a	24.2	190.50 a	35.1	210.17 a	83.5	121.71 a	40.6	–32.8	36.0	–9.8 z
blood	250.17 d	14.3	451.83 c	38.7	545.33 b	31.4	848.33 a	34.1	345.8 z	-50.7	–46.8 z
loss*	262.17 b	38.0	264.67 b	22.5	248.50 b	87.6	801.05 a	93.7	261.3 z	-275.0 z	8.1
other**	311.83 c	11.7	550.00 b	41.3	654.33 a	22.4	660.33 a	29.9	226.4 z	116.1 z	–52.2 z
total non-edible components	2981.49 d	121.6	5428.83 c	152.7	6199.52 b	77.7	8906.57 a	111.9	3347.9 z	–129.9	–385.3 z
Females											
fat and skin	186.53 d	8.3	426.52 c	9.9	555.04 b	60.6	1140.37 a	31.0	541.2 z	–172.7 z	–64.3 z
bones	616.22 d	15.4	945.23 c	11.8	1180.47 b	33.1	1974.81 a	26.6	796.9 z	–232.6 z	–117.6 z
head	77.31 d	3.1	100.00 c	1.6	122.76 b	3.3	158.05 a	1.9	51.8 z	–6.3 z	–11.4 z
feet	94.82 d	1.7	134.03 c	2.7	160.13 b	4.3	314.57 a	14.8	122.6 z	–57.4 z	–13.0 z
feather	225.04 b	41.0	295.10 b	21.4	241.00 b	31.2	471.86 a	37.4	96.4 z	–80.4 z	27.0
blood	207.55 c	10.6	265.21 c	43.3	357.89 b	13.5	530.28 a	40.6	207.8 z	–57.4	–46.3 z
loss*	95.30 a	18.6	165.82 ca	25.4	320.13 b	39.4	209.69 a	25.0	134.3 z	90.4 z	–77.1 z
other**	159.33 d	6.6	228.14 c	7.4	280.09 b	10.4	420.50 a	11.3	156.5 z	–35.8 z	–25.9 z
total non-edible components	1662.02 d	61.1	2560.14 c	61.0	3217.47 b	116.6	5220.11 a	64.7	2107.3 z	–552.2 z	–328.6 z

a, b, c, d – means within a row with no common superscript are significantly different ($P\leq0.05$).
z – significantly different ($P\leq0.05$) for the orthogonal contrasts.
* Loss = BW loss during dissection.
* Other = BW loss during post-slaughter processing.
[1] Values are means for 4 genetic groups (SG, SF, FS, FG) of 15 males and 15 females in each group.

The use of FG turkeys for crossing had a positive direct effect on dressing percentage and weight of edible and non-edible elements, which was indicated by significant (P≤0.05) positive additive effects (Tables 5 and 6). Negative values were demonstrated only in the case of the weight of feathers gISG , however they were not statistically significant. The weight of gizzard in male and female crosses significantly (P≤0.05) exceeded the value of this trait noted for the heavier parent (FG). A positive and significant (P≤0.05) heterosis was also observed regarding the weight of skin with fat in males. The highest value of this trait occurred in the FG group, but in both groups of hybrids (SF and FS) the weight of skin with fat was more similar to that of FG group and exceeded several times that of the SG group (Table 6). No positive effects of heterosis were noted in the case of other analysed traits ($h^{I}_{SG\times FG}$). No statistically positive maternal effects (g^{M}_{SG}) were observed in any of the analysed traits (Tables 5 and 6).

Discussion

The assumption of this study was to determine – based on production results – which variant of crossbreeding the slow-growing Bronze turkeys and fast-growing Big 6 turkeys is more appropriate for alternative rearing, and secondly, to determine the impact of the parental genotype (SG, FG) on the production results of hybrids.

Ample studies provided evidence that BW0 d depends most of all on egg weight, and thus directly on the genotype of dam (Nestor et al., 2005; Lilburn and Antonelli, 2012). This explained the higher $BW_{0\,d}$ of SF turkeys compared to FG birds. Sire had, however, a great impact on the course of growth curves of the hybrid poults immediately after hatching, which was indicated by significantly faster growth of both FS males and females (Figures 1 and 2). The results are therefore interesting, because authors usually point out a greater maternal effect on the growth of crosses. Nestor et al. (2005) achieved higher $BW_{16\,wk}$ in the crosses of turkeys where dam belonged to a heavier line (C) and lower $BW_{16\,wk}$ after dams from the lighter line (F). Nevertheless, these authors used for crossbreeding two lines of turkeys that only slightly differed in $BW_{16\,wk}$ (0.9 kg), whereas the $BW_{15\,wk}$ of turkey hens of the pure lines used in our experiment was as high as 7.4 kg. More diversified material in terms of BW was applied by Kirby et al. (1999), who used Giant Jungle Fowl (J) and heavy Hubbard (B) hens for reciprocal crossing, but also achieved higher $BW_{28\,d,\,42\,d}$ for J × B crosses. Literature lacks data on the crossbreeding of heavy commercial lines of turkeys with wild fowl, which could indicate whether the same tendency occurs in both species. In contrast, Larzul et al. (2006) achieved higher $BW_{15\,wk}$ in mule (Muscovy × Pekin) compared to hinny ducks (Pekin × Muscovy), which indicates a greater effect of sire genotype. Presumably, the differences in the growth of reciprocal crosses depend mainly on the applied genetic material (species, breed, line, direction of selection) and on differences between the pure lines of parents.

In the economy of poultry production, next to high BW, other key parameters include FCR and mortality rate (%), all the more that contemporarily expenditures incurred on feed provision reach 70% of total costs of rearing. The lowest FCR in the FG group was, probably, linked with a decreasing value of this parameter in commercial lines as a result of selection. A study by Havenstain et al. (2007) demonstrates that since 1966 the value of FCR in turkey toms at 20 wk of age has decreased by 20 to 50%. Results obtained in our experiment regarding the FCR values (SG < SF < FS < FG) are similar to data reported earlier by Nahashon et al. (1999) in their study on reciprocal crossing of a heavy line of White Plymouth Rock hens with a light line Livorno. Also Sarica et al. (2009) demonstrated that the FCR values were strongly correlated with the growth rate of birds. In the experiment of these authors, the Hybrid × Bronze turkeys demonstrated intermediate values of FCR compared to pure lines, regardless of the housing system. There is no explicit evidence in the literature for the effect of any direction of crossbreeding two healthy populations of birds on the increased mortality rate. The use of heavy Big 6 turkeys as a parental component could, however, predispose the SF and FS turkeys for reduced immunity and disorders of the cardiovascular and the locomotor systems (Julian, 2005; Cheema et al., 2007; Zhong et al., 2012). Apart from 3 cases of aortic rupture in males and 4 cases of perosis in females in the FS group the mortality rate of turkeys was low, and none of the above-mentioned causes of death occurred in the FG group. It could be due to the possibility of using free ranges by birds, as Fanatico et al. (2008) paid attention to the fact that the use of free range may reduce mortality even in birds of heavy commercial lines. In a study by Sarica et al. (2009), the mortality of turkeys kept in the free-range housing system was also low and did not exceed 5%, irrespective of birds origin.

It is obvious that the key criterion to producers of live turkey material is the final BW of birds. But for further distributors and retailers, significant will be the weight of carcass and the percentage content of edible elements in the carcass, particularly of the largest muscles. Among the presented types of hybrids, it is evident that the best results regarding these traits were demonstrated for FS turkeys (Table 3, Figures 3 and 4). Burke and Henry (1997) also achieved a significantly higher weight of breast muscles and of one of the leg muscles (*Semimembranosus*) in 21-day-old hybrids BrBa (Arbor Acres × Black Wyandotte Bantam) compared to BaBr. In contrast, Nestor et al. (2005) reported a higher muscle content in F × C hybrids compared to C × F birds, thereby demonstrating a significant impact of heterosis. A drawback of hybrids may, however, be significant adiposity of males (Figure 3). Deposition of fatty tissue is not only economically ineffective, and additionally such fat carcasses are less willingly bought by consumers. It may be presumed that the high fat content of experimental turkeys results from too high content of protein and energy in the feed mixture. On the Polish market, the adjustment of appropriate feed mixture to the needs of alternative systems of poultry production is difficult, and in the case of turkeys – there is not much choice to be made by poultry producers between one feed mixture available for turkeys kept in the free range system or the mixture of own production. In turn, the percentage content of skin with fat in BW of the FG turkeys was not high compared to the results reported by Murawska (2013) for Big 6 turkeys reared in the intensive system (males – ca. 8.8% in wk 20; females – ca. 10.9% in wk 16). It may be hypothesized that, owing to the lack of diverse genetic material on the market, the feed mixtures are manufactured exclusively for the production of fast-growing birds.

In summary, it may be concluded that higher BW, lower FCR and higher content of edible components in carcass (breast muscles in particular) indicate the cross-breeding of heavy Big 6 toms with light turkey hens to be more appropriate for alternative free range production. High adiposity of the hybrids shows, however, that it is necessary to develop special feed mixtures tailored to their needs. In the future, it would be advisable to confront production results of the discussed crosses reared simultaneously in two different production systems, which could provide a wider picture of birds response to various rearing conditions.

References

American Poultry Association (2001). The American Standard of Perfection. APA, Troy, NY.

AOAC (2005). Official Methods of Analysis of AOAC International, 16th Edition. Association of Analytical Chemistry, Arlington, VA, USA.

Berri C., Le Bihan-Duval E., Baèza E., Chartrin P., Picgirard L., Jehl N., Quentin M., Piccard M., Duclos J. (2005). Further processing characteristics of breast and leg meat from fast-medium- and slow-growing commercial chickens. Anim. Res., 54: 123–134.

British United Turkeys (2013). B.U.T. 6 Commercial performance objectives. http://www.aviagenturkeys.com/media/207198/v1_but_6_commercialgoals_uk.pdf.

Burke W.H., Henry M.H. (1997). Characteristics of the *Pectoralis superficialis* and *Semimembranosus* of broiler strain chickens, bantam chickens, and the reciprocal crosses. Poultry Sci., 76: 767–773.

Cheema M.A., Qureshi M.A., Havenstein G.B., Ferket P.R., Nestor K.E. (2007). A comparison of the immune response of 2003 commercial turkeys and a 1966 randombred strain when fed representative 2003 and 1966 turkey diets. Poultry Sci., 86: 241–248.

Damaziak K., Michalczuk M., Kurek A. (2012). Comparison of production performance of two genetic groups of turkeys reared in the semi-intensive system. JCEA, 13: 403–415.

Damaziak K., Pietrzak P., Michalczuk M., Mroczek J., Niemiec J. (2013). Effect of genotype and sex on selected quality attributes of turkey meat. Arch. Geflügelk., 77: 206–214.

Dickerson G.E. (1969). Experimental approaches in utilizing breed resources. Anim. Breed. Abstr., 37: 191–202.

Fanatico A.C., Cavitt L.C., Pillai P.B., Emmert J.L., Owens C.M. (2005). Evaluation of slower-growing broiler genotypes grown with and without outdoor access: Meat quality. Poultry Sci., 84: 1785–1790.

Fanatico A.C., Pillai P.B., Hester P.Y., Falcone C., Mech J.A., Owens C.M., Emmert J.L. (2008). Performance, livability, and carcass yield of slow- and fast-growing chicken genotypes fed low-nutrient or standard diets and raised indoors or with outdoor access. Poultry Sci., 87: 1012–1021.

Havenstain G.B., Ferket P.R., Grimes J.L., Qureshi M.A., Nestor K.E. (2007). Comparison of the performance of 1966- versus 2003-type turkeys when fed representative 1966 and 2003 turkey diets: growth rate, livability, and feed conversion. Poultry Sci., 86: 232–240.

Julian R.J. (2005). Production and growth related disorders and other metabolic diseases of poultry – A review. Vet. J., 169: 350–369.

Kamara D., Gyenai K.B., Geng T., Hammade H., Smith E.J. (2007). Microsatellite marker-based genetic analysis of relatedness between commercial and heritage turkeys (*Meleagridis gallopavo*). Poultry Sci., 86: 46–49.

Kirby Y.K., Anthony N.B., Hughes J.D., Mcnew R.W., Kibry J.D., Wideman R.F. (1999). Electrocardiographic and genetic evaluation of giant jungle fowl, broilers and their reciprocal crosses following unilateral bronchus occlusion. Poultry Sci., 78: 125–134.

Laird A.K., Tyler S.A., Burton A.D. (1965). Dynamic of normal growth. Growth, 29: 233–248.
Larzul C., Imbert B., Bernadet M.D., Guy G., Rémignon H. (2006). Meat quality in an intergeneric factorial crossbreeding between muscovy (*Cairina moschata*) and Pekin (*Anas platyrhynchos*) ducks. INRA, Anim. Res., 55: 219–229.
Lilburn M.S., Antonelli A. (2012). The effects of genotype on embryonic development in eggs from divergent turkey genotypes. Poultry Sci., 91: 823–828.
Mignon-Grasteau S., Beaumont C. (2000). Growth curves in birds (in France). INRA Prod. Anim., 13: 337–348.
Mikulski D., Celej J., Jankowski J., Majewska T., Mikulska M. (2011). Growth performance, carcass traits and meat quality of slower-growing and fast-growing chickens raised with and without outdoor access. Asian-Aust. J. Anim. Sci., 24: 1407–1416.
Murawska D. (2013). Age-related changes in the percentage content of edible and nonedible components in turkeys. Poultry Sci., 92: 255–264.
Nahashon S.N., Ayorined K.L., Drummond P., Dewes M., Smith E.J. (1999). Heterosis for growth related traits in White Plymouth Rock and single comb White Leghorn reciprocal crosses reared under two crude protein regimens. J. Anim. Feed Sci., 8: 51–61.
Nestor K.E., Anderson J.W., Hartzler D., Velleman S.G. (2005). Genetic variation in pure lines and crosses of large-bodied turkeys. 4. Body shape and carcass traits. Poultry Sci., 84: 1825–1834.
Richards F.J. (1959). A flexible growth function for empirical use. J. Exp. Bot., 10: 290–300.
Sarica M., Ocak N., Karagay N., Yamak U., Kop C., Altom A. (2009). Growth, slaughter and gastrointestinal tract of three turkey genotypes under barn and free-range housing systems. Brit. Poultry Sci., 50: 487–494.
Sheng Z., Pettersson M.E., Hu X., Luo Ch., Qu H., Shu D., Shen X., Carlborg Ö., Li N. (2013). Genetic dissection of growth traits in a Chinese indigenous × commercial broiler chicken cross. BMC Genomics, 14: 151–163.
Sola-Ojo F.E., Ayorinde K.L. (2011). Evaluation of reproductive performance and egg quality traits in progenies of Dominant Black strain crossed with Fulani Ecotype chicken. J. Agr. Sci., 3: 258–265.
Zhao X.L., Siegel P.B., Liu Y.P., Wang Y., Gilbert E.R., Zhu Q., Zhang L. (2012). Housing system affects broiler characteristics of local Chinese breed reciprocal crosses. Poultry Sci., 91: 2405–2410.
Zhong Z., Muckley M., Agcaoglu A., Grishan M.E., Zhao H., Orth M., Lilburn O., Akkus O., Karcher D.M. (2012). The morphological, material-level, and ash properties of turkey femurs from 3 different genetic strains during production. Poultry Sci., 91: 2736–2746.

Received: 28 I 2014
Accepted: 18 VI 2014