Carcass Traits and Reproductive Development at the Onset of Lay in Two Lines of Female Turkeys

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ABSTRACT A study was conducted comparing ovary and oviduct development following photostimulation in two lines of turkey breeder stocks (female line and male line). Birds were euthanatized for assessment of reproductive organ morphology at 3-d intervals following photostimulation (203 d of age) to 245 d and on the day following their first oviposition. The age at first oviposition was similar for both lines. Male line birds were 3 to 4 kg heavier than female line birds throughout the study, but had lower abdominal fat pad weights when expressed as a percentage of BW. Female line birds had significantly more total carcass lipid as a percentage of BW than male line birds (24.76 vs 22.79%, respectively). Male line birds had significantly more large ovarian follicles with a greater proportion in a triple or greater hierarchical arrangement at first egg. To determine the incidence of unreconciled ovulations (presumed to be internally ovulated follicles and defined as ovulations occurring prior to first oviposition), postovulatory follicles on the ovary were reconciled with observed ovipositions and the developing eggs that were in the oviduct at the time of study. On average, male line hens had 3.0 unreconciled postovulatory follicles at first egg, whereas the female line hens had 1.6. The incidence of birds with physical remnants of internal ovulation was correlated (r = 0.44) to the number of unreconciled ovulations. The developing oviduct of the female line birds reached its mature weight (84.8 g) 3 d earlier than the ovary did. The developing ovary and oviduct of the male line hens reached their mature weights on the same day. The development of the male line oviduct is seemingly accelerated relative to that of the ovary, resulting in lost ovulations early in lay.

(*Key words*: turkey, sexual maturation, ovary, oviduct, carcass composition)

1997 Poultry Science 76:1197–1204

INTRODUCTION

Determining the optimum age at which to initiate sexual maturation in turkeys has been the subject of considerable research, as evidenced in a recent review (Noll, 1989); however, there has been little published research to characterize the process of puberty in turkeys in terms of changes in carcass composition and development of the reproductive organs. The ovary and oviduct undergo extensive growth and development during the process of sexual maturation. Exposure to increasing day length triggers the commencement of ovarian and oviductal growth and the observed steady increase in the concentration of plasma luteinizing hormone (Sharp, 1980). Four to 11 d after photostimulation, a follicular hierarchy begins to form as yellow yolk is deposited into a relatively small number of follicles (Bacon and Cherms, 1968). The first oviposition occurs between 19 and 31 d after photostimulation (Bacon and Cherms, 1968), with considerable variability being observed under commercial conditions.

Male line and female line turkeys are the parents of commercial turkeys in modern breeding systems with the offspring of a cross of such parents being used in commercial turkey production. These two lines have resulted primarily from selection for growth and carcass traits in male lines, and for carcass characteristics and reproductive traits in the female lines. Under commercial practice with female breeders at a primary breeder site, male line birds and female line birds are photostimulated at 28 and 30 wk, respectively, allowing female lines birds additional time to accrue adequate carcass reserves of energy and protein to sustain high rates of lay and to try to maximize egg output from the male line hens (L. G. Bagley, Tar Heel Turkey Hatchery, Raeford, NC 28376, personal communication). Some insight into selection for meat production or reproduction can been had by comparing broiler breeders and egg-type hens. Hocking *et al.* (1987) and Lupicki (1994) found that full-fed broiler breeder hens had significantly more large ovarian follicles and poorer egg production than full-fed Leghorn hens. Feed restriction is a common

Received for publication October 8, 1996.
Accepted for publication April 14, 1997.
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TABLE 1. Number of turkey hens euthanized for each study time of Group A and Group B

Group	Age	Days after photostimulation	Male line n	Female line n
	(d)			
A	206	0	4	4
	209	3	4	4
	212	6	4	4
	215	9	4	4
	218	12	4	4
	221	15	4	4
	224	18	4	4
	227	21	4	4
	230	24	4	4
	233	27	4	4
	236	30	4	4
	239	33	4	4
	242	36	4	4
	245	39	4	4
B	1 d after first oviposition	21 to 43	24	24

practice in broiler breeder management, where it is used to restrict BW and improve production of settable eggs (Summers and Robinson, 1995); however, feed restriction has not become a standard practice in turkey breeder hen management (Renema *et al*., 1994). Hocking (1992) found that feed restriction was less effective in reducing the number of large yellow follicles and improving egg production in heavy weight lines of turkey hens than it was in relatively low weight lines.

A potential source of reproductive loss of heavy male line hens is that of "unreconciled" ovulations that occur early in lay (Renema *et al*., 1995). In hens euthanatized and dissected soon after the onset of lay, any follicles that have been ovulated [as seen by existing postovulatory follicles (POF)], and that cannot be accounted for by counting all previous ovipositions and eggs *in utero*, can be considered to be unreconciled. Renema *et al.* (1995) reported that male line hens killed at first egg had an average of 4.9 unreconciled POF. The fate of such follicles is not clear but presumably is explained by internal ovulation. Explanations or descriptions of unreconciled ovulations do not exist in present literature; however, it may be hypothesized that in male line hens relative oviduct development may be retarded, or, alternatively, relative ovary development is accelerated. Hence, ovulated follicles are unable to be released into the infundibulum and to be successfully transported through the oviduct, for deposition of albumen, shell membranes, and shell. It is also unknown whether the incidence of unreconciled ovulations is limited to stocks of turkeys that are intensively selected for growth rate, or whether this condition is also seen in lines of hens of lower BW that have been selected for reproductive traits as well.

This paper characterizes and contrasts the development of the reproductive system (ovary and oviduct), BW, and carcass characteristics in male and female lines of turkey hens during puberty and at first egg.

MATERIALS AND METHODS

Stocks and Management

A total of 300 female turkey poults (150 male line and 150 female line) were used in this experiment. The two stocks represent the male and female parent lines of commercial turkey breeders, and hence can be considered to be similar to parent stocks of commercial turkeys. The poults were hatched in March and were reared in a light-controlled facility in floor pens with straw bedding. The two stocks were reared in separate but adjacent pens and consumed feed *ad libitum* with common exposure to the same lighting and physical environment. Following exposure to decreasing day lengths of 8, 7, 6, and 5 h at 13, 17, 21, and 25 wk, respectively, birds were photostimulated at 29 wk from 8 h of light to 14 h of light (8L:16D to 14L:10D). At 28 wk of age, 100 out of the original 150 birds from each line were selected to participate in the study. This was done to reduce within-treatment variation and to maximize the likelihood of between-treatment variation. Within each line, the 100 birds with BW closest to the line mean 28-wk BW were randomly assigned to a study time (Table 1). Four birds from each line were randomly selected every 3 d for a 39-d period (Group A; 14 kill d in total) and blood sampled at 0800 h and euthanatized by lethal injection using T-61[2] (3 mL dosage). A second group (Group B) was used to investigate morphological differences between the lines at first egg. All birds were palpated daily each morning 1 h after the lights went on for the presence of a hard-shelled egg in the oviduct from 31 wk to the end of the trial. This palpation was carried out to ensure accurate determination of first egg (first oviposition). Birds were placed in a trap nest if a hard-shelled egg was detected. Nests were checked on an hourly basis (12 times per day). Immediately following

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first oviposition, Group B birds were deprived of feed and water and were killed the following morning at 0800 h as described above.

Reproductive Organ Morphology

In both Group A and Group B birds, the BW, weight of ovary, stroma (total ovary minus large yellow follicles with a diameter greater than 10 mm), oviduct, and liver were recorded. The abdominal fat pad including the fat surrounding the gizzard was removed to reflect changes in carcass lipid depots. All breast muscle (*Pectoralis major* and *Pectoralis minor*) was dissected from the keel to reflect changes in lean body mass. The number, weight, and diameter of large yellow follicles (diameter greater than 10 mm) and the number of POF and atretic large follicles (showing evidence of degeneration) was recorded. To determine the number of ovulations that occurred prior to the first oviposition, the number of eggs laid and developing eggs located in the oviduct were subtracted from the number of POF on the ovary the day following first oviposition. Incidence of internal ovulation was recorded as evidenced by the presence of yellow egg yolk residue in the body cavity. Large yellow follicles were sorted into a hierarchy based on size. To determine the potential for multiple ovulations, follicles of similar size (differing by less than 1 g and 1 mm diameter) were assigned to the same "position" in the hierarchy as described previously by Renema *et al.* (1995).

Plasma Traits and Carcass Composition

Individual blood samples were collected via the brachial vein immediately prior to killing. Plasma was stored at –15 C following centrifugation. Plasma lipid concentration was determined using the Folch lipid extraction method (AOAC, 1980). Dissected organs were returned to the carcass, which was stored at –15 C until whole carcass analyses was carried out as described by Renema *et al.* (1994). Briefly, frozen carcasses were cut into 10-cm pieces and processed twice through a large meat grinder. A 2-kg ground sample was pressure-cooked for 6 h and homogenized in a large blender. A 100-g subsample was freeze dried for 7 d and subsequently ground in a small feed grinder. Moisture loss during homogenization, storage, and freeze drying were corrected for and total carcass content of dry matter, crude protein, lipid, and ash were determined using chemical analysis procedures (AOAC, 1980).

Statistical Analyses

Two male line birds were removed from the data set, as they were determined to be outliers with greatly reduced ovarian and oviductal development (as determined by being three standard deviations from the mean of birds studied at the same age). Data were analyzed by one-way analyses of variance using SAS® (SAS Institute, 1992). Sources of variation were line (male line and female line) and error variation of birds within lines. Pearson correlation coefficients between reproductive characteristics were computed across lines. To compare the rate of ovary and oviduct growth, curves were tested using Kolmogorov-Smirnoff analyses (SAS Institute, 1992). Polynomial regression equations were computed for ovary and oviduct development as percentages of mature ovary or oviduct weight for each line. Mature organ weights were the mean values calculated for all Group B birds (for each strain) killed at first egg. The powers of the polynomial regression equations (fifth power for oviduct and sixth power for ovary) were those that gave goodness of fit similar to Lowess smoothing procedure (SAS Institute, 1992). The polynomial regression equations were used to estimate the age at which the ovary and oviduct of each line obtained 100% of its mature weight.

RESULTS AND DISCUSSION

Age at First Egg, BW, and Carcass Characteristics

Male line birds were significantly heavier than the female line birds at all ages studied (Figure 1). There was no significant difference in mean age at first egg (Table 2) for the female line and the male line (232 vs 233 d, respectively). First egg was reached 26 and 27 d after photostimulation for the female and male line hens, respectively. Bacon and Cherms (1968) stated that the first oviposition should occur 19 to 31 d after photostimulation, a range of 12 d. The birds used in the present experiment came into production near the latter end of this range. It is possible that with increased emphasis on selection for growth traits, age at first egg has been delayed and selection emphasis for reproductive traits has decreased

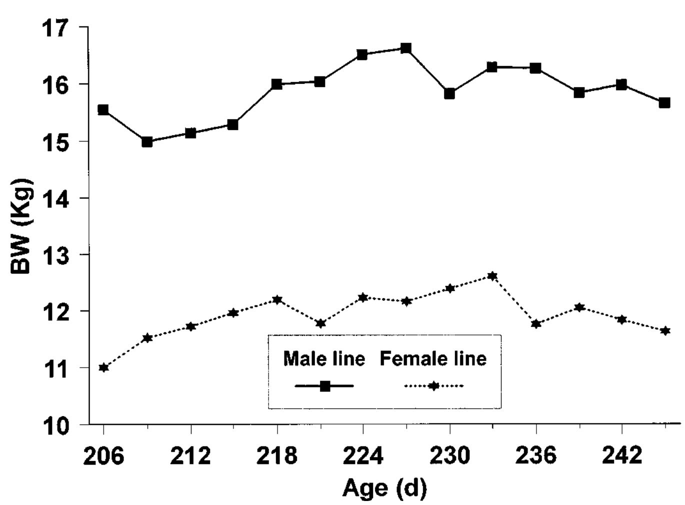

FIGURE 1. Body weight of male line and female line turkey hens from photostimulation to 245 d of age. Mean age at first egg was 232 d for the female line hens and 233 d for the male line hens.

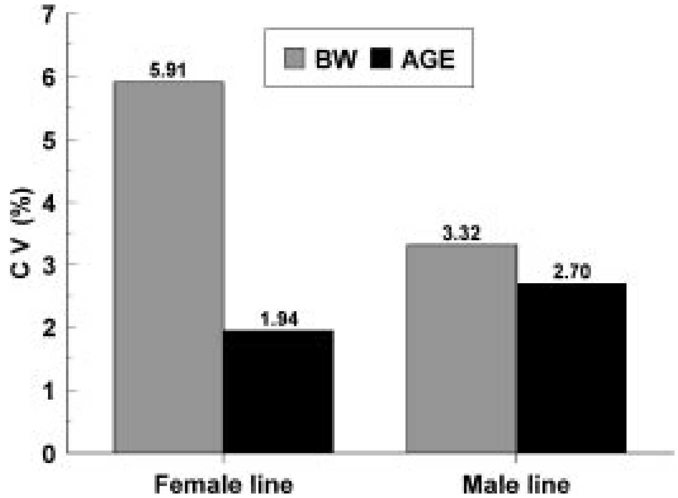

FIGURE 2. Coefficient of variation of BW and age at first egg of male and female line turkey hens.

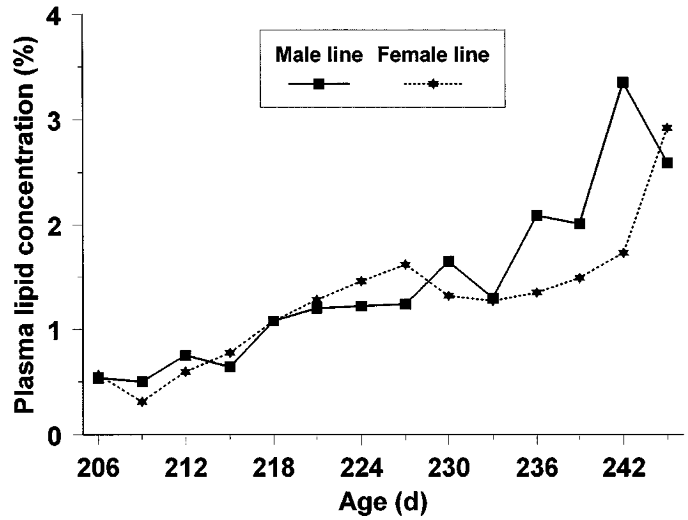

FIGURE 3. Plasma lipid concentration of male line and female line turkey hens from photostimulation to 245 d of age. Mean age at first egg was 232 d for the female line hens and 233 d for the male line hens.

age at first egg (Nestor, 1971). Male line birds exhibited more variation in the age of first egg (CV 2.70 vs 1.94%, respectively) and less variation in the BW at first egg (CV 3.3 vs 5.9%, respectively), than the female line birds (Figure 2). Robinson *et al.* (1996) found that in feed-restricted broiler breeders, the CV of age and BW at first egg decreased as the age of photostimulation increased. As the age of photostimulation increases, the flock responds more uniformly, possibly because more individuals in the population will have reached an optimum body mass or age to start laying under normal management conditions as used here.

The BW of the two lines at SM are presented in Table 2, with the male line hens being 3.76 kg heavier than the female line hens. Some of this difference can be attributed to increased breast muscle mass in male line birds (4.67 kg) compared to female line birds (3.06 kg). At first egg, male

TABLE 2. Age at first egg, body weight, and selected organ weights and plasma traits of female line and male line turkey hens euthanized on the day following first oviposition (Group B)

Variable	Female line	Male line	SEM
No. of hens	24	24	
Age at first egg, d	232.9	233.3	1.1
Reconciled age at first egg, d	230.3	230.3	1.3
BW, kg	12.14[b]	15.90[a]	0.13
Breast weight			
kg	3.06[b]	4.67[a]	0.061
% BW	25.16[b]	29.36[a]	0.35
Liver weight			
g	132.1[b]	170.3[a]	5.2
%	1.08	1.07	0.03
Fat pad weight			
g	295.8	298.6	15.1
%	2.43[a]	1.88[b]	0.10
Ovary weight			
g	187.1[b]	227.6[a]	8.0
%	1.54	1.43	0.05
Stroma weight			
g	18.9[b]	26.1[a]	1.2
%	0.16	0.16	0.42
Oviduct weight			
g	84.8[b]	109.2[a]	2.5
%	0.70	0.69	0.02
No. of large yellow follicles	14.5[b]	17.4[a]	0.7
No. of unreconciled postovulatory follicles	1.6[b]	3.0[a]	0.4
Plasma lipid concentration, %	1.59	1.55	0.79

[a,b]Means within a row with no common superscript differ significantly ($P < 0.05$).

TABLE 3. Carcass composition of female line and male line turkey hens euthanized on the day following first oviposition (Group B)

Variable	Female line	Male line	SEM
H_2O weight, % BW	47.33[b]	49.42[a]	0.76
Crude protein weight, %	22.63	22.75	0.31
Lipid weight, %	24.76[b]	22.79[a]	0.71
Ash weight, %	3.49	3.50	0.07

[a,b]Means within a row with no common superscript differ significantly ($P < 0.05$).

line birds had significantly greater absolute liver mass (170.3 vs 132.1 g) than female line birds (Table 2), whereas the absolute weight of the abdominal fat pad (298.6 g male line; 295.8 g female line) did not differ. As female line hens had a lower BW and a fat pad weight that was equivalent to that of the male line, fat pad weight, when expressed as a percentage of BW, was lower for male line hens than it was for female line hens (1.88 vs 2.43%, respectively). Nestor (1982) showed that selection for increased BW resulted in an increase in fat pad mass on both an actual weight basis and a percentage basis, however the strains used by Nestor were not commercial strains, as were the birds used in the present project.

Plasma lipid concentrations increased gradually for both lines throughout sexual maturation, as shown in Figure 3. The profiles were not significantly different between strains except on Day 242. The mean plasma lipid concentrations at first egg were also not different (Table 2). The mean values for carcass lipid content were significantly lower in male line birds (22.79%) than in female line birds (24.76%), as shown in Table 3. The female line hens had a significantly higher lipid mass when expressed on a percentage of BW basis. Hocking (1992) found no significant differences in carcass lipid levels in four strains of turkeys with 24-wk BW ranging from 7.4 to 18.9 kg. In that study, Hocking reported that the mean carcass lipid content (expressed on a percentage of BW basis) of three female lines was 24% and that of a male line was 24.6%. Emmans (1989) found greater carcass lipid levels in strains of turkeys that had heavier BW than in lower BW strains. Lilburn and Nestor (1993) reported carcass lipid levels on a percentage of dry matter basis of 52.4 and 59.2% for a female line and a male line respectively, whereas Renema *et al.* (1994) reported that the carcass lipid content of a population of male line hens was 14% of the whole wet carcass weight. The data in the present trial suggest that the female line hens had a higher percentage total carcass fat and a heavier abdominal fat pad (as a percentage of BW) than the male line hens. Total carcass water content was higher in male line hens than in female line hens (49.4 vs 47.3%, respectively) (Table 3). In summary, at first egg, female line hens had similar protein reserves to male line hens, but had a greater carcass fat content than the male line hens. The primary reason for such differences would appear to be related to relatively greater selection pressure for feed efficiency in the male line birds compared to the female line birds.

Reproductive Organ Development

Birds from both lines first experienced a significant increase in ovary weight from 224 to 227 d of age, which corresponds to 18 and 21 d after photostimulation for the male line birds and the female line birds, respectively (Figure 4). This greater than 200% increase in ovary weight was due to the rapid deposition of yellow yolk to a relatively small number of follicles. The oviduct of the female line had a significant increase in weight from 224 to 227 d, whereas in the male line this occurred from 227 to 230 d (Figure 5). Oviductal development occurred at a

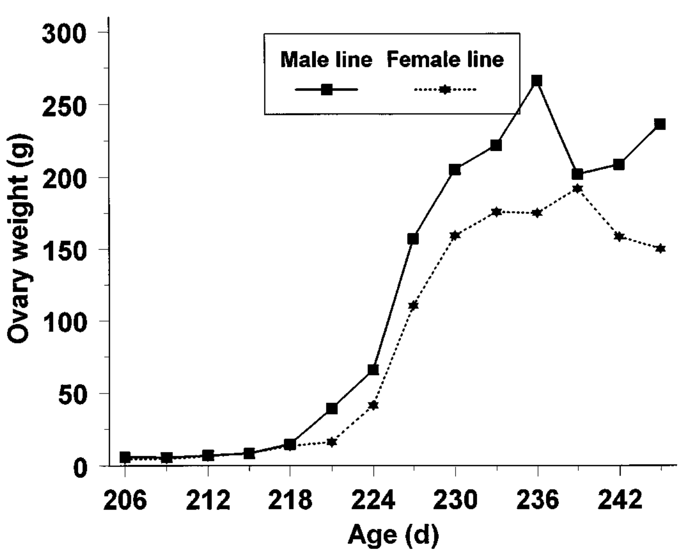

FIGURE 4. Ovary weight of male line and female line turkey hens from photostimulation to 245 d of age. Mean age at first egg was 232 d for the female line hens and 233 d for the male line hens.

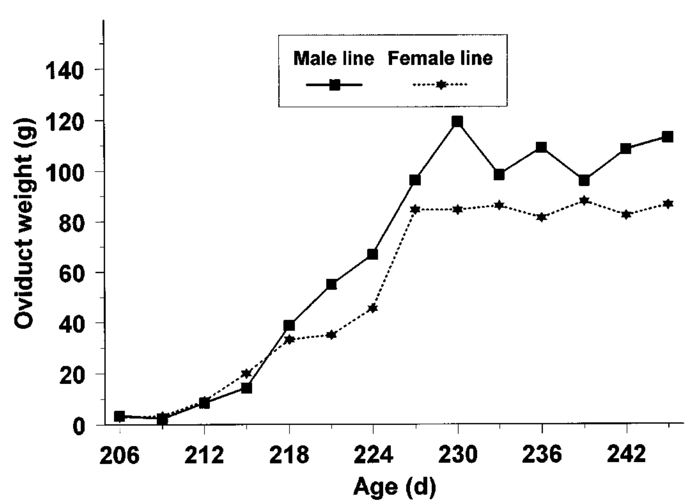

FIGURE 5. Oviduct weight of male line and female line turkey hens from photostimulation to 245 d of age. Mean age at first egg was 232 d for the female line hens and 233 d for the male line hens.

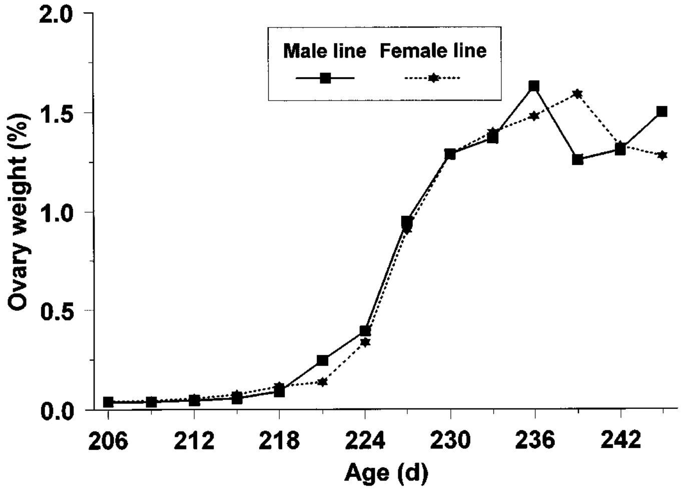

FIGURE 6. Ovary weight as a percentage of BW of male line and female line turkey hens from photostimulation to 245 d of age. Mean age at first egg was 232 d for the female line hens and 233 d for the male line hens.

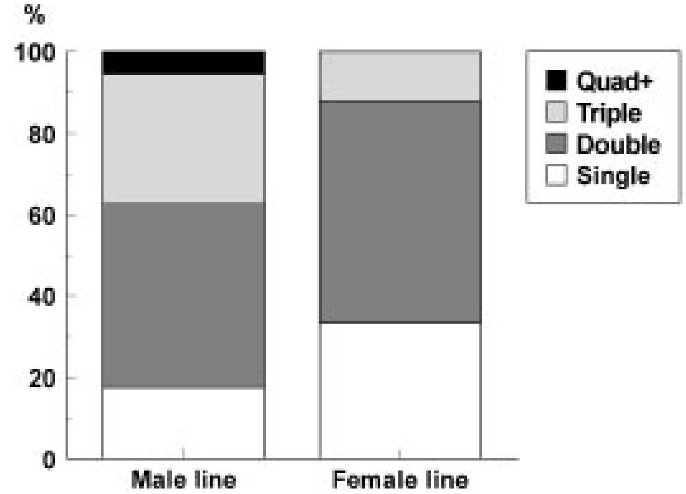

FIGURE 7. Multiple large yellow follicle arrangement in follicular hierarchy of male line and female line turkey hens.

similar rate in both lines, however oviductal growth in the female line reached a plateau at a lower weight. Rapid yolk deposition has previously been reported to occur 4 to 11 d after photostimulation (Bacon and Cherms, 1968). In the present experiment, significant increases in ovary weight occurred 18 d after photostimulation for both lines. The ovary weights as a percentage of BW of the two lines increased at the same rate (Figure 6).

Male line hens had more large follicles than female line hens at first egg (17.4 vs 14.5, respectively). Rapid yolk deposition may be occurring during the 18 d after photostimulation, but possibly not at a sufficient rate to cause significant changes in ovary weight between any 3-d study period. Selection for increased BW may have delayed the rate of yolk deposition (Nestor *et al.*, 1980). Follicles were more likely to be arranged in a multiple hierarchy (as evidenced by two or more follicles within 1 g and 1 mm diameter of each other) in male line hens, as the number of follicles was positively correlated with the proportion of follicles in a multiple arrangement ($r = 0.69$, $P < 0.0001$). At first egg, 83% of large follicles in the male line hens were in a multiple hierarchy, compared to 67% in the female line (Figure 7). For the female line, these levels are higher than the range of 25 to 50% observed in lower BW strains of turkeys (Hocking, 1992; Hocking *et al.*, 1992) and intermediate for the male line with reported ranges of 70 to 98% (Hocking, 1992; Renema *et al.*, 1995). Female line birds had a greater proportion of follicles in a single or double hierarchy arrangement than male line birds (Figure 7), whereas male line birds had a greater proportion of follicles in a triple or quadruple (or larger) hierarchical arrangement than female line birds. With multiple hierarchical arrangements, multiple ovulations are likely to occur (Yu *et al.*, 1992). Multiple ovulations can result in some degree of internal ovulation or in poor shell calcification if more than one developing egg is occupying the shell gland (Hocking *et al.*, 1992; Yu *et al.*, 1992). In the present experiment, the incidence of birds exhibiting signs of internal ovulation was not significantly different between lines (70.8% female line vs 87.5% male line). These values are not in agreement with a low of 13% in egg lines (Bacon *et al.*, 1972) and a range of 23 to 30% in meat lines (Bacon *et al.*, 1972; Renema *et al.*, 1995). Renema *et al.* (1995) theorized that hormonal control of ovulation has been compromised in large turkeys, thereby resulting in less specificity in the timing of ovulation. Internal ovulation may be the result of asynchronicity between the ovary and the oviduct. Erratic laying throughout a 24-h day suggests that ovulation in some hens may not be synchronized to the light period (Pyrzak and Siopes, 1989). It is possible that heavier BW strains are less light sensitive, which may affect the precision of hormonal control over ovulation (Hocking, 1992; Renema *et al.*, 1995).

The number of unreconciled POF seen at first egg was significantly greater in male line hens than in female line hens (3.0 vs 1.6, respectively). Renema *et al.* (1995) reported that male line hens had an average of 4.9 POF at first oviposition. The number of POF was correlated with the incidence of internal ovulation ($r = 0.44$; $P < 0.002$). This suggests that possibly with less hormonal control over time of ovulation, the infundibulum may lack a signal to surround the ovulating ovum, which is thus ovulated into the body cavity. Figures 8a and 9a show the ovary and oviduct as a percentage of the organ weights at first egg for female line and male line birds, respectively. The relative weight of the developing oviduct as a percentage of mature oviduct weight intersected the 100% line earlier than the developing ovary as a percentage of mature ovary weight in both lines. According to the predicted values seen in the polynomial regression, the development of the ovary in the female line was delayed by 3 d compared to the oviduct (Figure 8b), whereas ovarian and oviductal development occurred simultaneously in male line hens at 232 d (Figure 9b).

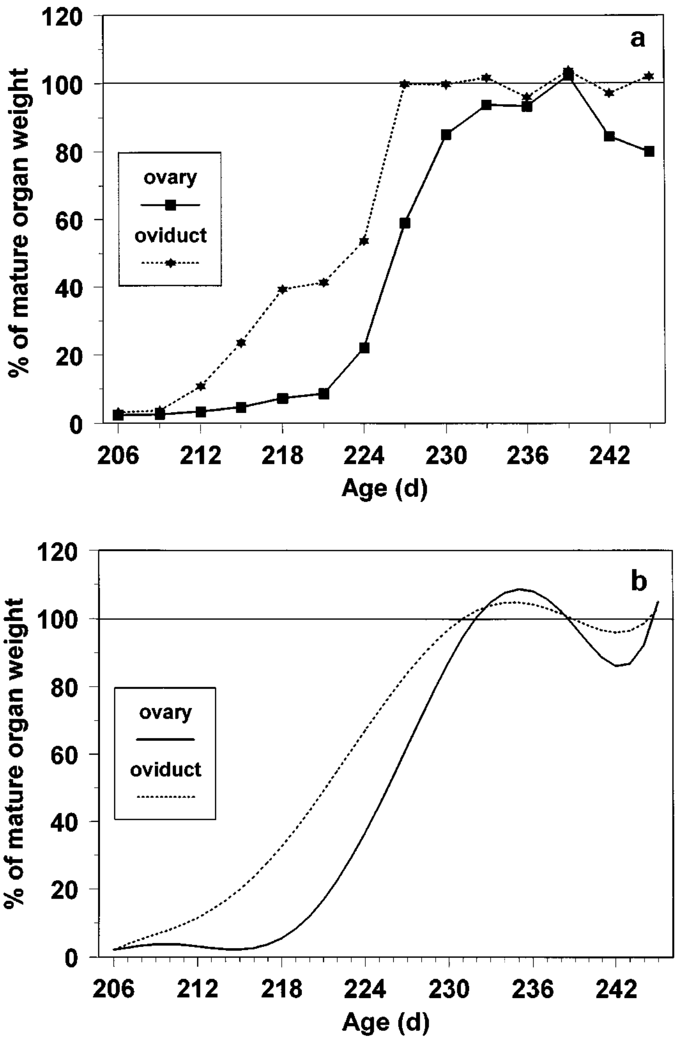

FIGURE 8. a) Ovary weight and oviduct weight as a percentage of mature organ weight in female line turkey hens. b) Predicted values of ovary weight and oviduct weight as a percentage of mature organ weight in female line turkeys.

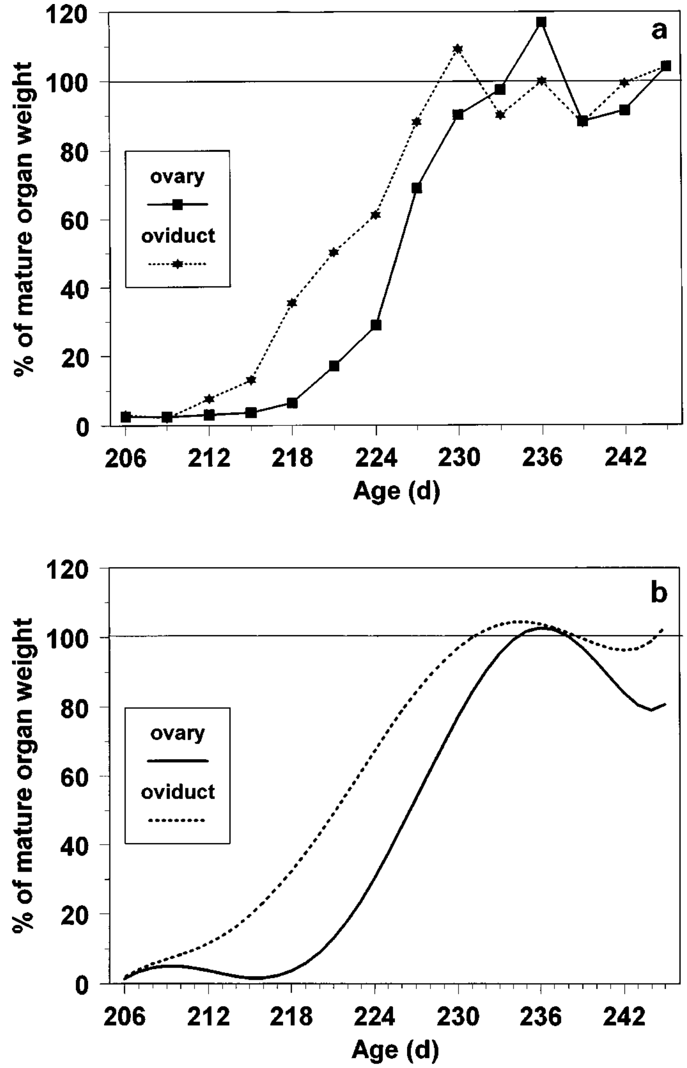

FIGURE 9. a) Ovary weight and oviduct weight as a percentage of mature organ weight in male line turkey hens. b) Predicted values of ovary weight and oviduct weight as a percentage of mature organ weight in male line turkeys.

The processes of ovulation and oviposition first occur when the oviduct and ovary are developmentally mature. If the ovary matures before the oviduct, ovulations can occur, resulting in internal ovulation rather than oviposition. These data indicate that the development of the ovary in male line hens may be accelerated relative to the development of the oviduct. The oviduct of both lines and the ovary of the male line reached their mature weights at 26 d after photostimulation (232 d of age), whereas the ovary of the female line reached its mature weight 3 d later (235 d of age). The female line had fewer unreconciled POF and a numerically lower incidence of internal ovulation compared to the male line. These data suggest that maturation of the ovary 3 d after that of the oviduct in the female line results in successful capture of follicles by the oviduct and subsequent oviposition. Managing male line hens in a manner to accelerate development of the oviduct or slow ovary development may permit breeders to obtain an additional two or three settable eggs. Furthermore, management of male line females in a manner that brings about a reduction in the extent of the multiple hierarchy would seem likely to result in increased egg production. Further research is needed to determine the extent to which management strategies such as lighting programs with gradual, long-term increases in day length may play a role in meeting this objective.

ACKNOWLEDGMENTS

This experiment was conducted at Hybrid Turkeys Inc., Kitchener, ON, Canada. The help and cooperation of Wayne and Debbie Seifried, Dave Johns, Rob Walker, and Sue Wagler at Hybrid Turkey Inc. are gratefully appreciated. Additional support was provided by the University of Alberta Poultry Research Centre and the matching grant program of the Alberta Agricultural Research Institute.

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