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Rearing system effects on live weight gain of Large White turkeys

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Abstract

The aim of this study was to determine the effect of three production systems on live weight gain (LWG) of white turkeys by repeated measures analysis of variance (ANOVA) and profile analysis. A total of 81 turkey poults were assigned to intensive (7 male and 19 female), semi-intensive (9 male and 19 female) and extensive groups (11 male and 16 female) at one day old. The poults were wing-banded at day 1 after hatching and weighed individually each week through 16 weeks old. The birds were managed similarly through eight weeks old. After that time, the intensive group was fed concentrated feed indoors. The birds of the semi-intensive group had access to pasture for eight hours a day, and received 50% of the concentrated feed that was consumed by the intensive group. The birds in the extensive group were kept outdoors with shade and grazed on pasture, but did not receive concentrated feed. The bi-weekly LWG of the extensive, intensive and semi-intensive groups were 1191.4 g, 990.6 g and 872.1 g, respectively. Through the 16 weeks of the trial, the effects on LWG of production system, age, and interaction of age and production system were highly significant (*P* <0.01) in the repeated measures ANOVA. The profile analysis also showed highly significant (*P* <0.01) production system effects and interaction of production system and age on LWG. Scheffe's test indicated that the intensive, semi-intensive, and extensive treatments differed (*P* <0.05).

Keywords: growth, profile analysis, repeated measurement analysis of variance
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Introduction

Turkeys complement other sources of animal protein and are becoming increasingly important to close the gap between consumer demand and supply (Kırkpınar & Mert, 2004; Ekinci, 2015; Küçükbayrak, 2015). The availability in the marketplace of less expensive turkey meat has led to increased production and consumption compared with red meats (Gülaç, 2011). Intensified production systems have resulted in increased live weight and carcass yield, whereas the ability to reduce feed costs by grazing in pasture is another important advantage of turkey production (Ekinci, 2015).

The efficiency of turkey production may be enhanced by their ability to select among dietary ingredients. Erener *et al*. (2006) presented raised rates of gain in turkeys using a free preference system. Live weight daily gain was increased for birds that were choice-fed wheat than for turkey poults that were choice-fed maize. However, Bennett and Classen (2003) suggested that reports of successful exploitation of diet selection were probably from excessive nutrient levels in the diet, instead of whole grains.

Various statistical methods have been applied to analyse LWG over time. Repeated measures ANOVA is the classical method (Krueger & Tian, 2004). Its implementation as a general linear mixed model accommodates missing data. Profile analysis is an extension of repeated measures ANOVA in which slopes between adjacent weights are compared. It was used previously to assess the influence of three lighting programmes on American Bronze turkeys (Mendes *et al*., 2005). Thus, the aim of this study was to compare two methods of data analysis, namely repeated measures ANOVA and profile analysis in assessing the effects of three production systems (intensive, semi-intensive and extensive) on LWG of turkeys over time.

Materials and methods

Bingöl University Experimental Animals Ethics Committee reviewed and approved this project (BAP-88-220-2014).

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A total of 81 turkey poults were assigned to intensive (7 male and 19 female), semi-intensive (9 male and 19 female) and extensive groups (11 male and 16 female) at one day old. The poults were wing-banded with a unique identification number on the day after hatching, and were weighed weekly through 16 weeks old. The birds of the intensive group were fed concentrated feed indoors. The semi-intensive group had access to pasture for eight hours a day and received 50% of the concentrated feed that was consumed by the intensive group. The extensive group were kept outdoors with shade and grazed on pasture, but did not receive concentrated feed.

The experimental unit comprised turkeys in the production system, and observations of their LWG were recorded at two-week intervals. Thus, there were three levels of production system and eight levels of age. Because repeated measures result from the serial measurement of a single characteristic (e.g., live weight) on an experimental unit (Field, 2013), a repeated measure ANOVA (Montgomery, 2013) was used to analyse the differences in live weight across the ages of the birds. In this analysis, the mathematical model was:

$$Y_{ijk} = \mu + A_i + C_{k(i)} + B_j + AB_{ij} + \varepsilon_{m(ijk)}$$

where: Y_{ijk} = LWG of the kth turkey that had been subjected to treatment i at age j;
μ = the overall mean LWG;
A_i: = the fixed effect of production system i;
$C_{\mathrm{k(i)}}$ = the random effect of bird k within production system i (error A for testing production system effects);
B_{j} = the fixed effect of age j;
AB_{ij} = the interaction of production system i with age j; and
$\varepsilon_{m(\mathrm{ijk})}$ = the difference between the observations and their expectation based on the model (error B for testing age and age by production system interaction effects).

These data were also analysed using profile analysis (Cronbach & Gleser, 1953; Stanton & Reynolds, 2000). This analysis is the multivariate equivalent of the repeated measures ANOVA. Statistical assumptions implied required in profile analysis are i) multivariate normal distribution of the response variables (Jarek, 2012), ii) homogeneity of their variance-covariance matrices (French *et al*., 2015) and iii) linear relationships among them (Tabachnick & Fidell, 2015).

The differences between the groups were determined by Scheffe's multiple comparison test (Şenoğlu & Acıtaş, 2010). Scheffe's procedure treats the mean square for any single contrast if it had the degrees of freedom of the between groups mean square (Oehlert, 2010).

Effect sizes were calculated to determine whether statistically significant results were large enough to be practically important (Mendes, 2013). The effect size (η^2) was defined as:

$$\eta 2 = \frac{SS_{effect}}{SS_{effect} + SS_{error}}$$

where: SS_{effect} = the sums of squares for the effect of interest, and
SS_{error} = the sums of squares for the associated error term (Tabachnick & Fidell, 2015).

All data analyses were conducted with SPSS 22.0 (IBM Corp., Armonk, New York, USA).

Results and Discussion

The significance of the interaction of production system with age indicated that the turkeys grew at different rates over time. Thus in interpreting these data, the effects of age and production system need to be considered jointly. For these data, the age effects on live weight were compared within production system and the effects of production system were compared within age. Age had the largest effect, although the effects of production system and interaction were substantial and more similar to each other. The repeated measures ANOVA table is shown in Table 1.

Table 1 Analysis of variance for repeated measurements of live weight gain of turkeys managed in intensive, semi-intensive and extensive production systems

Source	SS	df	MS	F	*P*-value	η^2
Production system (PS)	11015497	2	5507749	74.9	<0.001	0.512
Error A	10500377	78	134620			
Weeks of age (A)	173123778	7	24757392	336.9	<0.001	0.791
PS*A interaction	44468384	14	3176313	43.2	<0.001	0.492
Error B	45859369	624	73493			

SS: sum of squares, df: degrees of freedom, MS: mean square, η^2: effect size

Differences between groups were not expected through the eighth week, because the poults were all kept indoors., However, LWG was highest for birds allocated to the extensive system at the 2nd, 4th, 6th, 8th, and 16th weeks, for those allocated to the intensive system at the 10th and 14th weeks, and for those in the semi-intensive system at week 12 (Table 2). The greater performance of birds that were subjected to the extensive environment might have resulted from the allocation of more males to that group. At the eighth week, when the birds pf the semi-intensive and extensive groups were provided outdoor access, their performance showed a marked decrease, which might have resulted from adaptation to the new environmental circumstances. Other than this two-week period, the turkeys in the intensive and semi-intensive systems generally grew at an increasing rate over the experiment. However, the LWG of turkeys in the extensive system remained lower at 10 - 12 and 12 - 14 weeks. At the 16th week, the turkeys in the intensive production system were heavier than those in the semi-intensive and extensive systems. Turkeys in the extensive system were lightest at the end of the experiment.

Table 2 Bi-weekly growth rates of turkeys managed in intensive, semi-intensive and extensive production systems

Weeks	Production system		
	Intensive (N = 26)	Semi-intensive (N = 28)	Extensive (N = 27)
0 - 2	165.4 ± 7.2	176.1 ± 6.9	190.0 ± 7.0
2 - 4	426.2 ± 17.6	453.9 ± 17.0	459.8 ± 17.3
4 - 6	899.5 ± 31.0	851.2 ± 29.9	906.7 ± 30.4
6 - 8	1388.2 ± 42.0	1321.7 ± 40.4	1519.2 ± 41.2
8 - 10	1806.8 ± 44.1	624.9 ± 42.5	96.7 ± 30.6
10 - 12	1422.2 ± 59.2	1476.9 ± 57.1	890.4 ± 58.1
12 - 14	1390.8 ± 76.5	1375.6 ± 73.7	830.3 ± 75.0
14 - 16	2031.9 ± 91.4	1644.7 ± 88.1	2083.4 ± 89.7

Estimates of the correlations between the bi-weekly observations of LWG are presented in Table 3. They averaged 0.15. In repeated measures ANOVA, equivalence of covariance matrices within treatments were assumed for valid tests of significance. In the present experiment, Box's test for equivalence of the covariance matrices indicated that they were homogeneous (F = 1.02, *P* = 0.11). Levene's test indicated the residual variances were homogenous at each age (*P* =0.96–*P* =0.08).

Table 3 Estimates of correlation between measurements of bi-weekly live weight gain of turkeys managed in intensive, semi-intensive and extensive production systems

Weeks	2 - 4	4 - 6	6 - 8	8–10	10 - 12	12 - 14	14 - 16
0 - 2	0.370**	0.417**	0.173	-0.219*	-0.036	-0.169	0.266*
2 - 4	1	0.602**	0.377**	-0.163	0.083	-0.091	0.129
4 - 6		1	0.485**	0.064	0.132	-0.029	0.271*
6 - 8			1	-0.133	0.000	0.026	0.434**
8 - 10				1	0.504**	0.408**	0.111
10 - 12					1	0.463**	-0.059
12 - 14						1	-0.247*
14 - 16							1

* P <0.05, ** P <0.01.

An alternative to repeated measures ANOVA is profile analysis. Profile analysis asks three questions about the data (Rencher, 2002). In the context of this experiment, the questions were these. i) Do the birds in the production systems respond equally over time? ii) Do the production systems respond in a parallel way over time? iii) Are the responses to the production systems constant over time? Four alternative test statistics were used to test the multivariate hypotheses, namely Pillai's trace, Wilks' lambda, Hotelling's trace and Roy's largest root.

The first of the questions could be addressed by a simple comparison of means across all time points for each of the systems. This is equivalent to the test of production system effects in the repeated measures ANOVA. The birds in the intensive system had an average bi-weekly increase in live weight of 1191.4 g, which was significantly greater than the average LWG of 990.6 g attained by the birds in the semi-intensive system, which was significantly greater than the average bi-weekly increase in live weight of 872.1 g for birds in the extensive system.

The question of parallel responses was addressed by the multivariate test of the interaction of production system effects with age. Each of the four tests of significance led to the same conclusion: growth rates over time were not parallel for the three systems. The results of the multivariate test of the production system by age interaction effects are presented in Table 4

Table 4 Multivariate tests of significance of the production system by age interaction effects on bi-weekly live weight gain of turkeys

Test statistic	value	F	df_n	df_d	*P*-value	η^2
Pillai's trace	1.477	29.446	14	146	<0.001	0.982
Wilks' lambda	0.033	46.377	14	144	<0.001	0.982
Hotelling's trace	13.874	70.361	14	142	<0.001	0.982
Roy's largest root	12.651	131.930	7	73	<0.001	0.982

df_n: degrees of freedom for the numerator of the F statistic, df_d: degrees of freedom for the denominator of the F statistic, η^2: effect size

Finally, the question of responses being constant over time was addressed by the multivariate test of age effect (Table 5). Again, each of the four test statistics led to the general conclusion that LWG was not constant over time.

Table 5 Multivariate tests of significance of age effects on bi-weekly live weight gain of turkeys

Test statistic	value	F	df_n	df_d	*P*-value	η^2
Pillai's trace	0.982	551.202	7	72	<0.001	0.738
Wilks' lambda	0.018	551.202	7	72	<0.001	0.818
Hotelling's trace	53.589	551.202	7	72	<0.001	0.874
Roy's largest root	53.589	551.202	7	72	<0.001	0.927

df_n: degrees of freedom for the numerator of the F statistic, df_d: degrees of freedom for the denominator of the F statistic, η^2: effect size

The profile graph is presented in Figure 1. The lines with different slopes at various points in time suggest a significant effect for parallelism (the groups have different LWG profiles for age). The variations in slope are great, ranging from large positive to large negative values, and thus explain the highly significant effect that was found for the production system by age interaction or equivalently the parallel patterns of LWG across production systems.

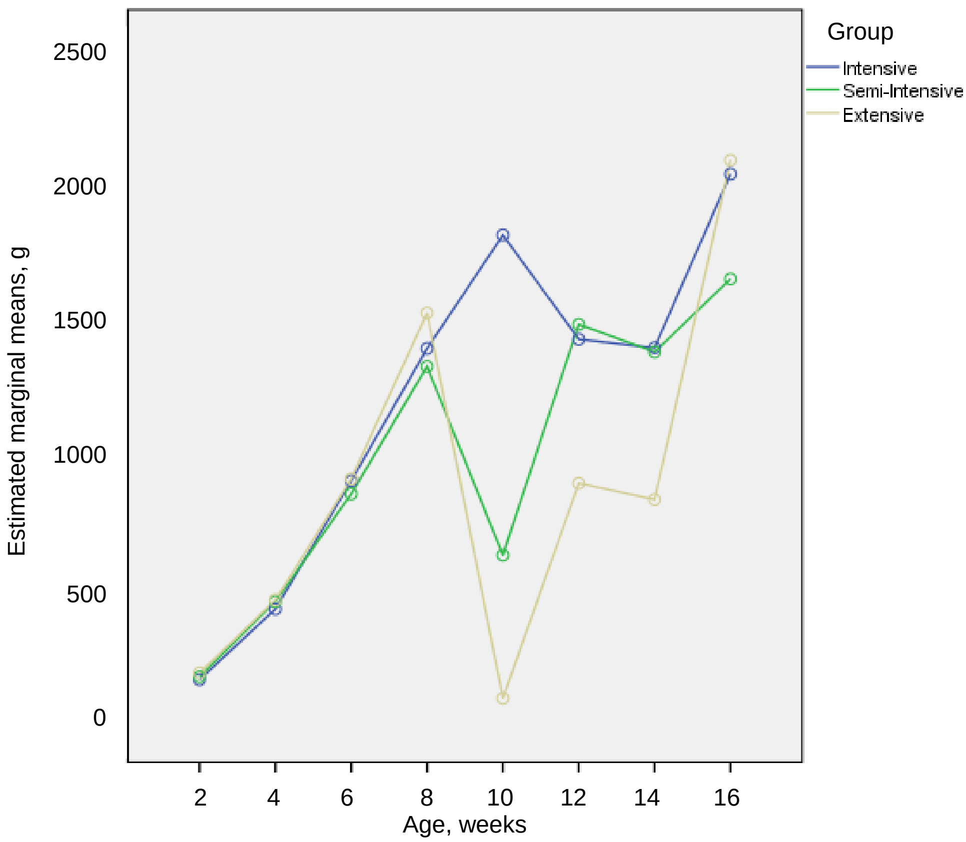

Figure 1 Profile plot detailing live weight gains attained by turkeys in intensive, semi-intensive and extensive production systems

In Ersoy *et al*. (2006) bronze turkey poults were fed a starter diet from hatch to 7 weeks old, then a grower diet in weeks 8 and 9, followed by a grower diet at 25 per cent of the previous level and ad libitum wheat for another two weeks, after which the birds were grazed on pasture. They found that males birds grew at a bi-weekly rate of 671.8 g between weeks 11 and 16, while females grew at a rate of 490.6 g over the same age interval. Karki (2005) and Oblakova *et al*. (2008) likewise documented substantial effects of sex on the growth of turkeys through 16 weeks old. Thus a sex effect may explain why the extensively managed group, with the greatest number of male turkeys assigned to it, had higher LWG during the in first eight weeks than the other two groups in this study.

Ersoy *et al*. (2007) found that between 1 and 10 weeks old, turkeys grew from an average weight of 98.6 g to 2179.5 g, indicating a bi-weekly LWG of 208.1 g. Similarly, Sharma *et al*. (2018) observed an average bi-weekly rate of LWG 216.3 g. Ersoy *et al*. (2007) reported that from 11 to 24 weeks old, tom turkeys increased in weight from 2228.0 g to 7754.9 g ,and hen turkeys increased in weight from 1847.6 g to 5541.1 g. These changes in weight implied an average bi-weekly LWG of 709.3 g, which was less than the level of performance that was achieved in the production systems in the present study.

In documenting differences among varieties, Işguzar (2003) reported that commercial white turkeys grew at a bi-weekly rate of 1308.8 g from hatching to 14 weeks old and that bronze turkeys grew at a bi-weekly rate of 624.8 over the same period. In evaluating two strains of commercial turkeys (British United Turkey and Nicholas), Brenøe and Kolstad (2000) observed that the strains did not differ in live weight with an average bi-weekly LWG of 1584.4 g between 4 and 17 weeks old, a value which was slightly higher than the performance that was achieved in the intensive production system of the present study.

Ad libitum or limit-feeding methods may be applied in feeding turkeys (Tumova *et al*., 2002; Mejia *et al*., 2010; Mejia *et al*., 2011; Sgavioli *et al*., 2013). Cetin *et al*. (2001) indicated that feed could be restricted to turkeys at up to 14% of ad libitum without lowering LWG. When the turkeys were grazed for eight hours a day, significantly decreased feed consumption was observed compared with the intensive system and therefore the semi-intensive system may be more economical (Özer & Özbey, 2013). Grimes *et al.* (2007) also stated that turkeys could be raised on pasture once they reached 1.5 and 2 months old.

Karki (2005) found the optimal age at slaughter was 16 weeks, which was consistent with the endpoint of the present study. The effects of compensatory growth in turkey (Tumova *et al*., 2002) may offset some of the adverse impacts of the environmental change at the eighth week when the birds allocated to the semi-intensive and extensive treatments were provided outdoor access. However, termination of this study at 16 weeks old did not result in full compensation for the change in environment.

Conclusions

Repeated measures ANOVA and profile analysis produced similar results in the analyses of the data from this study. However, because the effect sizes were consistently greater for the profile analysis compared with repeated measures ANOVA, profile analysis was deemed preferable. The interaction of production system with age was particular apparent when the turkeys were first provided with outdoor access. At 16 weeks old, turkeys that were managed intensively were heaviest.

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Authors' Contributions

HI, BS and TS contributed to the project idea, design and execution of the study. AYS and HI were in charge of laboratory analyses. HI, BS, SC and MI were responsible for supervising and writing the manuscript.

Conflict of Interest Declaration

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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