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Body mass index slopes of growth and fat content under different feed restrictions in broiler chickens

Zusammenhang zwischen dem Body Mass Index und dem Anstieg des Wachstums sowie des Körperfettgehaltes bei Broilern für verschiedene Futterrestriktionsprogramme

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Introduction

Most Body Mass Index (BMI = kg/m^2) studies are done in humans to measure obesity (Must et al., 1991). Obese livestock or poultry are rare, however, crossbreeding of broiler chickens for growth has increased growth rate but rapid growth has been accompanied by a number of negative consequences, including an increase in fat deposition (Griffin, 1996; Zerehdaran et al., 2004). Decreased fat content may be desired in meat products and this can be provided with decreased BMI. Ringdorfer, (2001) reported that heavy Boer x Saanen goat kids had higher levels of kidney fat than light kids. In addition, feed restriction or similar stressful situations may make the BMI a useful parameter. Pala et al., (2005) reported that over-conditioned goat kids (high BMI) were affected more severely from weaning stress compared to low BMI kids. The authors stated that overfeeding kids until weaning may waste valuable milk in dairy goats. The same can be stated for poultry, if *ad libitum* feeding results in similar weights as in restricted feeding. In addition, restricted feeding may increase the meat's market value by improving its leanness. An optimum feeding regime can benefit the producer by shaving the costs related to feeding as opposed to *ad libitum* feeding. Mendes et al. (2007) reported that male broilers fed *ad libitum* had higher BMI values compared to male broilers with restricted feeding.

Larger BMI values are associated with increased morbidity and mortality in adulthood and there are significant correlations between BMI values in childhood and in adulthood (Guo et al., 1994). This may suggest that birds with high BMI in week one may have steeper slopes due to accelerated growth, or those hatched smaller may have faster development. There is a positive correlation of birth weight and later weights in livestock (Milligan et al., 2002; Quiniou et al., 2002; Rehfeldt and Kuhn, 2006) and a positive correlation between hatchling weight and chick growth (Wilson, 1991).

Rehfeldt and Kuhn, (2006) reported that in the majority of low birth weight piglets, low numbers of muscle fibers differentiate during prenatal myogenesis and those with reduced fiber numbers are unable to exhibit postnatal compensatory growth. In contrast, Pala et al., (2005) showed that lighter goat kids had a compensatory growth after weaning. The BMI values in the first week may be an indication of the carcass quality and later growth, both in terms of carcass fat content and BMI. Early parameters may help distinguish animals better, and costs can be decreased with early selection because the light animals can be culled early without the expenses of feeding and maintenance.

Major purpose of this study was to investigate the effects of gender, feeding group, period and first week BMI values and first week weight on growth. Investigating these effects may provide evidence of feeding restriction effects on growth of chickens. The other purpose of this study was to investigate some chemical properties including fat content, dry matter and acidity.

Materials and Methods

The data for this study was collected from 60 Ross 308 line male and female chickens. The birds were divided into three groups: *ad libitum* (AD) group, the group with the 20% feed restriction based on *ad libitum* groups (RF), and the group that was not fed between 9 am and 3 pm (NF). There were 10 males and 10 females in each group. Feed restriction was applied to the chickens between seven days of age to 21 days of age. Starting from 22 days, all the groups were switched to *ad libitum* feeding until day 43. The animals were raised under intensive conditions with an artificial lighting program of 23 hour light and one hour dark (23L: 1D). The experimental rooms were designed for 18 chickens/m^2. Artificial light was controlled by a time clock. The temperature of the room was 33 Celsius degrees in the first two weeks, 30 Celsius degrees in the third week, and 27 Celsius degrees in the fourth week and 24 Celsius degrees in the fifth and sixth weeks of the study. Nipple drinkers and round feeders were used to satisfy the water and feed requirement of the chickens. Birds were fed with a starter diet between 0-3 weeks and with a growth diet between 4-5 weeks and with a finisher diet in the last week of the trial. The starter, grower and finisher diets of the animals included 24.09% crude protein and 2818 kcal/ME, 25.32% crude protein and 2892 kcal/ME, 22.38% crude protein and 2912 kcal/ME, respectively. The daily body weights (g) of male and female chickens were collected from 7 days of age to 42 days of age. Initial body weight and body weight change of chickens were measured by weighing the birds every day using a balance with five g. preci-

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sion. The animals were slaughtered at week six (43 days of age) of the trial. Three males and three females from each group were slaughtered. In these birds, rump and breast percent fat contents, acidity (lactic acid percent) and dry matter (percent) were analyzed in laboratory.

PALA et al., (2005) reported that analyses specifying random model and covariance structures did not have an advantage over an approach where slopes were manually calculated and analyzed as data using ordinary least squares. Effects of first week Body Mass Index (BMI= weight (g)/(height^2) on slopes were investigated (Equation 1). The body length was used as height. Regression lines were fit for each animal using proc REG of SAS V8 and the slopes were analyzed using proc MIXED in SAS V8 (SAS INSTITUTE INC., 1999). The slopes were calculated using weights and BMI values. Analyses using the slopes calculated from weights included the first week weight and first week BMI as the covariate. Analyses using the slopes calculated from BMI values included first week BMI as the covariate.

Statistical model used was:

$$Y_{iklm} = \mu + A_i + B_k + AB_{ik} + C_l + AC_{il} + BC_{kl} + ABC_{ikl} + D_m + e_{iklm} \quad (1)$$

where;

Y_{iklm} = individual slopes calculated from regression of weight on age or from regression of BMI on age.
μ = Overall population mean,
A_i = fixed effect due to group (fasting, feed restriction, *ad libitum*),
B_k = fixed effect due to gender (male, female),
AB_{ik}= group by gender interaction,
C_l = fixed effect due to period (weeks 1, 2, 3 are period 0 and weeks 4, 5, 6 are period 1),
AC_{il}= group by period interaction,
BC_{kl} = gender by period interaction,
ABC_{ikl} = group by gender by period interaction,
D_m = covariate, first week weight or first week BMI,
e_{iklm} = random error term assumed to be normally and independently distributed with mean of zero and variance σ^2_e.

The error term was assumed to be normally and independently distributed because slopes were used as the dependent variable. All two way and three way interactions were included in the model. Tukey multiple comparison test was used to determine differences (TUKEY, 1953).

Repeated measurement analyses (Eq. 2) were used to test whether the rump and breast regions were different for percent fat content, acidity and dry matter. The tests were also performed for the differences between the feeding groups and the interactions of group by body part. Bonfferoni multiple comparison test was used to determine differences. Statistical model used was:

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \pi_{l(ij)} + \gamma_k + \alpha\gamma_{ik} + \beta\gamma_{jk} + \alpha\beta\gamma_{ijk} + \gamma\pi_{kl(ij)} + \varepsilon_{m(ijkl)} \quad (2)$$

Where,

Y_{ijkl} : observed value for percent fat content, acidity and dry matter in kth region of lth chicken of jth gender in ith group,
μ : overall population mean,
α_i : effects of ith group (i=1, 2, 3),
β_j : effects of jth gender (j=1, 2),
$\alpha\beta_{ij}$: group by gender interaction,
$\pi_{l(ij)}$: random effect of the animal l in ith group and jth gender,
γ_k : effect of kth region (k=1=rump, k=2 breast),
$\alpha\gamma_{ik}$: group by region interaction,
$\beta\gamma_{jk}$: gender by region interaction,
$\alpha\beta\gamma_{ijk}$: group x region x gender interaction,
$\gamma\pi_{kl(ij)}$: animal l by region interaction in ith group and jth gender,
$\varepsilon_{m(ijkl)}$: random error term (WINER et al., 1991)

Results

The regression coefficient of first week BMI values on slopes was -0.276±0.023 (P<0.001). The birds with lower BMI values in the first week, those that are smaller, may have steeper growth curves when growth is measured in BMI. The AD group had the steepest slopes followed by RF and the NF group (Table 1, Figure 1). Differences between AD and RF (P=0.006), AD and NF (P=0.001), and RF and NF (P=0.001) were significant. The figure supports these results. This indicates that feeding practices affect growth curves when measured in terms of BMI. Differences between the genders were non-significant. Differences between the periods were large (P<0.001), indicating the changes in the feeding regime after day 21st affected the acceleration of BMI values. Interestingly, the second period BMI increase was lower than the first period BMI increase in all the feeding groups. Overall, BMI slopes

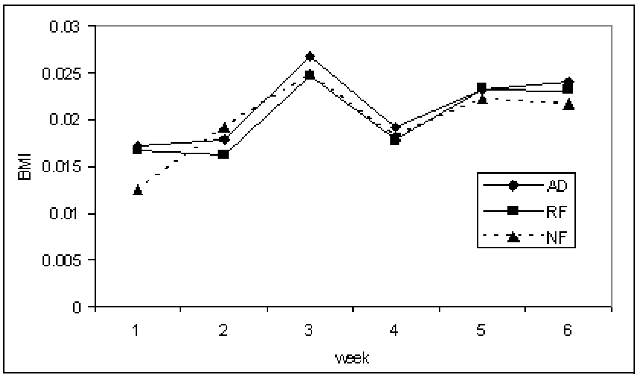

Figure 1. BMI by feeding groups over the experimental period
BMI für die Fütterungsgruppen über die Versuchsdauer

Table 1. Least Squares Means of slopes calculated by regression of BMI on age, for feeding group, gender and period
LSQ Means des Anstiegs des BMI für die Fütterungsprogramme, das Geschlecht und die Mastperiode, berechnet anhand der Regression zum Alter

Group				Gender			Period		
AD	RF	NF	SE^x	Male	Female	SE^x	0	1	SE^x
0.0041^a	0.0037^b	0.0031^c	0.0001	0.0036^a	0.0036^a	0.0001	0.0050^a	0.0023^b	0.0001

^{x} Pooled standard error based on most conservative number in a feeding, gender, or period group.
^{a,b,c} Row values with different superscripts differ (P < .05).

dropped from 0.005 to 0.002. The group by period interaction was significant and the drop was most pronounced in the NF group, dropping from 0.0053 to 0.0009. The RF group had the least amount of drop, from 0.004 to 0.003 (Table 1). Though males had faster growth compared to the females, the differences were non-significant.

The regression coefficient of first week weight on the slopes was 0.602±0.267 (P=0.024). Birds that are lighter in the first week may have steeper growth curves. Effects of first week BMI on weight slopes were negative, -5.58±3.5 and non-significant (P=0.679). In terms of weight, the AD group had the steepest slopes followed by RF and the NF group (Table 2). All differences were highly significant. This indicates that the fasting group (NF) grew slowest while the *ad libitum* group grew fastest. Differences between the genders were significant (P=0.010) and males were heavier than females. In contrast to BMI, the slopes calculated from the weights were steeper (P<0.001) during the second period, which is composed of 4th, 5th and 6th weeks.

The group by period interaction was significant also (P<0.001). Growth of the NF group, as determined by slopes, increased 3.31 times between the periods, followed by the RF group with 3.27 times and the AD group with 2.96 times. The feeding groups were affected in different manners; the group rankings changed for periods and for weight or BMI measure (Table 3). The AD group grew fastest in terms of weight during the first period while its BMI was close to the NF group. During the transition, it lost its advantage to the RF group though its drop was not as bad as the NF groups drop. BMI slopes indicated the RF group was advantageous over the other groups because it had the least amount of drop between periods and the situation was similar for RF when growth was measured in terms of weight slopes. The NF group had the highest growth in terms of BMI during the first period but had the smallest growth in terms of weight. Both measures indicated that the NF group was behind the other two groups because it could not adapt to the second period as much as the other groups and its BMI had the largest drop compared to the other groups (Table 3).

Differences between breast and rump were large enough to be significant in acidity and dry matter (Table 4; P=0.00). When both regions are considered, differences among the groups were non-significant for dry matter. However, the NF group meat had higher acidity and the differences were significant (P<0.05).

For the percent fat content, group by body part interaction was significant (P=0.046). This means that the differences between the fat content of the body parts changed according to feeding group (Table 5). Differences for percent fat content were significant between the AD and the other two groups while the differences between RF and NF were non-significant in the rump. In breast, RF differed from AD and NF while the differences between AD and NF were non-significant. Overall, the AD group meat had more fat percentage compared to the other groups and the differences were significant (P<0.05).

The RF group had the highest feeding efficiency (1.70) followed by AD (1.96) and NF (2.22). These numbers indicate the feed required per kg of body weight increase.

Discussion

Growth of the NF group, as determined by weight-slopes, increased the most, followed by the RF group and the AD group when going from weeks 1, 2 and 3 (period 0) to weeks 4, 5 and 6 (period 1). This indicates that weight is affected by the feeding regime. Although the NF group birds had a larger jump between the periods, their slopes increased insufficiently and persisted below the other groups. Overall, the AD and RF groups grew fastest and adapted better to the changes in the periods. The RF group had a smoother pass to the second period for BMI while the AD group was advantageous for weight. The restricted feeding group was the most consistent in terms of BMI slopes, experiencing a 0.001-point drop only, while the other groups dropped 4-5 times as the RF group. This could be because the RF group was fed in an optimum regime and they experienced less stress when the feeding regime changed in the middle of the experi-

Table 2. Least Squares Means of slopes calculated by regression of weight on age, for feeding group, gender and period.
LSQ Means des Anstiegs des Lebendgewichts für die Fütterungsprogramme, das Geschlecht und die Mastperiode, berechnet anhand der Regression zum Alter

Group				Gender			Period		
AD	RF	NF	SE^x	Male	Female	SE^x	0	1	SE^x
383.4^a	366.6^b	302.1^c	16.1	357.7^a	343.7^b	3.85	168.5^a	532.9^b	3.85

^{x}Pooled standard error based on most conservative number in a feeding, gender, or period group.
^{a,b,c}Row values with different superscripts differ (P < .05).

Table 3. Least Squares Means of slopes calculated by regression of BMI or weight on age for feeding group by period interaction.
LSQ Means des Anstiegs des BMI oder des Lebendgewichts für die Interaktion Fütterungsprogramm x Mastperiode, berechnet anhand der Regression zum Alter

group*period for BMI						group*period for weight					
AD0	AD1	RF0	RF1	NF0	NF1	AD0	AD1	RF0	RF1	NF0	NF1
0.0052^a	0.0029^b	0.0043^c	0.0030^b	0.0053^a	0.0009^d	193.7^A	573.0^B	171.7^A	561.5^B	140.1^A	464.2^C

^{a,b,c,d}Row values with different superscripts differ for BMI (P < .05).
^{A,B,C}Row values with different superscripts differ for weight (P < .05).

Table 4. Descriptive statistics for acidity and (dry matter) of parts (%)
Deskriptive Statistik für den Gehalt an Milchsäure und (Trockensubstanz) in den Teilstücken (%)

Groups		$\bar{x} \pm S_{\bar{x}}$	Rump + Breast
AD	Rump	0.871± 0.005[b] (28.3±0.97)[A]	0.992±0.006[b] (27.2±0.67)[A]
	Breast	0.121±0.008[a] (26.2±0.38)[B]	
FR	Rump	0.862±0.002[b] (28.7±0.57)[A]	0.979±0.002[b] (27.7±0.45)[A]
	Breast	0.117±0.007[a] (26.7±0.32)[B]	
NF	Rump	0.946±0.003[b] (28.6±0.38)[A]	1.069±0.004[a] (27.6±0.38)[A]
	Breast	0.123±0.003[a] (26.6±0.38)[B]	

[a,b]Column values with different superscripts differ for acidity (P < .05).
[A,B]Column values with different superscripts differ for dry matter (P < .05).

Table 5. Descriptive statistics for fat percent
Deskriptive Statistik der Verfettung (%)

Groups		$\bar{x} \pm S_{\bar{x}}$	Rump + Breast
AD	Rump	8.33± 0.62a	8.77±0.61[a]
	Breast	0.44±0.05B	
FR	Rump	6.50±0.65b	7.51±0.75[b]
	Breast	1.01±0.19A	
NF	Rump	6.97±0.56b	7.71±0.62[b]
	Breast	0.73±0.18B	

[a,b]Column values with different superscripts differ for acidity (P < .05).

ment, week 4. Deaton, (1995) reported that early feed restriction improved feed conversion in terms of grams of feed per body weight. Özdoğan, (2002) investigated effects of feed restriction with three groups including *ad libitum*, 8 hours of restricted feeding and alternating feeding regime groups. The author reported that feed efficiencies for the three groups were 1.95, 1.91 and 1.93, respectively. These numbers are very close to the results of this research in terms of feed efficiency, which were 1.70 for the RF group followed by 1.96 for the AD and 2.22 for the NF group.

Differences between the genders were significant for weight slopes and males were heavier than females while the differences were non-significant for BMI slopes. This indicates that males were heavier than females but the body lengths were not as different as weights. Kul et al., (2006) investigated weight differences for gender in Japanese quail and reported that the differences were large enough to be significant.

The weight slopes were steeper during both periods while BMI slopes decreased during the second period. This means that the weights kept increasing after the third week while body length growth slowed down drastically. Kul et al., (2006) wrote that growth period affects fattening performance and carcass characteristics.

Restricted feeding resulted in increased fat content in the breast area while decreasing fat content in the rump area. This is useful because increasing fat in the breast, which has little or no fat, improves taste, and decreasing fat in the rump, which has a high fat percentage, improves the health value of the meat. Shahin and Elazeem, (2005) reported that increasing crude protein fiber in diet resulted in lowering proportion of total fat in breast and thigh, but increasing proportion of total fat in drumstick and wing. In this research, when both regions were considered, the AD group meat had the highest fat percentage. Shahin and Elazeem, (2005) reported that increasing both protein and fiber in the diet lowered overall carcass fat, raising muscle to fat ratio.

Conclusion

The AD group had the steepest slopes followed by RF and NF group for BMI and the differences were significant. Similarly, fat percentage was higher in the AD group compared to the RF and the NF groups and the differences were significant. These results indicate that BMI may be used as one of the indicators for body fat. The result was the same for weight slopes, the AD group grew fastest followed by RF and NF. This suggests that heavy animals tend to have higher BMI values and fat percentage, especially with *ad libitum* feeding. Though RF and NF groups were both leaner than the AD group, RF group birds were more efficient in converting feed to meat compared to the NF group. Feeding birds *ad libitum* may result in wasting valuable feed in poultry increasing the costs and decreasing meat quality in terms of fat.

Summary

Major purpose of this study was to investigate the differences between three feeding regimes, namely *ad libitum* (AD), %20 restricted feeding based on *ad libitum* (RF) and fasting between 09.00 AM and 15.00 PM (NF), for Body Mass Index (BMI) and weight slopes and for percent fat content in broiler chickens. The data was collected from 60 Ross 308 line male and female chickens. BMI and weight slopes were calculated for each bird and were analyzed as data using ordinary least squares in addition to repeated measures analysis for acidity, dry matter and fat percent. The regression coefficient of first week BMI values on slopes was -0.276 ±0.023 (P<0.001). The AD group had the steepest slopes followed by RF and the NF group when the slopes were calculated using BMI values (P<0.01) or when the slopes were calculated using weight (P<0.01). The regression coefficient of first week weight on the slopes was 0.602 ± 0.267 (P=0.024) and that of first week's BMI on weight slopes was -5.58 ± 3.5 (P=0.679). Differences between breast and rump were significant in acidity and dry matter (P=0.00). Overall, the AD group meat had more fat percentage compared to the other groups and the differences were significant (P<0.05). These suggest that heavy

animals tend to have higher BMI values and fat percentage, especially with *ad libitum* feeding.

Key words

Broiler, growth curve, body mass index, fat

Zusammenfassung

Zusammenhang zwischen dem Body Mass Index und dem Anstieg des Wachstums sowie des Körperfettgehaltes bei Broilern für verschiedene Futterrestriktionsprogramme

Das Ziel der vorliegenden Studie war, die Auswirkungen verschiedener Fütterungsprogramme (AD – ad libitum, RF – 20% Restriktion im Vergleich zu AD, NF – Nüchterung zwischen 09.00 und 15.00 Uhr) auf den Body Mass Index (BMI), den Wachstumsverlauf und die Verfettung von Broilern zu untersuchen. Hierzu wurden 60 männliche und weibliche Ross 308 Broiler verwendet. Der BMI und der Wachstumsverlauf wurden für die einzelnen Tiere berechnet und anschließend mittels mehr-faktorieller Varianzanalyse ausgewertet. Zur Auswertung des Gehaltes an Milchsäure, Trockensubstanz und Fett in den Teilstücken wurde eine Repeated Measures Analyse durchgeführt.

Der Regressionskoeffizient zwischen dem BMI in der ersten Lebenswoche und dem Wachstumsverlauf betrug -0,276±0,023 (P<0,001). Die Behandlung AD zeigte den steilsten Anstieg, gefolgt von den Behandlungen RF und NF, wenn der Anstieg anhand des BMI (P<0,01) oder anhand des Gewichts (P<0,01) berechnet wurde. Die Regressionskoeffizienten zwischen dem Gewicht in der ersten Lebenswoche und dem Anstieg betrugen 0,602±0,267 (P=0,024) sowie zwischen dem BMI in der ersten Lebenswoche und dem Gewichtsverlauf -5,58±3,5 (P=0,679). Brust und Rumpf unterschieden sich signifikant im Gehalt an Milchsäure und Trockensubstanz (P=0,00). Insgesamt wiesen die Tiere die Behandlung AD im Vergleich zu den anderen Behandlungen einen signifikant höheren Fettgehalt auf (P<0,05). Dies deutet darauf hin, dass schwerere Tiere vor allem bei ad libitum Fütterung einen höheren BMI und eine höhere Verfettung als leichtere Tiere aufweisen.

Stichworte

Broiler, Wachstumskurve, Body Mass Index, Fett

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