Europ.Poult.Sci., **78.** 2014, ISSN 1612-9199, © Verlag Eugen Ulmer, Stuttgart. DOI: 10.1399/eps.2014.60

The impact of slaughter age on performance, carcass traits, properties of cut-up pieces of carcasses, and muscle development in broiler chickens

Einfluss des Schlachtalters auf Leistung, Schlachtkörpermerkmale, Eigenschaften der Teilstücke und Entwicklung der Muskeln bei Broilern

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Manuscript received 15 May 2014, accepted 23 July 2014

Introduction

In parallel with the increased demand for cut-up carcass pieces and processed products, the production of broiler chickens with good carcass traits, in other words, with high body weight, has also increased. As a result of the targeting of higher growth rates and breast meat yields in broiler chicken production, standard broiler chickens are reared for longer time periods (Baéza et al., 2012).

In broiler chicken production, the extension of the growth period affects profitability, due to several reasons, including altered feed conversion rates and reduced numbers of broiler chickens being able to be reared per unit area.

Meat quality has always been a major factor, which defines consumer preference. In line with the changes that have occurred in consumer preferences, in recent years, chicken meat has started to be presented in the form of cut-up pieces and processed products rather than as whole carcasses. Thus, the quality traits of cut-up pieces, including breast fillets, whole legs, chicken leg special and chicken drumsticks, have gained increased importance, and quality criteria such as colour, texture and pH have attained greater importance. The colour of poultry meat, which varies with the myoglobin level contained in the muscle tissue, depending on species, genotype, age and muscle type (Joo et al., 2013), is a quality attribute, which influences consumer preference. The water-holding capacity affects both the texture and tenderness of raw meat and the sensory properties of cooked meat. Drip loss and pH value are further quality criteria of poultry meat and are affected by several factors, including among others, pre-slaughter conditions, feeding and genotype. Alterations in the pH value of the muscles at the time of slaughter and the pH value of the carcass following slaughter define the level of drip loss. Furthermore, meat texture is defined by growth, slaughter and carcass traits of broiler chickens, and also by the muscle width and volume of connective tissue produced, depending on the level of growth (Bouton et al., 1975).

This study aimed at investigating the effects of slaughter age on profitability, in relation to feed consumption and growth levels and carcass traits, cut-up pieces of carcasses and meat quality criteria.

Material and method

The trial was conducted at the Poultry Unit of the Research Farm of Ataturk University, Faculty of Veterinary Medicine. The animals were reared in accordance with the Guidelines of the Canadian Council on Animal Care, for the duration of the trial (Canadian Council on Animal Care, 1993). Seventy seven day-old male Ross 308 broiler chicks, obtained from a commercial hatchery, were used in the study.

During the first six days, the chicks were maintained in a brooder. As from day 7, the chicks were randomly allocated to 1.0 × 1.0 m ground pens, of which the floor was covered with a 10 cm layer of wood shavings. During the first seven days of the trial, the animals were subjected to continuous lighting (24L 0D), whereas between days 7–56, the

lighting schedule was changed to 23L:1D. The pens were ventilated mechanically. The average pen temperature was 32˚C in the first week and was then gradually lowered to an average of 24˚C.

Up to day 42, the trial was conducted using 7 compartments, each containing 11 broilers (11 broilers/m^2), whereas from day 42 to 56, 7 compartments, each containing 9 broilers (9 broilers/m^2) were used. Thereby, the body weight per square meter was maintained below 34 kg throughout the trial.

The animals included in the trial were fed on a broiler chick starter diet (240 g/kg CP; 12 g/kg Lysin (Lys); 5 g/kg Methionine (Met); 9 g/kg Met + Cysteine (Cys); 12.9 MJ/kg) between days 1–21 and on a broiler chicken growing diet (200 g/kg CP; 10 g/kg Lys; 4 g/kg Met; 7.5 g/kg Met + Cys; 13.4 MJ/kg) between days 22–56. Throughout the trial period, the animals were provided with *ad libitum* feed and water.

Calculation of the Performance Values

Body weight and feed consumption values were measured on a weekly basis (1 g sensitivity). No mortality occurred throughout the trial.

Contribution Margin/Broiler

The equation given below was used for the calculation of the income. Body weight and total feed consumption values, estimated by the Gompertz growth model, were used. The fixed costs included the chick price, taxes, veterinary drug expenses, cost of litter and elimination of used litter, and energy, water, depreciation and repair expenses. When calculating the annual income, the sum of the total production period and the 15-day suspension period for cleaning and disinfection was divided by 365 days to determine the number of production cycles. The number of cycles was multiplied by the income calculated for each batch (Exchange rates: /€= 0.73482).

Income = (body weight kg × 1.003 €) –((feed consumption kg × 0.292 €) + (fixed costs 0.611 €)), (FAO, 2010).

Slaughter

On days 42 and 56, two chickens from each group, and in total 28 broiler chickens, were slaughtered with an aim to determine the carcass traits. The feed was withdrawn 12 h prior to slaughter, but the broiler chickens had free access to water until slaughter. After being electrically stunned, the animals were manually bled by severing the jugular vein, and bled out for 120 seconds. After the carcasses were scalded at 54°C for 30 s, the feathers were picked mechanically with the use of inline commercial defeathering equipment. Later, the carcasses were washed with cold water and drained for 10 minutes (YALCIN et al., 1999). After evisceration, the carcasses were stored at 4°C for 24 h, and then dissected (BARBUT, 2002).

pH analyses

pH values were measured using a portable pH meter (SCHOTT L 6880, Lab Star pH). pH measurements were performed by thrusting the probe of the pH meter into the breast muscle.

Colour measurement

The colour measurements were carried out using a tristimulus colorimeter (Minolta Chroma Meter Measuring Head CR-200, Minolta, Osaka, Japan). The device was used to objectively measure CIE-Lab values (L* measures relative lightness, a* relative redness and b* relative yellowness). Chroma (Cor*) is referring to colourfulness. Hue angle (h*) is'how we perceive an object's colour', for example, as 0^0 +a* (red), 90^0 +b* (yellow), 180^0 – a* (green) and 270^0 -b* (blue). Both chroma and hue are derived from a* and b* by using the following equations.

$Cor^* = \sqrt{(a^*)^2 + (b^*)^2}$

$h^* = \tan^{-1}(b^*/a^*)$

Before each measurement, the apparatus was standardized against a white tile. The colorimeter readings (L*, a* and b*) were always measured from the same points on the carcass surfaces (breast, leg) for all of the carcasses.

Drip Loss

Breast fillets were harvested from the carcasses stored at 4°C for 24 h, and their weights were measured. Samples taken from these breast fillets were placed in a netting bag and then suspended in an inflated watertight nylon bag, ensuring that the sample did not make contact with the bag and was sealed. After storage at chill temperature (4°C), the meat samples were taken out of the bag, dried with a paper towel and weighed again. The same samples were used for further drip loss measurements throughout a 9-day storage period, but in every case, the initial weight was used as the reference point. Drip loss is expressed as a percentage of the initial weight.

Histological analysis and tissue preparation

On days 42 and 56, tissue samples were taken from the superficial pectoral and biceps femoris muscles of 10 slaughtered chickens, immediately after killing and fixed in 10% neutral formaldehyde solution for 72 hours. After fixation, the tissue samples were dehydrated in an increasing gradient of alcohol concentrations, cleaned with xylene, and embedded in paraffin blocks. The paraffin blocks were cut into 5-mm-thick transverse sections. The sections of all the groups were stained with haematoxylin-eosin for stereological analysis.

Stereological estimation of muscle transverse area using the nucleator method

Useful techniques for estimating the transverse area of interesting tissues have been produced using isotropic uniform random sectioning (Unal et al., 2010). The histological sections were placed on a motor-driven stage attached to a microscope and tissue sections were projected onto the monitor via camera at x200 magnification. Each clearly defined muscle fascicle with predominant staining was examined by systematic sampling in a stepwise manner, moving the microscope stage from left to right and then down and across to avoid measuring the same muscle fascicle again. The transverse areas of muscles fascicules were estimated for each histological tissue section using the software Stereo Investigator (Microbrightfield Stereo Investigator software v. 9.0, Microbrightfield, Williston, VT). The transverse areas of interesting section obtained from *M. Pectoralis superficialis* and *biseps femoris* muscles tissue was estimated using the nucleator method following the formula:

$$Ta_{(N)} = \frac{4\pi}{3} l_n^3$$

Where $Ta_{(N)}$ is the number-transverse areas of muscle fascicles, l is length of intercepts, and n the number of nucleator estimates.

Certain requirements for obtaining full randomness in the section-sampling stage while estimating the volume of the small objects by the nucleator method have been mentioned in literature (Gundersen, 1988). The histologic muscle sections were obtained in the transverse plane without randomness in orientation and area calculations were applied as described by Dorph-Petersen (Dorph-Petersen et al., 2004).

Statistical evaluation

Winsor (1932) introduced the usage of the Gompertz as a growth function to explain the growth curve. This growth curve model was more fitted to body weight-age data of poultry than other non-parametric regression models, such as Richards, Logistic, Brody, and Von Bertalanffy, (Alkan et al., 2009, Kizilkaya et al., 2005). The daily body weight gain and daily feed conversion rate of the broiler chickens were estimated using the Gompertz growth model, which is a non-linear regression model. By multiplying the estimated daily feed conversion rate by the estimated daily body weight gain, the total feed consumption up to a given day was calculated.

$$Wt = Wmax * \exp(-b * \exp(-k * t))$$

The mathematical notations used in the model were as follows: Wt: The body weight measured at age t; Wmax: Maximum body weight at maturity; b: The initial body weight, k: The growth rate; t: The number of days post-hatching.

The slaughter and carcass traits were compared with the independent samples t-test. The areas of the superficial pectoral and biceps femoris muscles were analysed by using the general linear model and the repeated measures procedure. The statistical analyses were done by SPSS programme (SPSS, 2003).

Results

The parameters calculated for the daily body weight gains were as follows: Wmax = 7156 ± 574, b = 5.038 ± 0.157, k = 0.037 ± 0.002 and R^2 = 0.996. The parameters calculated for the feed conversion rates were as follows: Wmax = 17.0, b = 2.832, k = 0.007 and R^2 = 0.740. The daily body weight gains, feed conversion rates and estimated incomes calculated on the basis of these parameters are given in Figure 1. The body weights were estimated as 2467 and 3794 g on days 42 and 56, respectively. The feed conversion rates increased with age. The estimated incomes per batch for slaughter at 42 and 56 days of age were calculated as 0.379 €/chicken and 0.414 €/chicken, respectively. The income per batch increased progressively and reached its maximum level on day 49 (0.450 €/chicken), and displayed a tendency to decrease thereafter. On a yearly basis, the income was calculated to be highest between days 46 and 49 (0.256 €/chicken) (Figure 1).

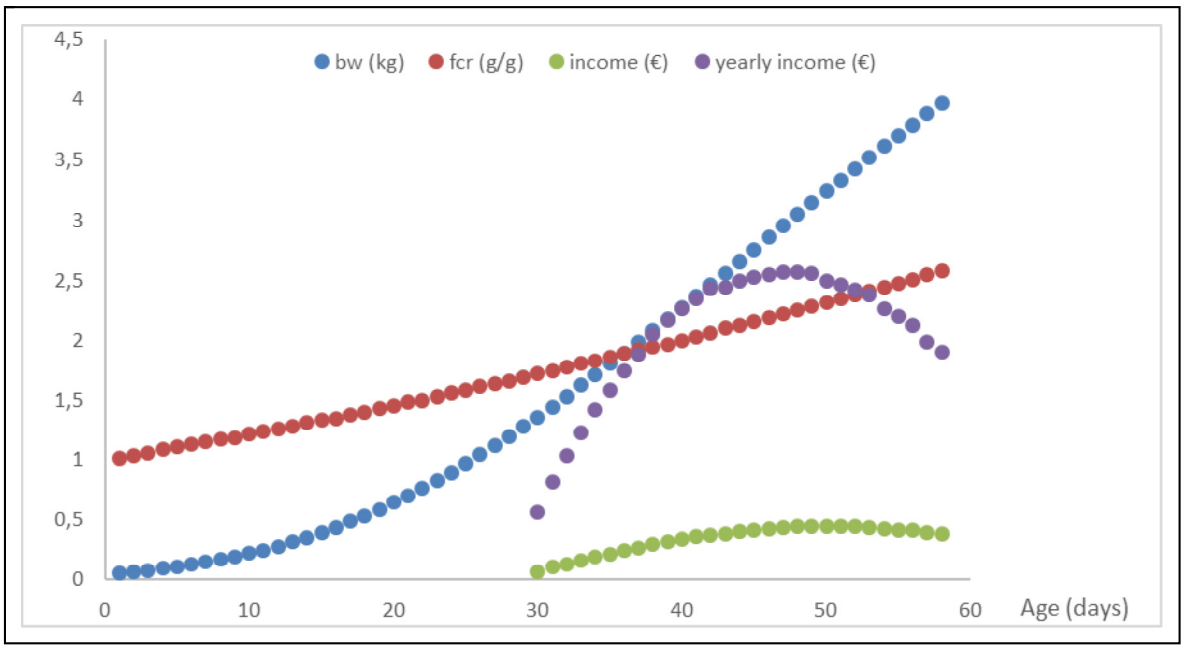

Figure 1. Live weight gain, feed efficiency and economic impact of slaughter age of broiler chickens

BW (kg): Estimated live weight (kg)

FCR (g/g): Estimated feed conversion ratio (g/g)

Income (€): Income derived at a batch (€/chicken)

Yearly income (€): 10* Income derived at a year (€/chicken)

Lebendmassezunahme, Futterverwertung und ökonomische Bedeutung des Schlachtalters bei Broilern

The weights of the animals slaughtered at 42 and 56 days of age were measured as 2435 g and 3690 g, respectively. It was determined that the carcass yield was higher by the end of the extension period ($P < 0.05$). While the blood weight (%) was observed to have decreased with the extension of the growth period ($P < 0.01$), the feather and heart weights (%) were observed to have increased ($P < 0.01$) (Table 1).

Table 1. Effect of slaughter age on the slaughter traits of chickens (mean ± SE; n = 14)

Einfluss des Schlachtalters auf die Schlachtmerkmale der Broiler (Mittelwert ± SE; n = 14)

	42nd day	56th day	
	X ± $S_{\bar{x}}$	X ± $S_{\bar{x}}$	P
Body weight before slaughter (g)	2435 ± 33.6	3690 ± 79.3	0.001
Hot carcass weight (g)	1791 ± 24.6	2768 ± 70.0	0.001
Blood (%)	4.34 ± 0.142	3.30 ± 0.117	0.001
Head (%)	2.56 ± 0.094	2.32 ± 0.058	0.071
Feather (%)	5.52 ± 0.140	6.51 ± 0.179	0.001
Offals (%)	5.00 ± 0.187	4.64 ± 0.193	0.195
Gizzard (%)	2.14 ± 0.107	2.27 ± 0.103	0.380
Liver (%)	1.79 ± 0.049	1.96 ± 0.085	0.098
Feet (%)	4.09 ± 0.072	4.10 ± 0.107	0.933
Heart (%)	0.55 ± 0.030	0.85 ± 0.087	0.005

The comparison of the cold carcass yields of the carcasses stored at + 4°C for 24 h demonstrated that the losses in the chickens slaughtered at 42 and 56 days of age were 0.68% and 0.10%, respectively. It was observed that in the chickens slaughtered on day 42 the neck yield (%) was higher ($P < 0.01$), while the leg yield (%) was lower ($P < 0.01$). No difference was determined to have occurred in the yields (%) of the wings, tail and breast meat with the extension of the growth period (Table 2).

Table 2. Effect of slaughter age on the carcasses and cut-up pieces of carcasses (mean ± SE; n = 14)

Einfluss des Schlachtalters auf die Schlachtausbeute und Teilstückanteile der Broiler (Mittelwert ± SE; n = 14)

	42nd day	56th day	
	X ± $S_{\bar{x}}$	X ± $S_{\bar{x}}$	P
Hot carcass yield (%)	73.6 ± 1.34	75.0 ± 1.21	0.001
Cold carcass yield (%)	72.9 ± 1.27	74.9 ± 1.32	0.001
Neck (%)	5.77 ± 1.00	4.84 ± 0.56	0.001
Whole Wing (%)	11.2 ± 0.69	10.9 ± 0.55	0.090
Whole Legs (%)	39.2 ± 1.67	41.4 ± 1.07	0.001
Tail (%)	1.11 ± 0.22	1.00 ± 0.15	0.083
Whole Breast (%)	45.0 ± 1.13	44.1 ± 1.13	0.062

Whole breast: Total weight of breast fillets, skin and upper portion with bone of breast fillets (front back).
Whole legs: Total weight of thigh, drumsticks and hind back.
Whole wing: Total weight of wing drumette, winglet and wing tip.

The measurements demonstrated that at 24 h post-slaughter the ultimate pH value was lower in the carcasses of the broiler chickens slaughtered at 56 days of age, compared to those slaughtered at 42 days of age ($P < 0.01$). The two groups were observed not to differ for drip loss ($P > 0.05$). Of the meat quality parameters, the redness (a*) and Cor* values of the breast meat, and the hue values of the legs were found to be lower in the carcasses of the broiler chickens slaughtered at 56 days of age ($P < 0.05$) (Table 3).

Table 3. Effect of slaughter age on meat characteristics of chickens (mean ± SE; n = 14)

Einfluss des Schlachtalters auf die Merkmale der Fleischqualität der Broiler (Mittelwert ± SE; n = 14)

	42nd day	56th day	
	X ± $S_{\bar{x}}$	X ± $S_{\bar{x}}$	P
pHu	6.15 ± 0.033	6.02 ± 0.021	0.005
Drip Loss	1.84 ± 0.082	1.89 ± 0.137	0.774
Breast L* value	54.50 ± 0.717	54.24 ± 0.812	0.818
Breast a* value	3.12 ± 0.277	2.01 ± 0.282	0.011
Breast b* value	6.48 ± 0.534	4.97 ± 0.546	0.064
Breast cor* value	7.29 ± 0.544	5.08 ± 0.575	0.012
Breast h* value	64.36 ± 1.928	66.57 ± 2.800	0.523
Leg L* value	58.20 ± 0.344	58.19 ± 1.240	0.992
Leg a* value	4.05 ± 0.203	4.39 ± 0.335	0.400
Leg b* value	5.54 ± 0.310	5.64 ± 0.597	0.884
Leg cor* value	6.91 ± 0.291	5.84 ± 0.589	0.122
Leg h* value	53.09 ± 1.502	46.48 ± 2.395	0.031

Based on the data presented in Table 4, it was ascertained that the width of the breast and leg muscles had increased with age. The percentage of increase was determined as 20.7% for the breast muscles and as 25.5% for the leg muscles. Measurements showed that on day 42, the width of the breast muscle was 13.2% greater than that of the leg muscle, while on day 56 this difference was at a level of 7.66% (Figure 2).

Table 4. Effect of slaughter age of chickens on estimation of the areas of the superficial pectoral and biceps femoris muscles by the stereological nucleator method (µm²; mean ± SE; n = 50).

Einfluss des Schlachtalters auf die anhand der stereologischen Nukleatormethode geschätzten Flächen des *Musculus pectoralis superficialis* und des *Musculus biceps femoris* (µm²; Mittelwerte ± SE; n = 50)

	42nd day	56th day	P
Superficial pectoral m.	1949 ± 34.2	2459 ± 34.9	0.001
Biceps femoris m.	1692 ± 56.8	2271 ± 35.7	0.001

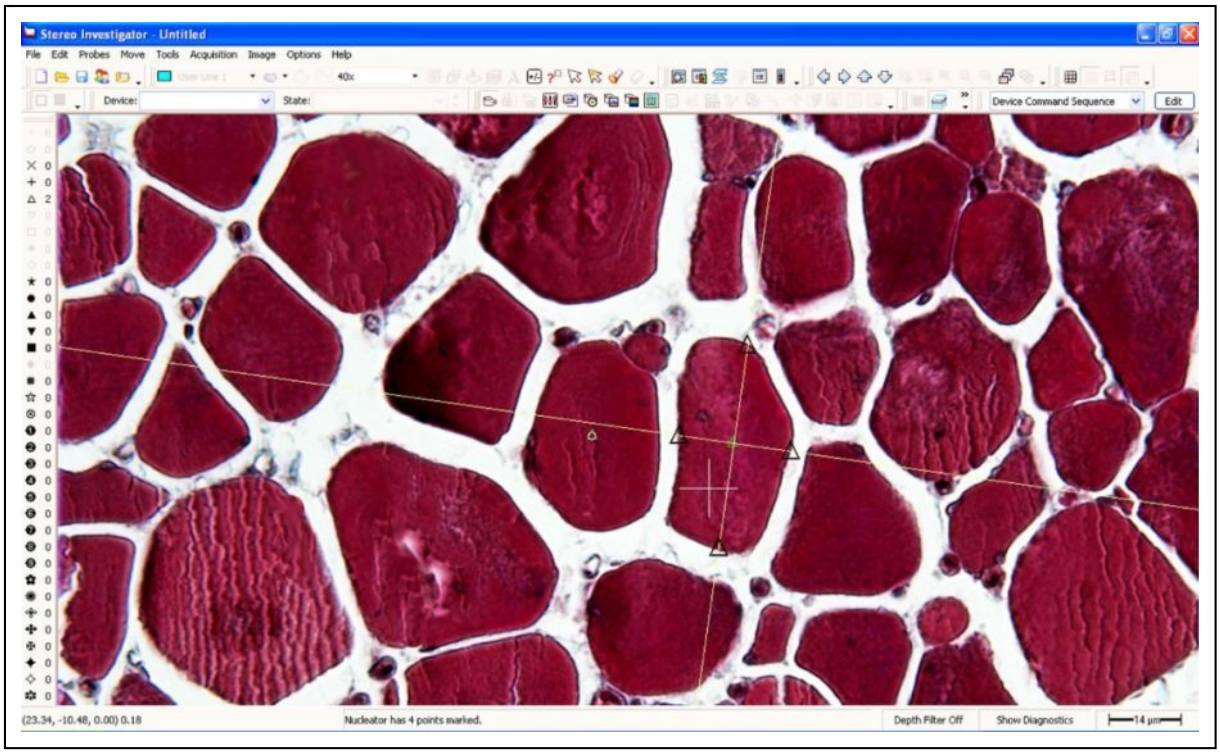

Figure 2. Illustration of the myofibre areas of the superficial pectoral and *biceps femoris* muscles of broiler chickens by using the stereological nucleator method

Illustration der Myofibrillen-Flächen des *Musculus pectoralis superficialis* und des *biceps femoris* von Broilern anhand der stereologen Nukleatormethode

Discussion

In previous research on growth performance of broiler chickens, it has been indicated that maximum income is obtained with 42 to 49-day-old broiler chickens, and that profitability decreases with extended growth periods (BAÉZA et al., 2012). Similarly, it has been suggested that the highest profitability is achieved with growth up to 49 days and that profitability decreases as from 49 days of growth.

Some researchers have suggested that while percentage of breast yields decrease percentage leg yields do not change with increased slaughter age (BERRI et al., 2005). On the other hand, POŁTOWICZ (2012) reported that the percentage of leg yield increased with increased slaughter age. Furthermore, YOUNG et al. (2001) indicated that the yields of all carcass parts, excluding wings and drumsticks, increased with advanced slaughter age. In the present study, it was observed that neck yield decreased, leg yield increased and yields of other parts of the carcass did not change with the extension of the growth period.

Muscle weight is the function of the total number of fibrils, the fibril cross-sectional area and the fibril length. Therefore, in broiler chickens, among animals of the same age, those with a greater muscle weight are considered to have a greater number of fibrils of a greater width and length. In chickens, the increase in the number of muscle fibrils occurs during the period just before hatching. As a result, an increase in muscle weight after hatching depends to a large extent on the increase in the width and length of the muscle fibrils (SWATLAND, 1984). Correlation coefficients determined for the fibril area of the superficial pectoral muscle and age, body weight, breast weight and percentage breast yield have been reported as 0.87, 0.74, 0.74 and 0.79, respectively (CHEN et al., 2007). BAÉZA et al. (2012) reported that the fibril cross-sectional area increased by 49% with the extension of the growth period from 42 days to 56 days. In the present study, it was determined that the extension of the growth period from 42 days to 56 days resulted in an average increase of 23% in the fibril cross-sectional areas of the superficial pectoral and biceps femoris muscles.

The pHu values of the broiler chickens slaughtered at 42 days of age were found to be higher than those of the broiler chickens slaughtered at 56 days of age. This finding complied with the report of BERRI et al. (2005). It has been reported that 7 h after slaughter the pH values of carcasses belonging to 24 h younger broiler chickens were higher

than those of carcasses belonging to older animals (KARAOĞLU et al., 2006). Previous reports suggest pHu values to increase with advanced slaughter age (BAÉZA et al., 2012). It has also been reported that increase in fibre cross-sectional area was associated with increased pHu values (BERRI et al., 2007). On the other hand, JANISCH et al. (2011) indicated that slaughter age did not alter pHu values.

Some researchers have indicated that as slaughter age increases, lightness and drip loss values decrease (BAÉZA et al., 2012). Furthermore, it has been reported that an increase in the fibre cross-sectional area of the superficial pectoral muscle was associated with a decrease in drip loss and lightness values, while no change was observed in the redness and yellowness values (BERRI et al., 2007). BERRI et al. (2005) reported that in broiler chickens slaughtered on days 42 and 56 of the growth period, only the redness value of the leg meat decreased with increased slaughter age while lightness and yellowness did not change. POŁTOWICZ (2012) indicated that slaughter age did not have any effect on carcass colour or drip loss rate. Similarly, SMITH et al. (2002) suggested that slaughter age had no influence on meat colour.

In the present study, it was determined that in the superficial pectoral muscle the a* (redness) ($P < 0.05$), b* ($P > 0.05$) and cor* ($P < 0.05$) values had decreased with the extension of the growth period. This result is in agreement with the report of KURNOTH et al. (1994) showing that the capillary density decreased with muscle growth. PAPINAHO et al. (1996) reported a correlation coefficient between the a* value and capillary density of 0.275. It is considered that in older broiler chickens the a* and cor* values decrease as a result of reduced colour intensity arising from an increase in muscle width and a parallel decrease in capillary density.

Conclusions

In conclusion, the present study demonstrated that the growth period of broiler chickens could be extended up to 49 days. It was ascertained that as from 42 days of age the width of the leg muscles increased at a higher rate when compared to that of the breast muscles. In support of this finding, it was observed that of the carcass parts the yield of the legs had increased. While no difference was observed between the trial groups for water-holding capacity, it was ascertained that the loss in the first 24 hours after slaughter, was higher in the carcasses of the broiler chickens slaughtered at a younger age. The results demonstrated that the slaughter age affected the colour parameters of the breast meat (a* and cor* values) and h* value of the leg meat.

Summary

This study aimed at investigating the impact of increased slaughter age on profitability, growth performance, carcass traits and cut-up pieces of carcasses in broiler chickens. For this purpose, 77 day-old male Ross 308 chicks were used. Parameters, pertaining to broiler chickens slaughtered at 42 and 56 days of age, were compared. Using the weekly body weight and feed consumption data of the animals the daily body weight gains and feed conversion rates of the broiler chickens were estimated by the Gompertz growth model. Accordingly, it was calculated that the highest profit per batch would be obtained with broiler chickens slaughtered at 49 days of age (0.450 €/chicken). From 50 days of age, profitability was reduced as a result of decreased body weight gain and increased feed conversion rates. The carcass yield of the broiler chickens slaughtered at 56 days of age was ascertained to be 1.4% higher. In broiler chickens slaughtered at 42 and 56 days of age the mean area of the superficial pectoral muscle was determined as 1,950 μm^2 and 2,460 μm^2, respectively, while the mean area of the biceps femoris muscle was determined as 1,692 μm^2 and 2,271 μm^2, respectively. With increased slaughter age, the neck yield (%) decreased and leg yield (%) increased ($p < 0.01$). Slaughter age was also observed to have an effect on the redness of breast meat ($P < 0.01$).

Key words

Broilers, age, economic analysis, histological parameters, meat quality, carcass quality

Zusammenfassung

Einfluss des Schlachtalters auf Leistung, Schlachtkörpermerkmale, Eigenschaften der Teilstücke und Entwicklung der Muskeln bei Broilern

Das Ziel der Studie war die Untersuchung des Einflusses eines zunehmenden Schlachtalters auf die Wirtschaftlichkeit, die Wachstumsleistung, einige Schlachtkörpermerkmale und die Anteile der Schlachtkörperteile bei Broilern. Hierzu wurden 77 männliche Eintagsküken der Herkunft Ross 308 verwendet. Die Parameter wurden am 42. und 56. Lebenstag erfasst und verglichen. Die tägliche Lebendmassezunahme und die Futterverwertung der Broiler wurden mittels Gompertz-Funktion aus der wöchentlichen Gewichtszunahme und Futteraufnahme geschätzt. Für die Broiler, die am 49. Lebenstag geschlachtet wurden, wurde die höchste Wirtschaftlichkeit (0,45 €/Tier) ermittelt. Ab dem 50. Lebenstag nahm die Wirtschaftlichkeit auf Grund der zurückgehenden Zunahmen und der sich verschlechternden Futterverwertung ab. Die Schlachtausbeute war am 56. Lebenstag um 1,4% höher. Die Fläche des *Musculus pectoralis superficialis* betrug am 42. Lebenstag 1.950 µm² und am 56. LT 2.460 µm². Die entsprechenden Werte für den *M. biceps femoris* lagen bei 1.692 µm² bzw. bei 2.271 µm². Mit zunehmendem Schlachtalter nahmen der Halsanteil ab und der Schenkelanteil zu. Das Schlachtalter wirkte sich ferner auf den Rotton des Brustmuskels aus.

Stichworte

Broiler, Alter, Ökonomie, Histologie, Fleischqualität, Schlachtkörperqualität

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