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Higher slaughter weight affects broiler meat quality and bird welfare

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ABSTRACT

An experiment was conducted to determine the influence of increasing broiler's slaughter weight on, carcass characteristics, meat quality, sensory evaluation, immunity, and welfare. Commercial strain "Vencobb-430" chicks (n=280) were randomly distributed among eight groups consisting of 35 chicks in each. The experimental birds were fed on commercial maize soya-based basal diet. The broiler chicks were reared for up to 48 days and slaughtered at a different live body weight of 1.0-1.2, 1.5-1.7, 2.1-2.2, 2.5-2.7, 2.8-3.0 and 3.3-3.5 (i.e 24, 28, 34, 39, 42 and 48-day slaughter day). The results revealed that dressing and breast % were significantly (P<0.001) increased whereas the giblet % significantly decreased with increasing slaughter age. The cooking yield in chicken meat reflected an increasing trend after 2.1-2.2 kg broiler slaughter weight. L*, a* and b* values of meat were significantly increased with increased slaughter weight. Significantly highest water holding capacity was recorded in 3.3-3.5 kg slaughter weight.The shear force, H/L ratio, and serum corticosterone values were significantly increased from 1.0-1.2 kg to 3.3-3.5 kg in broiler birds. Once the birds attended the slaughter weight >2.1 kg, an increasing trend of gait score and breast cleanliness was observed at each stage of slaughter weight. Based on the results, the broiler birds reared up to 2.1 to 2.2 kg live body weight resulted in better welfare, immune status, and meat quality parameters.

Keywords: Broiler, Immunity, Meat quality, Slaughter weight, Welfare

Commercial broiler production has a shorter rearing period of 5-6 weeks compared to other animal production systems. Genetic, nutritional, and managemental studies have provided significant improvements in the live weight performance of broiler chicks and have led to the decline of the slaughter age day by day. It was reported that the slaughter age decreased by an average of 0.75 days each year (Szollosi and Szucs 2014). Modern broilers attend higher body weights, increased breast yields and improved feed conversion ratios (Zuidh 2014). Rapid growth is associated with increased incidences of metabolic disorders, muscle myopathies (Kuttappan *et al*. 2016), skeletal disorders, and lameness (Wilhelmsson *et al.* 2019). Due to heavy weights, broilers spend their time sitting at one place with low locomotor activity. This implies an increased duration of time sitting or lying in contact with litter, which increases the incidence of contact dermatitis (Jong *et al.* 2014). Furthermore, broiler chickens face many threats in the oxygen stress, which is increasing disease susceptibility, mortality and affect the healthy growth and economic benefit of broiler chickens (Song *et al*. 2021). Increasing age at slaughter affects cooking yield and the shear force value of the cooked meat but not in a linear manner (Northcutt *et al.* 2001). Some aspects of broiler chicken welfare, eg. lameness, thermal discomfort and behavioural activity such as time spent lying or distance moved per h are also affected by age. However, the consequences of increasing age and body weight at slaughter, in terms of profitability, product quality, and bird welfare, have received little attention, especially for today's modern broiler strains available in the market.

Last few years, especially after corona pandemic the trend towards producing broilers with very hefty body weight is increasing due to the higher demand for cuts and processed goods in the hotel industry. The chicken flesh is mostly supplied in the form of cut-up pieces and dressed goods rather than entire carcasses in a metro city. Consumer preference has always been influenced by the quality of the meat. Due to the heavier size of broiler birds, the meat characteristics such as appearance, texture, juiciness, firmness, tenderness, odor, water-holding capacity, cooking loss, and flavor is affected, which is reflected in consumer demand and tastes. On the other side due to the margin of profit and economics, heavier broiler birds are in demand by traders. In the interest of the chicken consumer and entrepreneurs, it's a need of the hour to explore the proper age and body weight of broiler birds for slaughter.

Considering these facts, the present study was aimed to evaluate the effects of increasing the slaughter weight of

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broiler birds and its effect on carcass characteristics, breast meat quality, sensory quality, immunity and bird welfare.

MATERIALS AND METHODS

Animals and experimental design: Maharashtra Animal and Fishery Sciences University Commercial strains "Vencobb-430" straight run day-old broiler chicks (N=280) were procured from Sri Rajeshwara Hatcheries Private Limited, Nagpur. The procured broiler chicks were weighed and randomly distributed among eight groups consisting of 35 chicks in each and reared for seven weeks.

The birds were reared on a deep litter system and similar management throughout the study period (0-48 days). Brooding was done for the first two weeks of age by providing sufficient heat and light @ 2 watts per bird Artificial light was provided during night hours throughout the experimental period of seven weeks.Temperature and relative humidity were maintained within the optimum range. The birds were provided with 1.3 square feet of floor area till the end of the experiment. Standard managemental practices were followed to optimize the performance.

Diet and composition: The experimental birds were fed on commercial maize soya-based mash diet, which was procured from commercial feed manufacturer M/s Tirupati Feeds, Nagpur. The diet was iso-caloric and iso-nitrogenous for all the birds. The birds were fed on a pre-starter diet for initial ten days and then shifted to starter feed till 28 days. During the last phase, the birds were fed with finisher feed till 48 days, i.e. termination of the trial. The feed was formulated and prepared as per the commercial broiler's requirement presented in Supplementary Table 1.

The moisture content of the sample was determined by heating it to a constant weight in an oven at 100^0-105^0 C under air pressure. Dry matter was the consistent weight of a sample after it had been completely dehydrated. The Kjeldahl method was used to analyse total nitrogen content of the diets, and crude protein was expressed as nitrogen × 6.25 (AOAC, 2005). Ether extract content was obtained by the Soxhlet extraction using anhydrous diethyl ether. The crude fibre content was determined using 12.5% H_2SO_4 and 12.5% NaOH solutions. The samples were analysed for starch, sugar, ash, calcium, phosphorus according to the procedures of the AOAC (1980). Estimates for ME were based on protein, ether extract, starch, and sugar concentrations determined from the experimental feeds.

Traits measured: At each, slaughter weight eight birds (4 male: 4 female) close to the mean average body weight were sacrificedat an approx live body weight of 1.0-1.2, 1.5-1.7, 2.1-2.2, 2.5-2.7, 2.8-3.0 and 3.3-3.5 kg. The sacrificed birds were fasted for 8 hr with *ad lib.* fresh drinking water before the slaughter. The birds were slaughtered by the halal method.To record the carcass traits, viz dressed weight, fat percentage, cut-up part yields (breast, thigh, drumsticks, back, neck, and wing), and giblets (liver, heart,and gizzard). The breast muscle samples were stored at –20°C. The breast meat samples were further used for meat quality parameters.

Meat quality: Water-holding capacity, *p*H, Warner-Bratzler Shear force, cooking yield, sensory evaluation, colour and meat: bone ratio.

The water-holding capacity (WHC) of meats was assessed by method of Wardlaw *et al.* (1973). The *p*H of meat was determined by method of AOAC (2012). A 10 g sample was added in 50 mL of distilled water and a fine suspension was prepared. Then glass with a combined electrode of a digital *p*H meter (Sytronics digital *p*H meter model no. 802) was immersed in the suspension and the *p*H was recorded. The fresh breast muscle samples were used to test the *p*H meat.

Texture profile analysis (TPA) was conducted in triplicate on each sample at room temperature with a TA-XT2i texture analyzer (Stable Micro Systems, Godalming, U.K.) using P/36R cylindrical probe following the conditions with slight modification. The weight of meat before and after cooking was recorded. The cooking yield was calculated using the formula:

$$\text{Cooking yield (\%)} = \frac{\text{Weight of cooked meat}}{\text{Weight of raw meat}} \times 100$$

The colour of the meat sample (n=8 at each, slaughter weight) was determined using Hunter Lab Miniscan XE Plus Colorimeter (Hunter Associates Laboratory Inc., Reston, VA, USA) using illuminant D65 and the 10 O at standard observer angle. Meat colour was measured at the surface of the breast fillet 30 min after pack opening in order to allow colour stabilization on exposure to air and then lightness (L*), redness (a*), and yellowness (b*) values were measured.The meat-to-bone ratio in chicken is a measurement of the amount of edible meat on a chicken compared to the amount of bones.

For sensory assessing attributes, meat samples were allowed to thaw and further cut into 20 g pieces. The meat samples were cooked and examined by semi-trained sensory panel. A sensory panel comprising 16 members from academic, non-academic staff, and students of college evaluated the quality of the meat for various sensory attribute,s viz. colour,flavour and palatability by using 5 points hedonic scale. Immunological parameters consist of heterophil: lymphocyte ratio (H:L), and corticosterone was estimatedat slaughterlive body weight of 1.0-1.2, 1.5-1.7, 2.1-2.2,2.5-2.7,2.8-3.0 and 3.3-3.5 kg. Theheterophil:lymphocyte ratio (H:L) is haematological measure that has been documented as an index of stress in chickens (Gross and Siegel 1983). Heterophil to lymphocyte ratio was calculated as the method described by Gonzales *et al.* (2003).

In present study corticosterone has been analyzed by ELISA kit (Eiahcor 96-Invitrogen-Thermo Fisher Scientific). Serum samples for corticosterone estimation were obtained from 32 birds randomly selected from each group on different age of respected slaughter weight. The bleeding procedure was less than one min to minimize the influence of handling stress, which was common for all birds. All blood samples were allowed to clot for 1 h and serum was decanted in centrifuge tubes and stored at –20°C for further analysis.

During this experiment the welfare of 32 broiler birds were judged by physical indicators. All assessments wereperformed by the same person on all slaughter weights and in all groups.The welfare assessment included scoring of the following parameters:

Gait score: Repeated scoring could be used to keep track of lameness in a flock, and identify time points to take action. Broilers should take at least 3 consecutive steps to determine their gait score. Randomly thirty-two birds (>10 % of the flock) at each slaughter weight were used to know the gait score of broiler birds. To assess the gait score transparent mash-made partitions of height 1.5 feet were used to check the walking ability of the broiler birds. The individual bird was placed in the prepared partition in such a way that the bird should see a colleague flock so that bird will move to join the flock. To assess the gait score of broiler birds RSPCA Broiler Breeds Welfare Assessment Protocol was used with slight modifications. Gait score, on a scale from 0 (the bird displays normal, smooth, fluid locomotion) to 4 (incapable of walking).

Feather cover score: The thirty two birds were employed to check the feather cover score at each slaughter weight to know the feather score of broiler birds. Feather cover scoreon a scale from 0 (feather cover is full and even over body and wings) to 3 (body is bare of feathers and wings are patchy of feathers) was used.

Breast feather cleanliness score: As broilers grow fast and spend a lot of their time lying on the litter. Due to which the litter quality gets deteriorate ultimately it affects the feathers cleanliness. Dirtied plumage can lead to thermoregulation issues and skin infections since it doesn't protect against moisture, dirt, or faeces. Breast feather cleanliness scorewas assessed on a scale from 0 (plumage is clean) to 3 (large patches of dirty plumage on breast/ breast is completely covered in dirty plumage).

Foot pad dermatitis: Footpad dermatitis is found on the soft pad of the foot, where inflammation might occur from poor litter quality, eventually leading to ulceration. Extreme cases can spread to the toes. Foot pad dermatitis was evaluatedon a scale from 0 (no evidence of foot pad dermatitis) to 3 (entire foot pad is covered).

Hock burn score: Normally, hock burn is found on the back of the hock joint, where contact dermatitis might develop from poor litter quality. Hock burnwas evaluated on a scale from 0 (no evidence ofhock burn) to 3 (entire hock is covered).

Statistical analysis: All data were expressed as mean±SE by one-way ANOVA with weight at slaughter as the main factor using statistical software of SPSS Ver. 24 (IBM SPSS, 2016). Comparisons of means when the factor had a significant effect were obtained using Duncan multiple range test (1955). Replicates were used as the experimental unit for the analysis of all the parameters. A probability of $P<0.05$ was required for statements of significance.

RESULTS AND DISCUSSION

The data of carcass yield of broiler birds at the end of each different slaughter weights is presented in Supplementary Table 2. The data reveals a significant ($P<0.001$) effect of slaughter age on carcass traits excluding thigh, drumstick, back, and abdominal fat %.The dressing percentage was comparable up to G3, i.e. till bird weight reached 2.1 kg, whereas, significant differences were recorded once the birds slaughtered at 2.5 kg (G4) live body weight. The same trend was observed till 2.8 to 3.0 kg live body weight (G5). The birds slaughtered at live body weight 3.3 kg (G6) recorded the significantly ($P<0.001$) highest dressing percentage (73.40 %) and breast yield (29.96 %) among all the groups. A similar trend was observed for breast meat yield percentage, in fact the early significant ($P<0.001$) changes were observed in breast yield at slaughter weight 2.1 kg (G3). In broiler birds, carcass content increases approx 49 fold between 1 to 10 week periods. During these weeks the per cent of muscle tissue increases from 30.9 to 51.3 % of total body weight, by 16.5 % till 6 week of age and approx 4 % between 6 to 10 weeks of age (Murawska *et al.* 2011). In the carcass of two week broiler, approx 36 and 35 % lean meat is present in breast and leg muscles, respectively. As birds grow older the % of lean tissue increases in the breast (44%) and decreases significantly in the legs (32 %), relative to the total lean content of the carcass (Bochno *et al.* 2003). Present results were in agreement with previous researchers Baeza *et al*. (2012), Karaoglu *et al*. (2014), El-Waseif and Abougabal (2017), Abougabal and Taboosha (2020), defined that age impact was significant where chicken at the age of 49 and 56thday had a high dressing %, larger breast, and other carcass % when compared to chicken slaughter at age of 42nd and 35th day. Slaughter weight did not significantly ($P<0.001$) affect thigh, drumstick, back and abdominal fat % in all the groups at any slaughter age. The weight of the skin and subcutaneous fat increase, but their % share remains at a stable level, which results from a fast growth rate of muscle tissue (Murawska 2011). Whereas, Young *et al*. (2001) and Coban *et al*. (2014) Narinc *et al*. (2015), Nikolic *et al*. (2019), Ikusika *et al*. (2020), Park *et al*. (2021) also stated non-consistent age related yield pattern for wings or drumstick, thigh yields, and forequarters, whereas, breasts and fillets increased as slaughter age increased. In contrast to present findings, Murawska (2011) reported if the rearing period of a broiler is longer than 35-42 days; the broilers have higher carcass fat content. Increased fat deposition in the body cavity was observed in growing broilers. Adipose tissue is deposited as abdominal fat, peri-organ fat, and peri-intestine fat, thus increasing the weight of the slaughter offal (Murawska 2011). Interestingly, it was found that the giblet % significantly ($P<0.001$) decreased with increasing slaughter age. The highest giblet% was recorded 5.54 at 24 days of age (G1) whereas the lowest giblet % was 4.09 observed at 48 days of age (G6). Marapana (2016) also recorded similar kind of finding and noted that the weight of total giblets decreased (P<0.05) as the weight of the bird increased. Murawska (2011) stated that in broiler birds, between 1 to 6 week of age, heart weight increased by 11.3 fold, liver weight increased by 9.3 fold, and gizzard weight only 3.4 fold. In weeks 6 and 10, the total weight of the giblet accounts for 3.0 and 2.4 % of the live body weight, respectively. Until 10 weeks of age, the % content of the gizzard, liver, and heart decreases over 8 fold, 2.5, and 2 fold, respectively. In 6 week age broiler, edible components account for approx 63.0 % and their content increases to 67 % of live body weight at 10 week age.

Physicochemical properties of the breast meat sample were assessed through the measurement of several muscle characteristics including cooking yield, shear force, Colour, water holding capacity (WHC), *p*H, and meat:bone ratio. Results of physico-chemical properties are presented in Table 1. The cooking yield in chicken meat significantly (P<0.01) increased from 88.50 % at 24th days of slaughter in the G1 group to 93.75% at the 48th days of slaughter in G6. There was no significant difference in cooking yield % from age of slaughter > 2.5 to >3.3 kg. The shear force values was significantly (P<0.001) vary from weight of the bird > 1.0 kg (G1) to >3.3 kg (G6), whereas, shear force value found constant in between slaughter weight 2.5 to 3.0 kg (G4 and G5). As age increases, collagen content of meat increases which might have caused increased toughness in meat samples. L*, a* and b* values were significantly (P<0.001) highest (59.56, 9.39, 37.03) in G6 at 48th days of slaughter compared to all other treatment groups while significantly (P<0.001) lowest L*, a* and b* values (49.85, 6.02, 27.82) were observed in G1 group at 24th days of age. The myoglobin content increases with age, redness values are dependent on meat pigment content, the increased redness value justifies the findings in the present study.WHC values were significantly (P<0.001) increased in G6 group (34.88) at 48th days of slaughter where as the lowest values were recorded in the G1 group (19.88) at 24th days of slaughter. There was no change in WHC values in between G2 (1.5-1.7 kg) to G5 (2.8-3.0 kg). The protein content of meat increases with age and the water is present in free, bound and immobilised form. May be the protein played an important role in holding water. *p*H of meat was significantly (P<0.001) highest in between G1 (>1.0 kg) to G3 (>2.1) at 24th days of slaughter and then it gradually constant from G 4 (>2.5kg) to G6 (>3.3 kg) group i.e. 39th days to 48th days of slaughter weight. Different slaughter ages did not significantly (P>0.05) change meat: bone ratio among different treatment groups.

Similar to present study, most of researchers observed that physico-chemical properties of chicken meat increased with increase in slaughter age of birds. Fanatico *et al*. (2007) recorded significantly (P<0.001) increased a* values and cooking yield in breast meat of fast growing broiler birds. Baeza *et al*. (2011) reported increased a* and b* values in breast meat of broilers slaughtered at 49th and 56th days compared to early slaughtered birds. Coban *et al*. (2014) reported significantly (P<0.01) lower *p*H values in the carcasses of broiler chicken slaughtered at 56th days of age compared to 42nd days of age. Bosco *et al*. (2014) also showed significantly (P<0.05) increased L*, a* and b* values (60.3, 5.18 and 1.81) at 81st days of slaughter in Ross 308 broiler, respectively. Yalcin *et al*. (2014) observed higher breast *p*H values and lower (P<0.05) cooking loss in early slaughter birds than in late slaughter birds. Li *et al*. (2019) found significantly increased cooking loss values and shear force values at 180th days than 60th, 90th and 150th. Abougabal and Taboosha (2020) stated that marketing age significantly increases the WHC values of chicken breast meat from 50 days of age. Ikusika *et al*. (2020) noted that WHC and shear force values progressively increased (P<0.001) as slaughter age increased. Park *et al*. (2021) showed significantly (P<0.05) increased trend in WHC, cooking yields, shear force and redness values of breast meat while there was a decreasing *p*H values with an increase in slaughter weight of Ross broiler chicken.

In contrast with the present study, Fanatico *et al*. (2007) observed higher b* values in slow growing broiler meat compared fast growing birds, whereas L* values remain unchanged, *p*H of meat significantly (P<0.001) increased and drip loss % decreased in fast growing broilers. Baeza *et al*. (2011) showed significantly (P<0.001) increased *p*H of breast meat between 35th and 49th days of age, highest L* values in early slaughter age broilers than late slaughter age broilers. Baeza *et al*. (2011) also reported drip loss and cooking losses of breast meat decreased (P<0.001)

Table 1. Effects of different slaughter weight on physico-chemical properties of broiler meat

Group no	G1	G2	G3	G4	G5	G6	SEM	P-value
Live weight (kg)	1.0-1.2	1.5-1.7	2.1-2.2	2.5-2.7	2.8-3.0	3.3-3.5		
Cooking yield (%)	88.50^{c}	87.00^{c}	89.38^{bc}	92.00^{ab}	92.13^{ab}	93.75^{a}	0.55	P<0.01
Shear force (N)	22.85^{e}	25.89^{d}	30.70^{c}	34.87^{b}	36.13^{b}	39.40^{a}	0.87	P<0.001
L* Value	49.85^{c}	53.10^{b}	53.11^{b}	54.73^{b}	55.65^{b}	59.56^{a}	0.55	P<0.001
a* Value	6.02^{d}	7.14^{c}	7.04^{c}	7.83^{b}	7.84^{b}	9.39^{a}	0.17	P<0.001
b* Value	27.82^{e}	30.51^{d}	31.39^{d}	32.73^{c}	35.19^{b}	37.03^{a}	0.48	P<0.001
WHC	19.88^{c}	22.75^{b}	23.25^{b}	24.25^{b}	24.00^{b}	34.88^{a}	0.76	P<0.001
Meat *p*H	6.54^{a}	6.13^{b}	5.71^{c}	5.41^{d}	5.23^{d}	5.09^{d}	0.17	P<0.001
Meat : Bone ratio	1.74	1.90	1.83	1.77	1.83	1.50	0.15	0.066

SEM is standard error of difference between mean values. P-value is probable significance value.

Table 2. Sensory evaluationof broiler meat at different slaughter weight

Group no.	G1	G2	G3	G4	G5	G6	SEM	P-Value
Live weight (kg)	1.0-1.2	1.5-1.7	2.1-2.2	2.5-2.7	2.8-3.0	3.3-3.5		
Colour	3.63	3.63	3.50	3.50	3.50	3.25	0.14	0.978
Flavour	3.75	4.25	3.75	3.50	3.50	3.50	0.12	0.603
Palatability	4.50	3.88	3.88	3.63	3.50	3.38	0.10	0.088

SEM is standard error of difference between mean values. P-value is probable significance value.

between 35th and 49th days of age, shear force value of breast meat was not affected (P>0.05) by broiler slaughter age. Mikulski *et al*. (2011) opined that slaughter age had no impact on shear force, *p*H and WHC of breast muscle at 65th days of slaughter in broiler birds. Coban *et al*. (2014) noted significantly (P<0.01) increased a* values in breast meat while drip loss, L* value, and b* values of breast meat were not significantly changed at the 42nd and 56th days of slaughter age. Bosco *et al*. (2014) reported a significant change in the *p*H of breast meat of Ross 308 chicken at 70 and 81 days of slaughter. Yalcin *et al*. (2014) observed higher values in early slaughter birds than in late slaughter whereas, slaughter age did not change the L* and b* values of breast meat. Narinc *et al*. (2015) reported significantly (P<0.05) higher *p*H values whereas, L*, a*, and b* values were significantly (P<0.05) lowest in fast growing birds. Li *et al*. (2019) measured increased (P<0.05) *p*H values with growing age (180th days of age). Drip loss in younger birds was significantly (P<0.05) higher than in older birds (150thand 180thdays). Li *et al.* (2019) observed lower values of yellowness with the growing age of meat from 60th to 180th days of age. Nicolic *et al*. (2019) stated that slaughter age did not significantly (P>0.05) affect the *p*H value, a* and b* value of breast and thigh muscle in broilers. Abougabal and Taboosha (2020) recorded significantly (P<0.01) increased *p*H value with increasing marketing age in Cobb 500 broilers. Ikusika *et al*. (2020) recorded significantly (P<0.01) decreased cooking loss values with increasing slaughter weight in Ross broilers. Park *et al*. (2021) stated that the lightness of the thigh exhibited decreasing trend with slaughter age in Ross broiler chickens.

Sensory parameters such as colour, flavour and palatability were recorded and presented in Table 2. Broiler slaughter at different weights or age did not significantly (P>0.05) affect sensory attributes in the present study. The values of sensory evaluation were comparable among the groups. Similar to our study, Baeza *et al.* (2012) stated that slaughter age (35, 42, 49, 56, 63 days) had no significant effects (P>0.05) on the sensory properties of white cured-cooked meat evaluated by trained panellists. Ikusika *et al.* (2020) reported that aroma, flavour, juiciness, texture and overall acceptance of broiler meat were not significantly influenced by weight at slaughter.

The immune parameters such as heterophil:lymphocyte ratio and serum corticosterone levels are presented in Table 3. The H/L ratio values were significantly higher as the slaughter weight or age was in increasing trend (Gr. 1 to 5). The results of, H/L ratio was significantly (P<0.01) higher, i.e. 0.82 recorded in broiler weighing >2.8 kg live body weight (Gr.5). It shows higher the age or weight more the stress, whereas, surprisingly the birds weighed >3.3 kg (Gr. 6) recorded 0.72 H/L ratio. The reason of lower ratio in Gr. 6 is could not explained. Serum corticosterone values did not changed till birds achieve slaughter age 1.5 kg (Gr.2) later on the significantly increasing trend in serum corticosterone were recorded. The highest values of corticosterone (29.36) were found in the broiler birds achieved slaughter weight of >3.3 kg (Gr.6). This is major stress hormone in the birds and increase in corticosterone can have adverse effects on bird health (e.g. predisposition to disease) production performance. This could be the reason for higher mortality % at the end of slaughter weight. Similar to our study Quaid *et al*. (2016) reported significantly (P<0.001) increased H/L ratio with increasing age (0, 3, 6, 9 and 12 day) of Cobb 500 broilers. Weimer *et al.,* (2020) examined that H/L ratio which was significantly (P<0.01) increased from 0.09, 0.16, 0.19, 0.21, 0.25, 0.37 on 6th, 8th, 27th, 29th, 40th and 55th days of age in broilers, respectively.

Data on welfare parameters is presented in Table 4. As per the welfare assessment results, gait score was significantly (P<0.001) increased from 0.38 (Gr. 3) to 1.59 (Gr.6), during the span of 14 day period of experiment. Once the birds attained the slaughter weight >2.1 kg (Gr.3), increasing trend of gait score observed at each stage of slaughter weight. More or less similar observations recorded for breast cleanliness parameters which showed significant increase in breast cleanliness score in broiler weighing >2.1 kg (Gr.3), and it remained constant till the broiler birds attended >2.8 kg (Gr. 5). However, the birds weighed >3.3 kg (Gr. 6) recorded significantly highest breast cleanliness score. The hock burn score was found

Table 3. Immunological parameters in broiler at different slaughter weight

Group no	G1	G2	G3	G4	G5	G6	SEM	P-value
Live weight (kg)	1.0-1.2	1.5-1.7	2.1-2.2	2.5-2.7	2.8-3.0	3.3-3.5		
H/L ratio	0.48^{d}	0.40^{e}	0.51^{d}	0.60^{c}	0.84^{a}	0.72^{b}	0.02	P<0.01
Corticosterone(ng/ml)	11.90^{e}	11.77^{e}	14.10^{d}	16.63^{c}	20.68^{b}	29.36^{a}	0.92	P<0.001

SEM is standard error of difference between mean values. P-value is probable significance value.

Table 4. Welfare assessment in broiler at different slaughter weight

Group no	G1	G2	G3	G4	G5	G6	SEM	P-value
Live weight (kg)	1.0-1.2	1.5-1.7	2.1-2.2	2.5-2.7	2.8-3.0	3.3-3.5		
Gait score	0.00[e]	0.03[e]	0.38[d]	0.63[c]	1.25[b]	1.59[a]	0.05	P<0.001
Feather score	1.88[a]	1.09[b]	0.88[c]	0.72[c]	0.06[d]	0.00[d]	0.05	P<0.001
Breast cleanliness score	0.34[d]	0.22[d]	0.72[c]	1.19[b]	1.16[b]	2.00[a]	0.05	P<0.001
Hock burn	0.00[e]	0.41[d]	0.53[d]	0.94[c]	1.25[b]	1.88[a]	0.05	P<0.001
Foot Pad score	0.03[d]	0.13[cd]	0.25[c]	0.31[c]	0.72[b]	1.44[a]	0.05	P<0.001
Litter moisture %	7.95	8.78	7.96	7.96	7.99	7.89	0.10	0.070

SEM is standard error of difference between mean values. P-value is probable significance value.

significantly higher (P<0.001) and an increasing trend was seen once the birds attained the live body weight >2.5 kg (Gr.4). Feather cover score value decreases as weight increases. The foot pad score was found significantly higher (P<0.001) and reflected increasing trend once the birds attained the body weight >2.8 kg (Gr.5) and significantly (P<0.001) highest score of hock burn and foot pad score observed in the broiler birds weighed >3.3 kg (Gr.6). Litter quality is of great importance for the welfare of broiler chickens as they generally spend their entire life in contact with it. Goliomytis *et al*. (2003) reported reduced walking ability in Cobb 500 broilers because of lameness up to 154[th]days of age. Similarly, Baeza *et al*. (2011) stated that, occurrence and severity of contact dermatitis significantly (P<0.05) increased and walking ability significantly (P<0.05) decreased, gait score gradually increased in slaughter age from 35[th] to 63[rd] days of age. Incidence of pododermatitis increased (P<0.001) between 35[th] and 42[nd] days of age.Wilhelmsson *et al*. (2019) noted decreased plumage cleanliness with increased in slaughter weight, from 2 to 9 weeks in Roos broiler chicken.Many authors have found positive correlations between litter quality, particularly moisture, and incidence of footpad dermatitis. In contrast in this study the litter moisture was not significantly affected at any slaugher weight, though the foot pad score was differed (P<0.001) significantly.

The welfare of birds is of utmost impotance. Based on the results obtained through this study, the broiler birds reared up to 2.5 to 2.7 kg live body weight (39 days) gave higher meat yield. Beyond 39 days of age negatively reduces meat quality and welfare parameters of broiler production. The broiler birds reared up to 2.1 to 2.2 kg live body weight had a better welfare, immune status and meat quality parameters. Further research is required to find out optimal marketing age or weight in terms of consumer demand.

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