EFFECT OF AD LIBITUM LIQUID BOVINE COLOSTRUM FEEDING PERIOD AFTER HATCHING ON PERFORMANCE AND CARCASS CHARACTERISTICS OF ROSS 308 BROILER CHICKENS

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Abstract. The study was carried out to investigate the influence of ad libitum liquid bovine colostrum feeding periods after hatching on performance and carcass features of male Ross 308 broiler chickens (n = 180) aged one to forth two days in Limpopo province, South Africa. Chicks were randomly allocated into six treatments: a 20% crude protein (CP) broiler mash plus ad libitum *(*ad lib*)* liquid bovine colostrum feeding periods of 0, 12, 24, 36, 48 or 72 h after hatching, each treatment having 3 replicates and 10 chickens per replicate in a completely randomised design. At ages 1 – 21 days, liquid bovine colostrum feeding after hatching improved ($p < 0.05$) live weight, ME intake, CP digestibility of chickens. At ages 22 – 42 days, liquid bovine colostrum feeding period after hatching did not improve ($p > 0.05$) diet digestibility, ME intake, nitrogen retention, FCR and live weight of chickens. Liquid bovine colostrum feeding period after hatching improved ($p < 0.05$) carcass weight and meat tenderness of chickens aged 42 days. It is concluded that ad libitum liquid bovine colostrum feeding periods of 12, 24, 36, 48 or 72 h after hatching improved ($p < 0.05$) carcass weight and meat tenderness of male Ross 308 broiler chickens aged 42 days. Meat tenderness of the chickens was optimised at a calculated ad libitum liquid colostrum feeding period of 47 h after hatching. These results have an influence on ration preparation for broiler chickens.
Keywords: *digestibility, gut morphology, performance, sensory attributes, weight*

Introduction

Poultry meat is an important source of protein in the world (Boer et al., 2001). Thus, there has been a lot of improvement in poultry productivity through efficient breeding and nutrition (Tallentire et al., 2016). However, matching nutrition with the development and growth of broiler chickens after hatching is a challenge. Growth and survival of newly hatched Week one after hatching is a crucial period for the growth and survival of newly hatched chicks (Khoa, 2007). Chicks lose weight immediately after hatching and this has adverse effects on subsequent growth (Willemsen et al., 2010). This may be related to nutritional limitations immediately after hatching such as the adaptation of the gut to solid feed (Sklan et al., 2000). Thus, the utilisation of feeds like liquid bovine colostrum that is absorbed without being digested by young mammals may be helpful. After giving birth, mammals produce colostrum for their young ones to feed within 48 h after birth (Lin et al., 2009). Colostrum is a fluid that is nutrient-dense produced after parturition by female mammals (Georgiev, 2008). Colostrum extends strong antioxidant ability against the responsive oxygen species rising from oxidative stress in the metabolism (Zarban et al., 2009). Thus, colostrum provides nutrients and immunity to the young ones before they get adapted to solid feeds (Georgiev, 2008). Therefore, animals like calves attain rapid growth rates immediately after birth. These

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noticeable changes and developments in new-borns nourished with colostrum are the results of some notable factors. Hormones and growth factors, available in colostrum, efficiently cause DNA synthesis and cellular growth in neonatal calves (Kuhne et al., 2000), improve the amount of protein synthesis in skeletal muscles and some organs in new-born piglets (Burrin et al., 1992) and increase growth rate and feed consumption in pigs (Dunshea et al., 2002). On the other hand, chickens do not produce colostrum. Thus, immediately after hatching, chicks eat solid feeds while also depending on the remaining yolk on their body (Sklan, 2003). The result of this is that chicks lose weight immediately after hatching (Willemsen et al., 2010). However, when chicks are given liquid feeds such as glucose, they maintain weight and subsequently attain higher growth rates than those not offered glucose (McWhorter et al., 2006). In preceding studies, it was observed that concentrate or spray-dried of colostrum supplementation to broiler chickens, in a period of fourteen days, enhanced growth performance parameters such as feed conversion ratio, body weight gain and feed intake (King et al., 2005). However, it is unclear if the gut of chicks immediate after hatching is permeable to liquid colostrum. Thus, the response of chicks to liquid bovine colostrum feeding is not clear. Hence, objectives of the study were to: 1) examine the effect of ad libitum liquid bovine colostrum feeding periods of 0, 12, 24, 36, 48 and 72 h after hatching on digestibility, diet intake and growth of male Ross 308 broiler chickens aged one to 42 days, 2) examine the effect of ad libitum liquid bovine colostrum feeding periods of 0, 12, 24, 36, 48 and 72 h after hatching on gut morphology of male Ross 308 broiler chickens aged 21 and 42 days and 3) determine the effect of liquid bovine colostrum feeding periods of 0, 12, 24, 36, 48 and 72 h after hatching on carcass characteristics of male Ross 308 broiler chickens aged 42 days.

Materials and methods

Study site, preparation of the house and animals

The current work was performed at the University of Limpopo Animal Unit (latitude 27.55°S and 24.77°E), Limpopo Province, South Africa, from February to March, 2017. Ambient temperatures range between -5 and 28°C during winter and between 20 and 36°C during the summer (Manyelo et al., 2019). Prior to the arrival of the chicks, the house was cleaned and prepared for the commencement of the experiment as described by Siwendu et al. (2011). Briefly, the experimental house was divided into 18-floor pens of 2 m^2 per pen. Fresh sawdust was spread in each pen to a thickness of 8 cm high. The heating of the house was done using 250 watt-infrared lights (maintained at around 35°C during the first week, and then reduced to 28-30°C thereafter). Ross 308 broiler chickens were used as experimental animals. Ross 308 broiler chicks were found from Lufafa Hatchery, Tzaneen, South Africa. Commercial grower mash was acquired from Voorslagvoere Milling Company at Mokopane, South Africa. Bovine colostrum was obtained from the Limpopo Dairy, in Louis Trichardt, South Africa.

Experimental procedures, diets and design

Ross 308 broiler chickens were sexed at hatching; only males were used in the study since males grow faster than females (Kaminski and Wong, 2017). A total of 180 male Ross 308 broiler chicks were utilised. The chicks were randomly assigned to six treatment groups (*Table 1*) of bovine colostrum feeding periods of 0 or no bovine

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colostrum given (MCOL0), 12 (MCOL12), 24 (MCOL24), 36 (MCOL36), 48 (MCOL48) or 72 (MCOL72) hours after hatching in a completely randomised design with three replicates of 10 chicks in each.

Table 1. *Dietary treatments for the study*

Diet code	Diet description
$MCOL_0$	Male Ross 308 broiler chickens fed a 20% CP grower mash without liquid bovine colostrum
$MCOL_{12}$	Male Ross 308 broiler chickens fed a 20% CP grower mash plus ad libitum liquid bovine colostrum for 12 h after hatching
$MCOL_{24}$	Male Ross 308 broiler chickens fed a 20% CP grower mash plus ad libitum liquid bovine colostrum for 24 h after hatching
$MCOL_{36}$	Male Ross 308 broiler chickens fed a 20% CP grower mash plus ad libitum liquid bovine colostrum for 36 h after hatching
$MCOL_{48}$	Male Ross 308 broiler chickens fed a 20% CP grower mash plus ad libitum liquid bovine colostrum for 48 h after hatching
$MCOL_{72}$	Male Ross 308 broiler chickens fed a 20% CP grower mash plus ad libitum liquid bovine colostrum for 72 h after hatching

After 72 h of liquid bovine colostrum feeding plus grower mash, all the chicks continued feeding grower mash until the end of the experiment. Data collection was done from day-old up to 42 days of age. The trial was ended when chickens were 42 days of age. The initial live weights of the chicks were recorded using an electronic weighing balance and their initial mean live weight was 42 ± 2 g. The ingredients of the experimental diets are presented in *Table 2*.

Table 2. *Feed ingredients of the diets*

	Treatment *					
	$MCOL_0$	**$MCOL_{12}$**	**$MCOL_{24}$**	**$MCOL_{36}$**	**$MCOL_{48}$**	**$MCOL_{72}$**
Feed ingredient (%)						
Yellow maize	39.82	39.83	39.83	39.83	39.83	39.83
Soybean full fat	17.73	17.73	17.73	17.73	17.73	17.73
Wheat	15.00	15.00	15.00	15.00	15.00	15.00
Sunflower	12.39	12.39	12.39	12.39	12.39	12.39
Fishmeal	5.66	5.66	5.66	5.66	5.66	5.66
Vitamin + minerals premix	3.00	3.00	3.00	3.00	3.00	3.00
Oil sunflower	2.50	2.50	2.50	2.50	2.50	2.50
Na bicarbonate	1.50	1.50	1.50	1.50	1.50	1.50
Limestone	1.50	1.50	1.50	1.50	1.50	1.50
Salt	1.30	1.30	1.30	1.30	1.30	1.30
Monocalcium phosphate	0.20	0.20	0.20	0.20	0.20	0.20
DL methionine	0.15	0.15	0.15	0.15	0.15	0.15
L threonine	0.15	0.15	0.15	0.15	0.15	0.15
L lysine	0.10	0.10	0.10	0.10	0.10	0.10
Colostrum (h)*	0.00	12.00	24.00	36.00	48.00	72.00
Total	100	100	100	100	100	100

*Liquid bovine colostrum fed ad libitum for a period of 0 "no bovine colostrum" ($MCOL_0$), 12 ($MCOL_{12}$), 24 ($MCOL_{24}$), 36 ($MCOL_{36}$), 48 ($MCOL_{48}$) or 72 ($MCOL_{72}$) hours after hatching

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Bovine colostrum nutrient contents are indicated in *Table 3*. Feed intake was measured daily. Water and feed were given ad libitum during the experiment. The light was provided for 24 h per day throughout the experiment and mortality was observed daily throughout the study period.

Table 3. *Nutrient contents (units are g/kg DM except DM as g/kg and gross energy as MJ/kg DM) of bovine colostrum*

Component	Bovine colostrum
Dry matter	319
Crude protein (N×6.25)	766
Crude fat	8.9
Gross energy	20.6
Amino acids	
Alanine	28
Arginine	29
Aspartic acid	59
Cystine	8
Glutamic acid	144
Glycine	18
Histidine	20
Isoleucine	34
Leucine	68
Lysine	58
Methionine	19
Phenylalanine	33
Proline	65
Serine	47
Threonine	39
Tyrosine	39
Valine	49
Minerals	
Calcium	12.9
Phosphorus	9.1
Sodium	1.1
Potassium	4.6

Data collection

The initial live weight of the chicks was measured at the commencement of the experiment. Thereafter, average live weight and feed intake per bird were measured at weekly intervals. Growth rate of chickens was computed using live weights. Feed conversion ratio (FCR) was computed as explained by McDonald et al. (2010). Apparent digestibility was determined when the chickens were aged 14 to 21 days and 35 to 42 days. Two birds were selected randomly from each replicate and moved to the metabolic cage for the measurement of apparent digestibility. Apparent digestibility (AD) was computed using the following formula:

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$$AD\ (\%) = \frac{\text{Amount of nutrient ingested} - \text{Amount of nutrient excreted}}{\text{Amount of nutrient ingested}} X\ 100 \qquad \text{(Eq.1)}$$

After slaughter, the carcass weight of each chicken was measured only at the age of 42 days. Gastrointestinal tract, small intestine, large intestine lengths and caeca were determined using a tape measure. The pH of gut contents (crop, proventriculus, gizzard, ileum, caecum and colon) was measured using a digital pH meter (Crison, Basic 20 pH meter). Breast, drumstick, thigh, crop, proventriculus, gizzard, small intestine, caeca and large intestine weights were measured using an electronic weighing balance. Breast meat was prepared for sensory evaluation following the method explained by Pavelková et al. (2013). The following sensory attributes were evaluated by the sensory panel: tenderness, juiciness and flavour of meat samples. The sensory panel consisted of 20 trained panellists. Samples were cut into small 5 cm cubic pieces and fed immediately after cooking. The five-point ranking scale scores used in this study are as indicated in *Table 4*. Shear force assessment was done according to Warner-Bratzler Shear Force (WBSF) determination procedures as explained by Tyasi et al. (2021). Briefly, cooked meat was prepared by boiling breast cuts in a cylindrical pot using an electric stove and meat cuts were cooled down to room temperature for at least 2 h before WBSF measurements.

Table 4. *Evaluation scores used by the sensory panel*

Score	Sensory attribute		
	Tenderness	**Juiciness**	**Flavour**
1	Too tough	Too dry	Very bad flavour
2	Tough	Dry	Poor flavour
3	Neither tough nor tender	Neither dry nor juicy	Neither bad nor good flavour
4	Tender	Juicy	Good flavour
5	Too tender	Too juicy	Very good flavour

Source: Pavelková et al. (2013)

Chemical analysis

Dry matter of feeds, bovine colostrum, feed refusals, meat and faeces were examined by drying the samples in the oven for 24 h at a temperature of 105°C (AOAC, 2012). Neutral and acid detergent fibre contents of feed and faeces were determined according to Van Soest et al. (1991). Ash and nitrogen contents, gross energy and amino acid contents were analysed according to AOAC (2012). Metabolisable Energy (ME) and crude fat of the diet were determined following the methods of AOAC (2000).

Statistical analysis

Statistical Analysis System version 9.3 (SAS, 2011) was used for data analysis. General Linear Model (GLM) procedures were used to analyse data on feed intake, shear force, live weight, growth rate, digestibility, feed conversion ratio, metabolisable energy, gastrointestinal morphology, sensory evaluation and carcass characteristics. Tukey test was used where there were significant differences ($P < 0.05$) as mean separation procedure among treatment means. The responses in optimal feed intake,

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crop and gizzard weight, tenderness and shear force to bovine colostrum feeding periods were demonstrated by means of the quadratic equation below:

$$Y = a + b_1x + b_2x^2 + e \qquad \text{(Eq.2)}$$

where Y = feed intake, crop and gizzard weight, tenderness and shear force; a = intercept; b = coefficients of the quadratic equation; x = bovine colostrum feeding period and $-b1/2b2$ = x value for optimal response, e is the error.

The relationships between bovine colostrum feeding periods and optimal responses in growth rate, live weight, caecum length, small intestine, carcass and thigh weight were demonstrated using a linear regression equation below:

$$Y = a + bx \qquad \text{(Eq.3)}$$

where Y = growth rate, live weight, caecum length, small intestine, carcass and thigh weights; a = intercept; b = regression coefficient and x = bovine colostrum feeding periods.

Results

Nutrient composition

Outcomes of the nutrient compounds of the experimental diets are shown in *Table 5*. The diets in the current study had similar ($p > 0.05$) dry matter (DM), crude protein (CP), energy, acid detergent fibre (ADF), neutral detergent fibre (NDF), ash, calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), potassium calcium and magnesium (K/Ca + Mg), phosphorus (P), zinc (Zn), copper (Cu), manganese (Mn) and iron (Fe). However, the diets had different ($p < 0.05$) ad libitum liquid bovine colostrum feeding periods of 0 or no bovine colostrum given ($MCOL_0$), 12 ($MCOL_{12}$), 24 ($MCOL_{24}$), 36 ($MCOL_{36}$), 48 ($MCOL_{48}$) or 72 ($MCOL_{72}$) hours after hatching.

Performance parameters

Results of the effects of ad libitum (ad lib) liquid bovine colostrum feeding periods of 0, 12, 24, 36, 48 or 72 h after hatching on feed intake, digestibility, growth rate, live weight and feed conversion ratio of male Ross 308 broiler chickens aged 1 to 21 days and 22 to 42 days are presented in *Table 6*. At ages 1 – 21 days, ad lib liquid bovine colostrum feeding after hatching did not improve ($p > 0.05$) diet dry matter (DM), neutral detergent fibre (NDF), acid detergent fibre (ADF) and ash digestibility, and nitrogen retention, growth rate and feed conversion ratio (FCR) of male Ross 308 broiler chickens. However, liquid bovine colostrum feeding after hatching improved ($p < 0.05$) metabolizable energy intake, crude protein (CP) digestibility and live weight of broiler chickens aged one to 21 days. $MCOL_{72}$ and $MCOL_{36}$ were more efficient in improving the metabolizable energy intake and CP, while $MCOL_{72}$ was more effective in improving the live weight of broiler chickens. At ages 22 – 42 days, liquid bovine colostrum feeding after hatching did not improve ($p > 0.05$) diet digestibility, metabolizable energy intake, nitrogen retention, FCR and live weight of male Ross 308 broiler chickens. However, liquid bovine colostrum feeding after hatching improved ($p < 0.05$) growth rate of male Ross 308 broiler chickens aged 22 to 42 days. Similarly,

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an ad lib liquid bovine colostrum feeding period of 36 h after hatching improved ($p < 0.05$) DM intake of male Ross 308 broiler chickens aged 22 to 42 days.

***Table 5.** Nutrient composition of the experimental diets*

	Diets[#]					
Nutrient	**MCOL$_0$**	**MCOL$_{12}$**	**MCOL$_{24}$**	**MCOL$_{36}$**	**MCOL$_{48}$**	**MCOL$_{72}$**
DM	90.93	90.93	90.93	90.93	90.93	90.93
CP	20.00	20.00	20.00	20.00	20.00	20.00
Energy	16.92	16.92	16.92	16.92	16.92	16.92
ADF	9.26	9.26	9.26	9.26	9.26	9.26
NDF	12.54	12.54	12.54	12.54	12.54	12.54
Fat	2.27	2.27	2.27	2.27	2.27	2.27
Ash	10.28	10.28	10.28	10.28	10.28	10.28
Ca	1.57	1.57	1.57	1.57	1.57	1.57
Mg	0.22	0.22	0.22	0.22	0.22	0.22
K	1.24	1.24	1.24	1.24	1.24	1.24
Na	0.38	0.38	0.38	0.38	0.38	0.38
K/Ca + Mg	0.33	0.33	0.33	0.33	0.33	0.33
P	0.75	0.75	0.75	0.75	0.75	0.75
Zn	288.00	288.00	288.00	288.00	288.00	288.00
Cu	23.00	23.00	23.00	23.00	23.00	23.00
Mn	263.00	263.00	263.00	263.00	263.00	263.00
Fe	609.00	609.00	609.00	609.00	609.00	609.00
Liquid bovine colostrum*	0.00	12.00	24.00	36.00	48.00	72.00

[#]The treatments were bovine colostrum fed ad libitum to chicks for a period of 0, 12, 24, 36, 48 or 72 h after hatching
*Liquid Bovine colostrum fed ad libitum for a period of 0 (MCOL$_0$), 12 (MCOL$_{12}$), 24 (MCOL$_{24}$), 36 (MCOL$_{36}$), 48 (MCOL$_{48}$) or 72 (MCOL$_{72}$) hours after hatching
DM: dry matter, CP: crude protein, Ca: calcium, Mg: magnesium, K: potassium, Na: SODIUM, P: phosphorus, Zn: zinc, Cu: copper, Mn: manganese, Fe: Iron

***Table 6.** Effect of liquid bovine colostrum feeding on diet intake, digestibility, metabolisable energy intake, nitrogen retention, growth rate, feed conversion ratio and live weight of male Ross 308 broiler chickens aged 1 to 21 days and 22 to 42 days*

	Diets[# *]					
Variable	**MCOL$_0$**	**MCOL$_{12}$**	**MCOL$_{24}$**	**MCOL$_{36}$**	**MCOL$_{48}$**	**MCOL$_{72}$**
			1 – 21 days			
DMI	$86.0^{ab} \pm 0.80$	$83.0^{b} \pm 4.30$	$92.0^{ab} \pm 2.00$	$94.0^{ab} \pm 3.60$	$98.0^{a} \pm 2.10$	$97.0^{a} \pm 1.00$
			Digestibility (%)			
DM	$62.0^{a} \pm 9.30$	$60.0^{a} \pm 2.90$	$65.0^{a} \pm 5.80$	$70.0^{a} \pm 3.40$	$61.0^{a} \pm 2.20$	$67.0^{a} \pm 4.70$
CP	$50.0^{b} \pm 11.20$	$50.0^{b} \pm 5.70$	$55.0^{ab} \pm 4.80$	$64.0^{a} \pm 3.00$	$55.0^{ab} \pm 0.90$	$65.0^{a} \pm 4.90$
NDF	$48.0^{a} \pm 9.60$	$52.0^{a} \pm 2.60$	$46.0^{a} \pm 2.50$	$57.0^{a} \pm 3.90$	$58.0^{a} \pm 4.40$	$50.0^{a} \pm 5.80$
ADF	$52.0^{a} \pm 5.30$	$50.0^{a} \pm 2.20$	$55.0^{a} \pm 4.60$	$60.0^{a} \pm 2.60$	$50.0^{a} \pm 3.50$	$56.0^{a} \pm 3.80$
Ash	$31.0^{a} \pm 13.60$	$37.0^{a} \pm 3.00$	$37.0^{a} \pm 9.60$	$40.0^{a} \pm 7.00$	$36.0^{a} \pm 3.30$	$39.0^{a} \pm 8.20$
MEI	$10.5^{c} \pm 0.05$	$10.3^{c} \pm 0.03$	$11.0^{b} \pm 0.06$	$11.3^{a} \pm 0.02$	$10.3^{c} \pm 0.01$	$11.3^{a} \pm 0.02$
N-retn	$1.3^{a} \pm 0.27$	$1.2^{a} \pm 0.34$	$1.5^{a} \pm 0.18$	$1.6^{a} \pm 0.12$	$1.5^{a} \pm 0.14$	$1.9^{a} \pm 0.29$
GR	$25.0^{a} \pm 1.50$	$28.0^{a} \pm 1.60$	$30.0^{a} \pm 0.70$	$29.0^{a} \pm 3.40$	$30.0^{a} \pm 1.20$	$30.0^{a} \pm 1.90$
FCR	$3.5.0^{a} \pm 0.21$	$3.0^{a} \pm 0.23$	$3.1^{a} \pm 0.25$	$3.4^{a} \pm 0.42$	$3.2^{a} \pm 0.06$	$3.2^{a} \pm 0.18$
LW[1]	$396.0^{b} \pm 56.9$	$430.0^{b} \pm 35.7$	$470.0^{b} \pm 16.5$	$452.0^{ab} \pm 51.2$	$484.0^{ab} \pm 20.1$	$530.0^{a} \pm 26.9$

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22 – 42 days						
DMI	$183.0^{b} \pm 1.00$	$166.0^{c} \pm 1.10$	$160.0^{d} \pm 1.10$	$189.0^{a} \pm 1.40$	$148.0^{e} \pm 0.20$	$167.0^{c} \pm 0.30$
Digestibility (%)						
DM	$77.0^{a} \pm 3.40$	$76.0^{ab} \pm 2.20$	$72.0^{ab} \pm 1.40$	$70.0^{b} \pm 2.10$	$74.0^{ab} \pm 2.30$	$72.0^{ab} \pm 0.90$
CP	$75.0^{a} \pm 3.40$	$75.0^{a} \pm 2.10$	$70.0^{b} \pm 1.60$	$67.0^{c} \pm 0.80$	$71.0^{b} \pm 3.80$	$72.0^{b} \pm 0.90$
NDF	$48.0^{a} \pm 7.20$	$44.0^{ab} \pm 5.00$	$37.0^{ab} \pm 6.50$	$27.0^{b} \pm 4.00$	$39.0^{ab} \pm 4.10$	$36.0^{ab} \pm 3.80$
ADF	$59.0^{a} \pm 6.30$	$52.0^{ab} \pm 3.70$	$50.0^{ab} \pm 4.50$	$43.0^{b} \pm 2.50$	$48.0^{ab} \pm 3.00$	$53.0^{ab} \pm 1.40$
Ash	$76.0^{a} \pm 4.00$	$74.0^{ab} \pm 2.40$	$69.0^{c} \pm 1.90$	$67.0^{c} \pm 1.80$	$71.0^{b} \pm 2.70$	$71.0^{b} \pm 0.80$
MEI	$13.0^{a} \pm 0.02$	$12.9^{b} \pm 0.04$	$12.2^{d} \pm 0.05$	$11.8^{e} \pm 0.03$	$12.5^{c} \pm 0.01$	$12.2^{d} \pm 0.05$
N-retn	$4.8^{a} \pm 0.78$	$4.6^{a} \pm 0.45$	$3.9^{a} \pm 0.18$	$3.8^{a} \pm 0.17$	$4.3^{a} \pm 0.17$	$4.0^{a} \pm 0.50$
GR	$64.0^{b} \pm 5.10$	$88.0^{a} \pm 3.00$	$64.0^{b} \pm 3.60$	$64.0^{b} \pm 1.50$	$79.0^{a} \pm 1.80$	$61.0^{b} \pm 2.60$
FCR	$3.1^{a} \pm 0.53$	$2.2^{a} \pm 0.29$	$2.6^{a} \pm 0.08$	$2.5^{a} \pm 0.20$	$2.5^{a} \pm 0.43$	$2.4^{a} \pm 0.42$
LW^{2}	$1825.0^{a} \pm 190.3$	$1978^{a} \pm 104.0$	$1914.0^{a} \pm 72.40$	$1926.0^{a} \pm 38.80$	$1910.0^{a} \pm 83.6$	$2071.0^{a} \pm 61.50$

[*]Values presented as a mean ± standard error (SE)

[a,b,c,d]Means with different superscripts in the same row indicate significant differences between treatments ($p < 0.05$)

[#]Treatments were ad libitum feeding bovine colostrum to chicks for a period of 0, 12, 24, 36, 48 or 72 h after hatching (*Table 3*)

N-retn.: nitrogen retention (g/chicken/day), MEI: metabolisable energy intake (MJ/bird/day), GR: growth rate (g/bird/day), LW^{1}: live weight at 21 days old (g), LW^{2}: live weight at 42 gays old (g), FCR: feed conversion ratio, DM: dry matter, CP: crude protein

Table 7 shows positive relationships ($p < 0.05$) between bovine colostrum feeding periods and growth rates of male Ross 308 broiler chickens at ages of 1-7 days (r = 0.91), 7-14 days (r = 0.88) and 14-21 days (r = 0.89), and live weights at ages of 7 (r = 0.96), 14 (r = 0.96) and 21 (r = 0.96) days.

Table 7. *Relationships between liquid bovine colostrum feeding periods after hatching and growth rates and live weights at different ages of male Ross 308 broiler chickens*

Variable	Formula	r	Probability
Growth rate (g/chicken/day)			
Day 1-7	Y = 8.26 + 0.86x	0.91	0.01
Day 7-14	Y = 15.77 + 0.09x	0.88	0.02
Day 14-21	Y = 41.84 + 0.16x	0.89	0.00
Live weight (g/chicken)			
Day 7	Y = 111.83 + 0.57x	0.96	0.00
Day 14	Y = 219.75 + 1.25x	0.96	0.00
Day 21	Y = 405.86 + 1.70x	0.96	0.00

r : Coefficient of determination

Gut morphology

The effects of ad lib liquid bovine colostrum feeding periods of 0, 12, 24, 36, 48 or 72 h after hatching on gut organ digesta pH, length and weight of male Ross 308 broiler chickens aged 21 days and 42 days are shown in *Table 8*. Ad libitum liquid bovine colostrum feeding after hatching did not improve ($p > 0.05$) gut organ digesta pH, gut organ length and gut organ weight of male Ross 308 broiler chickens aged 21 days. Similarly, ad lib liquid bovine colostrum feeding after hatching did not improve ($p > 0.05$) gut organ digesta pH and gut organ length of male Ross 308 broiler chickens

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aged 42 days. Ad libitum liquid bovine colostrum feeding period after hatching did not increase ($p > 0.05$) caecum, small intestinal and large intestinal weights of male Ross 308 broiler chickens aged 42 days. However, liquid bovine colostrum feeding after hatching increased ($p < 0.05$) crop, proventriculus and gizzard weights of male Ross 308 broiler chickens aged 42 days. However, ad lib liquid bovine colostrum feeding period of 24, 36 and 48 h after hatching was more efficient in increasing the crop weight, whereas $MCOL_{24}$ was the best in improving the weight of the proventriculus and $MCOL_{48}$ was more effective in increasing the gizzard weight in broiler chickens. The gizzard weight of male Ross 308 broiler chickens aged 42 days was optimised ($R^2 = 0.926$) at a calculated ad lib liquid bovine colostrum feeding period of 55 h after hatching ($Y = 38.260 + 0.221x + -0.002x^2$). Crop weight of male Ross 308 broiler chickens aged 42 days was optimised ($R^2 = 0.904$) at a calculated bovine colostrum feeding period of 44 h after hatching ($Y = 10.31 + 0.17x + -0.00x^2$).

Table 8. *Effect of liquid bovine colostrum feeding period after hatching on gut organ digesta pH, length and weight of male Ross 308 broiler chickens aged 21 days and 42 days*

	Diets# *					
Variable	**$MCOL_0$**	**$MCOL_{12}$**	**$MCOL_{24}$**	**$MCOL_{36}$**	**$MCOL_{48}$**	**$MCOL_{72}$**
Gut organ digesta pH of chickens aged 21 days						
Crop	$5.0^a \pm 0.50$	$4.0^a \pm 1.40$	$4.0^a \pm 1.40$	$6.0^a \pm 0.60$	$5.0^a \pm 0.60$	$5.0^a \pm 0.60$
Proventriculus	$4.0^a \pm 0.80$	$4.0^a \pm 0.90$	$5.0^a \pm 0.40$	$4.0^a \pm 0.90$	$5.0^a \pm 0.50$	$4.0^a \pm 0.80$
Gizzard	$2.0^a \pm 0.80$	$2.0^a \pm 0.70$	$3.0^a \pm 0.40$	$2.0^a \pm 0.70$	$3.0^a \pm 0.50$	$2.0^a \pm 0.60$
Small intestines	$6.0^a \pm 0.20$	$6.0^a \pm 0.20$	$6.0^a \pm 0.30$	$6.0^a \pm 0.20$	$6.0^a \pm 0.20$	$6.0^a \pm 0.10$
Caecum	$7.0^a \pm 0.50$	$7.0^a \pm 0.50$	$7.0^a \pm 0.50$	$6.0^a \pm 0.50$	$7.0^a \pm 0.60$	$6.0^a \pm 0.60$
Large intestines	$6.0^a \pm 0.60$	$7.0^a \pm 0.60$	$7.0^a \pm 0.40$	$7.0^a \pm 0.40$	$6.0^a \pm 0.80$	$6.0^a \pm 0.70$
Gut organ digesta pH of chickens aged 42 days						
Crop	$5.0^a \pm 0.20$	$5.0^a \pm 0.10$	$5.0^a \pm 0.40$	$5.0^a \pm 0.30$	$5.0^a \pm 0.30$	$5.0^a \pm 0.30$
Proventriculus	$4.0^a \pm 0.60$	$3.0^a \pm 0.70$	$4.0^a \pm 0.70$	$4.0^a \pm 0.60$	$3.0^a \pm 0.80$	$4.0^a \pm 0.60$
Gizzard	$4.0^a \pm 1.60$	$3.0^a \pm 0.30$	$3.0^a \pm 0.40$	$3.0^a \pm 0.30$	$3.0^a \pm 0.50$	$3.0^a \pm 0.60$
Small intestines	$7.0^a \pm 0.70$	$6.0^a \pm 0.60$	$6.0^a \pm 0.50$	$7.0^a \pm 0.60$	$6.0^a \pm 0.50$	$6.0^a \pm 0.80$
Caeca	$7.0^a \pm 0.50$	$7.0^a \pm 0.50$	$7.0^a \pm 0.60$	$6.0^a \pm 0.80$	$7.0^a \pm 0.50$	$7.0^a \pm 0.50$
Large intestine	$7.0^a \pm 0.50$	$6.0^a \pm 0.80$	$7.0^a \pm 0.60$	$6.0^a \pm 0.70$	$7.0^a \pm 0.50$	$6.0^a \pm 0.70$
Gut organ length (cm) of chickens aged 21 days						
GIT	$140.0^a \pm 9.90$	$139.0^a \pm 1.60$	$142.0^a \pm 3.10$	$139.0^a \pm 8.20$	$138.0^a \pm 4.90$	$141.0^a \pm 2.80$
Small intestines	$129.0^a \pm 9.50$	$122.0^a \pm 10.20$	$125.0^a \pm 9.80$	$139.0^a \pm 9.00$	$125.0^a \pm 8.80$	$138.0^a \pm 10.50$
Caecum	$12.0^a \pm 1.50$	$10^a \pm 1.40$	$13.0^a \pm 1.60$	$11.0^a \pm 1.30$	$12.0^a \pm 1.90$	$12.0^a \pm 1.80$
Large intestines	$7.0^a \pm 0.60$	$7^a \pm 0.80$	$8.0^a \pm 0.90$	$7.0^a \pm 0.90$	$8.0^a \pm 0.80$	$8.0^a \pm 0.90$
Gut organ length (cm) of chickens aged 42 days						
GIT	$225.0^{ab} \pm 2.80$	$242.0^a \pm 17.0002$	$230.0^{ab} \pm 6.40$	$220.0^{ab} \pm 1.30$	$232.0^{ab} \pm 10.06$	$209.0^b \pm 14.80$
Small intestines	$195.0^a \pm 1.00$	$191^b \pm 1.90$	$197.0^a \pm 2.60$	$192.0^b \pm 1.90$	$197.0^a \pm 2.70$	$195.0^a \pm 1.0$
Caecum	$15.0^a \pm 3.80$	$19^a \pm 1.70$	$18.0^a \pm 2.60$	$18.0^a \pm 2.60$	$19.0^a \pm 1.80$	$21.0^a \pm 2.90$
Large intestines	$13.0^a \pm 1.10$	$15^a \pm 1.70$	$15.0^a \pm 1.20$	$14.0^a \pm 1.10$	$15.0^a \pm 1.00$	$15.0^a \pm 1.40$
Gut organ weight (g) of chickens aged 21 days						
Crop	$3.0^a \pm 1.30$	$3.0^a \pm 0.50$	$2.0^a \pm 0.60$	$2.0^a \pm 0.70$	$2.0^a \pm 0.80$	$3.0^a \pm 0.70$
Proventriculus	$3.0^a \pm 0.80$	$3.0^a \pm 0.70$	$4.0^a \pm 1.90$	$2.0^a \pm 0.90$	$2.0^a \pm 0.90$	$3.0^a \pm 0.80$
Gizzard	$22.0^a \pm 0.90$	$21.0^a \pm 1.90$	$21.0^a \pm 1.60$	$21.0^a \pm 2.00$	$21.0^a \pm 1.60$	$23.0^a \pm 1.80$
Small intestines	$36.0^a \pm 4.40$	$37.0^a \pm 1.10$	$35.0^a \pm 1.30$	$36.0^a \pm 1.70$	$35.0^a \pm 5.90$	$36.0^a \pm 1.70$
Caecum	$2.0^a \pm 0.20$	$2.0^a \pm 0.20$	$3.0^a \pm 1.00$	$2.0^a \pm 0.70$	$2.0^a \pm 0.50$	$2.0^a \pm 0.40$
Large intestines	$2.0^a \pm 0.90$	$2.0^a \pm 2.00$	$3.0^a \pm 1.60$	$3.0^a \pm 0.80$	$2.0^a \pm 0.80$	$2.0^a \pm 0.70$

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Gut organ weight (g) of chickens aged 42 days						
Crop	11.0[b] ± 0.40	11.0[b] ± 0.50	13.0[a] ± 1.20	14.0[a] ± 1.30	14.0[a] ± 1.80	11.0[b] ± 0.60
Proventriculus	9.0[b] ± 0.50	10.0[ab] ± 1.10	11.0[a] ± 0.60	9.0[b] ± 0.70	10.0[ab] ± 0.30	10.0[ab] ± 0.10
Gizzard	39.0[b] ± 3.70	40.0[ab] ± 2.30	41.0[ab] ± 1.50	45.0[a] ± 1.60	45.0[a] ± 2.0	44.0[ab] ± 1.30
Small intestines	111.0[a] ± 14.200	111.0[a] ± 12.30	103.0[a] ± 13.00	107.0[a] ± 5.60	103.0[a] ± 12.5	86.0[a] ± 15.80
Caecum	6.0[a] ± 1.30	7.0[a] ± 0.90	6.0[a] ± 1.80	9.0[a] ± 1.90	8.0[a] ± 1.00	7.0[a] ± 0.80
Large intestines	8.0[a] ± 2.80	10.0[a] ± 1.70	12.0[a] ± 2.40	13.0[a] ± 3.10	9.0[a] ± 1.50	12.0[a] ± 2.70

[*]Values presented as a mean ± standard error (SE)
[a,b,c]Means with similar superscripts in the same row indicate non-significant differences between treatments ($p > 0.05$)
[#]The treatments were ad libitum feeding bovine colostrum to chicks for a period of 0, 12, 24, 36, 48 or 72 h after hatching

Carcass characteristics

Ad libitum liquid bovine colostrum feeding periods of 0, 12, 24, 36, 48 or 72 h after hatching did not affect ($p > 0.05$) breast and drumstick weights of male Ross 308 broiler chickens aged 42 days (*Table 9*). However, a liquid bovine colostrum feeding period of 72 h after hatching improved ($p < 0.05$) carcass and thigh weights of male Ross 308 broiler chickens aged 42 days. However, ad lib liquid bovine colostrum feeding period of 72 h after hatching was more efficient in improving the carcass and thigh weights of male Ross 308 broiler chickens aged 42 days. There were positive relationships ($p < 0.05$) between liquid bovine colostrum feeding periods and carcass ($r = 0.90$) and thigh ($r = 0.93$) weights of male Ross 308 broiler chickens aged 42 days (*Table 10*).

Sensory evaluation

Results of the effects of ad libitum liquid bovine colostrum feeding periods after hatching on tenderness, juiciness, flavour and shear force of breast meat of male broiler chickens aged 42 days are presented in *Table 11*. Meat juiciness and flavour were unaffected ($p > 0.05$) by the bovine colostrum feeding periods after hatching. However, male Ross 308 broiler chickens fed with liquid bovine colostrum for 36 h after hatching had better ($p < 0.05$) meat tenderness values than meat from chickens on no colostrum feeding. Male Ross 308 broiler chickens on no liquid bovine colostrum feeding had higher ($p < 0.05$) meat shear force values (less tender) than those on colostrum feeding after hatching. Breast meat tenderness and shear force values of male Ross 308 broiler chickens aged 42 days were optimised ($R^2 = 0.99$ and 0.97, respectively) at calculated ad libitum bovine colostrum feeding periods after hatching of 47 ($Y = 2.73 + 0.03x + -0.00x^2$) and 43 ($Y = 19.55 + -0.34x + 0.00x^2$) hours, respectively.

Table 9. *Effect of bovine colostrum feeding period after hatching on carcass weights (g) of male Ross 308 broiler chickens aged 42 days*

	Diets[#,*]					
Variable	**$MCOL_0$**	**$MCOL_{12}$**	**$MCOL_{24}$**	**$MCOL_{36}$**	**$MCOL_{48}$**	**$MCOL_{72}$**
Carcass	1250.0[b]±159.40	1342.0[ab]±125.60	1358.0[ab]±59.20	1387.0[ab]±49.80	1350.0[ab]±90.20	1495.0[a]±59.50
Breast	215.0[a]±21.50	196.0[a]±29.40	207.0[a]±6.70	209.0[a]±17.00	210.0[a]±19.20	217.0[a]±22.10
Drumstick	86.0[a]±7.80	86.0[a]±7.60	91.0[a]±3.80	99.0[a]±4.70	89.0[a]±5.70	97.0[a]±5.20
Thigh	111.0[b]±2.60	123.0[ab]±10.30	121.0[b]±6.50	121.0[b]±6.50	128.0[ab]±7.50	139.0[a]±6.40

[*]Values presented as a mean ± standard error (SE)
[a,b]Means with different superscripts in the same row indicate significant differences between treatments ($p < 0.05$)
[#]The treatments were ad libitum feeding bovine colostrum to chicks for a period of 0, 12, 24, 36, 48 or 72 h after hatching

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Table 10. *Relationships between bovine colostrum feeding period after hatching and carcass and thigh weights of male Ross 308 broiler chickens aged 42 days*

Variable	Formula	R	Probability
Carcass weight	Y = 1275.63 + 2.75x	0.90	0.02
Thigh weight	Y = 113.24 + 0.33x	0.93	0.01

r: Coefficient of determination

Table 11. *Effect of bovine colostrum feeding periods after hatching on tenderness, juiciness, flavour and shear force value (kg) of breast meat of male Ross 308 broiler chickens aged 42 days*

	Diets # *					
Variable	$MCOL_0$	$MCOL_{12}$	$MCOL_{24}$	$MCOL_{36}$	$MCOL_{48}$	$MCOL_{72}$
Tenderness	$2.7^b \pm 0.43$	$3.2^b \pm 0.17$	$2.9^b \pm 0.26$	$3.7^a \pm 0.03$	$3.3^b \pm 0.18$	$3.3^b \pm 0.09$
Juiciness	$2.6^a \pm 0.24$	$3.2^a \pm 0.43$	$2.8^a \pm 0.09$	$3.3^a \pm 0.20$	$3.3^a \pm 0.48$	$2.9^a \pm 0.12$
Flavour	$3.2^a \pm 0.08$	$3.3^a \pm 0.06$	$3.4^a \pm 0.03$	$3.5^a \pm 0.15$	$3.5^a \pm 0.06$	$3.6^a \pm 0.04$
Shear force	$20.0^a \pm 1.60$	$15.0^b \pm 1.40$	$14.0^b \pm 0.70$	$11.0^b \pm 2.70$	$12.0^b \pm 1.70$	$13.0^b \pm 2.10$

[*]Values presented as a mean ± standard error (SE)

[a,b]Means with different superscripts in the same row indicate significant differences between treatments (P < 0.05)

[#]The treatments were ad libitum feeding bovine colostrum to chicks for a period of 0, 12, 24, 36, 48 or 72 h after hatching

Discussion

The diets in the current study had similar nutrient levels but different ad libitum liquid bovine colostrum feeding periods of 0, 12, 24, 36, 48 or 72 h after hatching. Liquid bovine colostrum is a very nourishing fluid, and it is vital for growth and immune status of new-borns (Godhia and Patel, 2013). The liquid colostrum utilised in the study contained high amounts of nutrients such as amino acids, carbohydrates, minerals, fats and globulins. Ad libitum liquid bovine colostrum feeding periods of 0, after hatching did not improve diet DM, NDF, ADF and ash digestibility, nitrogen retention, feed conversion ratio and growth rate of male Ross 308 broiler chickens aged 1 to 21. However, liquid bovine colostrum feeding period after hatching improved metabolisable energy (ME) intake, live weight and CP digestibility of broiler chickens aged one to 21 days. The improvement in the live weight of the chickens at the age of 21 days might have been because of improved ME intake and CP digestibility due to colostrum feeding. Improved live weight of the broiler chickens after colostrum feeding may have also been due to the presence of growth-promoting proteins (insulin-like growth factors 1 and 2), transforming growth factors-β and platelet-derived growth factors that allow better nutrient absorption and utilisation (Qureshi et al., 2004). Improved protein digestibility in the current study may have been because of the presence of growth factors in colostrum that allow better nutrient digestion and absorption (King et al., 2005). Indeed, in the present study there were positive relationships between liquid bovine colostrum feeding periods after hatching and growth rates and live weights of male Ross 308 broiler chickens aged 1 to 21 days. Qureshi et al. (2004) observed that spray-dried bovine colostrum inclusion in the diet increased feed consumption of broiler chickens aged 1 to 14 days. However, King et al.

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(2005) observed that the inclusion of spray-dried bovine colostrum, spray-dried bovine colostrum plasma and spray-dried porcine colostrum plasma did not affect feed intake of broiler chickens aged 1 to 14 days. Qureshi et al. (2004) reported that immune milk given via drinking water for 7 days after hatching improved growth rates of broiler chickens. Qureshi et al. (2004) reported that immune milk given via drinking water for 7 days after hatching improved growth rates of broiler chickens. King et al. (2005) observed that the inclusion of spray-dried bovine colostrum, spray-dried bovine colostrum plasma or spray-dried porcine colostrum plasma improved the feed conversion ratio of broiler chickens aged 1 to 21 days. Similarly, Campell et al. (2003) stated that the inclusion of spray-dried bovine colostrum serum through drinking water improved the feed conversion ratio of broiler chickens aged 1 to 14 days. Yi et al. (2001a) observed that dietary inclusion of spray-dried colostrum plasma did not affect the feed conversion ratio of broiler chickens aged 1 to 21 days.

At ages 22 – 42 days, liquid bovine colostrum feeding period after hatching did not improve diet digestibility, ME intake, nitrogen retention, FCR and live weight of male Ross 308 broiler chickens. King et al. (2005) observed that the inclusion in the diet of spray-dried bovine colostrum, spray-dried bovine colostrum plasma or spray-dried porcine colostrum plasma did not affect live weights of broiler chickens. Likewise, Yi et al. (2001b) observed no effect of dietary inclusion of spray-dried colostrum plasma on live weights of turkeys aged 21 days. In the current study, liquid bovine colostrum feeding period after hatching improved growth rate of male Ross 308 broiler chickens aged 22 to 42 days. Improved growth rate of the chickens after colostrum feeding may have been due to improvement of DM intake and also due to the presence of growth-promoting proteins (insulin-like growth factors 1 and 2), transforming growth factors-β and platelet-derived growth factors that allow better nutrient absorption and utilisation (Qureshi et al., 2004). Qureshi et al. (2004), also, reported that immune milk given via drinking water for 7 days after hatching improved growth rates of broiler chickens.

The outcomes of the current study show that bovine colostrum feeding periods of up to 72 h after hatching had no significant effect on gut organ digesta pH values, gut organ lengths and gut organ weights of male Ross 308 broiler chickens aged 21 days. Similarly, ad lib liquid bovine colostrum feeding after hatching did not improve gut organ digesta pH and gut organ length, and caecum, small intestinal and large intestinal weights of male Ross 308 broiler chickens aged 42 days. However, liquid bovine colostrum feeding after hatching increased crop, proventriculus and gizzard weights of male Ross 308 broiler chickens aged 42 days. No studies on the effect of liquid bovine colostrum feeding after hatching on gut organ digesta pH values, gut organ lengths and gut organ weights of broiler chickens were found in the literature.

Liquid colostrum feeding periods of up to 72 h after hatching did not improve the drumstick and breast weights of male Ross 308 broiler chickens aged 42 days. However, a liquid bovine colostrum feeding period of 72 h after hatching improved carcass and thigh weights of the chickens. The improvement in the carcass and thigh weights of the chickens aged 42 days might have been because of improved ME intake and CP digestibility (ages 1-21 days), and improved growth rate (ages 22-42 days) due to colostrum feeding. Colostrum feeding improves growth and integrity of the intestinal tract, thereby allowing better nutrient absorption and utilisation, resulting in higher live weights of the chickens (Qureshi et al., 2004). No studies on the effect of liquid bovine colostrum feeding after hatching on broiler chicken performance were found in the literature.

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The findings of the current study reveal that ad lib liquid colostrum feeding periods of up to 72 h after hatching did not improve male broiler chicken meat juiciness and flavour. However, liquid colostrum feeding for 36 h after hatching improved chicken meat tenderness. Similarly, liquid colostrum feeding hatching reduced meat shear force values. Optimal meat tenderness was achieved at a calculated ad libitum liquid colostrum feeding period of 47 h after hatching. It is possible that improved meat tenderness observed in chickens supplemented with liquid bovine colostrum might have been due to improved protein digestibility during the starter phase and the high amounts of amino acids in colostrum (Ojano-Diranin and Waldroup, 2002). No studies on the effect of liquid bovine colostrum feeding after hatching on broiler chicken performance were found in the literature.

Conclusions

Ad libitum liquid bovine colostrum feeding periods of 0, 12, 24, 36, 48 or 72 h after hatching did not improve feed DM intake, FCR, nitrogen retention and growth rate of broiler chickens aged 1 to 21 days and on a broiler mash diet having 20% CP. However, colostrum feeding after hatching improved diet ME intake and CP digestibility, thus contributing to improved live weight of male Ross 308 broiler chickens aged 21 days. The present results indicate that liquid colostrum feeding periods of up to 72 h after hatching did not improve ME intake, FCR and live weight of Ross 308 broiler chickens aged 22 to 42 days. However, ad lib liquid colostrum feeding improved carcass weight and meat tenderness of broiler chickens aged 42 days. Meat tenderness of the chickens was optimised at a calculated ad lib liquid colostrum feeding period of 47 h after hatching. These findings are important because today's consumers are very kin on high chicken carcass weight and better meat tenderness. Thus, these discoveries have more effects on ration formulation for broiler chickens. Hence, additional studies should be performed to confirm these responses. Further studies are also needed to determine economic potency of liquid bovine colostrum use in poultry rations.

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