



Influence of Defatted Winged Termite Meal (*Macrotermes natalensis*) Inclusion Levels on Gut Morphology, Carcass Characteristics and Meat Quality of Ross 308 Broiler Chickens

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ABSTRACT

Background: Winged termites (*Macrotermes* spp.) are highly nutritious edible insects containing 53,34% crude protein that could be economically beneficial when included in poultry diets. The present study aimed to evaluate the partial replacement of soyabean meal (SBM) with defatted winged termite meal (WTM) on viscera morphometry, intestinal morphology, carcass and meat quality traits of Ross 308 broilers reared for 42 days.

Methods: 150 one-day-old, unsexed Ross 308 broiler chickens were randomly allocated to 3 treatments × 5 replicates × 10 birds/pen in a completely randomized design. Three isonitrogenous and iso-energetic diets were formulated to replace SBM with WTM as follows: WTM0 = basal control diet without WTM; WTM5 = WTM0 diet with 5% WTM; WTM10 = WTM0 diet with 10% WTM. At the end of starter (day 1-14), grower (day 15-28) and finisher (day 29-42) phases, 2 chickens/treatment were humanely slaughtered for visceral organ weights and gut morphology measurements. However, carcass and meat quality traits were only evaluated on day 42 after slaughter.

Result: The findings showed WTM diets had no effect ($p>0.05$) on internal organ weights, gut morphological indices, carcass characteristics and meat quality traits of broilers fed incremental levels of WTM throughout the growth stages with exception of small intestines (SI), caeca (CW) and hot carcass (HCW) weights that varied significantly after 42 days. Broilers on WTM5 had heavier ($p<0.05$) SI than those on WTM0 and WTM10 diets. However, birds fed WTM10 had reduced ($p<0.05$) CW and HCW than other treatment groups. Thus, up to 10% WTM could be supplemented in diets as a partial replacement for SBM without adverse effects on visceral organ weights, gut morphological, carcass traits and meat quality of broiler chickens.

Key words: Broilers, Carcass traits, Gut morphology, Meat attributes, Organ weights, Winged termite meal.

INTRODUCTION

Meat from poultry makes up 33% of global meat, of which 87% is produced from chickens only (Melesse, 2014). In Southern Africa, poultry meat is a major source of protein, which is considered cheaper, more tender and palatable than animal-derived food sources such as beef and pork (Ebenebe *et al.*, 2020; Chenfang *et al.*, 2025). Besides carcass meat, chicken offal such as the intestines, hearts, livers *etc.*, also play a significant role as cheap boneless meat in rural communities since the prices of red and white muscle meat continue to elevate further in recent years (Mareko *et al.*, 2018). They are mainly responsible for digestion and absorption of nutrients, oral medication and vaccines for proper growth and development (Ding *et al.*, 2017). According to Al-Homidan *et al.* (2024), the abnormal growth and development of visceral organs may result in various diseases associated with heart attack and hormonal imbalance in broiler chickens, which indirectly affect their health and productivity. Again, poor carcass characteristics and meat quality could significantly affect consumer's meat acceptability or willingness to purchase meat and meat products (Akbar *et al.*, 2018; Mtolo *et al.*, 2022).

The functional capacity of gastrointestinal tract (GIT) and visceral organs of poultry species is highly influenced

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by factors such as environmental conditions, diet, breed and age of the chickens in which diet remain one of the main factors affecting health and performance of broiler chicken (Sánchez-Muros *et al.*, 2014). According to Freccia *et al.* (2020), lack of essential nutrients such as protein and amino acids in poultry could result in poor muscle and organ development, consequently reducing the overall yield

for chicken farmers. Thus, to produce nutrient-rich chicken meat, it is vital to provide a high-quality, balanced diet that meets the minimum nutrient requirements for broiler chickens. However, adverse effects of climate change and the expensiveness of main protein feed ingredients in poultry diets such as soyabean and fishmeal continues to pose an extensive threat in chicken production industry since they contribute reduced feed availability and elevated feed costs (Dobermann *et al.*, 2017). Hence, there is, therefore, a need to find alternative feeds that are cost effective and readily available to substitute conventional feed stuffs in broiler diets.

Edible insects including flies, mealworms, crickets, locusts and termites have been identified as a suitable alternative replacement of fish or soyabean meals in diets of fish and poultry (Freccia *et al.*, 2020; Nitharwal *et al.*, 2022). Recent studies reported positive impact of black soldier fly, house fly and yellow mealworms as partial replacement of SBM in diets in poultry diets, particularly on gut morphology, carcass traits and meat quality parameters (Onsongo *et al.*, 2018; Pieterse *et al.*, 2019; Mbhele *et al.*, 2019; Nagappan *et al.*, 2021; Elahi *et al.*, 2022). However, the incorporation of other edible insects such as winged termites (*Macrotermes* spp.) in poultry diets is under looked. Thus, the present objective was to evaluate the partial replacement of SBM with WTM on viscera morphology, carcass characteristics and meat quality of Ross 308 broiler chickens. It was hypothesized that the inclusion levels of WTM in diets will have no effect on gut morphology, carcass traits and meat quality of broilers reared in current study.

MATERIALS AND METHODS

Site description and ethics approval

The current study was carried out between August and September 2023 at the Izinkanyezi Chicken farm plots in Zuuberkom, Randfontein (1709 m altitude, 26°11'38"S latitude and 27°42'15" E longitude), Gauteng Province in South Africa. The ambient temperature around the study area ranges between 11.8°C and 29°C in summer, while in winter it ranges between 6.1°C and 22.7°C. The area receives a mean annual rainfall of 677.8 mm to 794 mm. This study was approved by the Animal Ethics Committee of the College of Agriculture and Environmental Science at the University of South Africa, with approval number 2022/CAES_AREC/150.

Rearing and management of chickens

A total of 150 days-old, unsexed Ross 308 broiler chicks (initial weight, 45±0.4 g) were purchased from National Chicks (Randburg, Gauteng, South Africa) and transported by road to Zuurbekom Research Farm in Randfontein, Gauteng. Materials such as drinkers, infrared light and feeders were acquired from the AFGRI retail store in Gauteng Province. Fresh, clean water and diets were offered *ad libitum* during the 42-day feeding trial. The chicks were

offered a stress pack (containing vitamins and electrolytes) administered through drinking water for the first three days of the trial. Lights were provided 20 hours (9 hours of natural light and 11 hours of bulb or artificial light) daily and maintained throughout the trial period with 4 hours of darkness to rest for sufficient sleep, hence, better health and productivity. All management and procedures in this study were carried out in strict compliance with the requirements of the University of South Africa Animal Research Ethics and Section 20 of the Animal Diseases Act, 1984 (Act No 35 of 1984) of South Africa. Sick birds were isolated and treated accordingly. Mortality was recorded instantly and thereafter; a post-mortem was conducted by a qualified veterinarian to determine the cause of death.

Purchase of chicks and experimental diets

Ross 308 broiler chicks were purchased at National Chicks (Randburg, Gauteng, South Africa). Winged termites were harvested in Venda, Vhembe district in Limpopo province, termites were further processed to produce defatted winged termite meal (WTM). The remaining ingredients including yellow maize, soya beans, etc. were all acquired from Simple Grow Agricultural Service company, which was responsible for mixing, crumbling or pelleting of chicken diets of the present study.

Experimental design and treatment description

A total of 150 Ross 308 broilers day-old chicks were assigned to a completely randomized design (CRD) replicated five (5) times with ten (10) birds per pen. Prior to feed formulation, proximate analysis of WTM was performed (Table 1). Thereafter, a three-phase feeding programme was used with starter diets fed to birds from day 1 to 14 days in crumbles form, grower diets from 15 to 28 days and finisher diets from 29 to 42 days of age as shown in Table 2. Broilers were fed isonitrogenous and iso-energetic experimental diets formulated to include WTM as follows: WTM0 = a control diet without WTM; WTM5 = basal broiler diet with 5% (50 g/kg) of WTM; WTM10 = basal diet with 10% (100 g/kg) of WTM to partially replace SBM. The experimental diets were formulated to meet or exceed the nutritional requirements for broiler chickens in each growth phase as recommended by Aviagen (2019).

Table 1: Proximate composition (%) of WTM (*M. natalensis*) used in feed formulation.

¹ Parameters	² WTM
Dry matter	95.60
Crude protein	53.64
Crude fat	22.51
Crude fibre	6.83
NDF	26.50
Ash	9.67

¹Parameters: NDF = Neutral detergent fibre.

²WTM: Winged termites meal, a by-product of *M. natalensis*.

Table 2: Ingredient and analysed chemical composition (%), unless stated otherwise) of experimental diets fed to broiler chickens aged during the starter, grower and finisher phases.

	3Diets (%)									
	Starter (1-14 days)			Grower (15-28 days)			Finisher (29-42 days)			
	WTM0	WTM5	WTM10	WTM0	WTM5	WTM10	WTM0	WTM5	WTM10	
1Ingredients (%)										
Yellow maize fine	51.97	53.00	48.74	61.81	55.00	55.51	67.63	68.00	52.43	
Pellibond (pellet binder)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Soy full-fat	8.99	-	-	-	-	-	-	-	-	
Soya bean meal 46.5%	20.52	24.98	17.05	24.00	14.00	4.61	18.25	7.58	4.18	
Sunflower oilcake 34%	10.79	3.00	2.00	6.00	8.21	10.05	5.61	10.04	-	
Termite meal	-	5.00	10.00	-	5.00	10.00	-	5.00	10.00	
Wheat bran	-	7.62	17.05	-	10.47	15.00	-	3.37	25.52	
Crude soya oil	3.00	1.49	-	3.51	2.80	-	4.50	1.76	3.39	
L-lysine HCL	0.47	0.44	0.56	0.44	0.59	0.74	0.49	0.60	0.63	
DL-Methionine	0.17	0.18	0.20	0.18	0.19	0.20	0.16	0.16	0.22	
L-Threonine	0.20	0.21	0.27	0.15	0.21	0.27	0.14	0.18	0.25	
L- Tryptophan	-	0.01	0.03	-	0.02	0.05	-	0.03	0.04	
L-Valine	0.09	0.07	0.14	-	-	-	0.08	0.14	0.22	
Feed lime fine	1.17	1.36	1.36	1.15	1.22	1.23	1.05	1.03	1.06	
MDCP	0.88	0.92	0.94	0.78	0.62	0.62	0.45	0.50	0.44	
Salt fine	0.20	0.20	0.20	0.27	0.21	0.15	0.20	0.20	0.18	
Sodium bicarbonate	0.14	0.11	0.08	0.25	0.10	0.20	0.15	0.12	0.12	
Choline chloride 60% powder	-	-	-	0.11	-	-	-	-	-	
Avatec 15% (coccidiostat)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
Zinc bacitracin 15% (AGP)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
AxtraPhy broiler phytase	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Broiler finisher Premix	0.30	0.30	0.30	0.25	0.25	0.25	0.20	0.20	0.20	
Total	100	100	100	100	100	100	100	100	100	
2Analysed nutrient composition (%)										
DM	89.07	89.03	88.59	89.18	88.84	89.31	89.34	89.11	89.48	
Ash	4.57	5.21	5.62	4.47	4.77	4.92	3.71	4.15	4.42	
CP	21.91	22.60	22.41	19.75	19.68	20.07	17.35	17.57	18.04	
CF	4.13	4.55	3.27	3.69	4.54	6.39	5.04	5.54	5.83	
EE	6.70	5.85	5.54	6.60	6.91	5.09	7.25	6.34	8.74	
ME (MJ/kg)	12.55	12.10	12.81	12.11	12.69	12.33	12.04	12.11	12.94	

¹Ingredients: MDCP = Monocalcium phosphate.²Analysed composition: DM = Dry matter, CP= Crude protein, CF= Crude fibre, EE= Ether extract, ME= Metabolizable energy.³Diets: WTM0 = Broiler diet without winged termite meal; WTM5 = Broiler chicken diet containing 5% of winged termite meal; WTM10 = Broiler chicken diet containing 10% of winged termite meal; '-'= Not incorporated.

Data collection

Slaughter procedure and viscera organ measurements

On days 14, 28 and 42, two (2) birds from each pen were randomly selected, starved for 12 hours to empty the digestive tract, weighed (Ebal WS-30 30 kg×1 g) and humanely killed by cervical dislocation method. Immediately after slaughter, visceral organs were harvested prior to various measurements (relative weight, length and pH). The organ weights, including GIT segments, liver, heart, spleen and pancreas, were recorded using the electronic weighing scale (Ebal WS-30 30 kg×1 g) and thereafter, the relative organ weights expressed in g/100 g of body weight. The size of intestinal organs, including the small intestine (SI) and its segments (duodenum, jejunum and ileum), large intestine (LI) and caeca were measured using a Dexter 3-meter measuring tape. The digesta pH of the gizzard, distal and proximal jejunum and ileum were measured using a pH meter (CRISON pH25, CRISON Instruments SA, Spain) equipped with an electrode.

Determination of carcass traits

After 42 days, two (2) birds from each treatment were initially weighed (LW) before being slaughtered to assess carcass the carcass traits. Immediately after slaughter, the feathers were removed using a feather plucker (2200w Stainless Steel Machine, South Africa) by dipping them in warm water for a few minutes. Thereafter, shanks, heads, necks and gastrointestinal tracts (GITs) were removed and the remaining carcasses were then weighed to obtain the hot carcass yield (HCW), which was used along with chicken live weight to calculate dressing percentage. Subsequent to that, meat cuts, including thigh, drumstick, breast muscle and wings of each bird, were also marked, weighed separately to determine pH, then only breast cuts were stored in a refrigerator at -4°C overnight (24 hours) for further analysis of cooking loss and shear force.

Determination of meat quality (meat pH, cooking loss and shearforce)

Meat pH

Muscle pH of breast, drumsticks, thighs and wings was measured immediately after slaughter using a calibrated (standard buffers at pH 4.0 and 7.0) Crison 506 portable pH meter. The measuring probe for both pH was placed in contact with the surface of the muscle cuts at three different points and the average was calculated for each portion.

Cooking loss

The refrigerated frozen breast cuts were thawed for 24 hours at 2°C then removed, tagged prior to cooking by boiling in a cylindrical pot using an electric stove. The stove was set on for 25 min prior to preparation in which breast cuts were boiled to an internal temperature of 35°C, then turned and finished at 70°C. Cooking losses were measured by recording weight of each breast before cooking (WBC) and after cooking (WAC) each breast meat

per treatment as shown in formula 1 below. Cooked breasts were then cooled down to room temperature (25°C) for at least 2 hours before prior to cooking loss and shear force measurements.

$$\text{Cooking loss (\%)} = \frac{(\text{WBC}-\text{WAC})}{\text{WBC}} \times 100 \quad \dots(1)$$

Meat shear force

Shear force assessment was done according to Warner-Bratzler Shear Force (WBSF) determination procedures. The cooled weighted breast cuts were exposed to a WarnerBratzler shear device mounted on a Universal Instron Apparatus (cross head speed = 200 mm/min, one shear in the centre of each core) in which three cylindrical samples (12.5 mm core diameter) of each cut were cored parallel to the grain of the meat and sheared perpendicular to the fibre direction to obtain shear force values in Newton (N). The procedure was repeated three (3) times for each breast at different locations such that the average of three peak force was obtained.

Statistical analysis

Data on internal organs, carcass characteristics and meat quality parameters were subjected to one-way ANOVA as contained in PROC GLM of SAS (2019) according to the following general linear model:

$$Y_{ij} = \mu + \text{di} + \text{Eij}$$

Where,

Y_{ij} = Response variable.

μ = General mean.

di = The fixed effects of winged termite levels.

Eij = Random error associated with observation.

ij = Assumed to be normally and independently distributed.

Where there were significant differences among treatment means, Tukey's HSD test was used to separate means. The level of significance was set at ($p < 0.05$).

RESULTS AND DISCUSSION

Gut morphology and viscera organ weights

The effect of partial replacement of WTM on viscera organ weights, lengths and pH of broiler chicken diets at the end of the starter, grower and finisher phases is represented in Table 3 to 6. Supplementation of WTM in broiler diets had no effect ($p > 0.05$) on gut lengths, pH and most of the organ weights (GIT, crop, gizzard, proventriculus, SI, duodenum, jejunum, ileum, LI, heart, liver, spleen and pancreas) throughout the growing period. However, only SI and caeca weights of broilers were affected ($p < 0.05$) by WTM inclusion at the finisher stage. Birds fed WTM5 had heavier ($p < 0.05$) SI weights than those fed diets containing WTM0 and WTM10, which were similar ($p > 0.05$). Lighter ($p < 0.05$) caeca weights were observed in birds on WTM10, WTM5 and WTM0, respectively. However, WTM0 and WTM5 had similar ($p > 0.05$) caeca weights. Similarly, the caeca weights of broilers fed 5 and WTM10 were the same ($p > 0.05$).

Carcass characteristics

The influence of WTM incremental levels on hot carcass weights (HCW), thigh, drumstick, breast and wing, as well as dressing percentage of broilers after slaughter (at day 42),

is represented in Table 7. There was no variation ($p>0.05$) in dressing percentage and weights of all meat parts of broilers fed incremental levels of WTM. However, HCW was significantly affected by the treatment diets. Chickens fed

Table 3: Effects of replacing SBM with WTM on gut relative organ weights (%) of Ross 308 broiler chickens at starter, grower and finisher phases.

¹ Parameters	Inclusion level (%) [*]			² SEM	P-value
	WTM0	WTM5	WTM10		
GIT					
0-14 days	6.41	6.50	6.04	2.048	0.31
15-28 days	7.54	7.63	7.32	0.567	0.92
29-42 days	8.15	8.71	7.67	0.312	0.14
Crop					0-14
days	0.67	0.60	0.57	0.144	0.21
15-28 days	0.71	0.64	0.63	0.095	0.80
29-42 days	0.71	0.86	0.65	0.105	0.23
Gizzard					0-14
days	1.36	1.25	1.13	0.356	0.78
15-28 days	2.14	2.17	1.98	0.270	0.98
29-42 days	2.38	2.32	2.22	0.141	0.18
Proventriculus					
0-14 days	0.56	0.51	0.54	0.08	0.11
15-28 days	0.58	0.51	0.55	0.06	0.67
29-42 days	0.66	0.64	0.55	0.05	0.13
SI					
0-14 days	1.78	1.64	1.60	0.15	0.47
15-28 days	3.01	3.02	2.99	0.25	1.11
29-42 days	3.46b	4.08a	3.24b	0.10	0.01
Duodenum					0-14
days	0.19	0.15	0.16	0.06	0.21
15-28 days	0.53	0.37	0.61	0.05	0.55
29-42 days	0.71	0.65	0.63	0.03	0.40
Jejunum					0-14
days	0.16	0.16	0.14	0.02	0.67
15-28 days	0.43	0.59	0.32	0.07	0.11
29-42 days	1.18	1.23	1.14	0.12	0.84
Ileum					0-14
days	0.13	0.15	0.14	0.07	0.34
15-28 days	0.42	0.47	0.61	0.13	0.85
29-42 days	1.07	1.17	1.09	0.06	0.12
LI					
0-14 days	0.21	0.36	0.24	0.49	0.81
15-28 days	1.68	1.83	1.59	0.06	0.06
29-42 days	2.52	2.49	2.11	0.11	0.64
Caeca					
0-14 days	0.45	0.26	0.21	0.10	0.31
15-28 days	0.56	0.47	0.83	0.13	0.21
29-42 days	1.68 ^a	1.34 ^{ab}	1.08 ^b	0.09	0.01

¹Parameters: GIT = Gastrointestinal tract; SI = Small intestine; LI = Large intestine.

²SEM = Standard error of mean.

^{a, b}: Means with different superscripts in the same column indicate significant differences between treatments ($p<0.05$).

^{*} Inclusion levels: WTM0 = Broiler diet without winged termite meal; WTM5 = Broiler chicken diet containing 5% of winged termite meal; WTM10 = Broiler chicken diet containing 10% of winged termite meal.

WTM10 diet had reduced ($p < 0.05$) HCW followed by WTM5 and WTM0, which had similar ($p > 0.05$) HCW. Additionally, the HCW of birds fed WTM5 and WTM10 were also non-significant ($p > 0.05$).

Meat pH, cooking loss and shear force

The effect of WTM inclusion levels on meat quality mainly meat pH, cooking loss and shear force of broilers after 42 days, is represented in Table 8. There was no variation ($p > 0.05$) meat pH as well as breast meat cooking loss and shear force of broilers.

Gut morphological parameters and organ weights

With the exception of small intestine (SI) and caeca weights at the finisher phase, the inclusion of WTM in diets did not significantly influence the majority of parameters mainly visceral organ weights, gut organ weights, lengths and pH of broiler chickens throughout the growth period. Hence,

suggesting that up to 10% WTM could be incorporated in broiler diets to partially replace soyabean without adversely affecting internal organs and gut morphological indices. Similar observations were made by (Shindi *et al.*, 2019) who supplemented *Macrotermes bellicosus* in diets. Possible explanation of heavier SI of chickens fed WTM5 compared to control group finisher phase could be due to the anatomical and physiological mechanism for utilizing high dietary fibre content (6.83%) observed in WTM. The cause of lower caeca weights observed in birds fed WTM10 at finisher phase is unknown however, reduction in caeca weights may cause detrimental effects on the quantity of solid and fluid mixtures (volume of gut digesta, enzymes and microbes) present in caeca (Morgan, 2023).

Carcass measurements

Non-significant effect on dressing percentage and external carcass parts of broiler chickens measured after 42 days

Table 4: Effects of replacing SBM with WTM on gut organ lengths (cm) of Ross 308 broiler chickens at the starter grower and finisher phases.

¹ Parameter	Inclusion level (%)*			² SEM	P-value
	WTM0	WTM5	WTM10		
GIT					
0-14 days	145.10	148.80	146.70	3.11	0.69
15-28 days	199.67	190.00	194.33	8.71	0.75
29-42 days	222.93	232.63	219.00	4.89	0.21
SI					
0-14 days	123.20	126.80	127.40	3.19	0.62
15-28 days	169.33	161.50	161.50	8.82	0.78
29-42 days	183.83	193.77	182.67	4.41	0.23
Duodenum					
0-14 days	18.50	20.30	19.70	1.31	0.62
15-28 days	28.33	25.00	28.00	2.08	0.50
29-42 days	30.33	33.67	28.67	4.15	0.70
Jejunum					
0-14 days	55.50	54.60	54.70	2.84	0.97
15-28 days	72.17	72.83	70.67	2.51	0.83
29-42 days	76.83	83.67	79.67	5.00	0.65
Ileum					
0-14 days	51.50	52.00	51.50	2.92	0.99
15-28 days	65.33	65.63	62.47	5.47	0.91
29-42 days	77.60	75.17	72.50	3.65	0.64
LI					
0-14 days	6.00	7.00	6.70	0.53	0.42
15-28 days	9.67	9.13	9.00	1.01	0.89
29-42 days	11.83	12.33	11.83	0.58	0.79
Caeca					
0-14 days	10.80	11.70	12.10	0.51	0.21
15-28 days	17.30	15.17	17.03	1.03	0.34
29-42 days	19.83	19.67	19.83	0.78	0.99

¹Parameters: GIT = Gastrointestinal tract; SI = Small intestine; LI = Large intestine.

²SEM = Standard Error of Mean.

^{*}Inclusion levels: WTM0 = Broiler diet without winged termite meal; WTM5 = Broiler chicken diet containing 5% of winged termite meal; WTM10 = Broiler chicken diet containing 10% of winged termite meal.

of growth periods. Thus, suggesting that WTM could be safely included in broiler diets without adverse effects on carcass traits and meat parts. The results are in agreement with those reported by Amobi and Ebenebe (2018), Marareni and Mnisi (2020) and Murawska *et al.* (2021), who included various insect meals as a replacement for SBM in poultry diets. However, reduced HCW of broilers fed WTM diets than control group could be attributed to chitin content found in termite alates, which has been reported to reduce digestibility and performance of broilers (Kim *et al.*, 2021). Termites has been reported to contain about 5.09 to 16.5% chitin contents (Redford and Dorea, 1984).

Meat pH, cooking loss and shear force

Meat quality parameters including meat pH, cooking loss and shear force are very important in determining the freshness, texture and acceptability of meat by consumers (Pieterse *et al.*, 2019). Hence, it is critical to analyse the changes in meat pH, cooking loss and shear force of poultry meat. In addition to non-significant effect of WTM on meat pH values of broiler chickens, the pH values of all meat parts were within the normal range (5.5 to 6.2) (Petracci *et al.*, 2017). Hence, suggesting that WTM could be supplemented in broiler diets without

Table 5: Effects of replacing SBM with WTM on gut organ digesta pH values of Ross 308 broiler chickens at the starter grower and finisher phases.

¹ Parameter	Inclusion level (%) [*]			² SEM	P-value
	WTM0	WTM5	WTM10		
Crop					
0-14 days	6.35	6.10	6.09	0.23	0.66
15-28 days	4.99	5.19	5.12	0.35	0.92
29-42 days	4.19	4.02	3.90	0.16	0.49
Gizzard					
0-14 days	3.73	3.99	4.01	0.35	0.83
15-28 days	3.81	3.72	4.26	0.36	0.57
29-42 days	4.46	4.25	4.21	0.33	0.86
Proventriculus					
0-14 days	5.22	5.15	5.18	0.08	0.84
15-28 days	5.19	5.67	5.69	0.32	0.49
29-42 days	4.61	4.98	4.67	0.19	0.38
Duodenum					
0-14 days	6.18	6.14	6.24	0.04	0.32
15-28 days	6.42	6.18	6.27	0.09	0.25
29-42 days	5.68	5.65	5.53	0.11	0.56
Jejunum					
0-14 days	6.38	6.32	6.49	0.11	0.51
15-28 days	6.18	6.19	6.23	0.13	0.96
29-42 days	5.58	5.37	5.61	0.18	0.62
Ileum					
0-14 days	6.38	6.33	6.38	0.11	0.92
15-28 days	6.40	6.30	6.24	0.15	0.77
29-42 days	5.14	5.45	5.73	0.35	0.52
LI					
0-14 days	6.46	6.49	6.42	0.11	0.91
15-28 days	6.37	6.24	6.40	0.11	0.58
29-42 days	5.40	5.68	5.58	0.19	0.62
Caeca					
0-14 days	6.60	6.99	6.94	0.14	0.18
15-28 days	6.64	5.31	6.41	0.57	0.29
29-42 days	6.11	5.83	6.01	0.21	0.62

¹Parameters: GIT = Gastrointestinal tract; SI = Small intestine; LI = Large intestine.

²SEM = Standard Error of Mean.

* Inclusion levels: WTM0 = Broiler diet without winged termite meal; WTM5 = Broiler chicken diet containing 5% of winged termite meal; WTM10 = Broiler chicken diet containing 10% of winged termite meal.

Table 6: Effect of replacing SBM with WTM on relative organ weights (%) of Ross 308 broiler chickens at the starter grower and finisher phases.

Parameters	Inclusion level (%)*			¹ SEM	P-value
	WTM0	WTM5	WTM10		
Heart					
0-14 days	0.70	0.75	0.62	0.0512	0.21
15-28 days	0.59	0.57	0.51	0.0579	0.61
29-42 days	0.81	0.82	0.76	0.0444	0.70
Liver					
0-14 days	3.94	4.50	3.93	0.3432	0.43
15-28 days	3.10	2.57	2.76	0.1824	0.41
29-42 days	2.42	2.43	2.31	0.1059	0.72
Spleen					
0-14 days	0.12	0.10	0.10	0.0151	0.49
15-28 days	0.17	0.16	0.16	0.0316	0.96
29-42 days	0.22	0.18	0.17	0.0153	0.07
Pancreas					
0-14 days	0.08	0.08	0.09	0.0236	0.63
15-28 days	0.24	0.24	0.22	0.0323	0.84
29-42 days	0.23	0.23	0.19	0.0229	0.42

¹SEM = Standard error of mean.^{*}Inclusion levels: WTM0 = Broiler diet without winged termite meal; WTM5 = Broiler chicken diet containing 5% of winged termite meal; WTM10 = Broiler chicken diet containing 10% of winged termite meal.**Table 7:** Effect of WTM inclusion levels on carcass traits (g, unless stated otherwise) of Ross 308 broiler chickens after 42 days.

¹ Parameters	Inclusion level (%) [*]			² SEM	P-value
	WTM0	WTM5	WTM10		
HCW	2210.00a	2074.00ab	1754.00b	128.77	0.02
Dressing (%)	83.91	73.67	71.96	4.75	0.24
Thigh	7.75	8.72	8.31	0.31	0.15
Drumstick	6.38	6.34	6.13	0.33	0.86
Breast	39.36	38.40	35.68	1.53	0.29
Wing	5.18	5.17	4.42	0.24	0.12

¹Parameters: HCW = Hot carcass weight.²SEM: Standard error of mean.^{a, b}: Means with different superscripts in the same column indicate significant differences between treatments ($p < 0.05$).^{*}Inclusion levels: WTM0 = Broiler diet without winged termite meal; WTM5 = Broiler chicken diet containing 5% of winged termite meal; WTM10 = Broiler chicken diet containing 10% of winged termite meal.**Table 8:** Effect of WTM inclusion levels on meat pH, cooking loss and shear force of Ross 308 broiler chicken meat cuts after 42 days of age.

Parameters	Inclusion level (%)*			¹ SEM	P-value
	WTM0	WTM5	WTM10		
Meat pH					
Thigh	5.92	5.89	5.88	0.1167	0.97
Drumstick	5.96	5.91	5.97	0.0633	0.71
Breast	6.06	5.76	5.71	0.1697	0.36
Wing	5.89	5.98	6.02	0.0714	0.47
Cooking loss (%)					
Breast	35.72	36.31	37.01	1.7821	1.77
Meat Shearforce (N)					
Breast	15.14	14.08	14.87	5.1290	0.99

¹SEM = Standard error of mean.^{*}Inclusion levels: WTM0 = Broiler diet without winged termite meal; WTM5 = Broiler chicken diet containing 5% of winged termite meal; WTM10 = Broiler chicken diet con.

tempering with meat pH values. The results agree with those reported by (Mbhele *et al.*, 2019; Marareni and Mnisi, 2020; Murawska *et al.*, 2021). In contrast, Mutisya *et al.* (2022) observed a reduction in pH values when supplementing black soldier fly up to 75% in broiler diets. This may be due to the use of different insect species and varying inclusion levels. Nonetheless, the non-significant effect of WTM inclusion levels on broiler breast meat cooking loss and shear force emphasize that WTM in the current study could be safely incorporated in broiler chicken diets without affecting vital meat quality parameters. Similar findings were observed by Deori *et al.* (2022) who included up to 15% termite meal in quail diets. However, further research is needed on evaluating meat quality attributes from other carcass parts such as drumsticks, thighs and wings.

CONCLUSION

Based on the outcomes of the current study, WTM of up to 10% could be included in broiler chicken diets as a partial substitute for SBM without any detrimental effect on gut morphology and organ weights, carcass characteristics and meat quality of broiler chickens. However, inclusion levels of WTM above 10% is recommended for future research.

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Conflict of interest

Authors have no conflict of interest for current study.

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